ATTACHMENT 13

U.S. FISH AND WILDLIFE SERVICE
PONDBERRY FINAL BIOLOGICAL OPINION

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Mississippi Field Office
6578 Dogwood View Parkway, Suite A
Jackson, Mississippi 39213

July 2, 2007

Colonel Anthony C. Vesay
District Engineer
U.S. Army Corps of Engineers
Vicksburg District
4155 Clay Street
Vicksburg, MS 39183-3435

Dear Colonel Vesay:

This document transmits the Fish and Wildlife Service's (Service) biological opinion based on our review of the proposed Yazoo Backwater Area Reformulation Project, and its effects on pondberry (*Lindera melissifolia*), an endangered species, in accord with section 7 of the Endangered Species Act (Act) of 1973, as amended (16 U.S.C. 1531 et seq.). Your December 4, 2005 request to initiate formal consultation was received on December 5, and formal consultation was initiated effective on January 18, 2006.

This biological opinion is based on information provided in:

1) the Draft September 2000, Yazoo Backwater Area Reformulation Report and Appendices, Flood Control, Mississippi River and Tributaries, Yazoo Basin, Mississippi; Supplement No.: 1 to the 1982 Yazoo Area Pump Project, Final Environmental Impact Statement;

2) the revised draft July 29, 2005 Appendix 1: Mitigation, and Appendix 10: Assessment of Wetland Resources and Evaluation of Flood Control Alternatives for the Yazoo Backwater Project;

3) the December 5, 2005 revised Appendix 14: Endangered and Threatened Species Biological Assessment; and

4) other information provided by the Corps during the consultation period, and other papers, reports, and data. A complete administrative record of this consultation is on file at this office.

Consultation History

April 7, 2000 – The Service reviews and provides comments to the Corps on a draft Endangered and Threatened Species Biological Assessment, noting that the elevations for certain pondberry sites appear to be on 2-5 year floodplains, and not the reported 15-20 year floodplain, indicating the project may affect pondberry.

April 26, 2000 – Service staff completed a review of the conclusions of the 1990 Pondberry Profile Workshop (e.g. expert panel) hosted by the Corps, and elevation and stage data used in assessments for the Upper Yazoo Project and the Sunflower River Project. These data indicated a similar error, that pondberry was not occurring only at or above a 15-year floodplain, but at lower sites where alterations of flood frequency would be more important.

April 27, 2000 – Service and Corps staff met to discuss the issues raised in the Service's April 7 review. Primary issues concerned the Corps' conclusions from the Pondberry Profile concerning circumstances when local hydrology is more important to pondberry than overbank flooding, the adequacy of pondberry surveys, and the elevation and flood frequency at pondberry colony sites. The Service informed the Corps the project may affect pondberry.

May 5, 2000 – Another meeting to discuss and identify elements to include in additional surveys for pondberry, with a need for all U.S. Forest Service data for sites surveyed and not surveyed previously on Delta National Forest. Discussed survey design and parameters, including areas and elevations, measures for pondberry vigor and health, and other features.

May 30, 2000 – Correspondence from the Service to Corps, reviewing and recommending modifications for the pondberry profile survey protocols, with additional pondberry attributes to measure, and procedures for formal section consultation.

June 9, 2000 – Service staff accompanied the Corps and the Corps' pondberry survey contractor, Gulf South Research Corporation (GSRC), to observe pondberry field survey protocols.

June 16, 2000 – Corps and Service staff meet to review issues and upcoming schedules for completion of the survey report, with the Corps anticipating they will make their finding whether the project may affect pondberry within the next 30 days.

August 15, 2000 – By telephone, the Corps informed the Service that the final pondberry survey report from Gulf South Research Corporation had not been completed, but that we would meet after the Corps had reviewed the final report, before making their determination whether the proposed project "may affect" pondberry, and before releasing the draft Reformulation Report and supplemental EIS appendices with the biological assessment to the public.

September 5, 2000 – the Corps released the draft Yazoo Backwater Reformulation Report and draft Supplement No. 1 to the 1982 Yazoo Area Pump Project Final EIS to the public on the Corps internet web site.

September 6, 2000 – The Corps and Mississippi Levee Board met with the Service to give a briefing on the released documents, with the basis of their finding that the proposed project is not likely to adversely affect pondberry. The Corps agreed to meet with the Service after reviewing the documents, to consider the Service's technical review and comment.

September 8, 2000 – The Service requested the Corps provide missing data and other information relevant to the recently released Appendix 14: Endangered and Threatened Species Biological Assessment.

October 2, 2000 – Telephone call from Service, informing Corps that we disagree with their finding the project is not likely to adversely affect pondberry, with a summary of underlying reasons.

October 3, 2000 – The Service provided the Corps with a draft of our technical review and comment of the Appendix 14 biological assessment, in which the Service disagreed with the Corps' finding the project was not likely to adversely affect pondberry.

October 16, 2000 – In correspondence to the Corps, the Service provides technical review of the biological assessment, with our finding that the project is likely to adversely affect pondberry, recommending that the Corps initiate formal section 7 consultation. By separate phone call to Corps, the Service requests a meeting to discuss these issues.

June 8, 2001 – The Service corresponded with the Corps, following a June 6 telephone conversation, primarily concerning the Service's Fish and Wildlife Coordination Act report, and to reiterate the request the Corps initiate formal section 7 consultation for pondberry.

July 18, 2001 – The Corps corresponds in response to the June 8 letter, informing the Service that information is still being assessed for pondberry, and a future meeting will be requested.

July 20, 2001 – The Service sends the Corps a copy of a survey report by Gulf Coast Biological Surveys (GCBS), entitled "Hydrology and Habitat Evaluation of Fifty-one Selected Colonies of Pondberry in Delta National Forest." GCBS, as contracted by the Service, conducted field surveys to assess evidence of hydrology by local ponding, finding no such evidence at most sites.

August 8, 2001 – The Corps corresponds to the Service, to dispute certain elements of the Service's October 16 review, to affirm their finding the project is not likely to adverse effect pondberry, to inform the Service of a pending interagency agreement with the USDA Forest Service to initiate conservation research to address problematic pondberry issues, and to invite the Service to be a part of the research and a signatory to the MOU.

September 24, 2001 – The Corp and Service meet to review the proposed goals and objectives of research and the MOU with the USDA Forest Service, Center for Bottomland Hardwood Ecology, collectively entitled "Experiments on Propagation, Ecophysiology, Ecology, and Restoration of Pondberry", including research on effects of flooding, plant competition, sunlight, and pathogens on pondberry.

September 26, 2001 – The Service provides the Corps with technical review and comment on proposed research objectives and projects to be investigated and covered under the interagency agreement for pondberry.

May 20, 2002 – The Service signs the interagency agreement with the Corps and the Forest Service, Southern Research Station, (Center for Bottomland Hardwood Ecology) executing research and reports over the next 6 years, funded with at least $5 million from the Corps and Forest Service, on the role of flooding and sunlight to pondberry growth, the impact of periodic flooding on interspecific plant competition, dynamics of pondberry colonies in response to the environment, the role of stem dieback and pathogens, population genetics, and pondberry restoration.

November 6, 2002 – The Service corresponds and provides to the Corps a Fish and Wildlife Coordination Act Report, which includes the Service's October 16, 2000 review of the Appendix 14 BA of the effects of the project to pondberry, requesting the Corps initiate formal section consultation.

January 14-15, 2003 – The Corps hosts an interagency meeting with the Service and EPA to review, among other issues, the Corps' revised jurisdictional wetland analysis, based on a 5% flood duration, with information on the spatial extent and location of wetlands to be adversely affected by the project.

March 24, 2003 – The Service provides the Corps with technical comments from the January 14-15 meeting.

June 2003 – At the invitation of EPA, Service staff participate in EPA's alternative statistical field sampling methodology to estimate the extent of wetlands affected by the project.

June 23, 2003 – In correspondence to the Corps, the Service requests an interagency meeting with the EPA to review the results of the ongoing statistical wetlands field assessment by EPA, once completed, as a comparison to the Corps' analysis.

July 23, 2003 – The Corps responds to the Service's June 23 letter, stating that a meeting will be convened if the EPA wetland analysis differs from the Corps'.

August 12, 2003 – The Corps writes in response to the Service's November 6, 2002 correspondence and report, stating the project is not likely to adversely affect pondberry.

August 25, 2003 – In response to the Corps August 12 correspondence, the Service notes the consultation dispute, and reiterates the need for formal section 7 consultation on pondberry.

December 17, 2003 – The Service writes EPA to request information from the Corps-EPA analysis of wetland data, and for the opportunity to participate and review the EPA Draft Wetland Report.

January 22, 2004 – Letter from Service Regional Director to EPA Regional Director requesting that the Service be allowed to review the ongoing Corps-EPA wetland assessment.

January 26, 2004 – Letter from Service Regional Director to Corps requesting the opportunity to review the preliminary or other results from the Corps-EPA reassessment of wetlands.

February 11, 2004 – Letter from Corps stating that the Service's request will be granted after the draft revised wetland appendix report has been completed.

March 8, 2004 – Letter from Corps District Engineer to Service Regional Director, in response to Service's January 26 correspondence, in dispute of coordination disagreements, stating the revised Wetland Appendix will be provided when completed.

April 5, 2004 – In response to the Service's August 25, 2003 letter and Fish and Wildlife Coordination Act Report, the Corps writes that the project is not likely to jeopardize the continued existence of pondberry based on the number of known colonies, the status of its habitat, and preliminary results of the recently initiated research project through the Forest Service.

April 12, 2004 – The Service responds to the Corps April 5 letter, noting that a colony is not biologically equivalent to a population for downlisting or delisting purposes, and disagreeing that there is any substantial information from the recently initiated and uncompleted research. To insure the project is not likely to jeopardize the species continued existence, the Service requested the Corps to enter formal section 7 consultation.

July 21, 2005 – Invitation from Corps to attend an interagency meeting and briefing on revised wetland and other appendices for the Yazoo Backwater Reformulation Project.

July 29, 2005 – Service staff attend the Corps interagency meeting and briefing to explain the most recent draft revisions to certain environmental appendices, including the wetland appendix, with an EPA briefing on the results of the EMAP investigation of wetland extent in the lower Yazoo basin. New information is provided regarding the Flood Event Assessment Tool, other features, and potential sources for the discrepancies between the EPA and Corps analysis. Copies of appendices are provided, with requests for technical review and comment.

August 19, 2005 – The Corps hosts a follow-up meeting for additional briefings and discussions on the revised environmental appendices.

October 11, 2005 – The Service provides the Corps with technical review and comment on the revised wetland and other appendices.

December 5, 2005 – The Corps provides the Service with a revised Appendix 14, "Endangered and Threatened Species Biological Assessment", including new information on the extent pondberry occurs in jurisdictional wetlands affected by the project and other factors. The Corps requests the immediate initiation of formal section 7 consultation for pondberry, although the Corps still concludes the project is not likely to adversely affect the species.

December 15, 2005 – The Service acknowledges by letter the Corps request for formal consultation, noting that new information not previously reviewed by the Service has been provided, and that the Service will review the new information for a 30-day period to determine if the initiation package is complete, in accord with section 7 regulations and policy.

December 20, 2005 – The Corps responds by letter in disagreement with the Service's authority to review the revised biological assessment (BA) for a 30-day period, insisting that formal consultation was initiated when the Service received the request on December 5.

January 4, 2006 – The Service provides the Corps a review of the revised BA, noting missing and other available information that should be provided to represent the best available scientific and commercial data available.

January 18, 2006 - In response, the Corps states that all available information has been provided, no additional requested analysis is warranted or will be provided, and any minor points of clarification or additions will be handled during the consultation period.

January 27, 2006 – The Service by letter accepts the Corps request to initiate formal consultation, effective January 18, with the provision that the Service must give the benefit of doubt to the species in the absence of the best available scientific and commercial data.

January 30, 2006 – The Mississippi Levee Board, as the local sponsor of the proposed project, requests to participate in future consultation meetings with the Service and Corps, and requests a meeting with the Service.

February 1, 2006 – The Service writes to the Mississippi Levee Board, informing them that the Corps must designate their organization as a party to the federal action and consultation, and not the Service.

February 8, 2006 – Service and Corps meet to start the review of consultation, information, and analysis issues identified in the Service's January 18 review of the revised biological assessment.

February 17, 2006 – Meeting with Corps, to review technical issues in the biological assessment.

March 1, 2006 – The Service meets with the Mississippi Levee Board, at their request, and discusses the general issues to be addressed during consultation and the consultation process.

March 10, 2006 – The Corps sends the Service a copy of correspondence to the Mississippi Levee Board, acknowledging that the Board will participate in future consultation meetings.

March 20, 2006 – Corps provides web site link for Service to download requested GIS data.

March 29, 2006 – Corps provides web site link for pondberry GIS data.

April 6, 2006 – Corps provides web site link for land use GIS data.

April 13, 2006 – Service and MS Levee Board meet, for update on status of pondberry consultation with Corps.

April 27, 2006 – Meeting with Corps and MS Levee Board, received new information from Corps on base wetlands assessment according to a 10-meter digital elevation model, with additional info on EPAs technical review and the Corps response to the wetland assessment. Service and Corps work to resolve technical problems and documentation for downloaded GIS data. Service requests copy of EPA technical comments and review on Corps wetland assessment.

May 3, 2006 – Corps provides Service copy of EPA's December 6, 2005 technical review and comment on the Corps draft wetland appendix (Appendix 10).

May 5, 2006 – Corps provides additional documentation for GIS land use data.

May 9, 2006 – Corps and Service meet to discuss data and analysis for assessing effects of previous flood control projects on reducing flood duration and frequency at pondberry sites.

May 18, 2006 - Corps provides data on median flood stage elevation for environmental baseline prior to the earlier completion of the Holly Bluff cutoff canal and the Yazoo Backwater levee system. Service responds with request for spatial data and tabulation of the 5% flood duration interval at pondberry sites to interpret the median flood stage data.

June 26, 2006 – Meeting with Corps, in which Corps describes and reviews GIS data for the coverage and change of 5% duration (jurisdictional) wetlands for the period 1901 to present, as affected by past flood control projects and climatic variation. Service requests copies of GIS shapefiles and data.

July 11, 2006 – Correspondence to Corps to request an extension of the consultation period to August 31, 2006, to complete the analysis of past effects data and write the biological opinion.

July 17, 2006 – Correspondence from Corps, denying the Service's request, but granting an extension of the consultation to August 16, 2006.

August 8, 2006 – Correspondence to Corps, to explain why a scientifically credible biological opinion cannot be produced by August 16.

September 26, 2006 – Service mails first draft of the biological opinion to the Corps for their review.

September 28, 2006 – Correspondence from the Corps, requesting that the Service expeditiously complete the BO.

November 1, 2006 – Service meets with Corps at the Vicksburg District office to discuss the biological opinion, and recommends that the Corps either modify the project or adopt conservation measures by propagating and stocking new pondberry populations to reduce adverse impacts

December 18, 2006 – Meeting at the Service's regional office in Atlanta, where the Corps provides their technical review document on the September 26 draft biological opinion, and the Corps presents their plan to propagate and stock pondberry to create two populations in wetlands. The Corps also provides new data from their recent field surveys to determine jurisdictional wetland status at profiled pondberry colonies/sites.

January 12, 2007 – Corps provides Service with a draft Memorandum of Agreement (MOA) between the agencies to guide the development and implementation of a conservation program by the Corps to propagate and stock pondberry, creating two new populations in wetlands that will not be affected by the project.

January 29, 2007 – Service provides Corps with written response to the draft MOA.

February 5, 2007 – Service meets with Corps at the Vicksburg District Office to revise the draft MOA.

February 28, 2007 – Service corresponds with Corps, approving and sending a signed MOA.

March 7, 2007 – Service sends Corps part of a revised biological opinion to review.

March 9, 2007 – Service sends Corps additional segments of a revised biological opinion to review.

March 12, 2007 – Service sends Corps other sections of revised biological opinion to review.

March 14, 2007 – Service sends Corps final sections of the revised biological opinion to review.

March 19, 2007 – Corps responds in letter to Service, also approving the MOA, signed and effective March 16, 2007.

May 2, 2007 – Service receives Corps technical review and comment on revised draft biological opinion.

June 11, 2007 – Service sends memo to Corps with data and analysis of new models of pondberry growth in response to flooding, requesting Corps comment and the value of additional analysis.

FWS Log No.: 43910-2006-F-0398
Date Started: January 18, 2006
Applicant: Vicksburg District
Project Title: Yazoo Backwater Area Reformulation
County: Humphreys, Issaquena, Sharkey, Washington, Warren, Yazoo

Application No.: COE
Ecosystem: LMAV
Action Agency: COE

BIOLOGICAL OPINION

DESCRIPTION OF THE PROPOSED ACTION

The proposed action is the Yazoo Backwater Area Reformulation, more commonly known as the Yazoo Area Pump Project (YAP). It is a descendant action from the 1928 Flood Control Act, with subsequent amendments, that has variously directed the Corps to investigate, design, and implement civil works projects for a wide range of objectives in the lower Mississippi River alluvial valley, including flood protection, navigation, fish and wildlife conservation, water quality, and recreation. Collectively, these various projects throughout the lower valley have become identified as the Mississippi River and Tributaries Project.

Other legislation and separate authorizations led to three major flood control projects in the Yazoo River Basin of Mississippi; the Yazoo Headwater Project Area, the Big Sunflower Project, and the Yazoo Backwater Area Project. The Backwater Project was first authorized by Congress in the 1941 Flood Control Act, with later amendments and other authorizations. The design of the Backwater Area Project, as completed to date, has included structural and non-structural features to reduce headwater flooding in the Yazoo River and tributaries, backwater flooding from the Mississippi River, and flood storage in natural sumps from the Mississippi River.

In 1991, the Office of Management and Budget (OMB) directed the Corps to review and reformulate Yazoo River Basin projects, including the Backwater Project, with structural and nonstructural alternatives for greater urban area flood protection, reduced agricultural intensification, and reduced adverse environmental impacts. The proposed action represents the Corps reformulation of the backwater pumping facility, which is the culminating project to previously completed levees, water control structures, canals and channel diversions in the Backwater Area. The proposed action represents the Corps preferred plan, Plan 5, as described in the September, 2000, Yazoo Backwater Area Reformulation Report, Supplement No. 1, to the 1982 Final Environmental Impact Statement, The Yazoo Area Pump Project, Flood Control, Mississippi River and Tributaries, Yazoo Basin, Mississippi (U.S. Army Corps of Engineers 2000).

The main elements of the proposed action, for the purposes of this consultation, are the construction of a 14,000 cubic feet per second (cfs) pumping plant at the Steele Bayou Control Structure, operating at a river stage elevation of 87 feet, acquiring conservation easements and reforestation on up to 55,600 acres of agricultural lands, and implementing a pondberry conservation project to propagate and stock pondberry for two new populations with a conservation research program.

The Steele Bayou structure is a set of flood gates located along the Yazoo River backwater levee at the southern end of the Yazoo Basin (Plate 1). Natural and diverted channel drainage by Steele Bayou, the Big Sunflower River, the Little Sunflower River, and Deer Creek from about 4,000 square miles of the basin must pass through the structure to enter a short, lower reach of the Yazoo River before entering the Mississippi River. The drainage area during floods has been confined to exit through the Steele Bayou structure due to the previous construction by the Corps of the Mississippi River mainline levee system to the west, and the backwater and other levees associated with the Yazoo River and the auxiliary drainage channel previously constructed to the east. These levees prevent flood water from overflowing into the basin from the Mississippi River and Yazoo River, except during extreme events.

During normal operation and headwater flood events in the basin, the Corps will open the gates for interior drainage when the water elevation behind the gates is higher than the elevation below and downstream. However, the gates are closed during flood stages on the Mississippi River to limit backwater from entering and flooding the basin. The ring system of levees also traps interior floodwater and drainage behind the Steele Bayou structure when the gates are closed since there is no other outlet or drainage. Thus, the Corps proposes to operate the pump when interior flooding behind the closed gates reaches 87 feet at the structure. The pump is intended to reduce interior flooding behind closed gates by lifting water over the structure and levee for discharge downstream into the Yazoo and Mississippi

Rivers. The Corps will cease pump operation when either the flood stage behind the closed gates is reduced to 87 feet, or the gates can be opened for tail water discharge because the downstream stage elevation is lower. In addition to the operation of the gates and pumps during flooding, the project also includes a modification to current operations so that during low flow conditions, the Steele Bayou structure will maintain a minimum water elevation between 70 and 73 feet. Currently, the gates are operated during low water to maintain water elevations between 68.5 and 70 feet.

In association with the proposed action, a pondberry conservation and recovery program will be implemented under a Memorandum of Agreement to artificially propagate and stock pondberry, creating two new populations in wetland habitat that will not be affected by the project. The Corps will also conduct a conservation research program to further assess the effects of hydrology, sunlight, competition, and pathogens to pondberry under forest conditions. The Corps and Service developed a Memorandum of Agreement, effective March 16, 2007, to guide and implement this action over the next 10 or more years (Appendix 1). The Corps and Service will mutually plan and agree upon all further elements required to implement this program. All funding for the project will be provided by the Corps.

The propagation phase of the project involves the tissue culture of pondberry meristems taken from plants already propagated and available at the U.S. Forest Service's Center for Bottomland Hardwoods Research (CBHR) to produce new plants. This will be the same micropropagation technique of axillary shoots recently used by the CBH to propagate more than 10,000 plants for conservation research (Hawkins et al. 2007). Two areas have been initially selected for stocking, on Mahannah Wildlife Management Area and Panther Swamp National Wildlife Refuge, both of which are located in the backwater area. Additional surveys and assessments will be conducted to determine their suitability based on forest stand conditions and hydrology. These as well as other suitable areas with wetlands and adequate management are candidate sites. As part of the MOA, site specific stocking plans will be developed, with measurable goals and objectives, and monitoring and annual reporting to determine effects, the need for modifications, and the success of the project. Also, the research protocols and experimental designs will be developed to accomplish the conservation research objectives. Much of the research likely will be conducted by scientists at the CBH, who currently are engaged in pondberry conservation research through other agreements with the Corps and Service.

STATUS OF THE SPECIES/CRITICAL HABITAT

Species description

Pondberry, *Lindera melissifolia* (Walt.) Blume, was first described by Thomas Walter as a distinct species in 1788, based on a collection from Berkeley County, South Carolina. Pondberry is a distinctive species, with diagnostic characters that clearly distinguish it from the other two species of spicebush in the southeastern United States, *L. benzoin* and *L. subcoriacea*. Pondberry is a deciduous shrub, growing from less than 1 foot to infrequently more than 6 feet in height. Leaves are aromatic, alternate, elliptical, somewhat thin and membranaceous, with entire margins. Shrubs usually are sparsely branched, with fewer branches on smaller plants. Plants are stoloniferous, frequently propagating by vegetative sprouts, forming colonies and clumps. Plants are dioecious, each plant a male or female, and produce clusters of small yellow flowers in early spring prior to leaf development, from buds on branches produced from the growth during the preceding year. Immature fruits are drupes, green, and ripen to red by fall.

Life history

Growth and reproduction

According to the National List of Plant Species that Occur in Wetlands (Reed 1988), pondberry is an obligate wetland species that occurs almost always (estimated probability >99%) under natural conditions in wetlands. Pondberry exhibits several characteristics and adaptations of a hydrophyte, including a very shallow root system, lacunae (arenchyma) tissue in roots that enhance oxygen diffusion, and abundant stem lenticels (Wright 1989a). These features promote the use of oxygen stored in tissues and gas exchange during anoxic, oxygen limited conditions when soils are saturated or flooded, which enhances continued metabolism, photosynthesis, and growth (e.g. Hook and Brown 1973, Whitlow and Harris 1979, Teskey and Hinkley 1977, Smith et al. 1986).

Pondberry is an understory shrub, adapted to shade conditions, with a peak photosynthetic capacity at low light conditions, though capable of responding to a limited amount of increased light with sun-shade leaf responses (Wright 1990; Aleric and Kirkman 2005). Photosynthesis declines at 100 percent sunlight, with a reduction in plant biomass (Aleric and Kirkman 2005).

Pondberry produces vegetative sprouts from stolons or the base of plants that grow as a single shoot from several inches to 2 or rarely 3 feet in the first year of growth, depending on site conditions. Deciduous leaves drop in the fall, and after winter, lateral and terminal branches are formed from axillary and terminal buds on stems formed during the previous year's growth. Plants grow with this annual cycle until about 7 to 10 years of age, when the number and length of new branches decline with plant maturity (e.g. Godt and Hamrick 1996; Devall et al. 2001). Stem dieback can be a natural feature of a mature or senescent plant (Godt and Hamrick 1996). Stem dieback at any plant age or size also is caused by the fungus *Botryosphaeria ribis* (Wilson et al. 2004). On larger plants with more branches, dieback can be partial, affecting one or several branches, and new growth continues from surviving branches. With more severe dieback, plants can form one or more new branches from the differentiation of adventitious meristems from the cambium on older surviving branch segments formed during previous years. With complete dieback, new branches sometimes form at the base of the plant, and in other instances the entire above ground plant dies.

Vegetative reproduction from stolons and sprouts frequently creates distinct colonial patches of plants. The term colony refers to group of individuals that are either clones of each other, or they are genetically closely related. Vegetative propagation from stolons and basal stem sprouts creates genetically identical clones, and colonial patches of plants actually represent one or a few genetically distinct individuals. A genetically individual plant, which is a genet, can consist of many separate shrubs within a colony. Thus, the terms plant, stem, and shrub in the literature have been variously used with different and potentially confusing meanings depending on the context. Recently, the term "stem" has been frequently used in literature and reports on pondberry, as in the number of stems in a colony, to refer to the number of shrubs, and not the number of branches or annual growth segments on a shrub. Here, the term plant will be used to refer to an individual shrub, represented by a single rooted stem with lateral stems-branches, unless otherwise clarified in context to mean a genetically distinct individual.

Genetic diversity in pondberry, assessed by allozymes, is low within and between pondberry populations, relative to that observed in other flowering woody plant species (Godt and Hamrick 1996). This is in part due to the restricted range and rarity of the species. It also reflects infrequent sexual reproduction with the successful production of fruits/seeds and seedlings. Within the populations sampled by Godt and Hamrick (1996), there were from one to 18 genetically different clones. The greatest genetic diversity occurs in two Mississippi populations in the Delta National Forest, at the Colby site and Redgum Research Natural Area. Much greater levels of genetic diversity have been detected using DNA microsatellites, but these studies have not been completed (Echt 2003). Nevertheless, Echt (2003) also found that colonies or clumps of plants mostly represented a single individual.

The density of plants in colonies commonly is one or more plants per square meter, and colonies can range from several plants to, rarely, several thousand plants. Distinct colonial patches can be difficult to recognize at rare sites where pondberry is locally abundant, dense, and widespread. Plants also occur without distinct colonial aggregations, scattered less densely among or separate from colonies. Small potential populations with one or a few colonies frequently are unisexual, most often males (Wright 1989a, 1989b). Males tend to outnumber females in Mississippi and Arkansas (Wright 1989a, 1989b; Devall et al. 2001), but females were more abundant at North Carolina sites (Leonard 1995).

Flowers are obligately insect pollinated, and cross pollination between male and female plants may involve up to a dozen potential pollinators, the most likely of which are various syrphid flies and ground dwelling or nesting bees, including digger bees (*Anthophora ursina*, *Ceratina calcarata*) and mining bees (*Andrena pallidifovea*, *Andrena imitatrix*) (Devall et al. 2001, 2004). No pollinator studies have been conducted, and the pollinator effectiveness of these or other species is unknown. Male flowers tend to open before females (Devall et al. 2004). Pondberry flowers in early spring, as early as late February depending on weather, and flowers are subject to damage due to late freezes (Tucker 1984; Devall et al. 2001). Seeds are fully formed within 90 days after flowering, and fruits reach maturity in July and August (Connor et al. 2006). Fruit production is erratic, although abundant in good years (Morgan 1983; Wright 1989a, 1989b; Devall et al. 2001). Poor fruit production at sites with few plants and colonies may be associated with unequal sex ratios, flowering asynchrony, or other factors that limit cross pollination (e.g. Wright 1989a, 1989b, 1994). Pondberry in South Carolina, in the Francis Marion National Forest and the Marine Corps Air Base Station has only rarely been observed to produce flowers (Eudaly 2005; Mackie 2006, pers. comm.).

Mature fruits are a bright red, firm, somewhat fleshy, one-seeded drupe, held by a persistent pedicel to the stem. Fruits of this type normally are expected to be eaten or dispersed by birds (Ridley 1930). Dispersal agents also may include mammals (Smith et al. 2004) and floods (Middleton 2002). Smith et al. (2004) identified and confirmed the hermit thrush as the only known and confirmed animal to consume and disperse pondberry seeds, although they also observed 11 other bird species on pondberry. Cardinals are seed predators that crush and swallow seeds. Hermit thrushes gulp fruit, and regurgitated seeds germinate successfully (Smith et al. 2004). The number of fruits on pondberry stems decline rapidly upon the winter arrival of hermit thrushes. The distances seeds are potentially dispersed by hermit thrushes are relatively short, about 160 feet (55 meters) due to their small winter home range. In *Lindera benzoin* (spicebush), a related species, seed germination is reduced when the fruit pulp is not removed, indicating that frugivory by animals likely is important for greater seed germination in pondberry as well (Aleric and Kirkman 2005). The percent germination of pondberry seeds with the pulp experimentally removed is greater than seeds with pulp (Wright 1989a; Aleric and Kirkman 2005; Connor et al. 2006), and can be as great as 90 percent (Wright 1989).

Seedlings have rarely been observed in pondberry colonies and populations, whether during studies at specific sites or during various surveys by a number of botanists and ecologists over the years (e.g. Wright 1989a, 1989b, 1990; Devall et al. 2001; Aleric and Kirkman 2005; Connor et al. 2006). However, Aleric and Kirkman (2005) have suggested that since pondberry seedlings do not possess distinctive cotyledons, then actual seedlings may have been present that were not recognized. Seed banks don't appear to exist, at least at Arkansas study sites (Wright 1989a, 1989b), although some seeds appear to remain viable in the soil for up to 7 years after planting (Smith 2003). Seed viability does not appear to be a significant factor limiting reproductive success. Other factors potentially responsible for low reproductive success and the production of seedlings include the effect of fruit pulp on seed decay, seed depth in soil, length of time in soil, flooding, and depredation have been investigated and are continuing to be studied. In experimental greenhouse treatments, seed germination was not affected by depth of planting and the presence or absence of flood treatments (Aleric and Kirkman 2005). Unprotected seeds on the soil surface with intact pulp are removed at high rates, presumably eaten by birds and mammals

(Aleric and Kirkman 2005). Seeds experimentally buried in the soil without pulp for two months, and removed for tests in the laboratory germinated at about 57 percent, greater than seeds left in the soil for shorter periods (Conner et al. 2006).

Demography

Pondberry experiences periodic episodes of stem dieback, whether by natural senescence or by fungal pathogens, so that an individual shrub rarely appears to live or persist for more than 10 years (e.g. Godt and Hamrick 1996; Devall et al. 2001). However, pondberry apparently is long-lived as genetic individuals (genets) in stable environments because of clonal growth following dieback from stolons and the production of new stems/shoots from adventitious meristems at or near the base of a surviving stem segment on the ground. An individual shrub may die, but the genet continues to exist by virtue of vegetative reproduction.

Because sexual reproductive success is rarely observed by the production of seedlings, pondberry demography is dominated by the dynamics of vegetative growth, survival, and mortality. These dynamics create size structure within colonies and populations, with shrubs distributed in small to large size classes depending on the total length of stems on each plant. The frequency distribution of plant size in a colony and population usually appears to be skewed, with proportionately smaller plants, and few large plants.

Annual recruitment begins in the spring with the formation new shoots/plants, although vegetative reproduction can occur anytime during the growing season. At the end of the growing season, changes in colony and population size-class structure depend on the number of new plants recruited, the annual growth of plants, the amount of dieback, and the extent of mortality.

In plants, size is a general indictor vigor, future mortality, and reproductive performance (Werner 1975; Solbrig 1981; Westoby 1982; Hara 1984; Hutchings 1989). The demographic performance of larger plants usually is greater than small plants. Pondberry fertility, expressed as the number of flowers per plant, is positively correlated with the size or total length of stems produced during the previous growing season (McDearman 1994a, unpub. data). Longer stems have more axillary buds that produce more flowers. Plant size also appears related to persistence during acute episodes of stem dieback (McDearman, 1994b, unpub. data).

When stem dieback occurs from stem canker, it normally proceeds from the tips of branches downward to older branch segments formed during previous years. Complete dieback on an individual shrub occurs when all branch segments have died back to the ground. The presence of dieback on any branch does not necessarily indicate that total dieback will occur. Observations during an acute episode of stem canker in Delta National Forest (DNF) indicated that smaller plants are more susceptible to complete dieback (McDearman 1994b, unpub. data.)

There are no detailed studies characterizing pondberry demography by size-stage or age dynamics, including survival rates, population rates of growth, and the factors affecting dynamics and rates in different environments. Net changes by general monitoring and observations of various colonies and sites indicate pondberry is not normally subject to annually extreme changes in colony or population size in the absence of land use changes. Significant changes have been observed, however, over the period of a single year in Mississippi, during late summer drought stress and an acute episode of dieback, presumably by *Botryosphaeria*. More than 50 percent of plants died in some plots, and 14 years later the number of pondberry in four of nine plots remained less than that prior to the acute episode of dieback (McDearman 1994b, unpub. data). In contrast, pondberry also is capable of relatively rapid growth (new plants) after acute dieback, and the number of plants at some colonies/sites in Delta National Forest has increased between 2000 and 2006 (McDearman 2006, unpub. data).

Colonies over longer periods of time are known to have declined and become extirpated. The number of pondberry monitored at 49 colonies/sites in the Delta National Forest in Mississippi declined overall by 42 percent from 2000 to 2005, and three colonies/sites were extirpated during this period (U.S. Army Corps of Engineers 2005). Pondberry at the Shelby site in Mississippi also has declined during the past 6 years (Devall 2006, pers. comm.; Echt 2007, pers. comm.). Other colonies/sites have declined and become extirpated in Delta National Forest (Devall 2006, pers. comm.; U.S. Army Corps of Engineers 2005) and Francis Marion National Forest in South Carolina (Raynor and Ferral 1988; Roecker 2001; Glitzenstein et al. undated).

Status and distribution

Pondberry was federally listed as an endangered species on July 31, 1986 (Federal Register 51(47):27495-27500). When listed, the species was known from 12 populations in Arkansas (4), Georgia (1), Mississippi (1), Missouri (1), North Carolina (1), and South Carolina (4). It was considered to be extirpated in Alabama, Florida, and Louisiana where it had been historically collected. The primary threats were inadequate reproduction, wetland drainage, clearing and conversion of wetland habitat, and certain timber harvest practices. The primary wetland habitat for these occurrences and populations represented Carolina bays, limesinks, sand ponds, and bottomland hardwood forests.

According to the pondberry recovery plan, a pondberry population is "one or more colonies that are in close enough proximity to regularly interbreed and be separated from other populations by a sufficient distance to preclude interbreeding on a regular basis" (U.S. Fish and Wildlife Service 1993). The recovery definition recognizes a population as a demographic and genetic unit. Demographically, pollination between male and female plants in a population must occur regularly and sufficiently as one component of reproduction to produce fruits and seeds. Genetically, plants within a population would not be isolated or significantly different from one another, by this definition, because they mostly would be offspring of parents from within the population.

The recovery plan does not further define a population according to a spatial function or distances between pondberry that would prevent regular interbreeding. This was identified as one of the recovery tasks to be completed. Based on long-distance flight distances of ground dwelling bees that pollinate pondberry, Devall et al. (2002) currently consider as an interim definition a pondberry population as a "colony or colonies separated by at least one mile from other colonies." In other words, pondberry colonies separated by more than one mile from other colonies would be separate populations. For this assessment and biological opinion, we have used their 1-mile spatial definition to define and identify pondberry populations. Additional information we considered in adopting this interim population definition is described in Appendix 2 of this biological opinion .

Additional pondberry surveys since listing and the completion of the recovery plan have generated new sites, occurrences, and populations (Plate 2). Most of these changes since listing represent an increase in the number of sites in the vicinity of previously known sites. Surveys in Alabama discovered the species at a site that historically was unknown. Surveys in southern Arkansas discovered pondberry in a rare wetland community type that was not previously known as pondberry habitat. Pondberry is still extirpated from Florida and Louisiana.

Currently, there are 54 potential populations from Alabama (2), Arkansas (19), Georgia (7), Mississippi (16), Missouri (1), North Carolina (2), and South Carolina (7) (Table 2). One of these populations occurs in both Arkansas and Missouri, across the state lines. The data for these population estimates is derived from Natural Heritage Programs in each state as reported by the Corps (e.g. U.S. Army Corps of Engineers 2005b), additional data and communications with Heritage Program and other personnel, and various surveys and monitoring reports. A population is defined by an interim standard as pondberry and sites/colonies within one mile of each other. This spatial function reflects the longest likely distance for potential pondberry pollinator flight, pollen flow, breeding, and gene flow (e.g. Devall et al. 2002). Effective pollination to produce even a small portion of seed or fruit in pondberry or other plant species separated by one mile is not known to occur. The longest effective distance for pollination and for seed production in a temperate North American woody plant is about 800 feet in honey locust (Schabel and Hamrick 1995). This pondberry population definition is conservative, however, because populations at this distance are not likely to be significantly genetically different (Echt, 2006 pers. comm.).

Most of the populations, including the largest, occur in bottomland hardwood forests of the Mississippi Alluvial Valley of Arkansas and Mississippi (Table 2). The largest population is in Arkansas and has been grossly estimated to far exceed 20,000 plants (Tables 2 and 3). It is primarily located in the St. Francis Sunken Lands Wildlife Management Area, managed by the Arkansas Game and Fish Commission, which is a mixture of state, federal (Corps), and privately owned land. The second largest population is in Francis Marion National Forest, South Carolina (Tables 2 and 3), with an estimated 49,000 plants (Glitzenstein and Streng 2004). The third largest population is the Shelby Site, in the Yazoo-Mississippi River delta region in Bolivar County, Mississippi, with at least 20,000 plants (Tables 2 and 3). It is on a single wooded tract, with two private landowners, where a conservation easement protects one of the parcels with about 25 percent of the population. Elsewhere, pondberry is probably most abundant in South Carolina, from populations in limesink ponds and related depressions on the Francis Marion National Forest, and in bottomland hardwoods of the DNF in the Yazoo Backwater Area (Table 2).

Habitat

Pondberry is classified as an obligate wetland species (Reed 1988), occurring in seasonally flooded wetlands of the Atlantic and Gulf Coastal Plain. These wetlands occur in at least five primary and distinctive hydrogeomorphic settings; Carolina bays, limestone or limesink ponds, sand ponds, lowland sand prairie depressions, and riverine bottomland hardwoods. With the exception of bottomland hardwood sites, most all others are geographically isolated wetlands with precipitation as the primary source of hydrology, although some bays and limesinks may receive shallow groundwater (Schalles and Shure 1989; Lide et al. 1995; Chmielewski 1996). Carolina bays and limesinks have been collectively described with other seasonally inundated depressions in the southeastern United States as seasonally ponded, isolated wetlands and non-alluvial depression wetlands (e.g. Kirkman et al. 1999) as a distinction from other wetlands affected by overbank flooding by streams and rivers. Bays and limesinks as referenced here do not include Citronelle ponds and Grady ponds in Alabama and Mississippi. Extant pondberry sites in Carolina bays are in North Carolina and South Carolina; sites in limesink and related depressions are in South Carolina, Georgia, and Alabama; sand ponds are in Arkansas; sand prairie depressions are in southern Arkansas, and bottomland hardwoods in Arkansas and Mississippi. In bottomland hardwoods, the hydrology at pondberry sites is maintained by either overbank flooding, local rainfall or storage in depressions or at sites with soils that impede drainage independent of overbank flooding, or a combination of the previous two factors. Atlantic or Gulf Coastal Plain depressions storing precipitation typically have subsurface soil or geological features that impede drainage.

Carolina bays – North Carolina

Carolina bays are distinctive elliptical depressions on the Atlantic Coastal Plain, oriented in a northwest-southeast direction, ranging from a few hectares to more than 3,600 hectares, with a hydrology dominated by rainfall and evapotranspiration (Sharitz and Gibbons 1982; Schalles and Shure 1989; Lide et al. 1995;

Sharitz 2003). The geologic origin of Carolina bays is still the subject of debate, but probably derived from wind blown waves in ponds and lakes created by fluvial, coastal, and aeolian processes dating back from 15,000 to 109,000 years (Sharitz and Gibbons 1982; Sharitz 2003). Carolina bays have clayey subsoils and hardpans impeding drainage, with surface soils that are mineral to organic depending on hydrology and fire history. Bays have fluctuating hydroperiods, usually with surface water in the center after prolonged rainfall, a high water table, and are wetter during winter and early spring (Knight et al. 1989; Schalles and Shure 1989; Lide 1995; Sharitz 2003). The variation in hydrology, geomorphology, soils, fire and other factors among Carolina bays is associated with at least 11 plant community types (Sharitz 2003; Schafale and Weakley 1990; Bennett and Nelson 1991). In seasonally flooded bays, trees and evergreen shrubs include pond cypress (*Taxodium ascendens*), black gum (*Nyssa biflora*), pond pine (*Pinus serotina*), loblolly pine (*P. taeda*), fetterbush (*Lyonia lucida*), gallberry (*Ilex glabra*), and titi (*Cyrilla racemiflora*).

Limesinks – Alabama, South Carolina, and Georgia

Limesinks are depressions on the lower coastal plain, formed by the subsidence and dissolution of underlying limestone and karst (e.g. Atlantic Coastal Plain Southern Depression Pondshore, Corner et al. 2005), and usually are surrounded by terrestrial vegetation of the longleaf pine ecosystem (Kirkman 2000). Precipitation is the primary source of water, although groundwater from seasonally high water tables may affect some sites (Torak et al. 1991). Limesink ponds typically are smaller than Carolina bays, lack deep organic soils, and do not always develop an extensive and dense evergreen shrub stratum. Limesinks can be small and shallow, less than a hectare in size, to many hectares and up to 20 feet in depth (Kirkman et al. 2000). The hydroperiod and depth of inundation can vary substantially among ponds (Hendricks and Goodwin 1952). Deep ponds have standing permanent water in the center with floating-leaved aquatic plants, and shallower ponds usually are filled only in winter and spring, both with a lateral vegetation gradient in shallower areas reflecting a decreasing hydroperiod (Corner et al. 2005). Vegetation types and gradients are affected by topo-edaphic conditions, fire, and hydrology, ranging from grass-sedge, savanna, and pond cypress-black gum associations (Kirkman et al. 1999; DeSteven and Toner 2004).

Sand ponds – Arkansas and Missouri

The "sand ponds" in Arkansas and Missouri are geomorphologically the rarest and most unique of all the wetland types inhabited by pondberry. Sand ponds occur in the Mississippi Alluvial Valley, but are isolated depressional wetlands. They are located on high terraces of valley train deposits from Late Wisconsin glacial outwash, in relict dune fields of wind-blown sands standing from six to 30 feet above lower landforms and terraces, scattered in a narrow band to the west of Crowley's Ridges in northeastern Arkansas into southeastern Missouri (Saucier 1978; Heineke 1987; Klimas et al. 2004). Ponds range in size from less than one to up to several hectares, and their hydrology is driven by precipitation. The hydroperiod is variable depending on rainfall, with standing water about 50 cm in depth from winter to as long June (Wright 1990). The system has been classified as the Lower Mississippi River Dune Woodland and Forest, overcup oak (*Quercus* lyrata) – pin oak (*Q. palustris*)/ swamp red maple (*Acer rubrum* var. *drummondii*) – pondberry (*Lindera melissifolia*) forest (Comer et al. 2003).

Pond vegetation mostly is closed forest, with an overstory of overcup oak, pin oak, sweetgum (*Liquidambar styraciflua*), Nuttall oak (*Quercus nutallii*), green ash (*Fraxinus pennsylvanica*), and infrequently black gum and cypress. Swamp red maple is common in the understory, with scattered button bush (*Cephalanthus occidentalis*) and Virginia willow (*Itea virginica*). The herbaceous plant layer is very sparse, with Ladies eardrops (*Brunnichia virginica*), jumpseed (*Polygonum virginianum*), and lizard tail (*Saururus cernuus*). The natural vegetation of surrounding areas grades into a more xeric sandhill forest community at the highest elevations, with post-oak (*Quercus stellata*) woodlands. Most of the surrounding forests and vegetation have been cleared for agriculture.

Lowland sand prairies - Arkansas

Lowland sand prairies are riverine wetland plant communities in extreme southern Arkansas, situated on lacustrine terrace deposits of beaches and sand bars derived from the Pleistocene Lake Monroe, and currently are periodically flooded by the Ouachita River in winter and spring with a seasonally high water table (Saucier and Fleetwod 1970; Saucier 1994; Pagan and Foti in preparation; Klimas et al. 2005). The natural vegetation is dominated by herbaceous plants, and has been classified as Arkansas Lowland Little Bluestem (*Schizachyrium scoparium*) – Switchgrass (*Panicum virgatum*) Sand Prairie (Nature Serve). The predominance of a prairie physiognomy has been considered the response to a mosaic of xeric-hydric conditions and potentially toxic accumulations of aluminum in soils (Pagan and Foti, in preparation). Woody plants mostly are restricted to the edge of the prairie, and occur sporadically within the prairie where they are stunted. These include button bush, sweetgum, deciduous holly (*Ilex decidua*), and honey locust (*Gleditsia tricanthos*). Soils are dominated by Haggerty series, and pondberry occurs on the Guyton frequently flooded series. The wetland prairies are surrounded by mature bottomland hardwood forests.

Bottomland hardwoods – Arkansas and Mississippi

The bottomland hardwoods of the lower Mississippi River Alluvial Valley in Arkansas and Mississippi are generally characteristic and similar to bottomland hardwood forest communities elsewhere in the southeastern United States. The formation and occurrence of major forest communities and types is affected by the frequency and duration of flooding, tolerance to inundation, landforms, and soils (Putnam and Bull 1932; Braun 1950; Penfound 1952; Shelford 1954; Brown and Lugo 1982; Conner and Day 1982; Wharton et al. 1982; Christensen 1988; Touchet et al. 1990; Brinson 1990; Sharitz and Mitsch 1993). Pondberry is not restricted to a single forest type or geomorphic landform, although it is not known to occur in cypress and gum dominated swamps in sloughs, isolated, or connected depressions. Bottomland hardwood forest types with pondberry are mostly mature forests, with various dominant and codominant trees that include willow oak (*Quercus phellos*), overcup oak (*Q. lyrata*), sweetgum, cedar elm (*Ulmus crassifolia*), American elm (*U. americana*), and winged elm (*U. alata*), box elder (*Acer* negundo), sugarberry (*Celtis laevigata*), green ash (*Fraxinus pennsylvanica*), water hickory (*Carya aquatica*), and pecan (*C. illinoensis*) (Tucker 1984; Devall et al. 2001; Hawkins et al. 2005; Attachment 1 - U.S. Army Corps of Engineers 2005).

These bottomland hardwood forests hydrogeomorphically occur as Riverine as well as Depressional wetland classes (Smith and Klimas 2002; Klimas et al. 2004, 2005). Riverine Backwater wetland subclasses occur on backswamp deposits, with such trees as green ash and Nuttall oak, and are subject to backwater flooding. Pondberry also is known to occur in included depressions (vernal pools) within Riverine Backwater subclasses. Two distinctive included depressional ponds (vernal pools) with pondberry are known on Delta National Forest (DNF), each about two acres, which store winter rainfall into spring and also are subject to and store backwater flood water. Overall, the source of hydrology at pondberry sites in bottomland hardwoods is derived from storage of rainfall in depressions, storage of floodwater in depressions, backwater and headwater flooding of streams, and combinations of these factors. These sources and combinations can vary at different sites.

State status

Alabama

Pondberry was rediscovered in Alabama at two sites in Covington County (Alabama Natural Heritage Program 2004), which comprise two separate populations. About 350 plants occur in one pond, with swamp tupelo, myrtle dahoon (*Ilex myrtifolia*), and red maple (*Acer rubrum*). Several thousand plants occur at one end of the other pond, where the other end recently was clearcut, bedded, and planted for pine production. Associated woody vegetation included swamp tupelo, laurel oak, myrtle dahoon, and slash pine (*Pinus elliottii*). Both ponds/sites are owned by a timber company, and at least one site is threatened by continued conversion to intensive pine plantation management.

Arkansas

From surveys after the species was listed, site occurrences increased to 45, representing 24 potential populations. However, these have now declined to 34 sites (Arkansas Natural Heritage Commission data) and 19 populations (Table 2). These changes have occurred in the sand pond communities of Clay, Jackson, and Lawrence Counties. Of the 13 sand pond sites considered as extirpated, eight were drained, cleared and converted to agriculture. One other extirpated sand pond was heavily logged. Pondberry in the four remaining sand pond sites became extirpated apparently due to natural factors associated with small colonies/populations. The largest remaining range wide population occurs in Arkansas, in the St. Francis Sunken Lands Wildlife Management Area.

The 17 extant sand pond populations consist of 32 sites or ponds, although, most populations are very small: 11 consist of only a single pond, five have from two to four ponds each, and one population consists of eight ponds. The number of colonies reported at each site/pond occurrence varies from one to 15, and the number of plants where described for a colony ranges from several to several hundred. No information is available for the number of colonies or plants for 19 of the 31 sand pond sites. A total of 50 colonies have been identified from general surveys at 12 sand pond sites. With this relationship, then there may be about 129 colonies for all 32 sand pond sites. The average number of pondberry in 49 profiled colonies in DNF from data by the Corps (U.S. Army Corps of Engineers 2005a) was 40 plants per colony. In the absence of other site specific data for sand ponds, the DNF data indicates the number of pondberry at each sand pond population may range from less than 500 plants to about 1,200 plants (Table 2). The estimated size of each population depends on the number of ponds and colonies per population.

The largest sand pond population is probably the complex along U.S. Highway 67, with eight ponds, and perhaps 1,200 plants. The population is highly fragmented, along and either side of the highway, and in land cleared primarily for agriculture. The second largest population probably is the Stateline Sand Ponds natural area, Clay Co., owned and managed by the Arkansas Natural Heritage Commission. It consists of two sites with about 15 colonies, estimated to have hundreds of plants.

Other than the Stateline Sand Ponds area, all other sand ponds are privately owned, and are considered to be threatened primarily by clearing and conversion to agriculture. All of these ponds are small woodland inclusions surrounded by agricultural fields. Farmers in recent years have increased the use of clearing and land leveling. Several sand ponds, though not necessarily with pondberry, have been cleared, leveled, and converted to agriculture in recent years (Osborne 2006, pers. comm.). Sand ponds previously were classified as wetlands, protected by section 404 of the Clean Water Act and Swamp Buster provisions, but the geographically isolated wetlands no longer appear subject to 404 wetland protections (Murray 2006, pers. comm.). Pondberry is extirpated in at least eight sand ponds that have been drained or filled and converted to agriculture (Table 2).

Pondberry populations in sand ponds also are threatened by the fragmentation and the conversion of the interconnected matrix of forests to agriculture. Each pond has a slightly different hydrology. Seed dispersal by hermit thrushes, for example, to reestablish pondberry in ponds after local extirpation is not likely because of the loss of the surrounding forests thrushes normally would use and require for resident habitat.

The lowland sand prairie population in Ashley County is within the Coffee Prairie Natural Area, Beryl Anthony-Lower Ouachita Wildlife Management Area, which is owned and managed by Arkansas Game and Fish Commission. The natural area is a state designation, and the site is considered to be protected. However, only about 10 pondberry plants occur at the site (Arkansas Natural Heritage Commission data), and the small population is highly vulnerable to local extirpation due to demographic and environmental stochasticity.

The last population is the most recently discovered and largest in Arkansas. Also, it is probably the largest of all remaining populations throughout the species range (Vanderpool et al. 2004). This population occurs in bottomland hardwood forests in Craighead and Poinsett Counties, in the St. Francis Sunken Lands Wildlife Management Area (SFSL WMA) along the St. Francis River, in the Mississippi Alluvial Valley. The SFSL WMA consists of mixed land ownerships, state, private, and the U.S. Army of Corps of Engineers. The WMA and the population are within a Corps designated and leveed floodway of the St. Francis River. The population covers at least 1,000 acres, with over 280 colonies, that has been described as having tens of thousands of plants, of which at least one-third are fruit producing females (Vanderpool et al. 2004; Osborne 2006, pers. comm.; Tucker 2006, pers. comm..; Margaret Devall, 2006, pers. comm.). In comparison to other pondberry populations in Arkansas, Vanderpool et al. (2004) considered that the flowering, fruiting, and reproduction in this population is probably intact. The Arkansas Natural Heritage Commission currently is working with the Arkansas Game and Fish Commission to develop a forest management plan to protect pondberry in the WMA (Osborne 2006, pers. comm.).

This population is annually flooded by the Corps operation of the floodway. The hydrology also may involve ponding of floodwaters, but the site specific factors have not been assessed. The site, while in the Mississippi River Valley, is on a terrace above the Mississippi River floodplain proper, created by the deposition of glacial outwash sediments during the Pleistocene. It is not flooded by the Mississippi River. Valley Train ponds are shallow, depressional basins on these terraces, associated with outwash deposits between the White River and Crowley's ridge, and the St. Francis River lowlands (Klimas et al. 2005). This large population may be associated with one or more valley train ponds, which stores floodwater as well as precipitation.

Florida

Pondberry is known historically from Florida only from collections by Chapman, without any other specific locality information on the specimens (Tucker 1984).

Georgia

Pondberry occurs at seven sites, each with small population in Baker, Calhoun, Effington, Wheeler, and Worth Counties, with probably no more than a total of 2,500 pondberry plants from all populations (Georgia Natural Heritage Program data). From 30 to 1,500 plants were described at each of five of these populations. No information is available to estimate the number of plants or colonies from two populations. Each population is associated with a single depression or pond.

The Baker County population, the largest, occurs in a single pond, with about 1,500 plants, on the Joseph W. Jones Ecological Research Center, where it is protected and managed. The Nature Conservancy owns and manages the property for the Wheeler County site/population, with about 200 plants. All other sites/populations are on private lands, with from 100-500 plants estimated for each (Tables 1 and 2). Overall, the populations in Georgia are vulnerable to local extirpation because of their very small size, and at least one pond has been disturbed by timber management and site-preparation for timber regeneration.

Two populations, with a single pond each, recently have become extirpated. One depression appears to have been adversely affected by hogs and cattle. Pondberry at the other pond site/population may have become extirpated due to effects of mowing and adjacent golf course management.

The habitat for these GA populations has been described as ponds, cypress domes, sink holes, and sandhill ponds. These are not uncommon variations or associations within the Atlantic Coastal Plain Southern Depression Pondshore wetland system (Corner et al. 2005), which accommodates limesinks, sandhill ponds, and other geographically isolated wetland types. The Wheeler County site/population, as described by Devall et al. (2002), appears to be an unusual variant, described as a bog, although it also is depressional.

Louisiana

There are two historical records, one from a specimen collected by Hale without any location information (Tucker 1984), and another record from Carpenter, described from low banks along the Ouachita River near the Arkansas line (Thomas and Allen 1998, e.g. U.S. Army Corps of Engineers 2005). The historical Ouachita River site could be related to the nearby low sand prairie terraces in Arkansas where pondberry occurs. Surveys in Louisiana have not found any extant populations.

Mississippi

When listed, pondberry was known from one population in Mississippi in the DNF. From subsequent surveys, pondberry currently is known from 16 potential populations, grossly estimated with a total of at least 44,000 plants (Table 2). These estimates are not derived from a sampling or statistical protocol designed to estimate population size. They are variously based on surveys and counts at selected colonies by the Corps (U.S. Army Corps of Engineers 2005b), samples from permanent plots in one population (McDearman 2006, in litt.), surveys and monitoring elsewhere in DNF and in Bolivar County by U.S. Forest Service scientists studying pondberry, and the opinions from those studying these sites in combination with monitoring and other data. Three of the 12 largest range wide populations occur in Mississippi (Table 3): the Shelby site in Bolivar Co. (>20,000 plants), the Colby population in DNF (>20,000 plants), the Red Gum population in DNF (8,200 plants), and the Spanish Fort population in DNF (3,900 plants).

The largest state population is in Bolivar County, with more than 20,000 plants. There are at least 35,600 plants from all 13 populations in DNF, where most occur in just three populations, with at least 20,000, 8,200, and 3,800 plants. The number of pondberry in each of the remaining populations ranges from about 60 to 360 plants. Elsewhere in Sunflower County, about 1,500 occur at two sites in a population on privately owned land. Collectively, there are at least 200 colonies associated with the populations in Mississippi.

The largest population in Bolivar County is a bottomland hardwood tract of about 640 acres, surrounded by agricultural fields, divided as two privately-owned parcels. One parcel is protected by a conservation easement with the Service, covering about 25% of the total population. The landowner of the other parcel does not farm, has been cooperative with the many investigators and ongoing pondberry studies at the site, and gives no indication of any immediate interest to convert the parcel to other land uses. However, pondberry at this site appears to be declining recently (Devall 2006, pers. comm), with substantial dieoff during the last few years in the southern part of this population (Echt 2007, pers. comm.), although the specific cause is not known. It could involve stem dieback and changes in hydrology, including excessive water, from runoff in adjacent rice fields. Hydrology at this tract, which is located on what currently is the 100-year floodplain in the Upper Yazoo Basin, appears to depend in part from periodic runoff from the adjacent rice fields. Otherwise, overbank flooding from streams is not currently an important factor affecting hydrology. The historic flood frequency prior to the completion of flood control projects in this area is not known. Currently, runoff from flooded rice fields could benefit pondberry and be a contributing factor maintaining this large population. If so, the presence status of this population would not reflect natural conditions, and any change in agricultural practices that reduce or eliminate runoff could reduce the population to lower, natural threshold. Alternatively, runoff for long periods during the growing season could be a negative factor. These factors are poorly known.

The U.S. Forest Service protects pondberry populations and stands in the DNF from adverse ground disturbance and other activities during forest management. The Service has concurred that their management is not likely to adversely affect pondberry as a result of informal section 7 consultation under the Act. Nevertheless, pondberry at 49 selected colonies monitored during 2000 and 2005 declined by about 42 percent, from 11,748 to 6,775 plants. Factors associated with this decline are described and assessed in more detail in the Environmental Baseline.

The other population on private land in Sunflower County is vulnerable to disturbances from nearby agriculture, where two colonies have been recently been extirpated. Colonies/sites in this population are located in small patches of woods, bordering a drainage ditch, adjacent to agricultural fields. In a manner similar to the Bolivar County population, certain colonies/sites in this population periodically are affected by water from adjacent rice fields, both beneficially and detrimentally.

A small population in Bolivar Co., with 500 plants in 2000, was listed as extirpated by 2005 (U.S. Army Corps of Engineers 2005a). During 2000, the site was flooded with water from rice fields during the growing season and plants were wilted. In 2006, however, the colony was relocated by GSRC during surveys for the Corps during leaf-off conditions, appearing similar in size to 2000, but could not be counted because of flooded conditions (U.S. Army Corps of Engineers 2007). Nevertheless, excessive flooding during the growing season from rice production may cause stress and decline in this population, or may even augment favorable conditions.

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Missouri

Pondberry in Missouri is represented by a single natural population at five sites in the Sand Ponds Conservation Area, Ripley County, owned and managed by the Missouri Department of Conservation (Table 2). This population, with at least 5,000 plants, is ranked as the ninth largest range wide (Table 3). The population is on the Arkansas-Missouri border, contiguous to and part of the same population in Arkansas at the Stateline Sand Ponds Natural Area in Clay County. The Missouri segment of the population occurs in at least five ponds/sites, collectively with at least 5,000 plants (Smith 2006, pers. comm.). The Missouri Department of Conservation attempted unsuccessfully to experimentally establish a second population in sand pond areas of Butler County, at the Corkwood Conservation Area (Smith 2003). There are probably 100 surviving plants at the Corkwood site.

North Carolina

Pondberry in North Carolina consists of two populations (Table 2), in Sampson and Cumberland Counties, both in clay-based Carolina bays, and mostly publicly owned and managed. The population in Sampson County has recently been acquired and protected by the North Carolina Plant Conservation Program. The population appears to be declining. In 1991, about 1,200 pondberry plants were estimated, and by 2000 it is described by the North Carolina Natural Heritage Program as consisting of about 250 plants.

The Cumberland County population at Big Pond Bay consists of 4,000 to 5,000 plants on about 4 acres in 1992. Of the three tracts, two are publicly owned and managed by the NC Plant Conservation Program. The private owners of the third tract are aware of the important pondberry population, and are considered to be cooperative owners for future conservation (Williams 2006, pers. comm.). One of the tracts was recently disturbed by a clearcut prior to its acquisition by the State. The removal of trees has increased sunlight and released the shrub layer, which is expected to increase shrubby growth, cover, and adverse competition to pondberry. Pondberry in the clearcut is being monitored, and this site and others probably will require future management to control adverse effects of shrub encroachment and overgrowth to pondberry (Suiter 2006, pers. comm.). This is ranked as 8th largest range wide population (Tables 2 and 3).

A third population in Bladen County has recently become extirpated. Tucker in 1979 described the Bladen County site to consist of "numerous" plants (Tucker 1984). From 50 to 60 plants were described later in 1983, and no plants subsequently have been found during surveys in 1994, 1995, and 1998. Leonard (1995) described the site as overgrown with a dense thicket of fetterbush. Pondberry is not considered to be very tolerant of interspecific plant competition, and the conditions described by Leonard (1995) are indicative of the likely source of decline. Tucker (1984) describes the site from 1979 as having been severely burned in the late 60's, killing most trees, and opening the understory to a dense growth and thicket of shrubs. These conditions are not uncommon in Carolina bays, which are known to develop impenetrable shrub thickets in the absence of periodic fire. Also, the site apparently has been adversely affected by drainage ditches for increased timber production. Hydrologists estimate the normally high subsurface water table in Bladen County has dropped by about two feet due to drainage in Carolina bays and related habitat types (LeBlond 2006, pers. comm.).

South Carolina

Pondberry in South Carolina consists of 14 sites representing 7 populations in Beaufort and Berkeley Counties (Table 2). Five of these populations are in Francis Marion National Forest (FMNF), one at the U.S. Marine Corps Air Base in Beaufort County, and one population on private land in Beaufort County. Pondberry sites in FMNF and the Marine Corps Air Base have been surveyed and monitored during recent years. Four of the largest 12 range wide populations occur in South Carolina: the Brick Church-Hoover Rd population in FMNF (50,000 plants), the Marine Corps Air Base population (8,600 plants), the Whiddon Bay population in FMNF (8,100 plants), and the FMNF Honey Hill population (3,500 plants) (Table 3).

The Brick Church-Hoover Road population in FMNF, with at least six sites, is the largest population in South Carolina, with at least 49,800 plants (Tables 2 and 3). Most of the pondberry occurs throughout one bay site where the longer hydroperiod limits encroachment by fetterbush and other competing shrubs to pondberry (Glitzenstein and Streng 2004). Segments of this population are declining, however, at two sites, apparently due to heavy encroachment of competing shrubs (Glitzenstein and Streng 2004). The Forest Service has prescribed fire to restore vegetation along the edge of bays and depressions, where competing shrubs have encroached in the absence of fire. The effectiveness and ability to prescribe sufficient fire to control fetterbush and other shrubs, without adversely affecting pondberry over the long-term, has yet to be demonstrated. A separate but nearby population is an experimental site where pondberry was reintroduced, with fewer than 100 plants.

The Whiddon bay population-site has about 8,100 plants in a single depression, the second largest SC population, which also is ranked as the 7th largest population range wide (Tables 2 and 3). Current habitat conditions indicate a program of prescribed fire will be needed in the near future to control competition and shrub encroachment (Glitzenstein and Streng 2004).

The largest historically known population in South Carolina is in FMNF, the Honey Hill area, where Raynor and Ferral (1988) estimated over 10,000 plants in this mosaic of limesinks in 1988. Thirteen years later, Roecker (2001) estimated the Honey Hill population had declined to about 300 plants, and Glitzenstein et al. (undated) separately estimated a decline to 1,048 stems from their surveys, with a loss of 27 of the original 54 colonies. The probable cause of the decline was a combination of drought, with the dense encroachment of woody shrubs and trees along the edge of pond, competing with pondberry in the absence of fire when ponds were at low water or without water. The Forest Service and South Carolina Native Plant Society, with support from the National Wildlife Federation, initiated a pondberry restoration plan by creating canopy gaps and hand-clearing competing shrubs. Monitoring has indicated that pondberry is no longer severely suppressed under competing shrubs, with an average plant size in the remaining colonies that has doubled after restoration treatment (Glitzenstein et al. undated), and an increase in the population to at least 3,567 plants (Glitzenstein and Streng 2004). The Honey Hill population is ranked as the 5th largest population in South Carolina, and the 11th largest range wide (Tables 2 and 3).

The Conifer Road population consists of about 2,000 plants at a single Carolina bay site. Frequent prescribed fire appears to have controlled the encroachment by fetterbush, but prescribe fire now may be too frequent, with suppressing effects to pondberry (Glitzenstein and Streng 2004).

The last FMNF population at Euchaw Road is extremely small, with less than 50 plants.

The Beaufort County population at the Marine Air base is the 3rd largest in the state (Table 2), and 5th largest range wide (Table 3). It consists of eight sites that have been surveyed and monitored annually by the Service over the past 5 years. The total number of pondberry in the population has annually ranged from 6,473 to 8,662 plants (Eudaly 2005). Management plans are being developed to control competing vegetation encroachment on the edge of ponds by prescribed fire and thinning.

Pondberry is protected by federal land and resource management plans in FMNF and the Marine Air base, and benefits from other actions intended to restore and maintain habitat.

The last population in the state is in Beaufort County, with no other information on relative abundance.

The primary threats to the larger populations on federal lands concern habitat restoration and maintenance to control encroaching shrubs and competition on the edge of bays, sinks and ponds. Pondberry in these wetlands also occurs on the fringe, where the vegetation naturally and historically was affected by fire. Periodic, frequent, low intensity fire historically controlled encroachment and competition by other shrubs and trees. Efforts to restore the population at Honey Hill, for example, have required hand-pruning and removal of shrubs because of heavy fuel loads that have accumulated in the absence of a natural fire regime. Pondberry appears resilient to low-intensity fire, but the effects of restoration treatments with more intense fire could be adverse. The problem, which has yet to be completely resolved, is how to restore habitat without causing a permanent loss to pondberry in the treatment.

Another threat is that pondberry has rarely been observed to produce flowers or fruits in these populations (Eudaly 2006, pers. comm..; Roecker 2006; pers. comm..). It is not known whether this is a response to small plant size in areas with heavy shrub encroachment, or if this is perhaps a genetic effect of local inbreeding. Periodic sexual reproduction and recruitment is required for long term genetic and demographic viability.

Limiting factors and recovery

According to the recovery plan, pondberry may be downlisted as threatened when 15 self-sustaining populations are protected, and delisted with the permanent protection of 25 self-sustaining populations (U.S. Fish and Wildlife Service 1993). Recovery plans, as defined by section 4(f)(1) of the Act, include actions necessary to achieve the plan's goal for the "conservation and survival of the species." Conservation is defined as all methods and activities to bring a listed species to the point where it no longer needs to be listed and protected under the Act (section 3(3)). Survival is not defined by the Act or implementing regulations, but is described in the Service's section 7 consultation procedures and policy. Survival is the species' persistence beyond conditions leading to its endangerment, with sufficient resilience to allow recovery from endangerment (U.S. Fish and Wildlife Service 1988). Survival is the condition in which "the species continues to exist in the future while retaining the potential for recovery."

The criteria defining a self-sustaining pondberry population and the geographical distribution of such populations were not defined in the recovery plan. A self sustaining population is equivalent to a viable population. These determinations were identified as recovery tasks, which have not been completed. These tasks, fundamentally, consist of a population viability analysis (PVA). The objective of a PVA is to predict and assess the probability that a population will either continue to persist in the future, or the likelihood that it will become extinct. PVAs typically are mathematical models and simulations of biological data to forecast and the future size, growth, or decline of populations and the environmental factors affecting such trends (e.g. Morris and Doak 2002). There are a number of methods and approaches to analysis, but in most instances, the data and models are demographic assessments of how stochastic or random demographic, genetic, and environmental factors affect population persistence and extinction (Groom and Pascual 1997).

Demographic PVAs require extensive data from studies of growth, reproduction, and survival of individuals at different ages or stages in populations. These or other data for different mathematical models currently are inadequate for a pondberry PVA. This is not an unusual condition for rare and endangered plants, where there are few detailed demographic and other comprehensive data to assess population viability (Schemske et al. 1994). However, the general attributes of a self-sustaining population are sufficiently known to assess the status of existing pondberry populations and their relative values for survival and recovery, according to the best available information. With the principles of conservation biology in the absence of comprehensive data for PVAs, the relevant factors to evaluate are life history traits that affect demography; the extent that numbers of individuals and populations are increasing, decreasing, or stable; and the biological or environmental factors likely to affect growth and survival (Schemske et al. 1994).

Self-sustaining pondberry populations for survival and recovery must be sufficiently large (number of individuals) to be demographically and genetically viable. Furthermore, there must be a dynamic balance among the populations and the patches of habitat they occupy in an area so that the rate of local extirpation in patches does not exceed the rate of seed dispersal and colonization creating new populations or population segments at other suitable habitat patches. Demography refers to the population dynamics of either a net increase or decrease in the size of the population as derived from individual growth, reproduction, and mortality, as well as the effects of the environment on these vital rates. Genetic viability consists of sufficient heterozygosity and polymorphism among individuals within a population to avoid adverse effects of inbreeding depression and genetic drift, while ideally retaining sufficient additive genetic variation to respond to natural selection. The dynamics among populations at local and regional scales, where local extirpation is balanced by colonization and the natural establishment of new subpopulations, are processes of a metapopulation.

Based on these factors, as further described in the following sections, the survival and recovery of pondberry depends crucially on the 12 largest remaining populations in large tracts of protected and managed lands in different regional environments with different hydrologies. The size, location, and distribution of these populations provide several functions important for survival and recovery, including: 1) the ability to avoid detrimental effects of small populations due to inbreeding depression and demographic stochasticity, 2) sufficiently large populations to survive the magnitude of declines recently observed in some large populations, 3) a regional distribution in different wetland environments to buffer against local climatic periods of drought, 4) a distribution in the Atlantic and Gulf Coastal Plain to avoid or minimize the adverse effects of laurel wilt disease which currently is spreading through the Atlantic Coastal Plain, 5) relatively large tracts of wetland environments and unoccupied but suitable habitat patches where new colonies and subpopulations can be established from infrequent sexual reproduction, seed production and dispersal to balance local extirpation, and 5) habitat restoration, management, and protection to geographically isolated wetlands that are no longer covered under section 404 of the Clean Water Act.

Population size, distribution, and management

Large pondberry populations are important for survival and recovery for a number of reasons, as indicated by many studies from other species. The size and distribution of plant populations are important factors affecting population viability through demographic, genetic, and metapopulation dynamics. Small populations in fragmented landscapes are more likely to experience the adverse effects of demographic, environmental, and genetic stochasticity, which negatively affect viability (Oostermeijer et al. 2003). Small populations are vulnerable to chance or random demographic events in the rate of growth, reproduction, or survival that can drive a population to extinction. These demographic consequences and risks usually are restricted to plant populations that consist of less than 50 plants (e.g. Keiding 1975; Menges 1991, 1992; Lande 1993; Oostermeijer et al. 2003).

Of the 54 pondberry populations, general estimates are available for the size of 51 populations (Tables 1 and 2). Most of these probably are not at a significant risk to local extirpation due demographic stochasticity in small populations. The size of only about four populations (AR-1, MS-3, Table 2) are less than 50 plants. This is due to the ecology of pondberry as a strongly clonal plant, where demographic recruitment and the size of populations is dominated by the vegetative, asexual production of new shoots either from rhizomes, root collars, or the base of senescent stems near the ground. Most of the shrubs in any pondberry population are clones or genets of a much smaller number of genetically unique individuals (Godt and Hamrick 1996; Echt et al. 2007; Echt pers. comm. 2007). Demographically, the growth, decline, and persistence of existing pondberry populations is mostly affected by the vegetative production and survival of stems and shoots. This is a common demographic and life history character among shade-tolerant, clonal, shrub species of a forest understory, with infrequent sexual reproduction (e.g. Silverton et al. 1993, 1996).

Other consequences of small plant populations are inbreeding depression and genetic drift (Ellstrand and Elam 1993). The ability of pondberry to reproduce vegetatively can avoid the adverse effects of demographic stochasticity in small populations, but one of the tradeoffs in the absence of frequent sexual reproduction and recruitment is the susceptibility to inbreeding depression and drift. This is because the number of genetically individual plants in a pondberry population is less than the number of actual clonal shrubs.

Inbreeding depression occurs in small plant populations where mating opportunities are limited and closely related individual plants mate, producing offspring with deleterious homozygous recessive alleles which reduce growth, reproduction, or survival (Barrett and Kohn 1991). Genetic drift is an outcome and process by which alleles are lost and genetic diversity decreases in small populations due to the random loss of individuals with such alleles. Small populations usually are less genetically diverse (Ellstrand and Elam 1993; Fenster and Dudash 1994; Fischer and Matthies 1998; Paschke et al. 2002), comprised of individuals that are less fit (e.g. Fischer et al. 2000; Pluess and Stocklin 2004). Generally, the potential for inbreeding depression and drift is most likely in populations with less than 50 individuals (Menges 1991). However, inbreeding depression also is known in larger plant populations (Keller and Waller 2002). The adverse effects of small populations and inbreeding depression include a reduction in seed germination rates (Menges 1991b; Heschel and Paige 1995; Newman and Pilson 1997; Richards 2000), number of seeds (Oostermeijer et al. 1994, 1995; Fisher and Matthies 1998; Morgan 1999; Kery et al. 2000; Lennartsson 2002), seed size (Karen 1989; Heschel and Paige 1995; Schmidt and Jensen 2000), and offspring growth and survival (Dudash 1990; Heschel and Paige 1995; Lennartsson 2002). The loss of genetic variation in small populations can reduce population growth, and cause extirpation or increase its likelihood (Menges 1991; Widen 1993; Oostermeijer et al. 1994; Newman and Pilson 1997; Saccheri et al. 1998; Brook et al. 2002).

Pondberry populations consist of only a few clones, and are genetically depauperate relative to most other woody plant species (Godt and Hamrick 1996). Of the 25 self sustaining pondberry populations required for recovery, currently there are only 12 large populations with potentially more than 50 genetically individual (genets) plants in each, where adverse effects of inbreeding depression and genetic drift on population viability may not be occurring. Each of these 12 populations consists of 3,000 or more plants (Tables 1 and 2), but most of these "plants" are clones. Of 49 pondberry colonies or patches profiled by the Corps (U.S. Army Corps of Engineers 2005b) in the Delta National Forest, MS, there were on average about 40 plants or shrubs per patch, with a range from 2 – 1,280 shrubs. As an estimate of the average colony size, then a population of at least 2,000 plants would be required to represent, on average, 50 individual plants. Each of the 12 largest remaining pondberry populations with more than 3,000 plants probably is large enough to consist of 50 or more genets to avoid the detrimental effects of inbreeding depression and genetic drift to viability. However, even some of these largest remaining populations may be at risk.

For example, Godt and Hamrick (1996) detected only 18 genetically different clones (genets) or individuals in the Colby population in Delta National Forest in their genetic study with allozymes, but this was the most genetically diverse of the populations throughout the range they assessed. Overall, they found that pondberry was genetically depauperate relative to other woody species. We currently estimate the Colby population to consist of at least 20,000 plants (Table 2), which would indicate in consideration of the clonal nature of this species that this and similarly large populations should not be at a significant risk for inbreeding depression. Echt (pers. comm., 2007) has found greater levels of genetic heterozygosity and polymorphism in pondberry during an ongoing study with DNA microsatellites, with at least 100 genets in the Colby population. Nevertheless, preliminary genetic data (microsatellites) from 14 populations across the range of pondberry statistically indicates inbreeding in the Colby and Spanish Fort populations in DNF, as well as in portions of the larger St. Francis River population (Table 3) in Arkansas (Echt et al. 2007). The St. Francis River population is estimated to consist of over 20,000 plants (Tables 2 and 3). Echt's genetic study has not been completed, but available data indicate that even some large populations may be at risk for inbreeding depression. Of 224 plants sampled and genotyped in the Red Gum population in Delta National Forest, Mississippi, which we estimate to consist of at least 8,200 plants (Table 2), there were only 38 genotypes or genetically unique (genets) individuals (Echt, pers. comm. 2007). In the St. Francis WMA population in Arkansas, with more than 20,000 plants (Table 2), Vanderpool et al. (2004) estimated there are 280 pondberry colonies based on colonial structure and patches, which would be indicative of a sufficient number of genets to avoid inbreeding depression. Yet, genetic sampling by Echt (pers. comm.. 2007) found only 110 genets, with evidence of inbreeding in portions of this population.. Of the 39 smaller pondberry populations, ranging from 100 – 3,000 plants (Table 1), most of these probably are vulnerable to the adverse effects of inbreeding and genetic drift.

These smaller pondberry populations also are likely to experience a lower level of seed production and recruitment of new plants by successful sexual reproduction. In plants that require pollinators for reproduction, small plant populations in fragmented habitat are susceptible to low reproduction and seed set (Aguilar et al. 2006), which can reduce population growth rates as well as lead to local extirpation or extinction (Groom 1998, 2001; Lennartsson 2002). The extent of such losses are affected by the plant breeding and pollination system. Pondberry is a dioecious plant, in which individuals are either male or female, and cannot produce seed without pollinators transferring pollen from one plant to another. Dioceious species are highly susceptible to a reduction or loss of reproductive success in small populations (Steffan-Dewenter et al. 2002; Aguilar et al. 2006). Diminished rates of seed and fruit production in small, fragmented populations arise from a variety of mechanisms that limit and alter pollinator attraction, flight behavior, and the amount and quality of pollen deposited (Didham et al. 1996; Kearns et al. 1998; Wilcox and Neiland 2002). These factors, collectively, are known as Allee effects, where there is low reproduction in response to low population size and density (Allee 1951).

As the distance to neighboring plant patches increases, pollen flow among patches by pollinators in small plant populations decreases. As this isolation increases, a threshold distance exists at which pollinators transport little or no pollen into the patch (With and Christ 1995; Groom 1998, Fahrig 2002; Wagenius 2006). The actual distance will vary depending on the species, plant breeding system, and plant-pollinator ecology. In small populations in some species, the threshold patch isolation distance can be as little 85 feet (26 m) (Groom 1998). Most small plant populations already are inherently vulnerable to extirpation due to demographic, environmental, and genetic stochasticity. Strong Allee effects further increase the vulnerability of small populations in increasingly isolated patches (Lande 1987; Dennis 1989; Menges 1992).

In contrast to the stochastic demographic and genetic risks of extirpation in small plant populations, environmental stochasticity can adversely affect small and much larger populations (Goodman 1987; Lande 1993; Menges 1990, 2000; Lennartsson 2002, and Oostermeijer 2001). Environmental stochasticity is the variation in the physical environment, causing good and bad years or periods in vital plant population demographic rates due to factors including rainfall, temperature, disease, herbivores, fire, and competition. For any given average demographic rate (growth, reproduction, survival), the risk of extinction or local extirpation increases as environmental variation and its effect on demography increases (Menges 1990, 1991, 1992, 2000).

Data on the rate of decline of pondberry at several sites and populations indicates that large populations are required to buffer against the risk environmental stochasticity and periods of decline. In the Francis Marion National Forest, for example, the Honey Hill population declined from about 10,000 plants in 1988 to less than 1,000 13 years later (Rayner and Ferral 1988; Roecker 2001). In DNF in Mississippi during 2000 to 2005, 49 profiled colonies/sites monitored by the Corps declined from 11,748 to 6,775 plants, a loss of about 4,900 plants, or 42% in 5 years. Declines of this magnitude, at a loss of up to 10,000 plants in 10 years at the Honey Hill population, could cause the extirpation of 47 of the 51 range wide pondberry populations for which there are estimates of population size, if such declines were to occur in these populations. There are only four populations with 10,000 or more plants that can survive a decline of this size (Table 1). Given the risks indicated by these magnitudes and rates of decline in South Carolina and Mississippi, larger populations than those currently existing probably will be required for long term survival and recovery.

As previously described in the South Carolina status review, the decline at the Honey Hill, SC population appears to be a complex response to periodic drought, in the absence of a natural fire regime, coupled with the encroachment of fire intolerant, competing shrubs, further into wetlands that suppressed pondberry. The wetland hydrology for pondberry is established and maintained by different sources regionally, with variation within and between regions. This hydrology is based on either local precipitation stored in depressions or at sites with other factors impeding drainage, overbank flooding from streams with storage in depressions, overbank flooding without depressional storage, or a combination of these factors. Large pondberry populations in different physiographic regions range wide are required for survival and recovery where the environmental factors affecting hydrology, on average, would be asynchronous.

The developmental sequence of drought that can adversely affect hydrology and pondberry begins with meteorological events reducing precipitation, followed by soil moisture drought, and eventually hydrological drought (e.g. Andreadis et al. 2005). Pondberry is susceptible to decline during drought cycles, especially in geographically isolated wetlands as Carolina bays, limesinks, related depressions in the Atlantic Coastal Plain, and the sand ponds of Arkansas and Missouri where the hydrology depends most directly on rainfall. The hydrology of these wetlands varies depending on rainfall, water storage, and the extent there is groundwater discharge (Sharitz 2003; De Steven and Toner 2004). Some limesinks, for example, have groundwater connections, while the hydrology of most other Atlantic Coastal Plain depressions is determined by precipitation. During the recent 1998-2002 drought in South Carolina, the hydrological conditions in Carolina bays varied, causing changes in vegetation and species composition that reflected hydrological dynamics during this period (Mulhouse et al. 2005). In bottomland hardwood systems in Mississippi and Arkansas, the frequency and duration of overbank flooding at pondberry sites and populations also can vary depending on climatic conditions within local watersheds as well as regional climatic conditions in the Mississippi Valley.

For recovery, large pondberry populations distributed among the diversity of landforms and hydrology are required as buffers to the variation in local and regional climatic patterns affecting hydrology. Using four measures of drought severity, Soule (1990) identified at least seven climatically different geographic drought regions in the United States. Periodic episodes of drought or low precipitation can last more than 10 years and recur on 30-year cycles in the southeast (Stahle et al. 1988). Rare plants can experience an adverse increase in competition from other species during these periods as the composition and structure of the wetland community changes in response to a reduction in the hydroperiod (Kirkman and Sharitz 1994). Pondberry in the geographically isolated wetlands of the Atlantic Coastal Plain occur in one of these regions, while pondberry elsewhere in bottomland hardwoods of Mississippi and Arkansas, and the isolated wetland sand ponds of Arkansas and Missouri tend to occur in a climatically different drought region. Furthermore, since backwater flooding in the Yazoo Basin also is affected by major flooding in the Mississippi River, other regional climatic patterns in the upper Mississippi River Valley and Ohio River Valley can affect flood stages, as well as the absence of flooding, in the lower Yazoo River basin.

The 12 largest remaining pondberry populations (Table 3) are distributed across the geographic range of the species. The distribution in different physiographic and climatic regions represents environments where regional meteorological patterns affecting drought, including the more widespread El Nino and La Nina oscillations, are not likely to adversely affect all populations equally, simultaneously, or with the same frequencies. Thus, drought periods or cycles affecting precipitation and hydrology in isolated wetlands on the Atlantic Coastal Plain are not likely to concurrently cause hydrological drought in the western Gulf Coastal Plain, reducing overbank flooding in the St. Francis River floodway in Missouri and Arkansas, or flooding in the Yazoo River Basin and hydrologically influential areas elsewhere in the Mississippi River Valley (Plate 38).

Furthermore, these large populations represent the remaining array of genetically different populations. At a regional scale, pondberry within bottomland hardwoods and sand ponds of the Gulf Coastal Plain of Arkansas, Mississippi and Missouri are genetically different from the populations in depressions in North Carolina, South Carolina and Georgia on the Atlantic Coastal Plain, revealing an ancient divergence between the eastern and western populations (Echt et al. 2007). At a more local scale, pondberry populations are genetically distinguishable as the Red Gum, Colby, Spanish Fort, and Shelby populations in Mississippi, as well as the St. Francis River and sand ponds populations of Arkansas and Missouri, and the Atlantic Coastal Plain populations Francis Marion National Forest, the Marine Corps Air Base, and elsewhere (Echt 2007, pers. comm.). As conservation units with the greatest potential to avoid deleterious effects of inbreeding, demographic and environmental stochasticity, these populations also provide the greatest remaining genetic diversity and potential for pondberry to genetically respond to future natural selection, including the impacts of disease.

Pondberry dieback caused by the fungal pathogen *Bortryosphaeria* sp. can be periodically severe, as more thoroughly described in a later section, and is probably exacerbated by moisture stress, drought, and its dispersal by a non-native, introduced ambrosia beetle, *Xylosandrus compactus* (Wilson et al. 2004, 2005). Pondberry stem dieback has been observed throughout the range of the species, but now there is an additional new and potentially threatening pathogen causing laurel wilt disease. This recently discovered disease is caused by the fungus *Ophiostoma* sp., which infects red bay (*Persea borbonia* and *Persea palustris*) trees and causes leaf wilt symptoms, frequently followed by death (Fraedrich 2005; Fraedrich et al. 2006). In a similar fashion to pondberry dieback, this fungus also is dispersed and carried by non-native ambrosia beetles (*Xleborus glabratus*), introduced from Asia, and first discovered new to the United States in 2002. Red bay trees experience extensive mortality, exceeding 92 percent in Duval County Florida (Bryant 2007), as has been observed and mapped in the coastal plain of South Carolina, Georgia, and Florida since 2003, where the disease is rapidly spreading (Plate 36, Fraedrich et al. 2006). This new disease has not been confirmed to affect pondberry yet, but there have not been any specific surveys or assessments of its incidence. Pondberry and red bay are within the laurel family (Lauraceae), and the disease is a significant threat since Fraedrich et al. (2006) confirmed by controlled experimental inoculations that the closely related spicebush (*Lindera benzoin*), and other species of the laurel family are susceptible. In southern Georgia, sassafras (*Sassafras albidum*), another member of the laurel family, has been found under natural conditions to be infected by this fungus and disease (Fraedrich et al. 2006)

Red bay is a facultative wetland species, which usually occurs in wetlands, within and near Carolina bays, pocosins, and related depressional wetland communities where pondberry also occurs in the Atlantic Coastal Plain. Thus, laurel wilt disease likely occurs or will occur in close proximity to pondberry. Boring ambrosia beetles, which carry the fungus, are strong fliers capable of spreading the disease from red bay to pondberry. Also, other native or introduced species of ambrosia beetle can spread the disease from red bay to pondberry. If laurel wilt disease spreads to pondberry, then the disease likely will eventually affect all Atlantic Coastal Plain pondberry populations because of their sympatric range with red bay. Red bay also extends across the lower Gulf Coastal Plain in bayheads, hammocks, mixed mesophytic hardwoods, and wet pine flatwoods from Florida to Texas (Godfrey and Wooten 1981). There is no treatment to stop the spread of the disease, and the U.S. Department of Agriculture, Forest Service will be convening an assessment task force in the spring of 2007, similar to that convened for the Sudden Oak Death/Decline issue. Laurel wilt disease is expected to continue to spread (Mayfield and Thomas 2006) eventually throughout the range of red bay.

Large pondberry populations in the bottomland hardwoods of Mississippi and Arkansas and the sand ponds of Arkansas and Missouri will be important for survival and recovery because these are the least likely to be affected by laurel wilt disease. This is because red bay (including swamp red bay) does not occur in bottomland hardwood communities, and its distribution is not contiguous across the lower Gulf Coastal Plain into the Mississippi River alluvial valley (Plate 37), where hosts and vectors for the spread of the disease aré in close proximity to pondberry, whether in bottomland hardwoods of Arkansas and Mississippi or the sand ponds of Arkansas and Missouri.

In addition to large populations, survival and recovery also depends on large tracts of suitable habitat because pondberry reproduces primarily vegetatively and clonally. Sexual reproduction by the production and dispersal of fruits and seeds, followed by seedlings is rarely observed. Furthermore, fruit production is limited in several of the large populations in Francis Marion National Forest and the Marine Air Base in South Carolina where pondberry produces flowers infrequently. Pondberry is dioecious, with plants of different sexes. Small populations with few colonies frequently are male-dominated or without females. The life history and ecology of pondberry reflects attributes of a species that is not a frequent colonizer of unoccupied but suitable habitats. Thus, colonies/sites that become locally extirpated are not likely to be replaced by new colonies from successful sexual reproduction and dispersal of seeds except possibly over long periods of time. Similarly, pondberry is unlikely to expand and establish new populations except over long periods of time. An initial colonizing event, either by fruit/seed dispersal and germination of a male or female plant, must be followed by another dispersal event at the same site with the opposite sex. Hermit thrushes, which are the only documented dispersal agent, generally are considered a forest interior species. Thus, long-term survival and recovery with the potential to increase existing populations with additional colonies and to establish new populations under natural conditions will require large tracts of long-term stable, suitable habitat. These conditions are restricted, generally, to populations and tracts in Delta National Forest, Mississippi, Francis Marion National Forest, South Carolina, and the St. Francis River population in the St. Francis Wildlife Management Area, Arkansas.

Finally, management will be required to restore, protect, maintain, and increase pondberry in many instances in geographically isolated Carolina bays, limesinks, and related depressions in the lower Atlantic and Gulf Coastal Plain where habitat is part of a fire-maintained vegetation type. Pondberry on the edges of depressional ponds is susceptible to potentially significant declines during drought and encroachment of competing shrubs in the absence of fire. Management programs to restore habitat will require careful treatments to remove competing shrubs, manually and chemically, with the reintroduction of fire at a frequency and intensity that does not permanently destroy pondberry. A successful restoration program has yet to be implemented and demonstrated. Also, pondberry in geographically isolated wetlands are not protected by section 404 of the Clean Water Act.

Of the 25 populations required for recovery, the 12 largest consist of 3,000 or more plants (Tables 1 and 3). Only four of these populations, with more than 10,000 pondberry in each, could have survived the decline estimated at the Honey Hill population if such a decline were to occur in these in the future. Ten of these 12 populations also are the only large remaining populations with protection and management programs on publicly owned land, on the largest remaining tracts. These are: St. Francis River WMA (AR-1), Francis Marion National Forest (SC-3), Marine Corps Air Base (SC-1), Big Pond Bay (NC-1), Delta National Forest (MS-3), and Sand Ponds Conservation Area (MO-1). Except for the Sand Ponds Conservation Area (MO) and St. Francis River WMA (AR), eight of the 10 largest and protected populations are known to have declined in the past, or require current and future habitat restoration and management. Larger populations likely will be required for recovery given the observed magnitude and rates of decline in South Carolina and Mississippi, the potential for inbreeding depression even in relatively large remaining populations, infrequent sexual reproduction with fruit production and seed germination, the loss of jurisdictional wetlands protection in geographically isolated wetlands, and the threats of existing pathogens causing dieback and future threats of an expanding laurel wilt disease.

ENVIRONMENTAL BASELINE

The environmental baseline includes the past and present impacts of all Federal, tribal, state, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process. The action area is the area affected directly and indirectly by the Federal action and not merely the immediate area involved in the action (50 Code of Federal Regulations [CFR] § 402.02).

The action area corresponds to the Yazoo Backwater Area, as delineated by the Corps (U.S. Army Corps of Engineers 2000). It is located on the Mississippi-Yazoo River alluvial plain, in west central Mississippi, between the Mississippi River east bank levee and, on the west, the fall line of upland loess hills (Plates 1 and 3). This is the area where backwater flooding will be affected by the proposed project, and the area within which pondberry, a federally listed wetland species, occurs.

Status of the species within the action area

Surveys

More surveys for pondberry have been conducted in the bottomland hardwoods of DNF than any other property. Largely, this reflects the Forest Service management to produce timber with procedures to survey and identify pondberry in stands or compartments prior to any mechanized activity or timber harvest that could adversely affect the species. Of 61,967 acres in the forest, 19,783 acres (31.9%) have been surveyed for pondberry.

During 1994, the Corps conducted pondberry surveys on all rights-of-way for the Yazoo Backwater Project, as well as a five percent survey (2,000 acres) of bottomland hardwood tracts considered to have the greatest potential for the occurrence of the species. These surveys included portions of the Twin Oaks Wildlife Management Area (WMA) and Mahannah WMA. As part of the Upper Steele Bayou Project, about 3,600 acres of bottomland hardwoods were surveyed, parts of which occur within the action area. No pondberry was found (U.S. Army Corps of Engineers 2005).

Elsewhere, smaller surveys by federal agencies have been completed by the Federal Highway Administration, the Corps, and Service. About 10 percent of the Panther Swamp NWR and Yazoo NWR have been surveyed in selected areas considered to be potential habitat by the Service, with negative results. The Corps surveyed 2,000 acres of forested tracts in proposed construction zones and selected areas for pondberry in the backwater area, with negative results. No systematic or comprehensive surveys have been conducted on lands managed by the Mississippi Department of Wildlife, Fisheries, and Parks.

Corps Pondberry Profile

In 1990, the Corps held a "Pondberry Profile Workshop" at the Vicksburg District as part of their assessment of the impacts from reformulated flood control projects to pondberry. The Corps invited personnel from other agencies and organizations with various knowledge and experience on pondberry[1] to consider the "direct impacts associated with project construction activities and indirect impacts associated with flood control measures such as changes in hydrology" (U.S. Army Corp of Engineers 1990). The

[1] Pondberry experts included Ken Gordon, Mississippi Natural Heritage Program-MS Department of Wildlife, Fisheries and Parks; Dr. Robert Stewart, Delta State University; Cary Norquist, U.S. Fish and Wildlife Service; Dr. Gary Tucker, U.S. Forest Service; Dr. Robert Wright, University of Central Arkansas, and Dr. Tom Foti, Arkansas Natural Heritage Commission.

workshop represented a phase of "expert consultation" to develop a pondberry profile and assessment. As part of these proceedings, the Corps had prepared a draft pondberry "profile" with data that characterized the species at 44 selected colonies/sites representing known occurrences. This data formed the basis of the Corps' later evaluation of flood control projects in the Upper Yazoo Basin, as well as to identify likely habitat for future surveys. The Corps has continued to use profile data for subsequent project assessments, including the proposed backwater project, although the more recently profiled pondberry colonies during 2000 and 2005, as described in later sections, are not necessarily the same colonies or sites initially assessed in the 1990 profile.

The 1991 pondberry profile report consisted of a literature search and review, expert consultation from the workshop, and the collection and analysis of field data (Geo-Marine 1991). The 44 sites selected for field characterization represented known colonies, mostly (41) on Delta National Forest. The field assessment was not a survey or design to search for new occurrences or estimate the abundance and distribution of pondberry as a random or stratified random sample relative to different environmental factors. The design simply characterized selected attributes at selected localities. From the original profile, these data at each colony/site consisted of soils, elevation (rod-instrument elevation determined at 13 sites) and topography, distance to a permanent water body, percent canopy cover, species (trees) composition in the canopy, a count of the number of pondberry plants, and a subjective assessment of colony health based live and dead stems, physical appearance of stems and leaves, colony density, an insect damage.

In the 1993 assessment of impacts due to flood control by the proposed Big Sunflower River Maintenance Project, the Corps surveyed the ROW along river and stream banks, and portions of selected off-channel forest tracts. Off-channel surveys covered about 670 acres. One new pondberry colony was found. The 1993 profile was based on the same colonies as the earlier profile, but elevations were determined by rod-instrument surveys at 25 DNF colonies that were not determined in 1991, for 38 colony elevations of the 41 DNF colonies. At that time, U.S. Forest Service staff had comprehensively surveyed about 6,840 acres of forest stands for pondberry.

The 2000, 2001, and 2005 profile data (Gulf South Research Corporation 2000, 2001, 2005), as variously used and referenced for the Corps' Biological Assessment (U.S. Army Corps of Engineers 2005b) included a total of 50 DNF colonies in the Yazoo Backwater Area action area. The basic profile methods remained the same, except that new field data included the percent ground cover of herbaceous plants, and the average height and stem diameter of pondberry at each colony. Average height and stem diameter, however, was not computed as the arithmetic mean from a sample or count of plant heights and diameters in the colony. "Average" represented the height of a plant in each colony subjectively selected as representative of an average plant.

By the time of the 2005 Corps assessment, the U.S. Forest Service had comprehensively surveyed 19,783 (31.2 percent) acres of the 61,967-acre forest for pondberry, a substantial increase from the 6,840 acres surveyed in 1993. Although the Corps did not conduct additional comprehensive surveys in DNF for the purpose of estimating pondberry abundance and distribution, the Corps used DNF data on the geographic occurrence of colonies/sites, together with the 50 colonies from the profile, to represent 182 colonies/sites on DNF.

Number, Distribution and Populations

Pondberry in the action area is only known to occur in the DNF where, according to the Corps, there are 182 colonies/sites (U.S. Army Corps of Engineers 2005b). The Corps included these 182 colonies/sites in their BA of impacts of the proposed project, but five colonies/sites do not occur in the action area. They are located in the southeastern corner of DNF, on the other side of the Yazoo Backwater levee, which will not be affected by the proposed project. We have removed these colonies/sites from our analysis, which leaves 177 colonies/sites in DNF in the action area. The 177 known colonies/sites represent 13 or more potential populations (Plate 7), with a grossly estimated minimal number of 35,600 pondberry plants (Tables 2 and 4). About 87 percent (153) of these 177 colonies/sites are associated with the three largest populations, which collectively represent about 90 percent (32,075) of the estimated pondberry in DNF. The largest population has at least 20,000 plants. The second and third largest populations are minimally estimated to consist of 8,200 and 3,800 plants. The other DNF populations are smaller, with about 1,300 plants in one, and less than 500 plants in the remainder (Table 4). The available data reveals a declining trend during this 5-year period. In 2000, the Corps counted 11,839 plants at profiled colonies/sites, which declined in the 2005 census to 7,083 plants, a loss of 40 percent. The largest population appeared stable during this period, but the second and third largest populations declined more significantly. If the selected and profiled colonies/sites are representative samples and the factors affecting pondberry during this 5-year period of decline are representative of continued and future conditions, then the largest population may be stable, but the second and third largest populations will decline substantially.

The general use of the term colony and the difficulties of delineating pondberry populations were previously described. The problems are similarly confounded for the data in the backwater area, depending on the source of the data and purpose of the surveys. The extent to which each of these 177 pondberry occurrences uniformly represents one or more colonies and sites, and the number of pondberry plants at each colony or site is not clear. The least common biological denominator for this data is that each is an occurrence where pondberry occurs. The number of plants and colonies, however, varies among these occurrences.

In assembling data for their review, the Corps obtained information from DNF on the occurrence of pondberry, as identified during comprehensive Forest Service surveys of particular stands and other field work. We are familiar with the Forest Service's stand data, having examined it earlier during related projects. In a survey of a forest stand prior to implementing any management, Forest Service staff typically note and record on stand maps the occurrence and distribution of pondberry. One of their primary concerns is geographic, to insure that places where pondberry occur are adequately identified to avoid any potential adverse effects by timber or other management. A discrete occurrence of a single colony, with no others, in a stand normally would be indicated by a point or small polygon on the map, with or without notes. In other instances, a single point could represent the occurrence of a just a few plants. When pondberry occurs more widespread but still in discretely separated, small patches throughout a stand, the occupied area may be delineated as multiple points or small polygons. In other instances where pondberry occurs much more widespread throughout an area in the stand, it usually is mapped as a polygon, and stands may have one or more polygons delineated. A larger polygon does not necessarily indicate there is more pondberry than smaller polygon. Polygons simply denote areas occupied by a sufficient number of pondberry plants that the polygons can't be subdivided and the area will require special consideration depending on management plans. Even in some stands, the occurrence of pondberry has been designated by one or several points or polygons, but the survey notes describe pondberry as occurring throughout the entire stand for the purposes of management.

The Corps also has used Forest Service data since 1991 to identify and select pondberry "colonies" for further field analysis as part of the Corps pondberry profile. Of the 177 occurrences on the DNF in the action area, 49 are selected sites where the Corps assessed various attributes of pondberry and its environment for the profile (Plate 7). The basis for selecting particular occurrences is not described and a "colony" is not defined. Profiled colonies, however, tend to represent relatively discrete patches of pondberry, while all remaining occurrences acquired from Forest Service stand records may represent one or more patches, colonies, as well as areas with multiple colonies and other pondberry that are not spatially structured as discrete small patches. Instead of referring to these occurrences as "colonies", for the remainder of this document we will reference these 177 occurrences as "colonies/sites."

The 177 colonies/sites in DNF occur in 67 forest stands. A stand, as routinely defined by the Forest Service, is a specific area occupied by a group of trees that are similar in species, age, and condition. Stands are the primary Forest Service management unit because each consists of a relatively homogeneous environment, in an area with similar soils, topography, or other factors associated with the development and management of a particular forest type. For stands with pondberry, there are 1 – 18 colonies/sites per stand based on these data. Most of these stands have few colonies/sites, with a median number of just 2 colonies/sites per stand. From the nature of this data, as previously described, stands with pondberry may actually have a greater number of colonies/sites than indicated.

From the 49 colonies/sites selected and profiled by the Corps in 2005, there were a total of 6,775 plants. An additional relatively small colony/site is not included in this tally because it occurs in a greentree reservoir, flooded annually for waterfowl management, where the number or trend in pondberry do not reflect naturally occurring hydrological conditions. The pondberry counts from the 49 profiled colonies/sites cannot be used, however, to accurately estimate the total number of plants in DNF. This is because the Corps' did not sample or attempt to estimate the total number of pondberry, and their method of acquiring colony/site profile data was not designed as a random, stratified, or any other type of sampling method to estimate the total number of stems on DNF. Furthermore, a colony/site selected by the Corps is not necessarily the same as colony/site identified or mapped by the Forest Service. Thus, the average number of stems for a colony/site, computed from the 49 selected profiled colonies/sites, can't be used to statistically extrapolate a highly accurate estimate for the total number of plants for all 177 DNF colony/sites. Nevertheless, this is the only and best available data for estimating pondberry population size, which is an important attribute of the species status and further analysis on the effects of the proposed project. Consequently, our use of this and other Corps data to estimate the total number of pondberry in populations in the action area is made with these precautions.

Scientific studies of plant ecology, as well as other field studies, are not always strictly based on completely random sampling, and to various extents may involve the selection of sample and experimental units. With non-random sampling, however, it is impossible to ascertain the extent that the selected and measured colonies/sites are a completely unbiased representation of pondberry as a whole on DNF. The purpose of random sampling is to acquire data and information to make strong inferences and deductions about the population as a whole, from which the samples were drawn. From our observations of the selected colonies/sites, it appears that the Corps included a wide range colonies/sites, from small to large colonies/sites. The selection and the resulting data, however, still depend on the extent that the range of colonies measured reflects their occurrence and proportion in pondberry colonies throughout the DNF. These uncertainties would be further complicated if the Corps had selected a very small number to measure in their profile. Their selection of 49 sites probably avoids the potential problems of a very small number as a representative "sample" for the DNF. Yet, the number of colonies actually represented in the 128 other sites from DNF data is not known and we don't know the true percentage that the 49 selected colonies/sites by the Corps is representative of all 177 colonies/sites in DNF. In using these data to estimate the total number of pondberry in DNF, our estimates our at best considered a gross approximation.

The distribution of the 177 colonies/sites on DNF represents at least 13 pondberry populations (Plate 7), based on the application of an interim pondberry population definition by the U.S. Forest Service Center for Bottomland Hardwoods Research (CBHR) (Devall et al. 2002) according to a long distance flight estimate of a potential pollinator. By this definition with the recovery plan definition, a pondberry population is a "colony or colonies separated by at least one mile from other colonies." (BO Appendix 2). We used their one-mile distance function for the 177 colonies/sites with GIS to delineate 13 populations (Plate 7). Based on genetic data (Echt et al. 2007, Echt 2997, pers. comm.), the largest populations as spatially delineated (Colby, Red Gum, and Spanish Fort) also correspond genetically as separate populations.

These populations actually may be subdivided into more than 13 populations due to other biological factors, particularly the patterns of gene flow and the distances between certain colonies/sites within a population. The provisional pondberry population definition is conservative in the sense that, in the absence of other more reliable data, the estimated number of populations may be a minimum estimate based on pollen dispersal. If so, then the size and viability of these pondberry populations as generally assessed in this biological opinion would be overestimated (BO Appendix 2).

DNF Pondberry Populations

Populations were spatially delineated with GIS using the Corps data for 177 known colonies/sites, and establishing appropriate buffers to link neighboring colonies/sites within one mile of each other. We also used GIS to measure the nearest colony neighbor distances within populations to evaluate the potential for population subdivision (Table 5). The area covered by larger populations was estimated by generating a minimum convex polygon around the perimeter of known colonies/sites.

Population size was estimated as the minimum number of pondberry from several sources of information that varied among populations. With data on the number of plants counted for selected colonies by the Corps pondberry profile, we checked the frequency distribution for normality, and transformed data when appropriate. We computed the 95 percent confidence intervals for the mean number of stems (plants) per colony within these populations where colony data was available. We also computed the overall mean number of plants per colony and the confidence interval for all colonies measured by the Corps without partitioning data in populations. These means and confidence intervals were used to extrapolate an estimate of the minimum number of plants in each population from the number of known colonies/sites in the respective population. This assumes that the colonies selected by the Corps for their pondberry profile are representative of other colonies/sites. As previously described, colonies measured during the Corps pondberry profile were not randomly selected, and they may or may not be highly representative of the number of pondberry in other colonies within the population for which we are using this data to estimate. For populations without any Corps profiled colonies/sites data – we estimated the minimum number of pondberry from the mean number of plants in colonies from all the Corps profiled colonies/sites on DNF in 2005, with the 95 percent confidence interval, relative to the number colonies/sites the Corps classified and reported from U.S. Forest Service data. We also used data from other sources where available, as described in the following sections, to estimate population size (Table 4).

For populations with profiled pondberry colonies/sites, the change in the number of pondberry from 2000 to 2005 is computed. The change in the number of pondberry is computed and referenced only to the data from the profiled colonies/sites, and are not extrapolated as the difference in absolute number for the entire population. However, if the colonies/sites selected and profiled by the Corps are representative samples of the population, then the relative change observed for the profiled colonies/sites is an estimate for the relative change in the population. The area (acres) according to the flood frequencies in each population is described from a GIS analysis of Corps spatial data for flood fequencies, from their FESM model. The number of colonies in wetlands maintained by overbank flooding is assessed by GIS from Corps spatial data. Also, the Corps conducted field surveys during the winter of 2006-2007 at 47 of their 49 profiled colonies sites to determine their jurisdictional wetland status, according to the Corps 1987 wetland manual based on hydrology, soils, and vegetation. Thirteen of these 47 surveyed colonies/sites were jurisdictional wetlands. Where colonies/sites were field determined as wetlands, but frequency and duration of overbank flooding were insufficient to establish wetlands according to the Corps FESM model, then wetland conditions were established by local hydrological factors independent of overbank flooding. Wetlands established by local hydrological factors depend on adequate rainfall, clayey soils with poor drainage, and at some sites the storage of rainfall in depressions. Issues concerning hydrology, the Corps FESM model, and pondberry trends are described in more detail in subsequent sections of the BO.

Colby population – population 1

The Colby population, with an estimated 20,000 plants, is the largest in DNF (Table 4). Most of the pondberry in this population occurs in two distinctive seasonally flooded forest pools (vernal pools). The population is situated on a backswamp landform, where the flood frequency varies from 2 – 5 years. It is a relatively stable population, although the number of pondberry from 1993 to 2006 has fluctuated at selected colonies, and indicators of net growth and decline have varied among plots and surveys.

The population is located in the northern part of DNF (Plate 7). From five colonies the Corps measured during their 2005 pondberry profile (GSRC sites 39-43), there was a total 2,048 plants (Table 4) In addition, McDearman (2006, unpub. data) established a set of nine permanent plots at other selected colonies in 1993, which were resampled in 2006 (McDearman 2006). Each of these plots was sampled with a number of 0.25 m^2 quadrats representing 10 percent of each plot's total area. The number of sampled plants ranged from 17 to 175 in each plot during 2006, with a total of 804 plants in all quadrats (Table 6). Extrapolating the 10 percent quadrat samples to the total plot area generates an estimate of 8,040 plants in the nine plots during 2006. One of the Corps five selected colonies included part of one of these nine permanent plots. Combining the data from the nine permanent plots and four Corps colonies generates an estimate of 8,814 plants (8,040 + 774). The actual population is larger because the selected colonies did not include all colonies. At least 10 other colonies of comparable size occur in this area as well as other plants not associated with colony patches. Our minimal estimate is that this population consists of at least 20,000 plants (Table 4)

The population covers about five acres (Plate 8), half of which has been comprehensively surveyed by the Forest Service for pondberry. The Forest Service first identified pondberry in this area during other surveys and work, and the ponded areas have been extensively examined and surveyed by various researchers and others working with pondberry.

This population occurs mostly in two closely associated depressional areas, in Nuttall oak-dominated stands, that store winter rainwater into the spring growing season. The depressions also capture and store periodic flood water, as observed during the 1991 flood. Fewer colonies and plants occur in adjacent sweetgum stands at a slightly higher elevation out of the seasonally flooded pools. The mean distance between mapped neighboring colonies is 425 feet (Table 5), but the population actually is much more aggregated because most colonies are not mapped and are not represented within the set of 177 colonies/sites. In the ponded areas, plants and colonies rarely are further than 100 feet from each other. Pondberry in these ponds is the most densely aggregated of the populations in DNF. Plants produce fruits most every year.

The population is located on a backswamp landform, on an elevation gradient with the 2-, 3-, 4-, and 5-year floodplain that covers, respectively, about 20, 18, 10, and 9 acres of the site. No jurisdictional wetlands from overbank flooding of rivers and streams, as determined by the Corps FESM 5 percent duration model, are within the population. The seasonal forest pools that are annually flooded by accumulated rainfall are on the 2- and 3-year floodplain, which also receive and store floodwater, as observed in 1991 (McDearman 1994a). Most of this population is concentrated in the forest pool depressions. Three of the five profiled colonies/sites within the depressions are in jurisdictional wetlands, according to the field wetland determinations by the Corps. The wetland hydrology for these three colonies/sites is established by local rainfall directly into the ponded depressions. The other two profiled colonies/sites, also within and on the edge of the northernmost depression/pond, were determined as nonwetlands by the Corps field survey.

Each pond is an irregularly shaped area, covering about 1 to 2 acres. They are distinctive and distinguished from other pondberry sites in DNF by the vegetation in the lowest area of the pond with the longest annual hydroperiod. Each of the lowest areas are about a tenth-acre (0.04 ha) with an open forest canopy. Fringe vegetation includes button bush, water elm (*Planera aquatica*), and a few cypress, which grades rapidly into the surrounding flats dominated by Nuttall oak and water oak. During winter and early spring, water depths in the center of these ponds exceed 7 feet. From the edge of this center, ponded areas vary in depth from about 3 feet in the transitional zone to less than 1 inch along the edge of the standing water. Most of the ponded area is covered by water about 1 to 2 feet deep within Nuttall oak stands.

Pondberry does not occur in the center of depression, but along the edge of the center and throughout the more shallowly flooded areas of the pool in the Nuttall oak stand. These vernal pools have been observed during winter and spring annually from 1991 – 2000, and 2005-2006. Standing water can persist, extending outside of the center zone into the month of June, especially with additional water from overbank floods are stored, as observed during 1991. The hydroperiod and the area covered with standing water can vary depending on winter and spring rainfall, but the edge of the pools at their maximum extent didn't vary by more than about 15 feet laterally between 1991 and 2000, except during the 1991 flood. As observed from 1991 – 2000, the ponds slowly dry as the growing season progresses, and most of the water evaporates by mid-May.

In 2000, the Corps counted 5,918 plants at five selected colonies (Table 4). From their 2005 census at the same colonies (2,048 plants), there was a decline by about 65 percent, representing an overall annual rate of decline of -0.212 (exponential growth). Four of these five colonies declined during this period, with the extirpation of the smallest colony. All of these colonies were within or along the edge of the northernmost pond.

McDearman (2006, unpub. data) also measured a net decline in the number of plants sampled at nine other colonies during 1993-1994, but by 2006 there was a net increase in the number of plants. The net change from 1993 (702 plants) to 2006 (804) represented an increase of 14.5 percent (Table 6). The increase, however, was derived primarily from growth in five colonies (plots) in the ponded area, while the net growth from four colonies that were outside of the pond depression declined (Table 7). The 1993 – 2006 overall annual rate of change for ponded colonies was 0.0219, and non-ponded colonies -0.0119. The overall annual rate of change (exponential growth rate) for all nine colonies (pond and non-pond combined) during 1993-2006 was 0.0104.

The Corps pondberry profile from five colonies indicated a different trend from the changes observed in the nine permanent plots (colonies). The data from the different colonies measured by these two surveys cannot be combined to assess change or trend because the selected sites and plots were measured at different times and intervals. The data illustrate how estimates of change and trend can be affected by the sampling procedures or methods to select colonies. All profile colonies were within the pond site, while four of the nine permanent plots were in adjacent colonies outside of the ponded areas. The dynamics of colonies from 1993, 1994 and 2006 within the pond appear different from those outside of the ponds.

Highly accurate estimates of population change and trend in this population, as elsewhere, require more samples or plots, established with a random, stratified design to account for potential differences between ponded and non-ponded sites, and other environmentally heterogeneous factors. The Corps profile data would indicate that pondberry within the ponds may be declining at a greater rate than detected from the permanent plots. One of the profiled colonies in the permanent plots within the pond declined by -64.4

percent between 1993 and 2006 (exponential growth rate R_e = -0.067). Colonies in ponds are not immune from a declining trend. The difference between the profile and permanent plots reflects different selected colonies.

Red gum population – population 2

The second largest potential pondberry population with 75 known colonies/sites is located in the far northern part of DNF (Population 2, Table 4, Plates 7 and 8). Based on the computed 95 percent confidence interval of the average number of plants per Corps profiled colony in 2005, these 75 colonies/sites would consist of 1,298 – 5,272 plants in the population. To this estimate we added 3,000 plants that Devall (2006, pers. comm.) independently counted and marked on transects within the 40-acre Red Gum Research Natural Area, which is within this population. This creates a minimal population estimate of 4,298 – 8,272 plants. We consider this a minimal estimate, underestimating the population because in several stands surveyed by DNF staff for pondberry, the stand maps and notes indicate pondberry was scattered throughout portions or most of the stand, but the Corps data only records one or a few "sites" for these occurrences. Thus, a single "colony/site" by these records is not restricted in all instances to a single colony.

The Red Gum population also has the greatest potential for subdivision as separate populations or subpopulations. The distance between nearest known neighbor colonies ranges from 13 to 3,334 feet, with about 31 percent (23) of the colonies/sites located at a distance of 790 feet or more from their nearest colony/site (Table 5, Plate 8). Almost half the colonies are more than 300 feet from the closest neighboring colony/site. Known colonies/sites in other populations are not as patchy or as fragmented. The Red Gum population area, defined as a minimum convex polygon for the known colonies/sites, covers about 5,708 acres. Of this area, the U.S. Forest Service has comprehensively surveyed 2,788 acres (48.8 percent) for pondberry. About half the area has not been comprehensively surveyed, and more pondberry is likely to occur within this population. The possibility that this population is subdivided may not be as great as currently indicated by the spatial distribution of known colonies/sites. Changes in the spatial delineation of this population, for example, using a 790-foot function instead of a one-mile distance, would change the estimated total number of populations and the number of plants in each population, but not the estimated total number of plants.

The population is within an environmentally heterogeneous area. Most of the area is on the 2-year floodplain (4,700 acres), with the remainder on the 3-5 year floodplain (935 acres). There are 1,089 acres of potentially jurisdictional wetlands within this 2-year floodplain, estimated by FESM, which is about 19 percent of the population area. Of the 75 colonies/sites, five 5 (6.6 percent) occur in jurisdictional wetlands where the wetland hydrology is maintained by overbank flooding, according to the Corps FESM 5 percent duration model. In addition, 17 of the profiled colonies/sites in this population were field surveyed to determine jurisdictional wetland status. Six of the 17 profiled colonies/sites are wetlands where the hydrology is established and maintained by local rainfall and local site factors, independent of overbank flooding.

Most of the area and colonies are on landforms created by point bar deposits from Holocene streams and rivers, which includes the Red Gum Research Natural Area. The underlying point bar terrain in the southern portions of this population with the Research Natural Area have been filled over by other deposits, and the landform is not developed into a distinctive delta ridge and swale topography as in the Spanish Fort population. The remaining colonies are on either backswamp deposits or associated with a clay-filled abandoned channel course.

The total number of pondberry at the 17 colonies in the Corps profile has declined by about 61 percent, from a total of 3,120 plants in 2000 to 1,205 in 2006, with an overall annual exponential rate of decline of

-0.190 (Table 4, Figure 2). Fourteen of the 17 colonies declined during this period, two of which became extirpated (Figure 1). Of the 16 surviving colonies in the 2005 profile, colony size ranged from 8 – 565 plants, with an average of 40 plants per colony (Table 4).

Spanish Fort population – population 3

The Spanish Fort population, which also is declined during 2000-2005, is the third largest with at least 65 known colonies/sites (Table 4), in an area of 649 acres (minimum convex polygon) on a separate tract of DNF land on the eastern edge of the forest (Plates 7 and 9). The tract is separated by about 4,000 feet across an agricultural field to the corner of the main tract of DNF. The site is dominated by a delta ridge and swale topography, originating from the underlying point bar landform in the bendway of the Big Sunflower River. No jurisdictional wetlands (FESM) are mapped in the population, most of which occurs on the 3-year floodplain (625 acres), with about 22 acres on the 2-year floodplain. Stands in about half the area (328 acres) have been comprehensively surveyed by the Forest Service for pondberry, but many colonies/sites are known and mapped in the areas that have been incidentally surveyed by DNF staff and other investigators.

Pondberry occurs on ridges and swales in relatively distinct patches, but the population is not likely to be as potentially subdivided as the Red Gum population. The mean nearest neighbor distance among the 65 known colonies/sites is 191 feet (163 – 223 feet, 95 percent confidence interval), with a range between 58 and 950 feet (Table 5).

The Corps pondberry profile included 21 colonies in this population (GSRC sites 1-21), with 1,688 plants in 2000 and 847 in 2005, a 50 percent decline (Table 4). All but four of the 21 profiled colonies declined during this period, with a -0.138 overall exponential rate of annual decline (Figure 1). In 2000, the mean number of plants per colony was 33.1, with a range from 2 – 244 plants. In 2005, the mean number per colony was 8.1, with a range of 2 – 240 plants. From the computed mean number of plants per colony and the 95 percent confidence interval of the 21 selected colonies in 2005, there is an estimated 630 – 2,184 plants from the 65 known sites/colonies. Using the mean number per colony and confidence interval computed from all of the Corps colonies selected on DNF, then there would be an estimated 1,742 – 3,880 from these 65 sites/colonies. Since pondberry has not been comprehensively from all areas within this population, and pondberry is not limited to 65 colonies in this population, we minimally estimate there are 3,880 plants in this underestimated population (Table 2).

There are no wetlands in this population maintained by overbank flooding, according to the Corps FESM model (Plate 9). Field surveys by the Corps field surveys of 19 of the 21 profiled colonies/sites determined that two sites were jurisdictional wetlands, where the hydrology would be established and maintained by local site factors, and not flooding.

Population 4

Population 4 has five colonies/sites on the edge of the DNF, and two profiled colonies, with at least 656 plants in 2000 and 657 plants in 2007 (Table 4). The site is located on point bar deposits, on the 4-year floodplain, with no jurisdictional wetlands (FESM) established by overbank flooding. Field determinations at the two profiled colonies/sites by the Corps were classified as nonwetlands. There are two distinct pondberry patches in this population, one with two colonies and the other three colonies, separated by about 1,000 feet. The median distance between nearest neighbor colonies is 110 feet, with a range of 59 – 144 feet (Table 5) From the mean estimate of Corps profiled colonies on DNF (40 plants/colony), we estimate a minimum of 780 plants in this population [657 + (2*40)] (Table 2).

Population 5

This population has six colonies/sites, though none were included in the Corps pondberry profile. The population encompasses about 78 acres, and the median nearest neighbor colony distance is 1,254 feet (range 164 – 1,515 feet) (Table 5). The site is located on backswamp deposits in wetlands maintained by overbank flooding, according to the FESM model. Except for a few acres, the Forest Service has comprehensively surveyed all stands within the small polygon covered by this population.

Population 6

This is another small population, with four known colonies/sites, on backwater deposits in jurisdictional wetlands maintained by flooding. None of these colonies were included in the Corps pondberry profile. The population covers about 131 acres, with widely spaced colonies that may be subdivided, with a median nearest neighbor distance of 2,159 feet (range 2,155 – 3,371) (Table 5). Based on the mean number of plants per profiled colony on DNF, the estimated population with four colonies/sites is 160 plants (Table 4). Only one of these colonies/sites occurs in a stand comprehensively surveyed for pondberry.

Population 7

Population 7 is a small patch on about two acres, with three colonies, with a median nearest neighbor distance of about 355 feet. One of these colonies was profiled, with 153 plants in 2000, and 130 plants in 2005 (Table 4). Colonies are on the 3-4 year floodplain, without jurisdictional wetlands established by overbank flooding. The estimated minimum population is 120 pondberry plants, within a stand that has been comprehensively surveyed by the Forest Service for pondberry.

Populations 8, 9, and 10

Each of these populations consist of one colony each, all of which were included in the Corps pondberry profile. All of these very small populations are on backswamp deposits in jurisdictional wetlands (FESM), and have increased in size between 2000 and 2005 (Table 4). The minimal estimate is 308 plants in Population 8, 558 in Population 9, and 1,280 in Population 10. According to Corps data, Population 10 at colony/site 56 increased from 94 plants in 2000, to 1,280 in 2005 (Table 4).

Populations 11, 12, and 13

These occur on backswamp landforms, in DNF stands comprehensively surveyed for pondberry, and with one colony/site each. There are no Corps profiled colonies/sites in these populations. The colony in population 11 is located in jurisdictional wetlands established by overbank flooding. The colony in population 12 is on the 3-year floodplain, although it is in a jurisdictional wetland maintained by local site conditions, independent of overbank flooding. Population 13 is on the 4-year floodplain. Populations 11 and 13 are each minimally estimated to consist of 40 plants, and population 12 consists of 12 plants (Table 4).

Factors affecting species environment in the action area

Historical land use and change

The backwater area encompasses about 1,446 square miles, or about 629,721 acres in the lower end of the Yazoo River basin. Drainage from the entire Yazoo River basin, an area of about 13,400 square miles, discharges through the Yazoo River at its confluence with the Mississippi River, at the extreme lower and southern end of the Yazoo Backwater Area (Plates 3 and 4). The primary tributaries in the backwater are the Big Sunflower River, Little Sunflower River, Deer Creek, and Steele Bayou, which generally course to the south (Plate 1).

The Yazoo "delta" is a relatively flat alluvial plain, sloping about 0.3 to 0.9 feet per mile. The alluvial landforms represent geomorphic features derived from the fluvial and depositional processes associated with the meandering course of the Mississippi River and tributaries during Holocene and Pleistocene periods. Major landforms are valley trains, backswamps, abandoned channels, abandoned courses, natural levees, and point bars (Kolb et al. 1968; Saucier 1994). Soils are fluvial in origin, ranging from heavy clays in backswamps, to more coarse soils on natural levees that usually occur on the highest elevations.

The backwater area was historically inundated by overflow from the Mississippi River, headwater flooding from the Yazoo River and tributaries, and backwater flooding from Mississippi River (e.g. Smith and Klimas 2002). Overflow, prior to the construction of mainline Mississippi River levees, occurred at high stages when water topped the natural levees and entered eastward into the basin. Headwater floods within the basin occurred in response to heavy rainfall and runoff within the Yazoo River watershed. In addition to the alluvial valley (delta) portion of the watershed, the basin includes an upland area (not in the action area) of 6,800 square miles in the hills of north-central Mississippi. Runoff from the hill region is drained by the Coldwater, Yocona, Tallahatchie, and Yalobusha Rivers before discharging into the Yazoo River (Plate 4). Local rainfall is usually greatest in late winter and spring (December – April), and lowest from August through October. Backwater overbank flooding occurred during flood or high stages on the Mississippi River, usually in late spring through early summer, blocking interior drainage of the Yazoo River tributaries.

According to Galloway's (1980) analysis of historical stage-gage data, the vast majority of the backwater area, and most of the entire delta region, historically was inundated by 2-year and 5-year floods (Galloway 1980). However, the Corps (U.S. Army Corps of Engineers 2006) currently does not consider this an accurate analysis, because Galloway assumed that flood stages would maintained at the same elevations laterally across the delta. According to the Corps, the peak stage at the Yazoo City gage during the devastating flood of 1927 was 8 feet less than the peak at Lake Providence, LA gage, which is at the same latitude. Thus, the Corps considers Galloway's analysis to overestimate the area flooded by 2-year and 5-year flood events under different scenarios without the mainline Mississippi River levees and without internal flood control structures or measures.

Bottomland hardwood forest communities dominated the backwater area during presettlement periods. These floodplain forests are characterized by a large number species, with varying degrees of flood tolerance and adaptation, that develop as relatively distinct community types in response to hydroperiod and landform (e.g. Conner and Day 1982; Wharton et al. 1982; Brinson 1990; Sharitz and Mitsch 1993). Smith and Klimas (2002) reviewed and described bottomland hardwood forest types in the Yazoo Basin and their general relationships to hydroperiod and geomorphology. The zonal concept of bottomland hardwood forest types, in relation to landform elevation, flood frequency and duration, is applicable in the Yazoo Basin, but does not strictly apply to a linear set of adjacent floodplain terraces of increasing elevation from a river channel, with less frequent flooding. This is because the geomorphological history in the basin is complex. Still, distinctive and comparable forest communities developed in the basin in response to site hydrology and landform (Smith and Klimas 2002). These community types include cypress-tupelo in sloughs, overcup oak-Nutall oak on poorly drained backswamp flats, hackberry-elm-ash on low ridges and flats, sweetgum-water oaks in first bottoms, cottonwood on front ridges and well-drained flats, as well as other types and mosaics of communities.

The history of land use and changes in land types have been intimately affected by natural flooding and efforts to control flooding. In 1860, the human population had grown to about 50,000 in the Yazoo delta, mostly north of the backwater area, but only about 10% of the land had been cleared for agriculture (Galloway 1980). Because of frequent flooding, farming was generally restricted to the highest ground along natural levees. Communities and landowners built and attempted to maintain small levees at that time, but the 1874 and other floods revealed their inability to control flooding. Federal intervention began in 1879 with the establishment of the Mississippi River Commission, which later expanded to include flood control. Nevertheless, two local levee boards, the Mississippi Levee Commission and the Yazoo Mississippi Delta Levee District, remained primarily responsible for the Mississippi River levees from Memphis, Tennessee to Vicksburg, Mississippi. With expanding flood protection, additional bottomland hardwood forests were cleared for agriculture, particularly cotton production. By 1937, about half (9 – 10 million hectares) of the bottomland hardwood forests throughout the Mississippi Alluvial Valley had been cleared (Smith et al. 1993).

Mississippi River and Tributary Projects

Following the historic flood of 1927, Congress passed the Flood Control Act of 1928, further increasing the federal role and the Corps' authority in planning and constructing navigation and flood control measures throughout the lower Mississippi River Alluvial Valley. As amended by numerous subsequent Acts, these projects today are collectively known as the Mississippi River and Tributaries Project (MR&T), which has been considered one of the largest flood control projects in the world (e.g. Smith and Klimas 2002).

With the Flood Control Act of 1928, the Mississippi River mainline levee was enhanced and completed from Memphis, TN to near Vicksburg, MS. The levee prevented flood overflow from the Mississippi River into the upper delta region, where at lower stages, flood water would drain through the lower basin and Yazoo River. Other Flood Control Acts extended the MR&T to the entireYazoo Basin, with projects in three authorized areas: the Yazoo Headwater Area, the Big Sunflower Area, and the Yazoo Backwater Area. The projects were designed to address various aspects of headwater and backwater flooding.

Structural flood control in the Yazoo Headwater Area consists of four reservoirs in the upland hills region of the basin, where about 50% of the rainwater runoff originates (Plate 4) (U.S. Army Corps of Engineers 1977). Sardis, Arkabutla, Enid and Grenada reservoirs variously were completed from 1940 – 1954. More than two-thirds of the peak downstream flows on the Little Tallahatchie River, Coldwater River, Yocona River, and Yalobusha River are eliminated by these reservoirs (e.g. Smith and Klimas 2002, Bolton and Metzger 1998). At flood pool level, these reservoirs inundate about 184,500 acres (U.S. Fish and Wildlife Service 1982). Other structural features included channelization, cutoffs, levees, and the construction of the Lower Auxilliary Channel (Will Whittington Canal). This canal and its levees reduce peak headwater flood stages by as much as seven feet in the upper reaches, by diverting and confining flow out of the Yazoo River, and passing it more rapidly downstream to lower reaches of the river (U.S. Army Corps of Engineers 1977). Collectively these projects confine floodwaters and accelerate flood discharge from the upper basin to the lower backwater area.

The Big Sunflower Area covers about 4,093 square miles on the alluvial plain, where projects have involved channel clearing and snagging (475 miles), channel enlargement (43 miles), and diversions (18 miles) on the Big Sunflower, Little Sunflower, Huspuckena, and Quiver Rivers and tributaries to reduce headwater flooding and increase discharge downstream through the backwater area (U.S. Army Corps of Engineers 2000). These projects began in the 1940's and were completed in the 1960's.

The Yazoo Backwater Area project was first authorized by the Flood Control Act of 1941. The project included the construction of backwater levees, channel diversions, water control gate structures, and a pumping station. The project was further organized in four areas: the Yazoo Area, Carter Area, Rocky

Bayou Area, and Satartia Area. With the Yazoo Area segment, the backwater levee was constructed to connect the eastern mainline levee on the Mississippi River with the western downstream levee of the Will Whittington Canal (Plate 1). Upon completion in 1978, the entire backwater area was isolated and protected from backwater flooding by a levee system, although the height of the backwater levee was designed lower than the mainline system to be overtopped during record floods. Thus, the backwater area originally was intended as a flood storage area during project design or severe floods.

Gated water control structures were completed in the Yazoo Area to regulate internal drainage and discharge from the backwater through the levee system into the Yazoo River, as well as to prevent backwater flooding from the Mississippi River to rise and enter the area. The original confluence of the Little Sunflower River and Big Sunflower to the Yazoo River was diverted by channels to the Steele Bayou Structure (Plate 1). The Pumps were first authorized in 1941, with three pumps and without any diversion canals, to evacuate interior flooding from the Backwater Area behind the Steele Bayou Structure and backwater levee when the floodgate is closed. The original design and Congressional authorization were intended to pump backwater over the levee into the Yazoo River when the stage at the Steele Bayou Structure was 90 feet or greater. Areas in the interior sump in lower backwater reaches, at or below the 5-year floodplain, would not be subject to pumping, and retained as a natural, mostly forested, flood storage zone.

In 1959, the Mississippi River Commission (1959) reevaluated numerous MR&T projects, finding that the need for the backwater pumping plant was not justified. This was in response to lowered stages in the Mississippi River following channel improvements and cutoffs, and a reduction in flood peak flows due to the Yazoo Headwater flood reservoirs and other projects. In 1982, the Corps reevaluated the feasibility of the Pumps, proposing a new plan to construct and operate the pumping station at 85 feet from December – March, and 80 feet at other times. Since the federal government did not acquire or otherwise protect the natural flood storage sump in the backwater area identified in the 1941 plan, with about 135,000 of forested wetlands, there had been subsequent agricultural encroachment into marginal lands in the sump area. When reevaluated in 1982, the Corps estimated that about 79 percent of economic benefits of the pump would be derived from agricultural production and expansion in the originally designated sump area. The lower pumping elevations of the 1982 plan would extend backwater flood protection into the previously identified 5-year flood storage sump. The pump construction site was cleared, but construction halted with the passage of the Water Resources Development Act of 1986, when Congress required that local (non-federal) project sponsors cost-share a portion of the project. Congress later exempted the cost-sharing requirement for this particular project, but following a review by the Office of Management and Budget in 1992, funding for construction was removed, with a directive to reformulate the project.

Agricultural Expansion

Agriculture began to shift from the higher, least frequently flooded sites to lower sites following the 1928 Flood Control Act and an increasing number of flood reduction projects in the Yazoo Basin. The change was more gradual in the Yazoo Backwater Area because it was lower and wetter. Benefited by agricultural mechanization as well, the expansion by the 1950s left a balance of 470,844 acres of bottomland hardwood forest in the backwater area, with most production still restricted to higher more moderately drained soils.

Agricultural expansion dramatically increased beginning in the 1950's, and extended to the 1970's in response to additional flood control projects, economically favorable world agricultural markets, and a 20-year climatic interval without a major flood on the Mississippi River. The Corps cost-benefit analyses for projects began to include flood reduction benefits to agricultural production. From 1957 to 1977, 317,000 acres of forested wetlands were converted to agriculture in the Yazoo Basin in Sharkey, Issaquena, Humprheys, Yazoo, Washington and Warren Counties (MacDonald et al. 1979). Instead of farming on the least frequently flooded sites, agriculture had moved to more frequently flooded, poorly drained, and marginally productive lands.

The massive flood of 1973 was followed by lesser but significant and more frequent flooding in 1974, 1975, 1979, 1982, 1983, and 1989. The agricultural economy declined, profit margins decreased, and the economic risks of farming on marginal lands increased, culminating in a significant number of delinquent loans and farm foreclosures in the 1980's. Land use changes stabilized during the 1980's, bringing an end to the period of large-scale agricultural expansion. Beginning in the 1950's, there were about 518,600 acres of bottomland hardwood forests remaining in the Yazoo Backwater Area. By the early 1990's, the period culminated with the loss of 56 percent bottomland hardwoods available in 1950, leaving about 231,000 acres (Plate 5).

The historical loss of bottomland hardwood forests and the conversion to agriculture has been affected by a combination of MR&T flood control projects, federal subsidies and support to agriculture, tax codes differentially affecting agriculture and forestry, agricultural market conditions, and climatic variation generating periods of more frequent and extensive floods. Of about 6.3 million acres of bottomland hardwood forests in the Lower Mississippi Alluvial Valley of Arkansas, Louisiana and Mississippi in 1935, about 3.6 million acres were converted to agriculture by 1985. An econometric statistical analysis of these and related factors revealed that the MR&T projects, including the Mississippi River mainline levee, accounted for about 50 percent of the acreage of bottomland hardwood forests converted to agriculture (U.S. Department of the Interior 1988). By reducing flooding, the profitability of converting bottomland hardwood forests to agriculture increased. The effect of rising agricultural prices on conversion was less than the MR&T, accounting for about half of the wetland forest losses attributed to the MR&T (e.g. conversion without the MR&T). The remaining forest losses were a combination of these factors.

Major patterns of land use change in the Backwater Area shifted in the 1990's, following the increased economic risk of farming marginal agricultural lands, the passage of the Food Security Act (FCA) of 1985, and the Food, Agricultural, Conservation, and Trade Act of 1990 (FACTA). The swamp buster provisions of the FCA and FACTA reduced incentives to convert wetlands to croplands by restricting a landowner's eligibility for federal funds under various agricultural programs. In contrast, the Wetland Reserve Conservation Program (WRP) and the Conservation Reserve Program (CRP) provided federally funded financial incentives to convert and reforest environmentally sensitive or marginal agricultural lands. As of 2005, private landowners have reforested marginal agriculture lands with about 36,780 acres in WRP and about 23,540 acres in CRP in the action area. Moreover, the number of landowner applications for enrollment has exceeded the availability of the programs.

Current land use

The backwater area encompasses 925,600 acres. Today, agriculture is the dominant land use in the backwater area, with 503,800 acres in crop production. Bottomland hardwood forests remain on 288,300 acres (Plate 6). About 36% (104,500 acres) of these forests are in public ownership managed by the U.S. Forest Service, Service, and Mississippi Department of Wildlife, Fisheries and Parks. These lands include Delta National Forest, the Theodore Roosevelt National Wildlife Refuge Complex (Yazoo NWR, Panther Swamp NWR, Holt Collier NWR, Theodore Roosevelt NWR), and state wildlife management areas and parks (Twin Oaks WMA, Mahannah WMA, Lake George WMA, Shipland WMA, and Leroy Percy Park).

Forest types and management

Pondberry in DNF occurs in several bottomland hardwood forest communities or types, dominated by various oaks, sweetgum, and elms. The most frequently occurring and locally dominant overstory hardwoods include willow oak (*Quercus phellos*), Nuttall oak (*Q. nutallii*), overcup oak (*Q. lyrata*), sweetgum (*Liquidambar styraciflua*), cedar elm (*Ulmus crassifolia*), American elm (*U. americana*), and winged elm (*U. alata*) (Attachment 1 - U.S. Army Corps of Engineers 2005). Other species, which can be dominant and codominant, include box elder (*Acer* negundo), sugarberry (*Celtis laevigata*), green ash (*Fraxinus pennsylvanica*), water hickory (*Carya aquatica*), and pecan (*C. illinoensis*) (Tucker 1984, Devall et al. 2001, Hawkins et al. 2005). These are mostly mature, sawlog-size stands. Pondberry is not narrowly restricted to a particular bottomland hardwood forest type or community, but it does not occur in bald cypress (*Taxodium distichum*), water tupelo (*Nyssa aquatica*), or swamp tupelo (*N. sylvatica*) forest types.

Forest management activities with potentially adverse effects to pondberry include the direct effects of mechanical equipment operations that crush and destroy plants, and the indirect effects of increased sunlight upon removing the overstory canopy and subcanopy upon timber harvest. Pondberry is shade adapted and photosynthetically competent under shade conditions, but looses plant biomass at 100 percent sunlight (Wright 1990; Aleric and Kirkman 2005b). The species also can also produce sun leaves in response to canopy gaps (1989a), but leaves also wilt and pondberry is susceptible to damage during dry summer conditions (Wright 1988). Drainage and canopy disturbances can promote vigorous understory growth of other species and competition that can adversely suppress pondberry (Wright 1989a, 1989b). Pondberry experts also identified the adverse effects of increased interspecific plant competition in the understory as an issue of concern (U.S. Army Corps of Engineers 1990). Competition was expected to increase with a reduction of hydrology, allowing less flood tolerant species to increase in abundance.

Clear-cutting historically seems to be the most prevalent method to regenerate commercially valuable bottomland hardwood oaks that are moderately intolerant to intolerant of shade (Clatterbuck and Meadows 1993), although regeneration of desired species will likely be reduced or fail without advanced oak reproduction prior to clear-cutting and other intermediate management treatments (Johnson 1981; Hodges and Gardiner 1993). Shade tolerance is the ability of species to persist at low light conditions in the forest understory because of physiological and morphological adaptations (Kramer and Kozlowski 1979). Shade intolerant to moderately intolerant bottomland oaks at sites with pondberry include Nuttall oak, willow oak, and overcup oak. Clear-cutting creates the most open, sunlit condition for bottomland hardwood oak regeneration, while single-tree selection harvests create the smallest openings that, usually, do not allow sufficient sunlight to reach the forest floor for development of shade-intolerant species (Meadows and Stanturf 1997). Harvests of intermediate size, such as group selection or patch cutting, establish areas smaller than clear-cuts, but larger than the gaps by single-tree selection and of sufficient size to allow adequate sunlight for successful natural regeneration (Meadows and Stanturf 1997).

The size and distribution of canopy openings for oak regeneration also stimulates growth of potentially competing trees, grasses, forbs, and other species (Streng et al. 1989; Billups and Burke 1999). Plant competition for light, nutrients, and water resources can become intense once a regenerated stand is initiated following timber harvest and release with greater sunlight (e.g. Beck 1970; Sander and Clark 1971; Sander 1972; Johnson 1975; Loftis 1983, 1988, 1990; Janzen and Hodges 1987; Nix and Cox 1987). Trees, woody plants, and herbaceous plants undergo self-thinning in dense populations n response to competition for light (Weiner 1988; Geber 1989; Weiner and Thomas 1986, 1992; Shabel and Peart 1994; Weiner and Fishman 1994). Environmental conditions become limiting during stand initiation, and competition through the stand initiation stage extends to the later stem exclusion stage of development, when the young stand develops a vertical stratification of trees as dominant and codominate species, to the exclusion of other stems and species (Meadows 1994; Stanturf and Meadows 1994).

Potential interspecific plant competition with pondberry has been observed to increase at certain sites when the tree canopy is removed or reduced. Incidental observations of several pondberry colonies in DNF where natural gaps occurred from treefall in the overstory indicated that pondberry was rapidly covered with the growth of *Rubus* sp., vines, and other species (McDearman 2006, pers. comm.). At one site in a ponded depression in the Colby population, with virtually no associated herbaceous plant species, however, pondberry responded with vigorous growth and little competition. Also, two small colonies of pondberry at two clearcut areas in DNF were completely overgrown by woody vines and weedy species during 1990, where the small size of pondberry plants indicated their growth had been suppressed (McDearman 2006, pers. comm.). The potential for rapid understory growth and competition upon canopy disturbance probably is a site specific factor, related to hydrology. Overgrowth is more likely to be adverse at sites where pondberry already occurs with competition from an associated herbaceous and shrub strata, and much less adverse if at all at sites where the ground vegetation layer is poorly developed. For example, the herbaceous plant layer associated with pondberry in seasonally flooded depressions by rainfall in the Colby population is mostly absent, with scattered American buckwheat vine (*Brunnichia ovata*).

The U.S. Forest Service completed informal section 7 consultation with the Service in 1988 on the effects of their forest management plan for pondberry. The plan involves surveys to identify pondberry in stands prior to timber harvest or other potential disturbances, restricting clearcutting and timber harvests at pondberry sites, and establishing protective buffers around pondberry where there will be no mechanical activities and canopy disturbances. The Service has concurred that with these provisions, forest and related resource management activities in DNF are not likely to adversely affect pondberry.

Pathogens, stem dieback, and patterns of decline

Pondberry stem dieback occurs at most colonies/sites, but the severity varies among sites and at different times. *Botryosphaeria ribis* has been identified as the likely fungal pathogen causing dieback (Wilson et al. 2004). Infected plants usually have stem cankers, and symptoms include blackened stems, death of terminal stems and meristems, with varying degrees of progressive dieback downward to main stems. When stems die back to the base of the plant, adventitious vegetative sprouts forming new shoots (shrubs) may form from the surviving basal stem segment or the root crown. In other instances, stem mortality is complete, with or without new shoots elsewhere from the rhizome.

The probable mechanism of dieback includes fungal damage to the plant vascular system, including the cambium and xylem, as is known from the effects of *Botryosphaeria* sp. to a number of different woody plant species. *Botryosphaeria* sp. are naturally occurring plant pathogens, but plants experiencing stress are more susceptible to infection and damage (Proffer 1989). Inadequate soil moisture is a stress factor associated with infection and dieback by *Botryosphaeria* in ornamental woody plants as well as native species including sweetgum and pond cypress (*Taxodium ascendens*) (Bacchus et al. 2000; Schoeneweiss 1978). In pondberry, symptoms associated with dieback are consistent with the mechanism of vascular tissue damage, a loss of internal water potential and transport to stems and leaves, and plant stress. As in other woody plants infected with *Botryosphaeria* sp., these symptoms include rapid leaf wilt and death without leaf abscission, accompanied by stem dieback. Stem damage also appears exacerbated by the black twig borer, *Xylosandrus compactus*, a non-native wood boring ambrosia beetle that prefers to bore in soft tissue of pondberry damaged by *Botryosphaeria* (Wilson et al. 2005). This beetle likely is vector for the stem canker fungus (Wilson et al. 2005), accelerating the incidence of disease.

The incidence of *Botryosphaeria* is widespread in the DNF (Wilson et al. 2004), and can be locally severe, causing a significant decline in the number of pondberry plants within colonies during a 1-year period, followed by either a continued decline, a recovery, or even a later increase in the number of stems. Pondberry appears relatively resilient to acute episodes of stem dieback in that catastrophic and widespread mortality with the loss of colonies is not known to occur immediately. The effects of stem dieback and mortality can be at least partially compensated by the vegetative production of new sprouts and plants. The net changes, however, at low rates of decline and over long periods as an additive effect to existing mortality can be difficult to detect without a specific monitoring program. Acute episodes of dieback, as well as long-term chronic effects, can potentially lead to extirpation in combination with other factors such as periodic soil moisture stress over a long period. Since *Botryosphaeria* is commonly associated with pondberry (Wilson et al. 2004), it probably affects pondberry acutely and chronically.

Colby Population

During pondberry monitoring that began in 1991 at the Colby population, a severe episode of dieback was observed and monitored in DNF (Colby site) from 1993 to 1995 in permanent plots, and later resampled in 2006 (McDearman 2006, unpub. data). The plots were established at selected colonies in 1993, as additions to earlier plots placed in the study area in 1991, during an investigation of patterns of plant growth and decline to assess indices and sample sizes for the design of future monitoring programs. More than 30 colonies occur in the study area, with many other plants not distinctly clumped as colonial patches. Based on general field surveys, it was estimated that 20,000 or more plants occurred in the study area. Colonies were selected in an attempt to represent that range of size variation and topographic position generally observed among the other colonies at the site. Five of the selected colonies were within or on the edge of two depressional ponds that stored winter rainfall as well as overbank floodwater. The remaining four colonies were in adjacent hardwood stands, about 2 feet higher in elevation, without any depressional water storage. Plants in each colony were randomly sampled in 0.25 m^2 quadrats at defined intervals on transects in each plot, designed to cover about 10 percent of the colony-plot area.

By late summer of 1994, over 50 percent of the plants experienced rapid leaf wilt, death and complete stem dieback during dry conditions. Between 1993 and 1994, the number of plants declined in eight of nine colonies, from 9 - 57 percent, and increased in one colony by 17 percent (Table 6). Every plant that either died or experienced substantial dieback displayed symptoms of stem canker. The actual plant mortality rate was greater than indicated by the change in number of plants because, even with a loss, the change included the production of new plants from sprouts and shoots. The net increase in one plot (Table 6, Plot 7) was due to vigorous sprouting from adventitious meristems at the base of surviving stem segments near the ground, and elsewhere from stolons. Vegetative reproduction was not sufficient, however, to compensate for overall mortality for the 1-year period until 1994.

To evaluate the response of pondberry in ponded and non-ponded sites to the acute phase of dieback, the number of pondberry during 1994 and 20065 were compared by contingency analysis to that expected based on an extrinsic hypothesis (e.g. Sokal and Rohlf 1981) that the number of plants by site (ponded and non-ponded) had not changed significantly relative to the site proportion in 1993 (Table 7). Of the 702 plants in 1993, 38.89 percent (273/702 x 100) occurred in non-pond plots, and 61.11 percent (429/702 x 100) were in ponded plots. Although the overall number of pondberry declined in 1994, the number in ponded and non-ponded plots did not significantly change relative to the expected number based on the proportion by site during 1993 ($G = 0.4190, p < 0.0001$). Effects of the acute phase of dieback on the number of pondberry in 1994 occurred independently of any site (ponded and non-ponded) factors relative to that during 1993 (Table 7).

By 2006, the total number of pondberry from all plots had increased (804) and was 14.5 percent greater than the number in 1993 (702) in both ponded and non-ponded sites (Table 6). However, pondberry now was more abundant at ponded sites ($G = 33.6788, p < 0.0001$) than non-ponded sites, relative to that in 1993. Pondberry at ponded sites in 2006 had surpassed the number in 1993, while pondberry at non-ponded sites (234) had not recovered to the amount in 1993 (273). Pondberry in or on the edge of the two vernal pools increased overall at a greater proportionate rate than pondberry in the non-ponded adjacent stands (Table 7). Even so, individual colonies within each site responded differently. The net increase in plants from three of the five ponded colonies exceeded the losses from the two declining colonies. In the non-ponded area, the number of plants by 2006 in two of the four colonies surpassed the number available in 1993, but the net increase was insufficient to compensate for the decline in the remaining two colonies.

The effect of site (ponded vs. non-ponded) on the number of pondberry also was evaluated more broadly, without the reference constraints of the 1994 and 2006 response relative to that in 1993. Site effects on the number of pondberry in 1993, 1994, and 2006 were assessed by a contingency analysis of the null hypothesis that the number of pondberry was independent of any site association. The expected number of pondberry by this procedure is based on another extrinsic hypothesis (e.g. Sokal and Rohlf 1981) to the tabulated data. If the number of pondberry is independent of site, pondberry abundance at ponded and non-ponded sites should be proportionate to the number of surveyed quadrats by site. The number of plots/colonies and the number of quadrats were not equal among ponded and non-ponded sites. Pondberry was censused/counted from 271 0.25 m^2 quadrats from five permanent plots in ponds, and 306 quadrats in four non-ponded plots (Table 6) These quadrats represent 67.75 m^2 at the ponded colonies and 76.5 m^2 at non-ponded colonies, for a total sample area of 144.25 m^2. Surveys in ponded plots accounted for 0.4697 of the total survey area, and non-ponded plots represented 0.5303 of the total area. If the number of pondberry in 1993 occurred independently of site, then of the 702 plants that year there would be 372.3 plants at ponded plots (702*0.4697), and 329.7 (720*0.5303) plants at non-ponded plots. The expected number in 1994 and 2006 also was computed by the same procedure.

By these data, pondberry overall was significantly more abundant at ponded sites, and less numerous than expected at non-ponded sites (G=280.2, p<0.0001). The effects of site occurred each year, when pondberry was more abundant from the ponded sites during 1993, 1994, and 2006 (Table 8). The deviation from that expected if pondberry occurred independently of site increased in 1994 and 2006 relative to 1993, reflecting the same trend as in the previous analysis when the number of pondberry during 1994 and 2006 by site was assessed relative to that in 1993. The difference by this analysis is that beginning in 1993, pondberry is found to already be more numerous at ponded areas. The net effects of the acute episode of dieback through 1994 affected pondberry independently of site, where pondberry remained more abundant overall at ponded sites concurrent with the 1993-1994 decline. By 2006, pondberry remained more abundant at ponded sites, but as in the previous analysis, the relative abundance at ponded sites or the deviation from expected was greater than in previous survey years. The changes from 1993 to 2006 altered colony and potential population structure due to site effects.

No other quantitative data are available on the short or long-term response of pondberry to this or related pathogens causing dieback. These data, the observations of the widespread incidence of stem canker and dieback, and the effects of *Botryosphaeria* in other woody species reveal that stem canker is a negative risk factor affecting pondberry growth and survival, particularly when plants are subject to stress associated with dry soil conditions. The deeply cracked, clay soils in parts of the vernal pools were indicative of local late summer drought conditions. The Corps (U.S. Army Corps of Engineers 2007) reported there was more than 62 inches of rain during 1994 at nearby Rolling Fork, which was 10 inches greater than average, with slightly above average precipitation from January through June. Clearly, there was no regional drought during this period.

The negative consequences of *Botryosphaeria* to plant mortality and stem dieback can acutely affect the demography of growth and survival over short periods, and over long periods as well, especially with periodic acute episodes. The factors specifically affecting dynamics of colony growth and decline between 1993 and 2006 were not assessed, but may include interactions among dieback, hydrology, interspecific plant competition, and natural canopy disturbances. Two colonies were affected by treefall that opened canopy gaps. Incidental observation during 2000 revealed that branches from about half the crown of an overstory tree at one colony (plot 7) in the non-ponded area had died, and between 2005 and

2006, the entire tree had fallen. The colony currently is overgrown by other understory plants, mostly *Rubus* sp., but pondberry increased in number more than any other non-ponded colony. In the ponded area, another colony (plot 4) was partially overgrown by understory plants from a tree canopy gap created during Hurricane Katrina (2005), but this colony also had increased to surpass the number available in 1993 (Table 6).

Stem canker likely is an important factor affecting pondberry because acute episodes of dieback have not been commonly and widely observed due to factors other than a potential pathogen. From 1993 to 2006, the estimated average annual exponential growth rate for each of these colonies ranged from -0.0795 to 0.0739 (Table 6), or about -/+ 7 percent. The colonies/plots were not censused annually after 1994, so the annual variation among years until 2006 is not known. The predicted number of plants in each year for each colony was back calculated based on exponential growth from 1993 and 2006, where $N_t = N_i(1 + r)^n$, and N_t = the predicted number of plants at year t, N_i = the observed number of plants in 1993, r = the average annual change for the colony between 1993-2006, and n = the number of years. If environmental conditions during this period continue in the future, the four declining colonies may persist at the current rate of annual change for many decades, although eventually becoming extirpated (Figure 4).

The available plot census data is inadequate to develop a robust demographic and stochastic model predicting future growth and decline in these colonies and population for specific future time intervals. A robust population model of future persistence or decline commonly is considered to incorporate sufficient field data to estimate the demographic parameters of population growth and decline, with the range of annual stochastic variation for the parameters in response to environmental factors and random events. The pondberry colony data from these three periods is not sufficient to develop such models with estimated probabilities of their persistence or extirpation at a defined future time interval. Such models would require data from additional colonies and populations, at more numerous census periods. The data are sufficient, however, to indicate in a simple deterministic fashion, without estimates of stochasticity, that the colonies with a net negative growth from 1993 to 2006 would be predicted to continue to decline, overall, in the future and eventually become extirpated if the environmental conditions during 1993-2006 are representative of future conditions.

These data also demonstrate that the number of pondberry can undergo substantial changes within 1 – 2 years that are not necessarily predictive of the future number of pondberry and the rate of growth or decline over longer periods. For example, the overall decline observed in the total number of pondberry at ponded sites during 1993-1994 did not continue unchanged, and did not represent the trend and final increase in number observed in 2006. None of these monitored colonies have become extirpated due to the direct or indirect effects of stem canker. To some extent, pondberry in large colonies appears resilient to stem canker due to the asexual capacity of vegetatively producing new plants from basal stem sprouts and rhizomes. Nevertheless, periodic acute episodes as well as low level chronic effects of dieback and mortality, in combination with other factors, may cause slow rates of decline over longer periods of time, leading eventually to local extirpation of colonies. Slow rates of decline can lead to long-term loss and eventual extirpation, although monitoring programs sensitive to this magnitude of change have not been designed or implemented. The observed patterns of colony growth and decline in this population also indicated variation among sites within ponds and within non-ponded areas. Overall on average, pondberry in the ponded areas would be more likely to persist in the future, although local changes also would be expected with a loss in the number of pondberry at some ponded colonies/sites. Pondberry at non-ponded sites would be expected to decline, overall on average, although the variation among these colonies indicates it would not be completely extirpated from non-ponded sites in the vicinity of these vernal pools.

Reproduction

Pondberry in the action area has the same life history attributes as described for the Status of the Species. Successful sexual reproduction and recruitment by the germination of seeds and production of seedlings has only rarely been observed. The dynamics of populations in the action area are regulated primarily by plant survival/mortality and vegetative reproduction. Successful seed germination and recruitment, whether by seeds falling from plants or dispersed by hermit thrushes or other species, apparently is a process that occurs only infrequently over a much longer period. Theses attributes indicate pondberry is not a rapid colonizer of unoccupied but suitable habitat. When colonies or populations become extirpated, they are unlikely to be replaced quickly if at all by seed dispersal and germination from other colonies and populations (e.g. Smith et al. 2004).

The DNF is the largest tract of bottomland hardwoods remaining in the action area with pondberry. The current distribution of pondberry in DNF reveals either a pattern of infrequent dispersal and successful establishment over a long period, or the absence of contemporary environmental conditions suitable for more frequent seed dispersal and successful establishment. Seeds are not sterile, as indicated by their germination rates in controlled environments and field conditions (Conner et al. 2006), although studies are continuing in DNF to assess factors affecting seed germination and seedling production. In the absence of controlled propagation and recovery management, DNF is an important tract because it provides the only area where pondberry can naturally disperse and potentially establish new colonies or populations (e.g. Devall et al. 2003).

Genetic diversity within and among pondberry populations is low, as expected from a clonally reproducing plant with low sexual reproductive success (Godt and Hamrick 1996; e.g. Hamrick et al. 1991). Genetic diversity in the Colby population and Red Gum population, however, is greater than other pondberry sites examined across the southeast (Godt and Hamrick 1996), probably because of the larger population size. Most of the genetic diversity and polymorphism occurs between populations and sites.

Hydrology

There are at least four hydrogeomorphic settings and processes affecting hydrology, wetlands, and habitat for pondberry, as an obligate wetland species, in the lower Yazoo Basin; the storage of rainfall in depressions, rainfall at sites (flats) with impeded soil drainage without depressional storage, depressional storage of overbank floodwater, and overbank flooding at sites without depressional storage. One or a combination of these sources affects pondberry habitat These hydrological descriptors are elements of a hydrogeomorphic (HGM) classification. The basis of the HGM approach is a classification of different wetland types and functions according to their geomorphic setting, water source, and hydrodynamics (Brinson 1993). Geomorphology is the landform and its topographic position on the landscape. Water sources are precipitation, overbank floodwater, and groundwater. Hydrodynamics refer to the direction and strength of water movement in the wetland. The two primary wetland classes in the lower Yazoo Basin are Depression and Riverine, and the major subclasses are Flats, Riverine Backwater, Riverine Overbank, Isolated Depression, Connected Depression, and Isolated Fringe (Smith and Klimas 2002).

Smith and Klimas (2002) and Klimas et al. (2005) have described these classes and subclasses in the lower Mississippi River Alluvial Valley of Arkansas and Mississippi. Depressions are topographically low sites, surrounded by higher ground, where water from precipitation, runoff, groundwater, or stream flooding can accumulate and remain for extended periods. In addition to the Isolated and Connected Depression subclasses, another type of depression is recognized as an "included depression", such as vernal pools that occur within the Flats and Riverine subclasses. Isolated and Connected Depression types usually are associated with abandoned channels or large swales on point bars. They collect and hold rain, ground, and flood water, filling during winter and drying slowly in spring, and may partially fill then dry after heavy rains during the growing season. Isolated or unconnected depressions may be affected by overbank or backwater flooding, but at intervals that exceed once every 5 years. Water in connected depressions includes precipitation, but also more frequent overbank and backwater flooding at least once during a 5-year interval. Included depressions (vernal pools) within Flats, Riverine Backwater, and Riverine Overbank subclasses can store overbank and backwater flood water, but precipitation is the primary and most frequent source, annually filling during normal periods of winter rainfall, drying within days or weeks in spring.

The Riverine Backwater and Overbank subclasses, with the exception of depressional inclusions, do not store floodwater in depressions. Floodwater at frequencies of 5 years or less overflow riverine sites, but recede slowly during backwater events and more rapidly during overbank or headwater floods.

According to the Corps, the existence of any hydrology at pondberry sites located above the 2-year floodplain would be dominated by local site conditions, and not overbank flooding. Also, the Corps contends that backwater flooding is not an important hydrological factor affecting the species under current conditions, and that pondberry does not depend on a jurisdictional wetland hydrology.

As evidence for these conclusions, the Corps presents data and information in the BA that:

- Pondberry colonies frequently are associated with localized depressions, which would be capable of storing rainfall and establishing or increasing a local hydroperiod ;

- Pondberry at some sites are jurisdictional wetlands where the hydrology is established by local factors, without overbank flooding at a frequency or duration to establish wetlands;

- Pondberry health was excellent to good at sites with infrequent flooding during the past 20 years;.

- There are no statistically significant relationships between flooding and measures of the number of pondberry or its growth, vigor, number, and health; and

- Pondberry occurs at infrequently flooded sites that are not wetlands.

By our analysis, we find that this evidence is subject to either scientific uncertainty or contrary conclusions based on the available data, so that:

- The existence and association with depressions at most pondberry colony/sites that are not wetlands has not been demonstrated by any scientific characterization a depressional hydroperiod and geomorphology.

- Jurisdictional wetland surveys documented wetlands established by local conditions, independent of overbank flooding, at 11 (23.4 percent) of 47 profiled colonies,

- Pondberry health ratings are not related to performance, as most colonies rated as excellent and in good health in 2000 declined substantially by 2005;

- Statistical relationships demonstrate pondberry is affected by flooding, where the average colony size is greater on more frequently flooded sites, significantly more pondberry is sustained in wetland than nonwetland colonies, the rate of pondberry persistence in wetlands is greater than nonwetlands during the 2000-2005 decline, and colony/site growth rates decline as flood frequency decreases; and

- Pondberry at some currently infrequently flooded sites were historically flooded more frequently prior to the completion of previous flood control projects.

The Corps' analysis includes other elements that, while not described in the above summary, are evaluated in more detail in the following sections. Given that pondberry is classified as an obligate wetland species, the first section to follow is a review of the hydrology pondberry likely requires. Wetland hydrology is defined by the hydroperiod, which is the duration of standing water or soil saturation, timing, and its frequency of occurrence (Mitsch and Gosselink 2000). This is related to the issue of depressional storage of precipitation in two ways. First, there is the question of the extent that pondberry is associated with depressions and the direct evidence that such features can store rainfall or otherwise affect hydrology. Secondly, if pondberry is not always associated with depressional wetlands at infrequently flooded sites, then what is the species response?

The next section is a description and assessment of the Corps methodology for assessing hydrology and the extent of jurisdictional wetlands due to backwater flooding and local conditions. The Corps data for frequency of backwater flooding is derived from standard methods and analyses of hydrographs, in conjunction with hydrological models. In addition, the Corps assessed the amount and distribution of jurisdictional wetlands by the frequency and duration of backwater flooding, corresponding to the hydrology criterion of the 1987 wetland manual, using two methods (FLOOD and FESM). The output from these two methods are geospatially explicit coverages of the estimated jurisdictional wetlands. Also, the acreage and distribution of wetlands by these two methods were evaluated relative to the estimates generated by a third method, implemented by the Environmental Protection Agency (EPA) through the Environmental Monitoring and Assessment Program (EMAP).

These methods, models, and data for the area and coverage of jurisdictional wetlands are important to the issue of hydrology and pondberry for several reasons. These are the primary sources of information on hydrology and hydroperiod, but the estimates of jurisdictional hydrology differ among the three methods. Assessments of hydrological factors currently affecting pondberry also may vary depending on the method, the accuracy and limitations of the method, and the kind of hydrology assessed.

These and other data on flood frequency and duration are described and evaluated relative the occurrence and distribution of pondberry. With this background information on pondberry and hydrology in the action area, the final sections addresses the nature of hydrology in the current and historical environment, and the species response.

Pondberry hydrology

According to the National List of Plant Species that Occur in Wetlands (Reed 1988), pondberry is an obligate wetland species that occurs almost always (estimated probability >99%) under natural conditions in wetlands. As such, it is reasonable to expect that the habitat for pondberry should have a wetland hydroperiod. There are no experimental studies or data available on the growth and reproduction of pondberry in response to different hydroperiods. The regulatory definition of a wetland hydroperiod probably is the best available data to characterize the hydrology that would be expected of habitat capable of sustaining pondberry, as an obligate wetland plant. The National Research Council has concluded than the basis for classifying wetland species is scientifically credible (National Research Council 1995).

Normally, plant tissues require oxygen for the essential life sustaining metabolic process of respiration. Aquatic and wetland plants possess structural and physiological adaptations to cope with periodic flooding, limited oxygen, and anaerobic conditions, particularly during the growing season (Mitsch and Gosselink 1993; Ernst 1990). Morphological or structural adaptations of species in bottomland hardwoods include shallow root systems, abundant stem lenticels for gas exchange, and adventitious roots (Hook and Brown 1973; Whitlow and Harris 1979; Teskey and Hinkley 1977; Smith et al. 1986). Other adaptations include the development of special tissues creating air chambers in roots, arenchyma or lacunae, which allow oxygen to be diffused downward from plant tissues above water and saturated soils

(Burdick and Mendelssohn 1990; Pezeshki et al. 1991; Mitsch and Gosselink 1993). Both of these morphological features use limited oxygen, enabling anaerobic respiration to continue by which the products of photosynthesis, sugar, are metabolized in the presence of oxygen to produce energy. In addition, other adaptations enable plant respiration to continue without oxygen in an aerobic environment, including alternative biochemical pathways to metabolize the products of photosynthesis (Smith and Rees 1979; Ernst 1990) and toxic accumulations of alcohol in plant tissue (Crawford and Tyler 1969; MacMannon and Crawford 1971; Mendelson et al. 1982; Smith et al. 1986).

Wetland plants do not necessarily require water saturated soils and anaerobic conditions for their growth and reproduction (Huffman and Forsythe 1981). These species are distinguished by their eco-physiological tolerance to such conditions. In a number of studies funded by the Service, hydric soils and vegetation were closely correlated (e.g. Scott et al. 1989). Data from studies on plant flood tolerance and hydrologic thresholds indicate hydric conditions exist with water inundation or saturation to a depth of 1 foot or less for at least 14 days in the growing season, once out of every 2 years (National Research Council 1995), which closely approximates the regulatory definition and its application in temperate bottomland hardwood systems in the southeast. These hydrologic conditions represent a minimum threshold, at least in most wetlands in the temperate southeastern United States, where most plants require some form of adaptation to survive.

Hydrology is the most significant factor controlling the abiotic and biotic characteristics of wetlands, which are major factors affecting the species composition, species distribution, and structure of the wetland plant community, including bottomland hardwoods (Conner and Day 1982; Wharton et al. 1982; Brinson 1990; Gosselink et al. 1990; Sharitz and Mitsch 1993; Cronk and Fennessy 2001). More specifically, the hydroperiod consists of the frequency and duration of flooding or water saturation in soils. Water saturated soils eventually become deficient in oxygen, altering biogeochemical pathways, soil nutrient availability, and plant metabolic and physiological processes. Plants with adaptations to anoxic conditions tolerate wetland environments, to the total or partial exclusion of other less tolerant and intolerant species. Hydrology directly affects pondberry by establishing a range of anoxic soil conditions to which the species is tolerant and capable of growth, reproduction, and survival. Also, hydrology indirectly affects pondberry by regulating the species composition and structure of the wetland plant community, which can positively or negatively affect growth, reproduction and survival by competition with other species for resources such as sun, space, and nutrients.

The national criteria for classifying plants, such as pondberry, as obligate wetland species for the National List of Plant Species that Occur in Wetlands (Reed 1988) was not based on empirical measurements of the hydroperiod associated with each species. The list of wetland species was prepared, classified, and reviewed by regional and national panels of botanists and wetland ecologists, according to the observed fidelity and estimated frequency of occurrence in wetlands. Wetland plants, as defined by the national list, are those

> "that have a demonstrated ability (presumably because of morphological and/or physiological adaptations and/or reproductive strategies) to achieve maturity and reproduce in an environment where all or portions of the soil within the root zone become, periodically or continuously, saturated or inundated during the growing season (adapted from Huffman 1981)."

According to the national classification, obligate wetland species almost always (>99%) occur under natural conditions in wetlands. Facultative wetland species usually occur in wetlands, 67% - 99% of the time, but occasionally can be found in nonwetlands. And by decreasing order of fidelity, other classes are those equally likely to occur in wetlands or nonwetlands (facultative, 34% - 66%), those usually occurring in nonwetlands but occasionally in wetlands (facultative upland), and those that almost always (>99%) occur in nonwetlands (obligate upland). The Service, through interagency national and regional scientific review panels, has prepared a 1996 National List of Vascular Species That Occur in Wetlands, as a draft revision to the 1988 list. Pondberry in the 1996 latest list also is classified as an obligate wetland species (Reed 1997).

The Service first drafted the list of hydrophytes in 1976, from a synthesis of the scientific literature and sources of information from various state, regional, and national flora manuals. As NRC has described, the list of hydrophytes when first published in the 1980's, but was based on a definition of hydrophytes that preceded the Corps 1987 manual for delineating wetlands regulated under section 404 of the Clean Water Act (CWA). The Corps 1987 manual was derived from earlier drafts and guidelines following the 1977 Clean Water Act amendments, which included wetland delineation criteria for hydrology, soils, and vegetation. Hydrophytic vegetation was defined in the Corps 1987 manual as:

> "[T]he sum total of macrophytic plant life that occurs in areas where the frequency and duration of inundation or soil saturation produces permanently or periodically saturated soils of sufficient duration to exert a controlling influence on the plant species present."

According to NRC (e.g. Tiner 1991), the similar definitions of a wetland plant or hydrophyte in federal delineation manuals and the list of hydrophytes were due to their derivation from the definition by Daubenmire (1968) as:

> "[H]ydrophytes are plants capable of growth in substrates that are at least periodically deficient in oxygen as a result of high water content." (e.g. Tiner 1991).

The Corps' 1987 wetland manual, which is the current regulatory delineation standard, is based on criteria and indicators for hydrology, soils, and vegetation. The hydrophytic vegetation criterion uses the National List of the Plant Species that Occur in Wetlands, with field procedures for assessing the prevalence of wetland species. The Corps 1987 hydrology threshold requires, on average, continuous inundation or saturation at the surface for 12.5 percent or more of the growing season, or from 5 – 12.5 percent with other evidence. This corresponds to 14 or more days of inundation or saturation in the lower Yazoo Basin, occurring on average with a frequency of once every 2 years (U.S. Army Corps of Engineers 2005a).

The National Research Council (1995) has evaluated the scientific basis for characterizing and delineating regulatory wetlands in a report and response to a request from Congress. Concerning the list of hydrophytic plants, the National Research Council (NRC) evaluated the definition of a hydrophyte and the procedures by which the list of hydrophytes was developed, concluding that the list is a scientifically and credible tool for identifying wetland vegetation.

The wetland plant list was not developed with specific consideration to the Corps hydrology threshold for the duration and frequency of inundation or saturation required for a regulatory wetland. Scientifically reliable relationships exist, however, from numerous experimental and field studies demonstrating the effects of hydrology and water saturated soils to the response and tolerance of plants to anoxic conditions, leading to the development of hydrophytic vegetation, particularly in the southeastern United States and in bottomland hardwood systems (National Research Council 1995). Furthermore, the scientific basis for using plants and vegetation to identify wetlands is based on the strong relationship between hydric conditions and distinctive vegetation that develops in response to soils saturated with water, which plant ecologists have used for decades to identify wetlands (National Research Council 1995).

The Corps definition for wetland hydrology in the jurisdictional delineation manual was developed independently of the national list of wetland plants, although the jurisdictional wetland manual uses the national list of wetland plants as part of the wetland vegetation criteria. The wetland jurisdictional manual and national plant list are based, however, on similar and related science. On the basis of its classification as an obligate wetland species, then the regulatory hydrological definition of a wetland in the Corps 1987 wetland manual probably provides the best available characterization of the wetland hydroperiod where pondberry should normally and successfully occur. By the relationship between the fidelity definition of an obligate wetland species and the regulatory hydrology threshold, then the occurrence of pondberry under natural conditions would be expected as "almost always (estimated probability >99%)" in wetlands with the regulatory defined hydroperiod. The regulatory hydroperiod in the lower Yazoo Basin is 14 or more days of continuous inundation or saturation during March 1 through November 27 (U.S. Army Corps of Engineers 2005a).

The regulatory wetland definition implies a cause-effect relationship among the hydrology, soils, and vegetation criteria used for delineation: "inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal conditions do support, a prevalence of vegetation typically adapted for life in saturated soil conditions" (Dewey et al. 2006). While there is ample scientific reason to expect this relationship in most instances, it also is well known that the hydrology, soils, and vegetation criteria do not always agree (National Research Council 1995, Dewey et al. 2006). Hydrophytes or obligate wetland species, for example, have not been classified only after extensive hydrologic studies affirmed that they almost always occur at sites where the hydrology conforms to the regulatory hydrology definition. The ecology and distribution of pondberry, as an obligate wetland species, also may not conform perfectly with the regulatory definition of hydrology. In the absence of any other data, our evaluation of the status of pondberry begins with an assessment of the distribution of wetlands according to the Corp regulatory definition of wetland hydrology.

FESM Wetlands

The model and methods

The Corps, in collaboration with EPA and ERDC, delineated the spatial extent of wetlands in the action area. The Corps used the jurisdictional definition of wetlands, as "those areas that are inundated or saturated by surface or ground water at a frequency and duration to support, and that under normal circumstances do support, a prevalence of vegetation typically adopted for a life in saturated soil conditions", as based on the hydrology criteria in the manual:

> "Areas that are irregularly inundated or saturated less than 5 percent of the growing season continuously are not wetlands. Areas that are inundated or saturated irregularly more than 12.5 percent of the growing season continuously are wetlands. Areas that are inundated or saturated between 5 and 12.5 percent of the growing season continuously may or may not be wetlands."

The Corps conservatively included land with at least a 5 percent flood duration as jurisdictional wetlands. Based on the average frost free days in the lower Yazoo River basin, this represents areas with at least 14 days of continuous inundation or saturation between March 1 and November 27, in most years (50 percent probability of recurrence).

In contrast to an onsite field determination of the location and extent of wetlands based on indicators of hydrology, soils, and vegetation criteria, the Corps used offsite or remote methods based strictly on hydrology. The two methods were the 5 percent Duration Flood Method (FLOOD), and the Flood Event Simulation Tool (FESM). Both methods incorporate GIS and the output consists of maps with the location and acreage of jurisdictional wetlands, with other land use information. Results from FLOOD were restricted to a delineation of current baseline wetland conditions. FESM also generated baseline wetland estimates, but the FESM method also had the advantageous use for modeling and predicting future wetland changes as affected by the proposed project.

The Corps Vicksburg District developed FLOOD as a method to estimate the area covered in a backwater flood with a 5 percent continuous flood duration, corresponding to the hydrology criterion of a jurisdictional wetland. Historical stream stage-gage data are first acquired from records and processed to compute the median elevation for the 5 percent duration backwater flood event. With these data, a suitable LANDSAT satellite image is selected that corresponds with the flood event, and with GIS, processed to depict the area and acreage covered by the flood event. Factors in the methodology affecting the wetland estimates include the period of record (POR) for flood stage data and the various hydrological models and other procedures to generate and process this data.

FESM is an enhanced model version of FEAT (Flood Event Assessment Tool), a prototype geospatial modeling tool intended to increase the accuracy and reduce the time required to determine dynamic flood surfaces (Ballard and Kress 2004). The model is programmed as an ESRI Arc-View GIS extension, with Spatial Analyst, to simulate flood surface events. FEAT was developed by the Army Engineering and Research Laboratory (ERDC) Environmental Laboratory for the Vicksburg District to determine wetland acreage under baseline (pre-project) and post-project conditions (U .S. Army Corps of Engineers 2000 - Appendix 6 and the 2005 revised Appendix 10,). Further details of the model, data, and algorithms are in Ballard and Kress (2004).

The process of simulating backwater flooding in the lower Yazoo River basin with FESM required creating input data, calibrating the digital model to a satellite flood image, verifying the model against another satellite flood scene image, and running the model to generate the spatial coverage and extent of wetlands (Figure 5).

Primary digital input data consisted of a digital elevation model (DEM), stage elevations for each stream gage, channel cross sections, and stream center lines. The Corps used stage-gage data from 1943 – 1997 as the period of record (POR), as adjusted for the effects of various flood control structures and measures constructed during this period. These data control and determine the distribution of the floodwater surface across the land base according to the flood elevation, land elevation, slope, and the extent that land surfaces below the flood elevation are not disconnected from the flood source by intervening lands of higher elevation or the absence of hydrological connection. The 5 percent duration backwater flood elevation data at six gages and other nodes used in FESM are the same data as acquired and processed for FLOOD. Stream channels were digitized from digital raster graphics (DRG) files of topographic quadrangles and hydrography files. The elevation model was a 30-meter USGS DEM from 7.5', 1:24,000 topographic quadrangles, with 5-foot elevation contours.

In addition to the Corps' wetland estimates from FLOOD and FESM, EPA used a probabilistic field sampling design in their Environmental Monitoring and Assessment Program (EMAP) to independently estimate wetland acreage for comparison to the Corps' estimates. EMAP is a program of the EPA Office of Research and Development to advance the science of natural resource monitoring. For such purposes, EMAP uses probabilistic random sampling designs to evaluate target populations at a defined level of statistical accuracy and confidence. The objective of this EMAP survey was to estimate the geographic extent (acres) of potential jurisdictional wetlands in the backwater area with known statistical confidence, specifically for comparison to the Corps' FESM estimates. The target population for random stratified sampling was all potentially jurisdictional wetlands within the Corps' delineated 100-year floodplain of the Yazoo Backwater Area.

The EMAP method was a field survey and determination, based on 144 random samples designed as generalized random tessellation stratified (GRTS) with reverse hierarchical ordering. At each site, a team representing EPA, the Corps, Service, and the National Resource Conservation Service (NRCS) conducted a standard field jurisdictional wetland determination based on hydrology, soils, and vegetation. The number of wet and not wet site classifications were the raw data used in the statistical procedure to the estimate the area covered by jurisdictional wetlands (e.g. Diaz-Ramos et al. 1996, Stevens and Olsen 1999, 2003, 2004).

FLOOD, FESM, and EMAP are similar in that they estimate the wetland area (acres) in the Yazoo Backwater Area. FLOOD and FESM are designed to remotely detect, directly or indirectly, and measure the area covered by standing floodwater for 14 continuous days in the growing season. In contrast, EMAP is a statistically based field survey of points where the existence of a wetland at each point is delineated by the combined jurisdictional criteria of hydrology, soils, and vegetation. The EMAP procedure generates a statistical estimate of the acres of wetlands, with confidence intervals, but does not spatially identify their location and coverage. FLOOD and FESM methods are spatially explicit, but the output in acreage of wetlands are expressed without a statistical confidence interval, which otherwise is technically feasible since the 95 percent confidence interval for the median stage-gage data for the 5 percent duration elevation can be computed, with the FESM wetland acreage for the interval. These three procedures differ in many other details, with technical strengths and weaknesses, and certain advantages and disadvantages. Many of these details are described further in the Corps draft revision of the wetland appendix for the backwater project (U.S. Army Corps of Engineers 2005a).

FESM-EMAP Comparative Results

The potential jurisdictional wetland acreages identified by these methods were 205,332 FLOOD, 189,600 FESM, and 212,284 EMAP (Table 9). The areas spatially identified by the FLOOD and FESM model are considered potential jurisdictional wetlands to distinguish these estimates of jurisdictional wetlands from an actual jurisdictional field determination. The FESM model, with a 10-meter DEM, was 180,899 acres. Differences between the estimates can be attributed to several sources, including methodology, the sample or delineation area, the resolution and accuracy of LANDSAT, GPS, GIS, and other factors. The Corps made adjustments for some of these factors to reduce the difference between the FESM and EMAP estimates. Some of the technical issues underlying these differences still remain unresolved in our opinion. Overall, the Corps selected and continued to use the FESM model, with a 30-meter DEM, in part because of its advantage to spatially estimate wetlands under baseline conditions and as affected in the future by the proposed project.

The EMAP survey was designed to sample three strata; the originally classified FESM forested wetlands (Tier 1) the Corps considered as the area of the 5 percent duration flood event, the forests outside the Corps FESM 5 percent duration flood area (Tier 2), and all other open lands above the 5 percent duration flood area (Tier 3). After the EMAP survey, the Corps further adjusted and calibrated their FESM model, which generated a slightly greater area of wetlands. These areas of additional wetlands appear in the FESM Tier 2 and 3 categories (Table 9).

Overall, the FESM model classified fewer areas as wetlands than the EMAP field procedure. In Tier 1, FESM classified a greater acreage than EMAP than in Tiers 2 or 3 (Table 9). The Corps conducted further evaluations using additional satellite scenes and other methods. Based on these evaluations, the Corps concluded that most of the differences between the EMAP and FESM classifications were due to local hydrology. The FESM procedure for delineating wetlands is based on the prediction of surface flood water at the 5 percent duration elevation. In the absence of visible water from satellite scenes at sites with contradictory classifications (wetland vs. not wetland) by FESM and EMAP, the Corps concluded that most of the differences between the FESM and EMAP classifications at field sites must be due to the existence of a local wetland hydrology in depressions, independent of overbank flooding, leading to a wetland classification by the EMAP field determination, and a nonwetland classification by

FESM. To resolve the mixed classifications, the Corps also considered the site elevation from the 30-m DEM in relation to the flood stage elevation at the nearest stream gages. This was based on remote data, and not a site or field evaluation of a depressional or local hydrology independent of overbank floodwater. The local hydrology explanation by the Corps means that sites classified by EMAP as wetland, but nonwetland by FESM, must be physically located above the elevation of the 5 percent flood duration event, and capable of collecting and storing rainfall to saturate soils for 14 or more days during the growing season.

In our review of the Corps data and evaluation, there appears to be evidence to support the Corps explanation for these differences, but it does not seem conclusive. In our opinion, there remains scientific uncertainty, and we are unable to clearly resolve the differences. One issue the Corps recognized is that the 10-meter DEM will generate differences relative to the 30-meter DEM. The 30-meter DEM probably is most the important source of data inaccuracy affecting the simulated flood surface (U.S. Army Corps of Engineers 2005a). The DEM is a digital representation of the terrain or landform, with elevations and slopes, which in this case were produced by USGS from their 7.5' topographic maps within the area. Although the 30-meter DEM and 10-meter DEM are derived from the same 5-foot topographic elevation contours from the 1:24,000 USGS topographic maps, they produce different terrains and in conjunction with FESM generate different wetland acreages (Table 10). FESM with the 30-meter DEM produces a wetland area estimate of 186,522 acres, which is 43,205 acres more than the FESM 10-meter estimate of 173,601 acres. Which is the most accurate?

The 10-meter DEM elevation grid is a more finely resolved surface than the 30-meter DEM grid. DEM grid cell size is known to significantly affect the modeled landform, accuracy, and hydrology (Li 1992; Thieken et al. 1999; Kienzle 2004; Wechsler 2006), as evident with these estimates. Generally, a 10-meter DEM with greater resolution is preferred over the more coarse 30-meter DEM, but higher resolution with smaller grid cell sizes does not necessarily generate better models or reduce DEM error (Wechsler and Kroll 2006). The USGS has classified three types of DEM errors, as either systematic, blunders, or random (USGS 1997). Sources of error include old elevation-topographic data, their measurement, and the mathematical algorithms and procedures to classify, interpolate elevations, and process the data (e.g. Burrough 1986; Wise 1988, 2000). Systematic errors follow fixed patterns and are caused by the procedures to generate the DEM. Blunders are elevation errors caused in the process of collecting elevation data. Random errors are those that remain in the data. As a measure of accuracy, the USGS reports the root mean square error (RMSE) for their DEM products. The RMSE, however, does not assess the extent that the elevation assigned to DEM cells actually reflect the true elevation, and instead, it represents the extent the DEM data correspond to the topographic map or other data from which it was generated (Wechsler 2006). A variety of methods are available to assess DEM uncertainty and error, but unfortunately, these factors infrequently are described or accounted for by DEM users with hydrologic applications (Wechsler 2003, 2006).

The Corps did not evaluate or report reasons why the 10-meter DEM produced a different classification relative to FESM with the 30-m DEM, or which is more accurate and why. Elevations are an important feature of these models because they determine the surface of the land, flood, and the area flooded. The National Academy of Sciences, for example, has determined that digital elevation data for national floodplain mapping should be derived from the more accurate light detection and ranging (LIDAR), and not the USGS National Elevation Dataset and photogrammetry which is the data source for USGS 10-meter and 30-meter DEMs (National Research Council 2007). LIDAR is a laser technology by which aircraft with these systems transmit hundreds of thousands of laser pulses per second to the earth surface, measuring laser pulse reflection and elevation. The Corps method included a calibration by comparing and adjusting the FESM flood surface relative to LANDSAT (satellite) scenes during representative 5 percent duration flood events. Nevertheless, we are left with the uncertainty that the FESM model with the 30-m DEM may be overestimating wetlands relative to a more accurate model with the 10-m DEM, while both FESM models with a 10-m DEM and 30-m DEM could be underestimating total wetlands relative to the area estimated EMAP in Tier 1.

More specifically, the subject of uncertainty is the baseline area of FESM wetlands as used by the Corps, as well in subsequent sections of this biological opinion, with GIS to assess the current and historical extent that the 177 pondberry colonies/sites are associated with wetlands, and other analyses.
The GIS coverage of the 5 percent duration flood event is the only source of wetland data for all 177 coloneis/sites. However, a different set of wetland and hydrology data also are available for 47-49 of these 177 colonies/sites, derived from site specific field wetland surveys at 47 colonies/sites, and physical elevation surveys with instrument and rod from established benchmarks at 49 colonies/sites. These data and other statistical analyses are described in subsequent sections.

Pondberry occurrence and distribution in wetlands from overbank flooding, and flood frequencies

FESM wetlands, established by overbank flooding, occur on 71 percent of the DNF. Of the 177 known DNF pondberry colonies/sites, only 9.6 percent (17) are in FESM wetlands. Sixty-seven percent of the stands comprehensively surveyed by the U.S. Forest Service for pondberry are in FESM wetlands. Most pondberry colonies/sites occur in nonwetlands (160 of 177 colonies/sites), relative to the number expected by a random distribution in wetlands and nonwetlands. Nonwetland sites are locations where the frequency and duration of overbank flooding are inadequate to establish a jurisdictional wetland hydrology. The predominance of colonies/sites in nonwetlands does not appear to be significantly biased due to disproportionate pondberry surveys in areas that are not wetlands. Most of the DNF is frequently flooded, located on the 0-2 year floodplain as spatially identified by FESM and a 30-m DEM. The flood frequency at most colonies/sites, according to the FESM-GIS with a 30-m DEM, is about 2 years. However, flood frequency is much less when determined according to the ground-surveyed elevations from established benchmarks at each colony/site.

The Corps used GIS and FESM to describe land use types and jurisdictional wetland coverage in the Yazoo Backwater Area. During this consultation, the Corps updated the land use coverage using 2005 satellite imagery. Based on this information, there are 288,310 acres of bottomland hardwood forests in the backwater area, which includes regenerated and reforested sites. Of the 169,466 acres of wetlands in the backwater area, 148,458 acres are bottomland hardwood forests (Plate 10). The DNF in the action area consists of about 61,840 acres of forests, of which 43,596 (71 percent) acres are wetlands by the Corps assessment. These are sites, by the FESM model and definition, estimated to receive 14 or more continuous days of backwater inundation during the growing season, on average once every 2 years. Most of the areas that are not wetlands are in the northern and southeastern portions of the forest.

Most of the 177 known colonies/sites are in areas that are not FESM jurisdictional wetlands (Plate 11). Of the 177 known pondberry colonies/sites in 2000, only 17 (9.6 percent) are in FESM wetland forests (Table 11). Only three (6.1 percent) of the 49 profiled (GSRC) colonies/sites are in FESM wetlands (Table 11). The 177 known colonies/sites in DNF also include the 49 GSRC (Corps) profile sites. To make independent estimates of the proportion of FESM wetland colonies/sites, we removed the 49 profiled colonies/sites from the set of 177 known colonies/sites. Of the 128 known colonies/sites that were not profiled by the Corps, 10.9 percent (14) are in FESM wetlands, compared to the 6.1 percent of the profiled colonies/sites in wetlands. Overall, these estimates of the proportion of colonies/sites in wetlands are not substantially different.

These data indicate that pondberry colonies/sites are not restricted to FESM wetlands, and that most occur outside of these wetlands. However, strong inferences from these data as representative samples of pondberry as a whole in DNF are more limited. The available pondberry occurrence data were not generated from a study designed with random sampling intended to assess the distribution and abundance of pondberry in DNF. Likewise, the Corps did not design or conduct surveys in their assessment as random, representative samples to make conclusions or inferences about the abundance and distribution of pondberry relative to FESM or other wetlands. Instead, the Corps used the available data from their profile, U.S. Forest Service stand surveys, and other information in stands that have not been comprehensively surveyed to make conclusions about the nature of pondberry. Also, it is difficult to interpret these "occurrences" from existing data because each can biologically represent different attributes, such as a single colony, several colonies, or many colonies and plants.

Based on this data, the Corps concluded there was a naturally low probability of pondberry occurring on or below the 1-year floodplain. Also, the absence of more frequent pondberry occurrences at lower elevations and more frequently flooded sites in DNF was not the result of limited or disproportionate surveys. The most significant source of potential bias in these data and the Corps conclusion is the extent that surveys have or have not been conducted disproportionately or in an unrepresentative manner relative to the area and acres of FESM wetlands in DNF. The Corps assessed the likelihood that the data are biased by comparing the acres of stands in DNF above and below the 1-year floodplain that had been comprehensively surveyed for pondberry (Table 12). The entire 1-year floodplain in DNF is a FESM wetland. According to the Corps (U.S. Army Corps of Engineers 2005b - Appendix 14, pg. 14-16), about 60 percent of the DNF is below the 1-year flood frequency, where about 24.4 percent of the stands have been comprehensive surveyed by U.S. Forest Service staff and about 12.6 percent of the known colonies are located. However, based on acres surveyed, the 1-year floodplain has been surveyed proportionately less than areas above the 1-year flood frequency (G =1,624, $p < 0.0001$, Table 13).

As the supporting basis for the Corps conclusion, these data are confounded, however, because the total number of known pondberry colonies/sites the Corps tallied for the stands comprehensively surveyed in DNF included known colonies/sites in stands that have not been comprehensively surveyed. There are two basic sources of data for known pondberry occurrences in DNF. One is from the comprehensive surveys the U.S. Forest Service completed before conducting or planning mechanical operations and timber harvest. The other primary source is from U.S. Forest staff and other personnel providing data on their observed occurrence of pondberry during their activities in stands that have not been comprehensively surveyed.

We evaluated the degree that the stands surveyed by the U.S. Forest Service are not disproportionately represented in FESM wetlands and nonwetlands by contingency analysis. Similarly, we compared the number of known pondberry colonies/sites in these areas by contingency tables. Both analyses compare the actual or observed values to that expected in the absence of any association or departure from independence. These two analyses are related because the expected number of pondberry, if it occurs independently of the land class (nonwetlands and wetlands), depends on the proportions of the land class types surveyed. Our data are not strictly comparable to that reported in the Corps BA for one primary reason. The Corps analysis included five colonies/sites in an area of about 1,650 acres in the southeastern corner of DNF that actually are outside the area affected by this project (action area). These colonies/sites are on the other side of the backwater levee, and are not within the backwater area. When this area and these colonies/sites are removed, then the acres and number of pondberry colonies/sites in DNF also changes.

From our comparison, it generally appears that the comprehensive surveys are not substantially biased, and the more relatively frequent occurrence of pondberry colonies/sites in areas that are not wetlands is not the result of any significantly disproportionate surveys. The frequency of pondberry colonies/sites in wetland areas is much less than the expected frequency if the species occurred independently (proportionately) to survey class (comprehensive or not) and wetland class (wetland or not). There are important considerations, however, to interpreting these data.

The contingency analysis for interactions between survey type (comprehensive or not) and land class (wetlands or not) reflects a Model II for a two-way contingency table where the marginal totals for one factor are fixed (Sokal and Rohlf 1981). The two factors are survey type and land class. The fixed total value is the total acreage comprehensively surveyed and not surveyed by the U.S. Forest Service. The stands and acreage surveyed were not selected or allowed to independently vary as part of any experimental design. They were chosen by the Forest Service for other reasons, and the total acreage surveyed (19,513) and not surveyed (42,327) is established. This affects how the expected acreage will be computed. In this case, the expected acres surveyed and not surveyed by independence for each land class type (wetland and nonwetland) is the proportion of each land class throughout DNF multiplied by the total acres for the particular survey type.

More wetland acres were surveyed than nonwetland, reflecting the general trend that there exists more wetland overall in DNF (Table 14). The actual wetland acreage surveyed, however, is less than expected by an independent or proportionate survey. Likewise, the actual wetlands that were not comprehensively surveyed are less than what would be expected. The differences are not substantial. The acres of nonwetlands surveyed (6,497) were about 12.0 percent greater than expected (5,796 acres), and the surveyed wetlands (13,016) were 5.4 percent less than expected (13,757). Unsurveyed nonwetlands (11,747 acres) were about 5.9 percent less.

Statistically, these differences would be significant, but what is more important is the relative magnitude of the actual survey to that expected. They are comparable. We used the data on the actual acres surveyed and not surveyed to generate a hypothesis that the frequency of known pondberry colonies/sites is not associated (independent) with hydrology (nonwetlands and wetlands). The expected frequency or number of pondberry is based on extrinsic data for the actual proportion of wetlands and nonwetlands by survey class. For comprehensively surveyed and unsurveyed stands alike, the number of known pondberry colonies/sites was greater than expected in nonwetlands and less than expected in FESM wetlands (Table 16).

Interpreting the data and results for pondberry colonies/sites in areas that have not been comprehensively surveyed is problematical. Of the 174 extant colonies/sites in 2005 (3 colonies/sites from 2000 were extirpated by 2005), 68 are known from stands that have not been comprehensively surveyed. Instead, these 68 occurrences have been generated by incidental or other work in parts of these stands by U.S. Forest Service and other personnel. Of the 1,445 stands in the DNF action area, 612 have been comprehensively surveyed for pondberry, with completely and exclusively positive or negative results. Of the 833 stands that have not been comprehensively surveyed, pondberry has been found in 25. In fact, most of the 68 colonies/sites in unsurveyed stands are near stands that have either been comprehensively surveyed or are where pondberry is otherwise known to occur (Plate 13). The extent that pondberry has been incidentally searched for with negative results in the remaining 808 stands without comprehensive surveys is unknown. So, the two sets of non-wet and wet acreages in the class of lands that have not been comprehensively surveyed do not combine as part of a common and exhaustive set with no more than a total of 68 colonies/sites. The contingency table is not exhaustive for this class.

Removing the analysis of pondberry colonies/sites in unsurveyed stands reduces the data for consideration, but the same general trend is apparent for the data in the comprehensively surveyed stands (Table 16). Pondberry colonies/sites in DNF tend to occur at a disproportionately greater frequency in FESM nonwetlands than wetlands. The data are inadequate, however to accurately assess the relative abundance of pondberry in nonwetland areas as compared to FESM wetlands.

<u>Pondberry occurrence by flood frequency according to the FESM-GIS 30-meter DEM estimate and ground-surveyed elevations</u>

According to Corps FESM-GIS data, most of the DNF (55,579 acres) is in the 2-year (0-2) floodplain, with about 9.7 percent (5,985 acres) in the 3-5 year floodplain (Table 17). The 3-5 year floodplain on higher elevations is located mostly along the edges of DNF (Plate 14). For 177 known pondberry colonies/sites in 2000, 85 (48 percent) were in the 0-2 year floodplain, and 92 (52 percent) were in the 3-5 year floodplain (Table 17). A smaller proportion of the Corps GSRC sites (49) selected for their pondberry profile are in the 0-2 year floodplain (19, 39 percent), with 30 sites (68 percent) in the 3-5 year floodplain (Table 17).

The frequency of flooding is a component of hydrology, regardless of whether an area or site is a jurisdictional wetland. Flood frequency is the probability that a site will receive overbank flood water, on average, according to the POR for the stream gage-stage elevations the Corps used to compute respective flood return intervals. The Corps data provide two different estimates of the flood frequencies at pondberry colonies/sites, depending on the method. Both methods rely on estimates of ground elevations, which are determined differently.

The Corps GIS also provides coverage for areas that are not FESM wetlands, with their estimated flood frequency intervals. An area with the 2-year frequency means there is a 0.50 probability in any given year of a flood. Likewise, a flood frequency of 2 means that the site or area is estimated to flood once every 2 years on average. An area with a 5-year flood frequency has a 0.20 chance of flooding each year, which is a flood once every 5 years on average. As the flood frequency interval numerically increases, the actual frequency of flooding decreases. The GIS coverage of areas with different flood frequencies, in conjunction with the locations of the known pondberry colonies/sites, were used to assess their flood frequencies. These flood frequencies depend on the elevation of the ground surface relative to the elevation of the flood stage. The elevations used by FESM and associated GIS are derived from a 30-m DEM.

By the other method, the Corps determined the elevations at each of the 49 profiled pondberry colonies/sites from a physical ground-survey by a engineering crew, with a rod and instrument, from established elevation benchmarks. Using these ground-surveyed elevation data, the Corp estimated the flood frequency at each profiled colony/site according to the computed elevations of the flood stages and their frequencies as interpolated from the stream stage-gage elevation. The FESM method and GIS provides a flood frequency estimate for any of the 177 colonies/sites with known location. In contrast, the flood frequencies from ground-surveyed elevations can only be determined for those physically surveyed colonies/sites. The Corps GIS provides flood frequency estimates for all 177 colonies/sites, while the flood frequencies at the 49 ground-surveyed colonies apply only to those physically surveyed colonies.

The FESM-GIS elevation data and flood frequencies for 177 colonies/sites range from the 0-5 year floodplain. Flood frequencies for the colonies/sites with physically surveyed elevations range from the 0 – 17 year floodplain (Table 18). The 49 profiled colonies/sites are more hydric and frequently flooded according to the FESM-GIS 30-meter DEM.

There are two trends within this data and comparison. The FESM-GIS 30-meter DEM flood frequencies at 13 of the 49 colonies/sites are less[2] than the ground surveyed elevation frequency data (Table 19): the

[2] Flood frequencies are "greater" when the numerical value for frequency return interval is smaller. For example, a site that floods, on average, every year (1-year frequency) floods more frequently than an estimate or site with a 2-year flood frequency, which floods on average every other year. The 49 profiled pondberry colonies/sites have flood frequencies, from the ground surveyed elevation data, by rank descending order from more frequent to less of 1, 2, 3, 4, 5 . . . 17 (Table 19). A site with a 17-year flood frequency floods once every 17 years, on average, and has a 0.0588 probability of flooding during any given year (1/17).

GIS DEM data underestimate flooding. The GIS flood frequencies at these 13 pondberry/colonies range from 1 to 4 years, while the flood frequency from ground surveyed elevations ranges from 0.1 – 2.5 years. In contrast, the GIS flood frequencies at the remaining 36 profiled colonies/sites are overestimated more substantially (Table 19) relative to the ground surveyed elevation flood frequencies. For example, there are seven profiled colonies/sites with a 2-3 year flood frequency according to the GIS DEM, which are flooded only once every 15-17 years according to the frequency data from ground surveyed elevations (Figure 6, Tables 18-20).

The differences between the two methods of determining flood frequency primarily are due to differences in the elevation assigned to each colony/site. Colonies/sites with a substantially lower flood frequency interval (less flooding), according to ground surveyed elevations, have higher elevations than those assigned by the GIS DEM. The elevations derived from the 30-meter DEM used in the FESM-GIS model are not as accurate as the elevations determined from the ground survey. Also, most of the colonies/sites with the greatest discrepancies between flood frequency estimates tend to occur in the Red Gum population. This is the northernmost population where the frequency of flooding will decline much greater in magnitude than in southern populations for any given increase in elevation.

Given these two methods and estimates for flood frequencies, the Corps mostly used the 49 profiled colonies/sites with frequencies according to the ground surveyed elevations in their statistical analyses of the relationships of colony/site characteristics to flood frequency and hydrology. Accordingly, we have followed the same protocol.

Evidence for Ponding and Local Hydrology

Jurisdictional wetland field determinations

As previously described, there are at least four hydrogeomorphic settings and processes affecting hydrology, wetlands, and habitat for pondberry, as an obligate wetland species, in the lower Yazoo Basin; the storage of rainfall in depressions, rainfall at sites (flats) with impeded soil drainage without depressional storage, depressional storage of overbank floodwater, and overbank flooding at sites without depressional storage – and combinations of these conditions at different sites.

Participants in the Corps 1990 Pondberry Profile Workshop concluded that local precipitation and hydrology have more of an influence on pondberry colonies than overbank flooding since most of the known colonies in DNF at that time were located above the 15-20 year floodplain (U.S. Army Corps of Engineers 2005c). Since that time, the Corps has profiled other colonies and provided additional data on the frequency and duration of flooding, indicating that most colonies/sites are located on the more frequently flooded 0 – 5 year floodplain (Tables 18 and 19). The extent and role of a local hydrology at colonies/sites, where soils are saturated by rainfall and stored in depressions, has been an issue of disagreement between the Corps and Service that preceded this consultation (e.g. U.S. Fish and Wildlife Service 2000). The Service disagreed with conclusions by the Corps that pondberry colonies were associated with depressions where the hydrology was dominated by local rainfall, instead of inundation by overbank flooding.

The Corps BA for this project includes the 1991 profile report with the results of the 1990 pondberry workshop (U.S. Army Corps of Engineers 2005b - BA Attachment 2), and other references that "extant [pondberry] populations in Mississippi are all associated with bottom-land hardwoods at elevations where rainfall/local hydrology dominates the hydrologic conditions at the pondberry colony site" (BA pg. 14-5, U.S. Army Corps of Engineers 2005b). After the Corps prepared the BA for this project, they acquired additional data with other analyses during this consultation, from which both agencies have modified or clarified their earlier findings and positions about the extent and role of local hydrology and wetlands independent of overbank flooding. The most important information is the new data the Corps recently provided on the jurisdictional status of wetlands at profiled colonies/sites based on jurisdictional field determinations.

These surveys and determinations were completed for 47 of the 49 profiled pondberry colonies/sites (U.S. Army Corps of Engineers 2006). The jurisdictional field determinations were made according to the 1987 wetland manual, based on hydrology, soils, and vegetation.

Of the 47 surveyed colonies/sites, 13 were field determined to be jurisdictional wetlands (Plate 12). Two of these profiled (GSRC) wetland colonies (colony/sites 54 and 56) are the same two identified as wetlands by FESM (Table 11), indicating that the wetland hydrology is established by a sufficient frequency and duration of overbank flooding. The remaining 11 colonies/sites determined as wetlands by the jurisdictional field survey are identified as nonwetlands by FESM (Table 21). Assuming the FESM classification is correct, then the source of the hydrology for these 11 wetland colonies/sites cannot be exclusively from overbank flooding. Instead, the wetland hydrology must be dependent on rainfall at the site, independent of floodwater, where soils are sufficiently saturated because of local ponding and storage in depressions, or impeded soil drainage with or without depressional ponding on the surface. These factors will be referred to as local conditions.

Flood frequencies at the 11 wetland colonies/sites with a local hydrology range from 2 – 3 years according to FESM-GIS with a 30-meter DEM, and 1.5 – 17.0 years as estimated from ground-surveyed elevations (Table 21). The wetland hydrology at colonies/sites with a flood frequency of 2 years or less but not identified by FESM as a wetland site because of an insufficient flood duration can be established by a combination of local conditions with overbank flooding, or local conditions without flooding. By the jurisdictional hydrology definition, FESM wetlands are those with 14 or more days of inundation during the growing season, on average once every 2 years. There are six wetland colonies with a 2-year flood frequency interval, based on the FESM-GIS with a 30-m DEM (Table 21). In contrast, there are only three wetland colonies with 2-year or less flood frequency based on elevation data from ground surveys (Table 21). The Corps considers, and we agree, that the elevations and flood frequencies determined by the ground surveys are more accurate than the 30-meter DEM. Thus, the Corps data indicate that eight of these colonies/sites with flood frequencies greater than 2 years have a wetland hydrology established by local conditions independent of overbank flooding, three wetland colonies/sites with flood frequencies from 1.5 – 2.0 year are affected by both overbank flooding and local conditions, and two colonies are flooded with a sufficient frequency and duration to establish a wetland hydroperiod (FESM) based on overbank flooding (Table 21). Elsewhere from the survey, 34 colonies/sites are not in jurisdictional wetlands.

Two of the wetland colonies/sites (GSRC 42 and 43) that are not FESM wetlands, but were determined as jurisdictional wetland sites from the field survey, occur in the seasonally ponded area or vernal pools of the Colby population (Plate 12). As previously described for this population, there are two depressions that capture and store winter rain, inundating the depressions into the spring growing season, as we have variously observed since 1991. These depressions also capture and store floodwater, as observed during 1991. Interestingly, three other profiled and field surveyed colonies/sites occur on the edges of the same depression/vernal pool, but were jurisdictionally determined to be nonwetlands. The flood frequency and elevations of the two jurisdictional wetland colonies/sites, from ground-surveys, are 2.0 years and 94.2' for GSRC 42, and 2.5 years and 94.46' for GSRC 43. The flood frequency and elevation for GSRC 40 and 41, which were not jurisdictional wetlands, are 2.0 and 94.21', and 2.0 and 94.28' respectively. The flood frequencies and elevations of the two nonwetland colonies/sites within the depression are equal to or less than that for the wetland colonies/sites. We would have expected that GSRC 40 and 41 would have been field determined by the Corps to be wetland colonies/sites, instead of nonwetland, based on their location within the vernal pool area, their estimated flood frequencies, and their elevations relative to the wetland colonies/sites in the depression.

The nine remaining colonies/sites with a local wetland hydrology are in the Red Gum population (6), Spanish Fort population (2), and population #12 (1). The six colonies/sites with a local wetland hydrology in the Red Gum population comprise at least three relatively distinct sites (Plate 33). Four colonies are aggregated at one site, and one colony occurs at each of the two remaining sites. Two colonies/sites are in the Spanish Fort population, representing two sites (Plate 34). The remaining colony/site with a local wetland hydrology is the sole colony/site in the isolated population #12 (Plate 12).

Of the 177 pondberry colonies/sites, 17 are wetlands identified by FESM with a 5 percent duration flood once every two years on average, and 160 colonies/sites are not wetlands established by overbank flooding. From the 47 colonies/sites that were jurisdictionally field surveyed, 45 colonies/sites were not wetlands established exclusively by overbank flooding with a sufficient duration and frequency, of which 11 (24.4 percent) were wetlands by virtue of local site conditions. We used these data, assuming they are representative and unbiased samples, to estimate that 39 (24.4 percent) of the 160 colonies that are not FESM wetlands are wetlands established by local site conditions. Combined, there are 56 wetland colonies/sites (17 + 39) of the 177 known colonies/sites, or 31.6 percent of the known colonies/sites. These are not strong inferences because the colonies/sites originally selected for the profile survey were not randomly sampled in a design to assess the distribution and frequency of colonies with a local wetland hydrology. Also, the 47 selected colonies/sites for the profile frequently are spatially aggregated in many instances, and may not be independent samples of geographic localities and associated environments. If biased, our use of the data could overestimate or underestimate the number colonies/sites with a local wetland hydrology. We generally consider this as a maximum estimate.

Other evidence of local hydrology

The jurisdictional field surveys and determinations at 47 selected colonies/sites, relative to the estimated flood frequencies and the FESM wetland determinations, provide the most direct and best evidence that a local wetland hydrology exists at certain colonies/sites. A local wetland hydrology without overbank flooding depends on adequate precipitation at the site and factors that impede drainage. The vernal pools or seasonal forest pools (e.g. Tiner 2003; Brooks 2005) in the Colby population are classic examples of seasonally ephemeral wetlands where the surface of the heavy clay soil is flooded by local rainfall, captured and stored in shallow depressions beginning in winter, and extending into the spring growing season before drying. The irregularly shaped depressions, from 1 – 2 acres, are most evident when flooded. Otherwise, they can be difficult to physically identify during the summer dry periods from adjacent habitat and stands. Once identified and especially during inundation, these seasonal forest pools clearly possess a distinctive hydrogeomorphology.

The Corps (e.g. U.S. Army Corps of Engineers 1991, 1996, 2005d) and the Service (e.g. Gulf South Biological Survey 2001) have at various times surveyed pondberry colonies/sites in the action area. General observations at colonies/sites during these surveys were made for site topography, drainage, and the potential of sites to pond rainfall and surface water. These characterizations were made in an attempt to assess the likelihood of a local wetland hydrology, or regardless of jurisdictional status, the role of local conditions that may affect hydrology other than overbank flooding. When the general observations from these surveys at profiled colonies/sites in DNF are compared to the results of the field jurisdictional determinations, the observations – whether from the Corps or Service – are not highly reliable indicators of the presence or absence of jurisdictional wetlands, as established wholly or partially independent of overbank flooding. Questions about the extent of any local wetland hydrology at profiled colonies/sites has mostly been resolved by the Corps's jurisdictional field surveys, but this issue is related to the question of whether other evidence is available to accurately predict the extent that wetlands exist due to local hydrological factors at the remaining 130 colonies/sites that were not jurisdictionally surveyed. In our assessment, no other better data currently is available. In the following sections, we describe the other information we considered, and how we used the available data to estimate the extent that the known 177 colonies/sites occur with a local wetland hydrology.

Hydrogeomorphic (HGM) approach

Elsewhere in the southeastern United States, isolated or semi-isolated depressional wetlands with distinctive vegetation and hydrogeomorphology have been well recognized and studied, including Carolina bays (Sharitz and Gibbons 1982), cypress ponds and domes (Ewel and Mitsch 1978, Ewel 1998), seasonal forest pools (Brooks 2005) and other depressional ponds by different names (Sutter and Kral 1994; LaClaire 1995; Kirkman et al. 1999; Kirkman et al. 2000). They share a common hydrology predominated by direct, local rainfall, at sites with poor drainage (e.g. Kirkman et al. 1999; Tiner et al. 2002; Brooks 2005). They vary in size, shape, and depth, where the hydrology is governed by the amount of rainfall, storage and surface area, evapotranspiration, percolation through soil, and other factors (e.g. Mitsch and Gosselink 1993, Richardson 1983, Heimburg 1984, Kantrud et al. 1989; Brooks 2004; Lide et al. 1995; Mansell and Sun 2000). The distinctive vegetation of these isolated wetlands frequently is a function of their landscape position, in addition to hydrology, where there is a sharp transition from the depressional wetland vegetation types to upland vegetation.

In contrast to these wetland types, the ecology and hydrology of seasonal forest pools or other sites with a local hydrology, with or without pondberry, and with or without depressions in bottomland hardwoods is much more poorly known and studied. It is a fact that depressions exist in bottomland hardwood systems. These oxbows, sloughs, and related geomorphic features also can be considered classic, well-known depressions, that receive and store overbank floodwater (e.g., Gosselink et al 1990; Scott et al. 1990; Sharitz and Mitsch 1993), although they are not habitat for pondberry. However, the hydrology, hydroperiod, and characteristics of seasonally flooded pools, vernal pools, or depressions by any other name in the backwater area has not been basically assessed by standard hydrological methods.

General information is available from the hydrogeomorphic approach (HGM) about wetland functions in the Yazoo Basin. These data currently are inadequate to assess the hydroperiod of pondberry at all colonies/sites. HGM is a method developed by Corps scientists at the Environmental Laboratory to classify, measure, and assess wetland functions (Clairain 2002). The Corps used the HGM approach to assess wetland functions from backwater flooding as well as mitigation on the Yazoo Backwater Area project. HGM is an example of a method that, if fully developed and used, can document and verify hydrological attributes of depressions and wetland functions. HGM has been fully applied to assess hydrology and functions in vernal pools, for example, in California (Butterwick 1998). Vernal pool depressions also have been classified as inclusions in two HGM wetland subclasses in the Yazoo Basin, but there is no data to characterize their attributes, variation, or functions.

Wetland hydrogeomorphology consists of the characteristics of the landform, the source of water, hydrodynamics and their interactions to produce wetland functions (Brinson 1993). The geomorphic setting is the landform and position of the wetland on the landscape. Source is the origin of water as precipitation, floodwater, or groundwater. Hydrodynamics is the energy and direction that water moves through the wetland. In the HGM approach, wetlands are first classified, then reference wetlands are selected and characterized for each class or subclass, and a functional capacity index is computed based on the observed and modeled functions. The complete process also involves peer review and field investigations to calibrate and validate models for classified wetland types (Clairain 2002).

The HGM involves a classification of wetlands based on geomorphology, water source, and hydrodynamics. Reference wetlands are then selected and characterized, representing the range of variation for the respective wetland class or subclass. Reference wetlands establish the physical basis for definition and characterization, which can be independently and repeatedly measured. The attributes measured for reference wetlands reflect different wetland functions, which specifically can vary depending on the wetland class or subclass.

Smith and Klimas (2002) classified seven regional HGM wetland subclasses in the Yazoo Basin with two depressional types: Isolated Depression and Connected Depression. In addition to these two depression subclasses, they also recognized "included depression" phases within the Flats and Riverine subclasses. The Isolated and Connected Depressions are the classically recognized geomorphic features of abandoned river channels and courses. Connected Depressions receive overbank floodwater in addition to precipitation. Isolated Depressions are not affected by backwater or overbank flooding occurring at 5-year or more frequent intervals. Isolated Depressions collect and hold rain, ground, and flood water, filling during winter and drying slowly in spring, and may partially fill then dry after heavy rains during the growing season. The vegetation in Isolated or Connected Depression typically is dominated by bald cypress, swamp tupelo, swamp privet, and button bush (Smith and Klimas (2000). Pondberry is not associated with these depression classes and vegetation types.

Included depressions in Flats and Riverine subclasses are smaller areas that are not abandoned courses and channels, but are still lower in elevation than the surrounding land. As vernal pools, they fill with precipitation and/or floodwater and can dry in days or weeks (Smith and Klimas 2000). The two pondberry vernal pools in the Colby population would be classified as inclusion depressions within the Riverine Backwater subclass, according to Smith and Klimas (2000).

The various functions of HGM wetland subclasses in the Yazoo Basin are to detain floodwater, detain precipitation, cycle nutrients, export carbon, maintain plant communities, provide fish and wildlife habitat, and others. The Yazoo Basin HGM Guidebook (Smith and Klimas 2002) parameters have been based on routine standards which include reference standard wetlands, verification, and field testing by the standard HGM protocol (Smith and Wakeley 2001). Included depressions as well as microdepressions are such small areas that they are not class or subclass in the HGM classification which require reference standard wetlands. Thus, the HGM classification and procedures do not provide the HGM is not currently fully developed, and does not include the establishment of reference standard wetlands, verification, field testing, and validating assessment models according to the complete HGM protocol (Smith and Wakeley 2001).

Microdepressional ponding (V_{POND}), for example, is a HGM variable referring to small topographic depressions that collect and hold rainwater for short periods. Microdepressions are created from tree falls and "tip-ups" of tree roots (Smith and Klimas 2000). Smith and Klimas (2000) surveyed the percentage cover of microdepressions in Flats, Riverine Backwater, and Riverine Overbank subclasses in parts of the Yazoo Basin. Microdepressions are such small areas, on average, that they may represent the features the Corps refer to in some cases as depressions with pondberry, especially since the Corps recently defined a depression to be as small as 10 square feet. We also have seen and recognize the existence of microdepressions. What is unknown, however, is the extent that such a small depression has the capacity to capture and retain rainfall of a sufficient extent to create a wetland hydrology for pondberry independent of flooding. Microdepressions are a variable included in the HGM approach, but there are no reference standard wetlands for vernal pools, inclusion depressions, or microdepressions in the Yazoo Basin with hydrological data on the frequency and duration of standing or flooding from precipitation (Smith 2006, in litt.). Thus, the HGM classification and protocol does not provide any additional hydrological information about such depressions.

Depressions

The only other available data that may provide information about the association of pondberry colonies/sites with depressions and a local wetland hydrology is a 10-m DEM and raster for depressions prepared by the U.S. Geological Survey (O'Hara et al. 2000). The DEM and depressions raster were prepared as part of a study to develop a prioritized decision-making system on the selection of sites for wetland restoration in the Yazoo Basin. We used the depression raster and GIS to compare the occurrence of 177 pondberry colonies/sites to these depressions, which we will refer to as GIS-depressions. Also, we compared the occurrence of the 47 profiled colonies/sites with field surveys for jurisdictional wetland determinations to areas with and without GIS-depressions. From this analysis, colonies/sites with a local wetland hydrology are not restricted to these GIS-depressions. By a contingency analysis, colonies/sites with a local wetland hydrology are statistically more likely to occur in GIS-depressions than in areas without GIS-depressions (Table 22), but the data for this analysis from the selected colonies/sites may not represent a random, unbiased, and representative sample. If the profiled colony/site survey data are unbiased, independent, and representative, and the USGS GIS-depressions raster accurately depicts depressions, then 177 colonies/sites would consist of about 23 colonies in depressions and 19 colonies outside of depressions, both with a local wetland hydrology (Table 23).

GIS-depressions in DNF cover 19,656 acres, or about 32 percent of the forest (Plate 27, Table 24). GIS-depressions range in size from less than an acre to as large as 3,582 acres, with an average size of 14 acres (Table 25). Most GIS-depressions are much larger than the microdepressions that would be considered by the HGM approach, and the 10-m DEM depression raster did not likely identify these very small depressions. Also, the GIS-depression raster failed to identify the two seasonal forest pool depressions in the Colby population. Where depressions actually exist with soil factors inhibiting drainage, they are potentially capable of storing flood water, which would increase the hydroperiod separately or in conjunction with local site factors. Otherwise, the actual accuracy of the GIS-depression raster in identifying true depressions is not known. Most of DNF currently is located on the 2-year floodplain, according to FESM, and most of these GIS-depressions would be inundated by 2-year floods. However, the likelihood that the large depressions increase the local hydroperiod by their capture and storage of precipitation in excess of that lost by internal drainage, evaporation, and evapotranspiration is unknown.

The distribution of depressions is not uniform among the DNF pondberry populations. Of the 177 pondberry colonies/sites in DNF as of 2000, 47 (26.5 percent) occur in these GIS-depressions (Table 24). In the Spanish Fort population, about 31 percent of the known pondberry/colonies sites are associated with these depressions (Plate 28, Table 24). A smaller proportion is associated with GIS-depressions in the Red Gum and Colby populations (Plate 29, Table 24). Overall, less than one-quarter of the 177 colonies/sites are potentially associated with GIS-depressions.

Wetland colonies/sites occur in GIS-depressions as well as areas that are not depressions. However, colonies/sites with a local wetland hydrology do not occur in GIS-depressions independently of areas without depressions ($\chi^2 = 5.79$, $p = 0.0161$, Table 22). The number of colonies/sites with a local wetland hydrology (11) is only 24.4 percent of all colonies/sites (45) with a field jurisdictional wetland determination, but the proportion of wetland colonies in depressions is 3.3 times the proportion of wetland colonies not in depressions. Also, a colony/site with a local jurisdictional wetland hydrology is 5.6 times more likely to occur in areas with GIS-depressions than areas without depressions (Table 22, Odds Ratio = 5.6, 95% C.I.= 1.28<O.R.<24.56.). More wetland colonies/sites are in GIS-depressions, and fewer wetland colonies are in areas without depressions than expected if the landscape (depressions vs. no depressions) had no effect, as characterized by the USGS GIS-depressions raster.

From the available survey data (Table 22), 50 percent of colonies/sites in GIS-depressions have a local jurisdictional wetland hydrology, while 15 percent of colonies/sites that are not in depressions have a local wetland hydrology. Of the 177 known colonies/sites, 47 colonies/sites are in 23 different depressions (Plate 27), each of which ranges from 0.4 to 1,332 acres in size (Table 25). There are 160 colonies/sites that are not FESM wetlands, with 41 colonies/sites in GIS-depressions and 119 colonies/sites not in depressions (Table 23). If the available data are representative and independent samples of the 177 colonies/sites, then by inference for the 160 colonies that are not FESM wetlands there would be an estimated 21 colonies/sites (41x 0.5) with a wetland hydrology in GIS-depressions, and 18 colonies (119 x 0.1515) not in depressions with a local wetland hydrology (71). The total estimated number in wetlands with a local hydrology is 39 colonies/sites. The earlier estimate of 39 wetland colonies with local hydrology was based on the proportion (0.244) of such colonies from the survey of 11 colonies/sites with a local hydrology from the 45 surveyed colonies that were not FESM wetlands. By spatially associating the distribution of colonies/sites with a local wetland hydrology to these depressions with GIS, general estimates of the number and distribution of wetland colonies in DNF populations can be derived. Most of these estimated colonies/sites with a local wetland hydrology occur in the Red Gum and Spanish Fort populations (Table 23).

Overall, about 32 percent (56) of the 177 colonies/sites are estimated to have a wetland hydrology, with 17 in FESM wetlands established by overbank flooding, and about 39 colonies with a local hydrology. About 121 colonies/sites (68 percent) lack a jurisdictional wetland hydrology from either overbank flooding or local hydrological factors.

Here again, these statistics of association must be interpreted cautiously for several reasons in addition to the factors previously described for survey data that were not acquired or specifically and randomly sampled for this purpose. The selected and profiled colonies/sites include groups of sites that are aggregated or located closely to each other. Of the 12 jurisdictionally surveyed colonies/sites located in GIS depressions (Table 22), eight are located in eight different depressions, while four are located closely to one another in the same depression. One of the requirements for contingency analysis (e.g. 2 x 2 tables) is that the observations (data) must be independent (Everitt 1992). The four wetland colonies/sites in the same depression are located, generally, within about 150 feet of each other. Instead of representing four different, independent sites, the factors affecting and establishing the local wetland hydrology for these four colonies/sites may be the same because of their proximity. Furthermore, the sample sizes are small for wetland colonies/sites and GIS-depressions, especially relative to GIS-depressions (Table 22). The 10-m DEM depressions raster prepared by USGS identifies 1,386 different depressions in DNF. These field surveyed colonies/sites occur in only eight GIS-depressions, which is a small sample relative to the set of factors in depressions associated with the presence or absence of a local wetland hydrology. For these reasons, we consider the estimate of 39 colonies/sites with a local hydrology as a maximum estimate.

Changes in hydrology due to past flood control projects

Most of the known pondberry colonies/sites in DNF occur in areas that are not FESM wetlands. Only 10 percent (17) of the 177 colonies/sites currently have a FESM wetland hydrology from backwater and overbank flooding. About 23 percent of colonies/sites have a jurisdictional wetland hydrology due mostly to local hydrological factors without overbank flooding. In general, an obligate wetland species as pondberry would be expected to have a strong association with the occurrence jurisdictional wetlands, especially if the actual hydrology of obligate wetland species corresponds to the Corps definition of hydrology for jurisdictional wetlands, as further identified by FESM. However, the hydrology in the Yazoo Backwater Area and the Yazoo River Basin has been extensively altered by numerous flood control projects (U.S. Army Corps of Engineers 2005a). Current patterns of backwater flood duration intervals and flood frequencies do not reflect natural conditions. Using FESM with adjusted historical stage-gage data, 47 percent (82) of the localities for the 177 known colonies/sites were wetlands during 1901-31, prior to the completion of most major structural flood control features in the basin. The historical changes in hydrology due to flood control have not been uniform in the largest DNF pondberry populations. The Spanish Fort population, which is the least hydric today according to FESM, also was the least hydric historically. In contrast, 96 percent of the Red Gum population area were wetlands during 1901-31, which have been reduced by 81 percent today. Overall, the historical wetland hydrology from overbank flooding since 1901 has been lost at 79 percent (65) of the locations of colonies/sites today.

Prior to this consultation, a site specific or detailed analysis of the historic and cumulative changes to the frequency and duration of flooding by previous flood control projects in this area had not been conducted, to our knowledge. Otherwise, the only available information appeared to be Galloway's (1980) assessment of the conditions that would have existed in the Yazoo-Mississippi Delta with and without flood control and water resources development. Galloway used historical stream stage-gage data to determine the adjusted elevations for the 2-, 5- , and 25-year flood without the mainline Mississippi River levees, and with mainline levees but without interior structural flood control measures. These elevations were plotted on topographic maps and, in conjunction with other information, he estimated area covered by each flood interval. According to Galloway, the entire Yazoo River Delta region would have been inundated by a 5-year flood, including all of the Yazoo Backwater Area (925,507 acres).

Today, the 5-year flood in the backwater area, based on the Corps GIS, inundates 548,527 acres, a reduction by about 41 percent of the historical area flooded according to Galloway. However, the Vicksburg Corps has concluded that several of Galloway's assumptions were not correct, and his assessment of the area inundated was not accurate. For the without-levees condition, he assumed that the water surface of the Mississippi River for the 2- and 5-year floods would extend laterally across the Delta with no change in the water surface elevation. Because the peak observed stage elevation during 1927 flood at Yazoo City was eight feet less than the peak at the Lake Providence gage at the same latitude, according to the Corps the water surface was not level.

One of the advantages of the FESM modeling approach is a geographically explicit coverage of the flood event of interest, based on stage-gage data. During this consultation, we requested that the Corps assess historical data using FESM to compare changes in the 5 percent duration flood event in response to past flood control projects. The Corps used the same basic methods in this historical approach as previously described for FLOOD and FESM. One of the differences was that historical stage-gage data was not adjusted to compensate for the effects of structural flood control features, such as levees, as was done to estimate the current baseline conditions. The Corps selected three historical periods that generally corresponded to the existence and completion of various structural flood control measures affecting the Yazoo Backwater Area. The gage data for these periods represent conditions as they existed at that time.

The Corps began recording stream stage data in the Mississippi River in the mid-1800s, which followed in the Yazoo Basin with the first gage on the Yazoo River at Yazoo City in the early 1900's. With data from two other gages added in 1932 on the Big Sunflower River at Sunflower and Holly Bluff, the Corps used stage data to compute the stage elevations for the median 5 percent flood duration interval. Compared to current gage stations, this was a limited set of data. The Corps interpolated along the slope elevation for the 5 percent duration to generate missing data. The FESM model with historical data was a much simplified version of the baseline model because of limited historical stage-gage data, without extrapolated simulated nodes, and no off-channel nodes. The model with historical data maintained those simulated nodes where the water surface elevation was calculated by interpolation along the slope between the available gages. Also, the model was not further calibrated with satellite imagery of representative 5 percent duration flood scenes because there were no scenes prior to 1972.

The Corps assessed historical changes relative to four periods associated with different events. The 1901-1931 period is prior to the advent of the Mississippi River and Tributaries Project, which first began with the passage of the 1928 Flood Control Act. Structural flood control measures largely were limited to levees mainly on the Mississippi River, constructed and maintained by various districts, which provided substantial protection. However, the Mississippi River mainline levee system was not complete at that time.

During 1932 – 1957, the mainline Mississippi River levee was completed (Plate 1), and other structural projects had either been initiated or completed in the Yazoo River Basin. Most of the cutoffs on the Mississippi River channel as they exist today had been dredged, and flood control reservoirs in the upper Yazoo River basin (Enid, Grenada, Arkabutla, and Sardis) were operational (Plate 4). Channel dredging and cutoffs had been completed, and were continuing on all major and most minor tributaries in the Yazoo Headwater Area. Work also began for clearing, snagging, realigning, and enlarging the Big Sunflower River and tributaries.

The 1958 – 1978 period culminated with the completion of the levees on the Whittington Auxilliary Canal that directed and confined Yazoo River floodwater from the headwater regions through the lower basin (Plate 1). The Yazoo River Backwater Area levee system was finished, with the construction of several gated water control structures to eliminate and control backwater flooding. Other channel work and diversions were completed on the Big Sunflower River and tributaries.

From 1979 – 1997, no structural flood control measures were initiated or completed. The Corps reformulated and completed work on the Upper Steele Bayou Project, which mostly consisted of channel dredging and enlargement. Over 65 water control structures were constructed, but their purpose was to reduce head-cutting and erosion where stream discharge and gradients had been increased by previous flood control projects.

We compared the change in FESM wetland coverage for these periods to the known pondberry colonies/sites as of 2000 in DNF, based on the GIS and data provided by the Corp. Whether or not these 177 pondberry colonies/sites existed during the past periods is unknown. These extant colonies/sites provide reference locations for a comparison of the hydrological conditions where the species exists today to the estimates of historical hydrological conditions and change at these sites. Pondberry in the largest three populations in DNF (Colby, Red Gum, and Spanish Fort), and perhaps others, likely existed during these historical periods. Pondberry is not known to be a rapid or even frequent colonizer of unoccupied but potentially suitable habitat by seed dispersal and successful seed germination. Nearly annual observations at the Colby population in DNF since 1991, which is the largest known DNF population, reveals that no new, large colonies have been formed in habitat where numerous other colonies exist. Pondberry is not a short-lived plant of ephemeral environments, with high reproductive rates and fecundity, and high natural rates of local population extirpation that are compensated by colonization and replacement in other habitat. Pondberry at these DNF sites, particularly with the larger populations, most likely are descendants from plants that have historically occupied these areas.

The estimates and pondberry comparisons are based on several additional assumptions. First, the types and distributions of soil, drainage, and topographic characteristics required to establish a jurisdictional wetland hydrology independent of overbank flooding have remained constant during the historical period. The amount of precipitation may vary, but these physical factors do not significantly change by geomorphic or other processes by this assumption. For example, two (GSRC 54 and 56) of the 47 jurisdictionally field-surveyed colonies were jurisdictional wetlands, where according to FESM, the hydrology is established by floods of sufficient frequency and duration. Without sufficient flooding, these two sites may have adequate soils, topography, rainfall, and other site factors sufficient to establish jurisdictional wetlands based on local conditions. Whether or not adequate local conditions exist in the absence of flooding is not known.

However, suitable local conditions sufficient to establish jurisdictional wetlands independent of flooding do exist at 11 (24.4 percent) of the 45 jurisdictionally field surveyed colonies/sites. Using this as a sample, we estimated that 24.4 percent or 39 of the 160 colonies that are not 5 percent duration wetlands according to FESM are wetlands due to local conditions independent of overbank flooding. If all 39 of these sites historically were flooded sufficiently to establish a wetland hydrology, then local soil, topography, and other conditions capable of establishing wetland conditions without flooding would not cease to exist. The only difference is that these local conditions would be not be the primary factors operating to create a jurisdictional hydrology when flooding was sufficient to do so. The potential of each of these 39 sites to function with a local hydrology continues to exist, but only operates when overbank flooding is insufficient to establish wetland conditions. This means that any site with local conditions adequate to establish a jurisdictional wetland hydrology will always be a jurisdictional wetland during the historical period of analysis, regardless of changes in the frequency and duration of overbank flooding. When overbank flooding is inadequate, the site is a wetland due to the function of local factors. When overbank flooding is adequate to establish a wetland, the site is still a wetland. Thus, there are at least 39 reference colonies/sites of the 177 known reference colonies/sites that always are wetlands during the historical analysis, assuming that precipitation remains adequate (e.g. no significant drought) when local conditions must function to establish a wetland hydrology.

The second assumptions is that the number and distribution of sites with soils and a topography that are not capable of establishing a local wetland hydrology by rainfall, either independent of overbank flooding or in combination with flooding, remains. Finally, the Corps field survey and results for jurisdictional determinations at the 47 selected colonies/sites must be representative samples that are not significantly biased for all 177 known/colonies sites.

The frequency and duration of flooding can change with these assumptions and conditions, increasing or decreasing the number of FESM wetland sites, but without changing the proportion of non-FESM sites that are either wetlands with a local hydrology, wetlands depending on a combination of flooding with local conditions, and nonwetlands. From the recent Corps field survey, 45 of 47 colonies/sites are not FESM wetlands. About 24.4 percent (11/45 x 100) of the non-FESM wetlands were wetlands by virtue of a local hydrology or local site conditions in combination with flooding. The estimated number of sites with a local wetland hydrology for the 1901-31, 1932-57, 1958-78, and 1979-97 periods are 24.4 percent of the number of non-FESM wetlands during each period.

Results

The FESM wetland acreage in DNF and in known pondberry colonies/sites was historically greater than today, but the acreage has not declined uniformly during the four periods of analysis (Table 26, Figure 7). More wetlands occurred in DNF during 1901-31 (56,993 acres) than any other period, covering most all of the forest except fringe areas on higher elevations in the northern and southern portions (Plate 15). This was the period of greatest wetland (FESM) coverage relative to known pondberry colonies/sites. These wetlands would have covered 84 (47.5 percent) of the known pondberry colonies/sites (177) of 2000 (Table 26). Of the total area within large pondberry populations known today, about 20 acres (35 percent) in the Colby population, 4,681 acres (96.0 percent) of the Red Gum population (Plate 19), and 89 acres (14 percent) of the Spanish Fort population were in wetlands (Plate 23, Table 27). About 74 percent (54) of the Red Gum colonies/sites (73) were in wetlands, while only 12 percent (8) of the Spanish Fort colonies/sites were wetlands (Table 27).

The coverage of FESM wetlands decreased during 1932-57 (Plate 16), and reached its lowest period during 1958-78 (Plate 17, Figure 7). Only 32 percent (19,673 acres) of the DNF had wetlands in 1958-78 (Table 26). This was a reduction of 37,320 acres, a decline of 35 percent, of the 1901-31 wetlands. Similarly, the wetland coverage of pondberry colonies/sites was at its lowest during this period, with only two percent (4) of the 177 colonies/sites in these wetlands (Table 26). Wetlands were lost on all the point bar geomorphic landforms, which typically are at higher elevations in the delta, but also included backwater geomorphic areas as well. None of the major pondberry populations today would be located in wetlands during this period. The shift, compared to 1901-31, was from east to west. The only pondberry colonies/sites continuing to reside in wetlands were on backwater landforms.

During 1979-97, the wetland area actually increased relative to the previous low period, and exceeded the coverage during 1932-57 (Plates 18, 22, and 26). The Corps did not specifically assess or report the factors causing or associated with this reversal. Nevertheless, it is generally known that the period of the 50's through the early 70's was marked by infrequent flooding in the backwater area, followed in the 70's and 80's by more frequent and major flooding. The trend probably is climatic. Even though the wetland extent increased during this period, it would have been even greater but for structural flood control measures completed by the Corps in the Yazoo River basin. Overall, the pattern and coverage of wetlands (44,870 acres) and pondberry colonies sites in wetlands (22) during 1979-97 was similar to 1932-57 (Table 26).

The current baseline conditions are those the Corps estimated using FESM for the adjusted 1943 – 1997 POR. The stream stage-gage elevation data was adjusted by various models during past periods to account for the effects of structural flood control features that would have been absent during those periods. By these adjustments, the Corps changed the stage elevation data to model what the stages would have been with current structural and other measures in place during past (1943 – 1997) periods. With FLOOD and FESM, these data represent the estimated baseline conditions as well as what would be predicted on average in the future without the proposed project. The historical analysis was unadjusted, reflecting the features as they existed at that time together with climatic and other effects of flooding on the Mississippi River. There are periods of apparent climatic variation affecting backwater flooding and the extent of the 5 percent duration wetlands. The baseline FESM model and 5 percent flood duration elevation only simulates the overall median elevation of the 5 percent duration event for this period of record. FESM can be used to portray the variation in wetland extent and coverage around this median event, but the Corps did investigate or spatially depict this range of variation for the historical analysis. The expected trend of wetland change accompanied flood control projects is a uniform decline. The observed historical variation must reflect climatic variation during these periods that otherwise is incorporated as the median 5 percent duration elevation for the baseline model 1943-1997 adjusted POR.

Historically, pondberry colonies/sites and the areas of their populations have experienced changes in the coverage and extent of wetlands due to flood control and apparently natural climatic conditions affecting backwater flooding. Natural variation with wetter and drier periods can still occur under current baseline conditions without the project, although the extent of the variation independent of structural flood control features is not known. Current baseline conditions are more hydric than the 1958-74 period, but not as wet as the 1901-31 period (Figure 7). Under baseline conditions, on average, 17 (9.6 percent) of the 177 pondberry colonies/sites occur in 5 percent duration wetlands (Plate 15). Compared to the 1901-31 period, 79.3 percent (65) of these baseline colonies/sites have lost the 5 percent duration wetlands of this earlier period (Table 27). There were 93 colonies/sites outside of 5 percent duration wetlands during the most hydric 1901-31 period before major flood control projects were completed. Under current baseline conditions, the addition of the 65 colonies/sites that lost 5 percent duration wetland (FESM) coverage has increased the colonies/sites outside of FESM wetlands to 158, an increase of 70 percent.

The percentage of FESM wetland sites, compared to non-FESM sites, was greatest at 47.5 percent during 1901-31, declined to a low of 2.3 percent during 1958-78, then increased to the current condition of 9.6 percent (Table 26). The same general trend holds when the estimated number of sites with a local wetland hydrology are added to FESM wetland sites for all wetland sites, but the proportions of all wetland sites are different (Table 28). The estimated number of sites with a local wetland hydrology during each period varies with an opposite trend to the number of FESM wetlands (Figure 7). The lowest number of reference colonies/sites with a local hydrology (23) occur during 1901-31 when overbank flooding is the most extensive and the number of FESM sites are greatest (Table 26). As overbank flooding decreased after this period to the low of 1958-78, colonies/sites with a local wetland hydrology increased to 42, the maximum of any period. When flooding and FESM wetlands decrease, the number of sites with a local hydrology increase because they are no longer sufficiently flooded, but retain the site factors for establishing a local wetland. The proportion of sites capable of sustaining a local wetland hydrology remains constant, at 24.4 percent of the non-FESM wetlands, but the number of sites changes depending on how many of the 177 colonies/sites are sustained by the 5 percent duration flood (FESM) event and the number that are not FESM wetlands. The existence of sites with a local wetland hydrology reduces the overall magnitude of change by FESM wetlands at different periods, but does not completely compensate for such change. By current baseline conditions, the total number of wetland sites (FESM and local hydrology) is about 52 percent (56) of the 107 sites estimated during 1901-31.

The overall absolute and percentage changes from 1901-31 to current conditions do not uniformly reflect the same kinds of changes within the largest DNF pondberry populations due to differences in population size, population area, landform, and elevation. The greatest changes have occurred in the Red Gum population (Table 27). During 1901-31, the 5 percent duration wetlands covered 4,681 acres (96 percent) of the population area (Plate 19). These wetlands have been reduced today to a 905-acre area, a decline of 81 percent (Plates 19 - 22, Table 27). The population area formerly was dominated by wetlands, but is now dominated by nonwetlands that cover 4,804 acres, or about 84 percent of the area. This addition of former wetlands (3,776 acres) has more than tripled (367 percent increase) the 1901-31 nonwetland area (1,028 acres) today. The change in pondberry colonies/sites with wetlands is similar to the acreage changes. Of the 54 reference colonies/sites historically in wetlands, there are now only five, a reduction of 91 percent. The 49 former wetland colonies/sites increased the nonwetland sites by 258 percent from 19 to 68 colonies/sites under baseline conditions.

Pondberry in the Colby population is more dense than any other population in DNF. Most of this population, as previously described, is associated with two seasonally flooded or vernal pools that can store precipitation as well as flood water. About 35 percent (20 acres) of the population area (57 acres) were 5 percent duration wetlands in 1901-31, which included the ponded depressions (Plate 19, Table 27). Under current baseline conditions, none of the population area is within the 5 percent backwater flood area.

The Spanish Fort population in ridge and swale topography in the southern portion of DNF was the least hydric of these major populations, with 89 acres (14 percent) and 8 colonies/sites (12 percent) within 5 percent duration wetlands during 1901-31 (Plate 23, Table 27). Today, none of this area (649 acres) or colonies/sites (65) is within FESM wetlands.

The historical analysis by the Corps was limited to FESM duration wetlands that, by the hydrological definition, must be inundated 14 or more days once on average every 2 years. The analysis did not consider or provide data on changes to the frequency of backwater flooding. Changes in the area of FESM wetlands also were accompanied by changes in flood frequencies at intervals other than the 0-2 year flood, but the flood frequencies were not computed or reported for the intervening periods (1932-57, 1958-78, and 1979-97). However, the net changes in flood frequency generally can be evaluated by the FESM flood frequency definition and data for baseline conditions. The extensive coverage of FESM wetlands in DNF during the 1901-31 indicates the vast majority of this area (61,840 acres) occurred at least on the 0-2 year floodplain. The net change in DNF from a 0-2 year flood frequency during 1901-31 to current baseline conditions has been a reduction in flood frequency to a 3 – 5 year event on about 5,985 acres.

Pondberry health and performance in relation to backwater flooding

Another reason the Corps concluded that backwater flooding is not important to pondberry is their analysis of pondberry health and other indicators of performance in relation to the frequency of backwater flooding. These assessments are in the form of an evaluation of correlations, F-statistics, and related measures for pondberry attributes and flood frequency during 2000 and 2005. In addition, the Corps evaluated a subjective classification of pondberry health relative to the frequency of flooding. In our review of these analyses, we reach a different conclusion for particularly important factors. These differences are based on the same data. Overall, the total number of pondberry at profiled colonies/sites declined substantially between 2005 and 2006, and was affected by flood frequency.

Health

As part of their evaluation of the potential effects of overbank flooding, the Corps evaluated the health rating at profiled pondberry colonies/sites relative to the frequency of flooding. They concluded that pondberry was in excellent or good health, and that since most of the colonies/sites were either infrequently flooded or not in wetlands, then overbank flooding is not likely to be critical to pondberry health.

The Corps pondberry profile of selected colonies/sites has included a subjective health rating for each colony since the profile began in 1991. The standard health ratings are either excellent, good, fair, or poor based on the physical appearance of leaves and stems, insect damage, live and dead stems, and colony density. The Corps selected the frequency of overbank flooding during the 20-year period from 1984 to 2003 as the POR because they considered this to be a representative recent period of actual conditions. Using actual stage-gage data, the elevation at each colony/site was compared to the recorded flood stage by interpolating the stage elevation between respective gages. The Corps assumed that if the elevation of the colony site was below the stage-gage elevation, then the colony received flood water during that particular episode. This was a conservative assumption because floodwater may not actually have reached every colony site because of an intervening area or landform at a higher elevation. With stage-gage data for the 20-year period, the Corps tallied the number of growing and dormant season events at each of the profiled colonies/sites.

Overbank flooding occurred much less frequently during this period (1984-2003) than expected by the computed flood frequency of each site according to the 1943 – 1997 POR. Evidently, this recent period has been a cycle of less frequent flooding. Twenty-eight of the 49 profiled colonies occur on the 2-5 year floodplain according to the 1943-1997 POR, which would be expected to receive flooding from 4 - 10 years during the 20-year period (1984-2003). Twenty-three of these 28 colonies were flooded only once during the 20-year period, and three flooded only twice. Also during this period, 63 percent of the 49 colonies had no overbank flooding for 12 consecutive years, and 18 percent went without such flooding for 20 consecutive years. From these and numerous other comparisons by the Corps, these colonies clearly experienced a greatly reduced frequency of flooding relative to that expected by the 1943 – 1997 POR.

The greatest change in colony health ratings between 2000 and 2005 was in the excellent category (Table 22). In 2000, about 40 percent of the colonies were rated excellent, which was reduced to 13 percent in 2005. This shift from excellent to good health ratings increased the number and proportion or colonies in the good category. Even with these changes, the Corps concluded that the flood frequency of a site is "likely not an important factor in determining apparent colony health" when compared to the health of each colony, (U.S. Army Corps of Engineers 2005b - BA, pg. 14-19). Given this finding, the Corps sought other evidence to account for the apparent health of colonies in the absence of any important relationship to the frequency of flooding. Annual precipitation was 50 or more inches during this period, and average monthly rainfall from November through April was more than 5 inches. The Corps found that annual rainfall "may help explain excellent or good apparent colony health despite less than predicted frequency of overbank flooding" (BA pg. 14-28).

Implicit to the concept of colony "health" is an expectation that colonies with good or excellent health ratings are somehow more vigorous with a capacity for greater performance and persistence than colonies with fair or poor status. The Corps did not explicitly define health categories by these parameters. The use of health categories in relation to flood frequency, however, is only meaningful unless health can be related to some actual measure of plant, colony/site, or population performance or persistence. One such measure is the actual number of pondberry in relation to health, and the change in the number of pondberry during 2000 and 2005 by health ratings. If colony "health" is informative about actual performance, it should be related to measures of colony growth and decline.

Logit analysis of health category rating

We used a logit analysis of ordered categories to evaluate whether the qualitative health rating was associated with the change in the number of pondberry at profiled colonies between 2000 and 2005 (e.g. Allison 1999). Given the qualitative scores for health (excellent=4, good=3, fair=2, poor=1), the categories of change represented whether the number of pondberry in each colony either increased, decreased, or remained stable with no change during this period relative to the health score. As a relative magnitude of change, the ordinal ranking was based on percent change in the number of plants. Colonies that increased by 10 or more percent were assigned a rank of +1, those that decreased by 10 percent or more -1, and colonies that did not change by +/-10 percent were ranked 0. Also, the association was compared to a more simple binary logit analysis to insure the cumulative logit (-1, 0, +1) ordinal classification was not biased. Change in the binary model was either scored as positive, when a colony increased in the number of plants (+1), or negative when there was a decrease (-1).

There was no association between colony health classification rank and the rank change in number of pondberry from 2000 and 2005 from either the cumulative logit analysis ($\chi^2 = 0.0074, p > 0.93$) or the binary model ($\chi^2 = 0.0635, p > 0.80$). Colonies with a higher health score were not associated with colonies that were stable or increased in the number of plants. This was because the number of plants in most colonies declined between 2000 and 2005 regardless of health rating (Tables 30 - 33). A greater proportion of colonies with excellent health declined than colonies with good health. Eighty-four percent of the colonies with an excellent health rating declined, and 72 percent of good colonies declined. When the change in number of plants was classified by three categories (Table 31), most of the colonies with excellent health declined (68 percent) as did most of the colonies with good health (60 percent). Overall, the total number of plants in the 49 profiled colonies declined by 42 percent, from 11,748 in 2000 to 6,775 in 2005, and the greatest absolute and proportional decline occurred in colonies with excellent health (Table 32).

Most of the colonies with excellent health in 2000 were reduced in their classification to good health in 2005 (Tables 29 and 33). To a certain extent, this and related changes where the colony health rating declined from 2000 and 2005 is reflected in the decline in the number of pondberry. However, the health classification in 2000 was not a reliable indicator of future performance in 2005 when the number of plants is a factor. Likewise, the health assessment as of 2005 is not likely to be an accurate index of population stability or response to flood frequency. Whatever the health ratings are classifying, they are not associated with changes in the number of pondberry at profiled colonies/sites, where most have declined.

Pondberry association and response to wetlands and hydrology

As described in a previous section, the health of pondberry according to the Corps health rating was mostly excellent to good in 2000, but 84 percent of the colonies rated as excellent and 72 percent of the colonies in good health declined by 2005 (Tables 29-33). The health rating system was not related to or predictive of future status and trend during this 5-year period. Also, pondberry declined during an acute episode of dieback from the pathogen *Botryosphaeria ribis* independent of site effect (vernal pools or no-ponds) in the Colby population during 1993-1994, but by 2006 the number and recovery rate of pondberry in vernal pools was significantly greater than colony/site plots without ponded areas. Using the available Corps data, we further evaluated the associations and response of pondberry at wetland and nonwetland sites, as well as to flood frequency, as described in the following sections. The null hypotheses were that the number of pondberry and colony/site growth rates would not be affected by wetlands or flood frequency. We generally expected the alternative to be true, that the number of pondberry and colony/site growth rates should be affected by hydrology. Overall, the results of the statistical analyses in this section are that pondberry is affected by wetlands and flooding.

In summary, site status (wetland or nonwetland) significantly affected the number of pondberry (p = 0.0682) with an average of 93 plants per wetland colony/site and 33 plants per nonwetland colony site during 2000-2005. Also, site and year affected pondberry (p = 0.0765), where the average number in nonwetland colonies declined significantly (p = 0.0132) from 2000 (42) to 2005 (26). During 2005, the number of pondberry in the average wetland colony (102) was almost four times larger than the average nonwetland colony (26) (p = 0.0183, Table 34). The number of pondberry that persisted from 2000 to 2005 was affected by wetland status (χ^2=188.4, p = 0.0000), where the odds of persisting in wetlands were 1.7 times that of persisting in nonwetlands (95% C.I.: 1.6<O.R.<1.8). Also, the total number of pondberry and the change in the total number of pondberry from 2000 to 2005 was affected by flood frequency class (G = 726.6, p = 0.001). The total number of pondberry declined in the 3-5, 6-10, and 11+ year flood frequency classes, which weren't significantly different from each other (G_H = 1.8, $p > 0.05$). The only net increase in the number of pondberry was in the 0-2 year floodplain, which was significantly different from the net change in all other less frequently flooded classes. The colony/site growth rate from 2000 to 2005 was not significantly different in wetlands and nonwetlands (p = 0.1910), or significantly different among the 0-2, 3-5, 6-10, and 11+ flood frequency classes (Kruskal-Wallis H=1.34, p = 0.72). However, colony/site growth rates, by three different measures of growth, declined as a significant linear and nonlinear function of decreasing flood frequency. In these nonlinear regression models, positive colony/site growth rates on average were predicted generally within the 0 – 3 year floodplain, depending on the particular model. Negative colony/site growth rates either continued to decrease as the flood frequency interval increased (e.g. less flooding), or the negative growth rates decreased to a maximum and remained constant as the flood frequency interval increased. The profile data on observed colony/site growth rates were highly variable, and limited at the most frequently flooded classes. Two colonies/sites in wetlands on the 0-2 year floodplain with the largest observed positive growth rates of all colonies/sites during 2000 – 2005 were highly influential data in linear and nonlinear regression models assessing the effects of flood frequency intervals.

According to the Corps in their BA and other analyses conducted during this consultation, there are no statistics indicating pondberry is affected by overbank flooding. This is primarily based on their analyses with single factor and repeated measures Analysis of Variance (ANOVA), and multivariate analyses (canonical correlation analysis and discriminate functions analysis) of the relationships of various pondberry attributes to flooding. Our disagreement regarding the significance of the repeated measures ANOVA appears mostly due to our use of a different level of statistical significance for a Type I error rate. We used a 0.10 rate, while the Corps chose a 0.05 level. These differences reflect a different tolerance and risk for error in concluding that the evidence either was sufficient or insufficient that pondberry was affected by flooding. Considering the limited data and its highly variable nature, we chose the 0.10 rate which is relatively common in environmental studies and recommended by the National

Research Council (1995b) for endangered species studies. Our statistical concern was to reduce the risk of falsely concluding that flooding does not affect pondberry. In contrast, the Corps procedure of adopting a 0.05 rate reduced the chance of falsely concluding that flooding affected pondberry. Regarding the multivariate studies, we don't disagree with the Corps that these fail to demonstrate a relationship or effect of flooding. We disagree, however, in our interpretation of the importance, relevancy, and rigor of these tests. These and related issues are described in more detail in Appendix 3 to this biological opinion (BO Appendix 3).

Methods

We used a repeated measures ANOVA to evaluate if the abundance of pondberry at profiled colonies/sites was affected by wetland status (jurisdictional wetland or nonwetland) and year (2000 and 2005), or by an interaction between wetland status and year. Abundance is the average number of pondberry per colony/site, by wetland status and year. Because the number of pondberry at colonies/sites was not normally distributed, the data were log-transformed, (Zar 1999), which met the Shapiro-Wilk statistic for normality and the assumption of homogenous variances using Levene's test. Wetland status was determined by the Corps jurisdictional field survey at 47 profiled colonies/sites, where 13 colonies/sites were wetlands, with 34 nonwetlands. Wetlands included FESM wetlands (n=2) and sites with a local hydrology (n=11) wholly or partially independent of overbank flooding. The assumptions of equal variance among groups and subjects (sphericity) were satisfied, as indicated by autoregressive and compound symmetric covariance structures. Statistical significance was evaluated at $\alpha = 0.10$.

Contingency analyses were used to categorically assess the effects of wetland status on pondberry persistence from 2000 to 2005, and the effects of flood frequency class interval on the change in number of pondberry. The first analysis compared the effect of wetland status at 47 colonies/sites on the total number of pondberry that persisted at colonies/sites in 2005relative to the number lost between 2000 and 2005. For each wetland class (wetlands [n=13], nonwetlands [n=34]), pondberry persistence is the total number of pondberry in 2000 that continued to exist in 2005. Persistence does not mean that an individual plant was marked in 2000, and found once again to exist in 2005. The Corps pondberry profile methods did not include individually and uniquely marking each plant at each colony/site. Persistence in this analysis is an arithmetic value of change. For example, if 100 plants existed in 2000 and 100 plants were counted again in 2005, then persistence is 100. If there were 100 plants in 2000 and 50 plants in 2005, persistence is 50. These may or may not be the same individual plants (stems) because some may have died and others were produced. The pondberry loss is the difference in the number of pondberry in 2000 minus the number in 2005. The null test of independence (2x2 table) is that the number of pondberry that persisted and lost was independent (not associated) with wetland status, as measured by chi-square (χ^2) with one degree of freedom, and the 0.05 (α) level of significance. To further evaluate the significance of any association, the odds-ratio of the likelihood of a colony/site persisting in wetlands relative to nonwetlands was computed, with its 95 percent confidence interval. In the second test, the total number of pondberry in 2000 and 2005 from 49 profiled colonies was tallied according to four flood frequency class intervals. We used *G*, the likelihood-ratio chi-squared test statistic (Agresti 2007), with unplanned tests of homogeneity (Sokal and Rohlf 1981) to evaluate if the number of pondberry was independent of flood frequency. This test evaluates if the overall percentage change in pondberry from 2000 to 2005 as pooled from all flood frequency class intervals is independent of flood frequency interval, and if not, identifies which flood frequency class intervals are different from others.

The effect of wetland status (jurisdictional wetland or nonwetland) on colony/site growth during 2000 – 2005 was compared by the Mann-Whitney-Wilcoxon U test. The growth rate for each colony was computed as exponential growth, as $r = \frac{[\log(P_f / P_i)]}{n}$, where n is the number of years (5), P_f is the number of pondberry in 2005, and P_i is the number of pondberry in 2000. A nonparametric test was used because colony/site growth rates were not normally distributed.

The relationship between flood frequency and growth rates at each colony/site were further evaluated by least squares linear and nonlinear regression. Colony/site growth rate was represented by three different measures: exponential growth, geometric, and the percent change. The exponential growth formula previously was described. Geometric growth was $R_e = (e^{[(\log(P_f / P_i))/n]}) - 1$, where P_f = the number of pondberry in 2005, P_i = the number of pondberry in 2000, and n = 5, the number of years. The percent change in number of pondberry was $R_p = \log(P_f / P_i)$. Colony/sites determined as jurisdictional wetlands by the Corps jurisdictional field survey with a local wetland hydrology and a flood frequency interval of more than two years were removed from analysis. These eight wetland colonies/sites were not wetlands by virtue of the 5 percent duration flood event within the 2-year floodplain by FESM. The flood frequency intervals for these wetland colonies ranged from 2.5 to 17.0 years (Table 21), and are confounding observations to the linear and nonlinear analysis of effects of flood frequency interval. Because wetland status and flood frequency affects the number of pondberry, as described in the following sections, these colonies/sites attain wetland status because of local site factors where, otherwise, their flood frequency intervals are greater than 2-year interval within which overbank flooding with a 5 percent duration can establish wetlands. Of the eight colony/sites in the 0-2 year floodplain, two (GSRC 54 and 56) are FESM wetlands, and three (GSRC 2, 21, and 42) are jurisdictional wetlands with a local hydrology as determined by the Corps field survey. The wetland hydrology of these three colony/sites with a local wetland hydrology are included because their wetland hydrology also can depend in part on the flood frequency within the 0-2 year floodplain.

An initial set of more than 10 nonlinear equations were developed, applied, and tested for each measure of growth. Models without any relationship between flood frequency and colony/site growth were removed and are not reported here. A model set consisted of 17 basic nonlinear models for colony/site growth in response to flood frequency (Table 35), according to colony/site flood frequencies computed from the same period of record, an in which the three measures of colony/site growth were computed from the same set of data on the number of pondberry in 2000 and 2005. A single model is the nonlinear equation for the effect of flood frequency on colony/site growth, according to the specific measure of growth (geometric, exponential, or percent change) and the POR from which the flood frequency at each colony/site was estimated. The response by geometric growth was evaluated with six basic models, exponential growth by six basic models, and percent change with five models (Table 35).

Our first nonlinear analysis of models during this consultation was based on colony/site flood frequencies derived from the 1943-1997 POR. We used these flood frequencies and POR because the Corps had based various statistical and other analyses in their biological assessment (U.S. Army Corps of Engineers 2005) and associated appendices of profiled pondberry colonies/sites in 2000 and 2005 relative to flood data from the 1943-1997 POR. According to the Corps, the 1943-1997 POR was selected as the period flood data from which to estimate the 5 percent duration flood event and wetlands (FESM) because a longer POR is more likely to include significant hydrological events and variations, and Corps guidance for selecting an appropriate POR must include all significant hydrological events (U.S. Army Corps of Engineers 2005a, Wetland Appendix 10). Later during this formal consultation and after the completion of their biological assessment, the Corps commented in their technical review of a draft biological opinion that these nonlinear models and other assessments of the change in pondberry colony attributes between 2000 and 2005 should only be compared to observed floods during the 2000-2005 period, and not to the flood frequencies from the 1943-1997 POR (U.S. Army Corps of Engineers 2007). The underlying rationale for this comment is that colony/site changes during 2000-2005 in response to hydrology could be more in response to flood events during the same period, rather than flood frequencies at these sites estimated from the longer 55-year 1943-1997 POR.

Accordingly, we also assessed the nonlinear response of colony/site growth during 2000-2005 to flooding during the more recent 20-year 1984-2003 period and the 10-year 1994-2003 period as a comparison to the response calculated from the 1943-1997 POR. Flooding during the brief 2000-2005 period was insufficient to provide adequate data for these analyses. Corps data for the 1984-2003 period was provided in their biological assessment. These data tabulated the number of flood events each year at each profiled pondberry/colony site. The Corps tallied the occurrence of flooding when the interpolated flood elevation from stage-gage data was equal to or greater than the colony/site elevation as determined by the ground-surveyed elevations. When a colony/site had at least one flood during any given year, it was classified as flood year, which we summed for each colony/site during the 1984-2003 period and 1994-2003 period. Flood event data were converted to an annual flood probability and used as the flood frequency interval. For example, a colony/site that received flooding during 2 of 20 years (1984-2003) had an annual flood probability of 0.1 and a flood frequency interval of 10 years. The flood frequencies at colonies/sites that did not receive any flooding during the 20-year 1984-2003 period were coded at a 21-year flood frequency, to represent a flood frequency interval greater than 20 years. Likewise, colonies/sites without flooding during the 10-year 1994-2003 period were coded at a 11-year flood frequency. These colonies/sites later were excluded because the artificial frequency could potentially affect the response.

The final nonlinear analysis consisted of 10 sets of models, each set with three measures of colony/site growth in response to flood frequency and 17 individual models (Table 35), for a total of 170 models.

Growth models for the 1943-1997 POR were assessed by two sets of models. One set consisted of all colony-sites (n=38), and in the second set colonies/sites 3 and 32 were excluded as statistical outliers (n=36).

Colony/site growth for the 1984-2003 POR was evaluated by four sets of models. One set consisted of all colonies/sites (n=38). Colonies/sites 3 and 32 were removed as outliers in the second set (n=36). The third set consisted of all data, as in the first, but colonies/sites without any flooding that were coded by a 21-year flood frequency were removed (n=30). The fourth set was the same as the third, but without colonies/sites 3 and 32 which were removed as outliers (n=28).

Growth models with the 1994-2003 POR also consisted of four sets of models. All colonies/sites were included in the first set (n=38). Colonies/sites 3 and 32 were removed as statistical outliers in the second set (n=36). The third set was the same as the first, except that all colonies/sites that did not flood during the 10-year period were removed (n=15). The fourth set was the same as the third, but colonies 3 and 32 were excluded (n-13).

There are no prior experimental or empirical data establishing a specific relationship between flood frequency and pondberry colony/site growth rate. In the absence of such data or other information, the null hypothesis was that colony/site growth rate is not related to flood frequency. The alternative of interest, as a species classified as a wetland obligate, was that colony/site growth should increase with increasing flood frequency. We evaluated the distribution of residuals, including the effects of outliers, with other standard assessments for least squares regression analysis.

The nonlinear models for each growth measure represented a variety of nonlinear trends. We computed the Akaike information criterion (AIC) (Akaike 1974), following the procedures by Burnham and Anderson (2002), to select the best models with the least uncertainty that accounted for the variation and response of colony/site growth rate growth to flood frequency. AIC is

$$AIC = -2\log(L(\hat{\theta}|y)) + 2K$$

where $\log(L(\hat{\theta}|y)$ is the log likelihood function of the model, given its parameters. For least squares regression, the information criterion is

$$AIC = n\log(\sigma^2) + 2K$$

where K is the total number of estimated regression parameters, and the estimated variance is

$$\sigma^2 = \frac{\sum \varepsilon^2}{n}$$

where ϵ are the estimated residuals for the model. By these methods, AIC corrected for small sample size was computed for each model as:

$$AIC_c = [n \times \log(\sigma^2) + 2K] + [2K(K+1)/(n-K-1)],$$

where n is the number of observations (colony/sites), σ^2=SSE/n and SSE is the sum squares error, and K is the number of estimated parameters. A "model" consists of the data (flood frequencies and colony/site growth rates), and the given and estimated parameters in the nonlinear equation for the particular estimate of growth rate. Models with different estimates of growth rate, the response variable, are different models. For each measure of colony/site growth, we compared and ranked models by first computing AIC_c differences, as

$$\Delta_i = AIC_i - AIC_{\min},$$

where AIC_{min} is the model with the least value, and AIC_i is the model being compared. Models with Δ_i values ≤ 2 were considered to have substantial support, $\Delta_i = 4\text{-}7$ have considerably less support, and $\Delta_i > 10$ have essentially no support (Burnham and Anderson 2002). The relative strength or probability of each model was the Akaike weight,

$$w_i = \frac{\exp(-\frac{1}{2}\Delta_i)}{\sum_{r=1}^{R}\exp(-\frac{1}{2}\Delta_{r})},$$

where R is the set of models compared. The ratio of Akaike weights for two models (w_1/w_2) is the evidence ratio.

Akaike's Information Criterion can not be interpreted to compare different models, which in this case consist of different measures of colony/site growth and when based on a different set of flood frequency data or colony/site data (e.g. Burnham and Anderson 2002). AIC differences (ΔAIC_c) and weights were used to assess the most likely models among those for a particular growth measure computed from the same set of flood frequency and colony/site data. Relative comparisons of different models of growth were based on the coefficient of determination (r^2) and its probability.

Results

Results of the repeated measures ANOVA for 2000 and 2005 revealed that the average colony/site size (number of pondberry) was affected by both flood frequency ($p = 0.0847$) and year (p=0.0130), but the effects of each were not modified by the other (e.g. no interaction of main effects, $p = 0.5529$, Table 36). Colonies/sites in the 0-2 and 3-5 year floodplain were larger, with more pondberry on average than in the less frequently flooded 6-10 and 11-20 year floodplain. The mean number of plants per colony in the 0-2 year floodplain (54.8) was significantly greater ($p = 0.0953$) than in the 11-20 year floodplain (14.7). Also, the number of pondberry in the 3-5 year floodplain (62.8) was significantly greater than pondberry in the less frequently flooded 6-10 year floodplain (19.2, $p = 0.0832$) and in the 11-20 year floodplain (14.7, $p = 0.0287$). The magnitude of the greatest flood frequency effects were between the 0-2 and 11-20 year floodplain, where mean colony/site size in the 0-2 year floodplain (54.8) was 3.7 times larger than in the 11-20 year floodplain (14.7). Pondberry colonies/sites in the 3-5 year floodplain, on average (62.8), were larger than colonies/sites in the 0-2 year floodplain (54.8), but the differences were not statistically significant.

Pondberry declined overall between 2000 and 2005 ($p = 0.0130$), from a mean 39.8 to 25.0 plants per colony/site (back transformed mean values). The average colony/site declined within all flood frequency classes during this period, but there were no statistically significant differences among the flood frequency classes even though the magnitude of the decline increased with decreasing flood frequency (Table 36). At one extreme in the 0-2 year floodplain, there were 59.4 pondberry per colony/site in 2000 and 50.5 in 2005. At the least frequently flooded 11-20 year class, the average colony/site declined from 22.6 plants to 9.4 during 2000 – 2005. The absence of any statistical significance for these data reflects in part that the number of pondberry per colony/site were highly variable within and among these flood frequency classes, with small sample sizes.

The Corps pondberry profile and the selection of these colonies/sites were not executed as part of a prospective research design based on preliminary samples and statistics to determine the sample size to acquire at a desired level of precision and statistical power to assess the change in the average number of pondberry as affected by flood frequency class and year. This doesn't mean a repeated measures ANOVA shouldn't be assessed. It means that sample size, precision, and statistical power could be inadequate to detect a biologically meaningful difference at a statistically significant level. Statistical power is the probability of detecting an effect when it occurs, and correctly rejecting a false null hypothesis of no effect. Power increases as sample size, effect size, and Type I error rate increases, and the variability of the data decreases (Cohen 1988). In this case, the null hypothesis of no interaction and effect between flood frequency and year is accepted (e.g. the null hypothesis is not statistically rejected with the acceptance of an alternative hypothesis). There can be several alternative hypotheses for the interaction of main effects, but one of interest is that the mean number of pondberry in the 0-2 year floodplain increased during 2000-2005, while the mean number in the 6-10 year floodplain decreased during this period. If the number of pondberry per colony/site are naturally highly variable, the ability to detect differences at different flood frequency classes at a statistically significant level will depend on increasing the sample size (number of profiled colonies/sites) and precision. We aren't advocating additional sampling until a statistical effect of any small size is detected. The important question is the biological meaning of the apparent differences. We consider the differences between a mean of 59.4 pondberry in 2000 and 50.5 in 2005 on the 0-2 year floodplain as biologically small and meaningful relative to the larger differences from an average of 22.6 pondberry in 2000 to 9.4 in 2005 on the 11-20 year floodplain, as well as the comparable declines in 3-5 and 6-10 year floodplains (Table 36) – yet the available data are statistically insignificant for these changes. This and related issues are further assessed in Appendix 3 of this biological opinion.

Nevertheless, these data indicate that pondberry colonies/sites are on average more productive with a greater number of pondberry at the most frequently flooded classes. Flood frequency, however, is only one measure of hydrology. Of the 47 profiled colonies with a jurisdictional field survey, 27.7 percent

(13) were wetland and 72.3 percent (34) were nonwetland sites. In another repeated measures ANOVA (Table 34), the performance of pondberry colonies/sites during 2000 – 2005 was significantly affected by site status (wetland vs. nonwetland, $p = 0.0682$) and the interaction of year (2000 vs. 2005) and site ($p = 0.0765$). The average colony in wetlands during this period (93 plants) was almost three times greater than nonwetland colonies (33) ($p = 0.0682$). From 2000 to 2005, the number of pondberry in nonwetland colonies declined from 42 to 26 plants per colony ($p = 0.0132$), while the average number in wetland colonies increased from 84 to 102 plants ($p = 0.0183$).

The greater average number of pondberry per colony/site in wetlands in 2005 was not based on actual growth and an increase from that in 2000. Overall, pondberry declined in wetlands and nonwetlands during 2000 – 2005 (Table 38), but the overall rate of decline was greater in nonwetlands and less at wetland colonies/sites. There were 6,502 pondberry in wetland and nonwetland colonies/sites during 2005, where pondberry in wetland colonies/sites comprised 64 percent (4,127), and pondberry in nonwetland colonies represented 36 percent (2,375) of all pondberry. The greater average number of pondberry per wetland colony in 2005 (Table 34) reflects a lower rate of decline and greater rate of persistence in wetlands. Pondberry persisted at wetland colonies/sites at a significantly greater rate than nonwetlands ($\chi^2 = 188.4$, $p = 0.0000$) from 2000 to 2005 (Table 37). Sixty-three percent (4,127) of the pondberry at wetland colonies/sites persisted from 2000 to 2005, compared to 50 percent persistence at nonwetland colonies/sites (Table 37). Persistence in wetlands was 1.7 times greater than in nonwetlands (odds ratio 1.69, 95% C.I. $1.57<\text{O.R.}<1.83$).

If site status (wetland and nonwetland) did not affect the total number of pondberry and colony/site size, we also would expect the actual number of pondberry in wetlands and nonwetlands to be proportional to the number of wetland and nonwetland colonies (sample size). However, site status significantly affected pondberry ($G = 51.8$, $\chi^2 = 10.828$, $p = 0.0001$) (Table 38). The 13 wetland colonies/sites represented only 27 percent of the field-surveyed colonies/sites (47), but produced 60 percent (10,683) of all pondberry (17,806) for 2000 and 2005 combined (Table 38). The total number of pondberry declined in wetland and nonwetlands colonies, but wetland colonies/sites sustained 2.16 times more pondberry than that expected, and nonwetland colonies/sites produced 44 percent less than that expected if the number of pondberry was proportionate to the number of colonies/sites in wetlands and nonwetlands. Most of the pondberry sustained during 2000 – 2005 was in wetland colonies/sites. Wetland colonies/sites were more important and productive than nonwetland sites.

The total number of pondberry also was significantly affected by flood frequency interval ($G = 726.6$, $\chi^2_{(.001,3)} = 16.27$) (Table 39a). This data set consisted of all 49 profiled colonies/sites, including those with a Corps field determination for jurisdictional wetlands and nonwetlands at 47 colonies/sites, and two colonies/sites without field determinations. Overall, there was a -42.3 percent decline in the total number of pondberry from 2000 to 2005, where the decline ranged from 50.0 – 56.3 percent on the 2.1 – 5.0, 5.1 – 10.0, and >10.0 year floodplains. Pondberry in the most frequently flooded 0-2 year floodplain actually increased by about 10 percent, from 2,454 to 2,694, while the species declined at all other less frequently flooded class intervals. When the flood frequency classes are partitioned by the G_H statistic into homogenous groups, the change in the number of pondberry in the 0-2 year floodplain where pondberry increased were significantly different from the 2.1-5.0, 5.1-10, and 10.1-20 year flood frequency classes (Table 39a). The same trend is apparent when the eight colonies/sites with a local wetland hydrology above the 2-year floodplain (Table 21), independent of overbank flooding, are removed from the set of data for 47 profiled colonies with field wetland determinations (Table 39b).

The total number of pondberry from colonies/sites in the 0-2.0 and 2.1-5.0 year floodplains during 2000 and 2005 was greater than expected, and the number in less frequently flooded class was less than expected ($G_H = 748.3$, $\chi^2_{(.001,3)} = 16.27$, $P < 0.001$) based on an extrinsic hypothesis that the number in each flood frequency class should be proportionate to the number of colonies (Table 40). Eighteen percent of all profiled colonies were in the 0-2.0 year floodplain, where 21 percent of all pondberry occurred during 2000. During 2005, the number of pondberry in the 0-2.0 year floodplain increased to 39.8 percent of all pondberry. The 23 colonies/sites in the 2.1-5.0 year floodplain represented 47 percent of all colonies/sites in 2000, with 72.1 (8,467) percent of all pondberry, then decreased in 2005 to 54.6 percent (3,696) of the total pondberry in 2005 (Table 40a.). The number of pondberry in less frequently flooded classes (5.1-10.0 and >10.0) consisted of from 7 to 9.7 percent of all pondberry in 2000 and 2005, where 16.3 - 18.4 percent of all colonies were located.

Colony/site growth rates were not significantly different and negative in wetlands and nonwetlands (Mann-Whitney-Wilcoxon statistic = 271.00, $z = 0.6236$, $p = 0.5329$). The median colony/site rate for exponential, geometric, and percent change growth in wetlands was slightly less than nonwetlands (Table 41). Median colony/site growth rates in wetlands mostly differed by a minimum (lowest) negative value that was greater than in nonwetlands, and more wetland colonies/sites had positive growth rates than nonwetlands.

Linear and nonlinear models

All previous analyses involved different measures of pondberry performance relative to flood frequency class intervals or site categories (wetland vs. nonwetland). The response of pondberry also is evident as continuous relationships without class categories. For example, the number of pondberry at each profiled colony site in 2005 is highly correlated with the number in 2000 (Figure 8, $r^2 = 0.6384$, $p = 0.0000$), with a fitted linear regression line indicating the decline in the population of colonies/sites. The underlying changes in the actual number of pondberry at colonies/sites are more evident by the relationships of their growth rates.

All nonlinear models for pondberry growth in response to flood frequency were statistically significant ($p < 0.05$) in the set of models with flood frequency intervals determined from the 1943-1997 POR that were further evaluated for the most likely models. Colony/site growth rates from the least squares regression line were positive when flood frequency intervals were less than 1.1 to 3.0 years, depending on the model. Positive growth rates in most models declined sharply to the point of zero growth, and then more gradually as rates became negative at less frequent flooding (Figures 9 – 24).

The first analysis of residuals, outliers, and influential observations and outliers was applied with this set of models. A residual is the numerical difference between the observed colony/site growth rate during 2000-2005 and the growth rate predicted by the fitted least squares nonlinear regression. An outlier is a colony/site with a growth rate that statistically is unlikely relative to the probability distribution of growth rates by the respective model. An influential observation is a colony/site growth rate, regardless of whether it is statistically an outlier or not, that highly affects the fit of the least squares regression and the residual variation for observations about the regression line. For this analysis, a highly influential colony/site would change the shape and values of the fitted growth curve. In the statistical literature, influential observations also have been described as statistical outliers or extreme observations. In any case, observations are statistically influential if they significantly change the outcome of the analysis when removed (Freud and Wilson 1997). Statistically, there are several procedures for evaluating the effects of suspected outliers, depending on the particular analysis. These procedures in regression analysis vary from strictly numerical analysis with the use of Cook's distance, Mahalanbois distance, residual and standardized residuals, Z scores, or other tests as well as visual inspection of the data in graphs or other aids (Belsley et al. 1980; Zar 1984; StatSoft 1995). The purpose of such analysis is to identify influential and outlier data, and then assess the extent that they are anomalous, erroneous, unrepresentative, violations of the required assumptions for statistical analysis, or otherwise inappropriate for the analysis (Barnett and Lewis 1984). At the same time, such data must be judiciously considered and retained, instead of discarded, because they could be real, reflecting naturally inherent variation in the data, providing important information about the population of interest (Orr et al.1991; Freud and Wilson 1997).

We considered colonies/sites 54 and 56 as influential, and 3 and 32 as non-influential statistical outliers. Generally, the effect of any single one of these colonies/sites is not highly influential. Their influential effects occur as combinations, as for colonies/sites 54 and 56. For example, the Z scores for colonies/sites 54 and 56 range from 2.0 to 2.3 for the geometric (R_g5A), exponential (R_e5A), and percent change (R_p5A) growth models $y = a - b(\log x)$ (Table 47). Z is a standardized normal variable, with a mean of zero and a unit standard deviation of 1, which is used as measure of the probability distribution of observed colony/site growth rates from the normal or Gaussian distribution. In the geometric growth model R_g5A (Table 47), colony/site 56 had a geometric growth rate of 0.6858, with a Z score of 2.3615. The probability of a colony/site with a greater rate of geometric growth and a greater Z score is only 0.0091. This is an unusually large colony/site growth rate, relative to this particular model, where 99 percent of all other predicted colony/site growth rates are less. In other words, if there were 100 additional random samples of different colonies/sites where growth rates were measured, then on average only about 1 percent of these would have a greater growth rate. Statistically, the probabilities of colonies/sites having such a large growth rate are very small and unlikely according to this model. As a general rule in regression analysis, observations with a Z score greater than 2 should be of concern, and when greater than 3 there should be serious consideration for their effects and their possible removal from the analysis. In all other models, the Z scores for colony/sites 54 and 56 growth rates were less than 2.0.

In contrast, Z scores for colonies/sites 3 and 32 consistently were greater than 2.0, and frequently greater than 3.0 for all three measures of growth in most models (Tables 43-47). Colony three at a frequently flooded 1.5 year interval had the lowest negative rate of growth by any measure for any colony/site (Table 42). Colony/site 32 had the third largest growth rate of any colony/site, with a flood frequency interval of 4.0 years (Table 42). The probability is only about 0.0013 that a colony/site would have a more extreme positive or negative growth rate when the Z score is 3 or -3.

We further evaluated these colonies/sites using Cook's distance, Mahlanbois distance, and by other considerations, concluding that colonies/sites 54 and 56 should be retained, while colonies/sites 3 and 32 can be considered statistical outliers. Outliers can represent real biological data that, by rare chance, have been included in a survey or sample data set. Depending on the sample data, outliers may or may not have an important effect. When influential outliers are sampled and the biological or other meaning of the data are relatively well known from previous studies, it is not unusual for investigators to remove outliers when they are influential and unrepresentative. The probabilities of selecting colonies/sites 54 and 56 with such large growth rates, however, are functions of the actual data set from the colonies/sites selected for the profile. Colonies/sites 54 and 56 are two of only four profiled colonies/sites selected that, upon later analysis, were found to have a flood frequency of 1.5 years are greater. Also, these are the only two colonies/sites surveyed in the 1-year floodplain. From these four colonies (GSRC 2, 3, 54, and 56), there was a very wide range in the number of pondberry during 2000 and 2005, as well as their growth rates (Table 42). At one extreme, colony/site 3 is a nonwetland, with a 1.5 year flood frequency and the largest negative growth rate for any of the 49 profiled colonies/sites. At the other extreme are colonies/sites 54 and 56, within the 1-year floodplain, with the greatest growth rates of any of the profiled colonies/sites. Between these growth rates and these flood frequencies, there are no other data to clarify these relationships. Had more colonies/sites been selected and profiled at these frequently flooded sites, the data would have been more precise, without such a wide range of variation. Thus, the limited sample size or the number of profiled colonies/sites at frequently flooded sites is one reason these data may be unusual.

Since data sometimes are recorded or transcribed in error, we inquired and the Corps confirmed that our data for the number of plants recorded in 2000 and 2005 at colonies/sites 54 and 56 were the correct data.

Furthermore, these two colonies/sites are located in two different populations (Populations 9 and 10), located more than five miles apart (Plate 8). It is highly unlikely that these large growth rates were an aberrant response to a single site with an unusual environmental feature. As previously described, the Z scores and standardized residuals for these colonies only rarely exceeded 2.0. Nevertheless, their biological and mathematical influence in these nonlinear regression models are evident when both are removed (Figures 25-28). When only one is excluded, there are relatively minor changes to shape and characteristics of the fitted growth cure in response to flood frequency interval (Figures 25-28). When both colonies/sites are removed, there is no longer any significant relationship between colony/site growth and flood frequency. Mathematically, these two colonies/sites adequately fit the requirements for least squares regression. Statistically, they significant influence the fitted growth curve for each nonlinear regression model. Biologically, they also exert a significant influence on the interpretation of colony/site growth in response to flood frequency.

Overall, colonies/sites 32, and 3 had the largest residuals, standardized residuals, and Z scores, which varied somewhat depending on the model, but frequently exceeded a 3.0 Z score (Tables 43 - 47). Colony/site 32, with a flood frequency of 4, is within the 3 – 5 year floodplain, where about 12 other colonies/sites had substantially lower growth rates. Based on its probability, colony/site 32 is a highly unusual sample relative to the others. Colony/site 3, with a flood frequency interval of 1.5 years, does not occur with a large number of colonies/sites with frequent flooding for comparison. Statistically, these are outliers. However, they are not highly influential, overall, to the vast majority of growth models. Relatively minor changes in the location and shape of the fitted nonlinear growth curve accompany the exclusion of colonies/sites 3 and 32 (Figures 9 – 24). The primary effect of their removal was a reduction in the overall residual variation, and an increase in the coefficient of determination (r^2) for the amount of variation accounted for by the model. Consequently, we have excluded these two colonies/sites from most of the following reports of the nonlinear analysis, but include them as reference in other instances and models.

The nonlinear regression analysis for all three measures of colony/site growth identified two general types of colony/site response to flood frequency interval. One type is characterized by maximum or near maximum positive growth rates at frequent flood intervals, mostly in the 2-year floodplain, which decline rapidly to the point of 0 colony/site growth, and continue to decline but at a smaller rate at negative growth rates at less frequent flood intervals. The second type is similar, but with lower positive growth rates with a more gradual overall rate of decline to the point or 0 growth and negative growth.

The maximum growth response curves are evident with two models, $y = a + b(\exp^{-cx})$ and $y = a + b(\exp^{1/x})$ for all colony/site geometric, exponential, and percent change growth. These characteristics also are present in a third model equation $y = x^a - b$, but only for percent change growth. For example, models for $y = a + b(\exp^{-cx})$ fit the least squares regression line very close to colonies/sites 54 and 56, which reduces their residual error (Figures 9, 14 and 20). The fitted regression is nearly a vertical line at these two points, where the observed flood frequencies are 0.7 and 0.8 years. From this point, the positive growth rates fall quickly to the point of zero growth, on average, at flood frequency intervals of 1.1 to 2.1 years for regressions with the 1943-1997 POR, depending on the model (Table 48). When flooding is more frequent than 1.1 to 2.1 years, colony/site growth on average by this model increases substantially. The observed geometric growth rate at colony/site 54 was 0.6402 (model R_g1A, Table 48.A.1), and the least squares regression geometric growth model, without excluding colonies/sites 3 and 32, predicts on average that colony/site 54 would have a 0.7815 growth rate, which would double the number of pondberry every 1.2 years. If there were 100 plants at this colony/site, after one year of growth there would be 178 plants, on average. These rates are only slightly greater than that actually observed for this colony/site during 2000-2005, and are considered maximum because no greater growth rate currently is known. The geometric growth model with this equation and parameters provides a least squares fit minimizing the overall residual variation or differences between the observed colony/site growth rates, as annualized from 2000 to 2005, and the predicted rates. In achieving this mathematical property, the fitted least square function solved for these colonies/sites have large annual growth rates at the most frequently flooded sites.

The models $y = a + b(\exp^{1/x})$ with geometric, exponential, or percent change in colony/site growth have the same general properties of the previous regression with maximum growth rates (Figures 10, 15, and 21). Once again, the least squares regression line for the average predicted growth rate minimizes the total residual variation among colonies/sites by fitting the data very close to colonies/sites 54 and 56, with the largest growth rates and the most frequently flooded sites. The flood frequency at zero growth, below which negative growth occurs, is at 1.7 to 2.1 years (R_xA2 and R_xB2, Table 51). The rate of increasing negative growth at less frequent flood intervals slows, then declines only at very small intervals. In contrast, the lowest negative colony/site growth rates are more rapidly reached at less frequent flood intervals in the maximum growth models with $y = a + b(\exp^{-cx})$, at which the lowest negative growth rate remains constant over increasingly less frequent flood intervals (Figures 9, 14, and 20). Characteristics of the percent change growth model $y = x^a - b$, with maximum growth (Figure 23) are most similar to maximum growth models by $y = a + b(\exp^{-cx})$.

None of the other nonlinear models of colony/site growth rate minimize the overall variation and increase the proportion of growth rate variance accounted for by flood frequency in the same manner as these models, with regression functions fitted as near as possible to sites 54 and 56 with the greatest observed growth rates. The rate of positive colony/site growth from the flood frequency at zero growth, which ranges from 1.2 to 2.1 years with the 1943-1997 POR, depending on the model (Table 51), increases at a lower rate in comparison to the maximum growth models. Similarly, the maximum predicted growth rate is less than that by the maximum growth models. This set can be further subdivided according to the pattern of colony/site growth at flood frequencies where negative growth develops and colonies/sites are predicted to decline. For example, geometric (R_g3), exponential (R_e3), and percent change growth models (R_p3) with $y = a^x - b$ (Figures 11, 16, and 22) reach a lower asymptote, at which growth rates do not decrease further and remain constant, on average, as flooding continues to decrease. In contrast, once negative and declining growth begins in other models, it continues to decline without reaching a final limiting rate. These models include geometric (R_g4-Figure 12, R_g5-Figure 13), exponential (R_e4-Figure 17, R_e5-Figure 18, R_e7-Figure 19), and percent change (R_p5-Figure 24) growth models.

Geometric growth (R_g) with flood frequencies determined from 1943-1997 POR

With few exceptions, the nonlinear regression models for geometric growth statistically accounted for more of the variation in the observed growth rates among these profiled colonies/sites than did exponential and percent change growth models. For the models with colony/site flood frequencies determined by the 1943-1997 POR and with colonies/sites 3 and 32 excluded as statistical outliers, model R_g3B ($y = x^a - b$) had the greatest coefficient of determination (r^2 =0.7568), in which the fitted regression curve accounted for almost 76 percent of the variation in the observed colony/site growth rates (Table 48 B.1.). Models R_g1B ($y = a + b(\exp^{-cx})$, r^2 =0.7512) and R_g2B ($y = a + b(\exp^{1/x})$, r^2 =0.7065) were statistically significant similar (Table 48.B.1).

For the nonlinear regression with colonies/sites 3 and 32 excluded as statistical outliers, models R_g1B (Figure 9) and R_g2B (Figure 10) are the most likely of this set of geometric growth models, based on AIC differences from 0 – 3.4127, and particularly R_g1B with an Akaike weight of 0.8705 (Table 48.B.1). For the set of models compared, the Akaike weight (w_i) is the weight of evidence for a model being the best Kullback-Leibler information model, given that one of the models must be the best (Burnham and

Anderson 2002). The evidence ratio for model R_g1B relative to R_g2B is generally high, at 5.51 (0.8705/0.1580 – Table 48.B.1), while the evidence supporting models R_g3B, R_g4B, and R_g5B is much lower, with much greater uncertainty. Both of these are maximum growth models, where positive colony/site growth rates increase rapidly as flooding occurs more frequently from the point of zero growth at 1.4 years (R_g1B) and 2.1 years (R_g2B) (Table 51). The fitted regression line in Model R_g1A depicts a very sharply declining average growth rate (Figure 9). Once the average growth declines to 0 at the 1.1-year flood frequency interval, the rate of negative growth quickly reaches its limit at -0.084 at the 2-year flood interval, where the average negative growth rate remains constant across the increasing intervals between flooding (Figure 9). Models with the same nonlinear equations also are the most likely (R_g1A and R_g2A) when colonies/sites 3 and 32 are not excluded (Table 48A.1).

The range of flood frequency intervals at positive average colony/site growth rates in models R_g2A (2.0 years) and R_g2B (2.1 years) are slightly greater than models R_g1A (1.2 years) and R_g2A (2.0 years), declining to 0 growth at the 2.0 year (R_g2A) and 2.1 year (R_g2B) flood frequency interval (Table 51), below which there is negative growth and declining colonies/sites on average. Zero growth in models R_g2A and R_g2B occur, respectively, at the 1.2 year and 1.4 year flood frequency interval. Negative growth rates reach a lowermost threshold where it remains constant in models R_g1A and R_g1B (Figure 9), while negative growth rates continue to decline, although slowly, as flooding decreases in models R_g2A and R_g2B (Figure 10).

Models R_g3A (Figure 11), R_g4A (Figure 12) and R_g5A (Figure 13) are not likely based on AIC differences and weights, relative to R_g1A and R_g2A (Table 48A.1). Counterpart models R_g3B (Figure 11), R_g4B (Figure 12) and R_g5B (Figure 13) with colonies/sites 3 and 32 excluded also are the most uncertain and unlikely (Table 48B.1). These regression models are not characterized by maximum or near maximum rates of positive colony/site growth.

Geometric growth (R_g) with flood frequencies determined from 1984-2003 and 1994-2003 PORs

The estimated flood frequency for each colony/site changes when based on the shorter periods during 1984-2003 and 1994-2003 (Table 42). Generally, flooding occurs less frequently during these periods, relative to the frequencies estimated from the 1943-1997 POR. The number of pondberry does not change for the census in 2000 and 2005, nor do the observed growth rates computed for geometric, exponential, and percent change growth (Tables 42 and 35). However, the changes in flood frequencies affect the nonlinear regression models for the response of growth rate to flood frequency. Models R_g1 and R_g6 are the most likely with the 1984-2003 POR (Tables 49C.1 and 49D.1, Figures 29 and 30). With the 10-year 1994-2003 POR, models R_g1, R_g4, and R_g6 are the best (Table 50G.1, 50.H.1, 50I.1, and 50J.1, Figure 31). All of these are maximum growth models.

Ten sets of regression models, each with six models, were assessed for geometric colony/site growth for a total of 60 geometric growth models (Table 51). The 1943-1997 POR included two sets (12 models). The 1984-2003 POR consisted of four sets (24 models), and the 1994-2003 POR had four sets (24 models). The most likely models with each set were identified using the computed AIC and Akaike's weights. Each set usually consisted of two most likely models. Overall, 20 models were identified as the least uncertain and most likely. Models in different sets cannot be compared by Akaike's criterion, and in general we did not attempt to further distinguish any overall best set of models using other comparative measures such as the regression coefficients, F-statistics, or sum and mean squares errors estimates. By classical statistics, models with the greatest coefficients of determination usually were associated with those in which colonies/sites 3 and 32 were excluded as statistical outliers. For example, the greatest and most statistically significant coefficient of determination was by geometric model R_g1B (Table 48B.1, Figure 9), with $r^2 = 0.8705$, $p = 0.0000$, where the model accounted for about 87 percent of the variation in geometric colony/site growth was accounted for by colony/site flood frequency interval. However, using all the most likely models from the model sets provides a range of values for which to estimate growth response. In this case, the nonlinear patterns of growth response were very similar among all the best models, with generally small differences for the flood frequency interval at zero growth.

From the 17 most likely models with the 1984-2003 POR and 1994-2003 POR, zero colony/site growth on average ranged from 2.1 to 4.0 years (Table 51), with negative and declining growth at less frequent flood intervals. Zero growth for 15 of the 17 models was within the 2.0 – 2.9 year flood frequency interval. Flooding was most frequent for the best models with the 1943-1997 POR, from 1.2-2.1 years. No significant trend or pattern was evident for the flood frequencies at zero colony/site growth with flood frequencies computed from periods when flooding generally was less frequent, during 1984-2003 and 1994-2003 (Table 51). Generally, the range of flood frequencies at zero growth in these tended to include a few less frequent interval values. Flood frequency intervals at zero growth varied from 2.1-3.4 years with the 1984-2003 POR, and 2.0-4.0 years with the 1994-2003 POR for the best models.

Akaike's weights usually clearly delineated a single best model in a set, frequently with a weight of 0.8000, with sufficient remaining evidence to include a second model, although with less evidence than the first. In one instance, however, the geometric model set with the 1994-2003 POR and exclusion of colonies/sites 3 and 32 as outliers provided four models with evidence as the most likely (Table 50H.1). The individual model weights ranged from 0.3844 to 0.1076, indicating there is relatively high uncertainty about which particular model in the set is best. Of these, the R_g2H model was the weakest of any model, but was included because of the overall uncertainty with the other most likely models.

Exponential growth (R_e) with the 1943-1997 POR

Models R_e1A (Figure 14) had the greatest supporting evidence (w_i = 0.7861), followed by R_e2A (w_i = 0.1687, Figure 15, Table 48A.2). These are maximum growth models with the same equations as the geometric models R_g1A, R_g2A, except for the growth measure. They are very similar, except that flooding is slightly more frequent for positive average growth intervals in R_e1A (<1.1 years) and R_e2A (< 1.7 years). As average positive growth rates decline, zero growth for R_e1A is attained at the 1.1 year flood interval, and 1.7 years for R_e2A (Table 51) The growth rate continues to decline gradually in R_e2A, until the 16-year flood frequency interval where the lowest rate (-0.1376) is reached.

The same pattern is evident with the 1943-1997 POR frequency data with the exclusion of colonies/sites 3 and 32 as statistical outliers. Models R_e1B and R_e2B (Figures 14 and 15) are the most likely (Table 48B.2), with a zero growth flood frequency respectively of 1.3 and 1.8 years (Table 51). Negative growth rates in R_e1A and R_e1B, once reached, are constant without any further decline as flood frequency intervals continue to decrease. In contrast, negative growth rates continue to decrease, although at a slow rate, as the flood frequency interval increases in R_e1B and R_e1B. Coefficients of determination were lower for the most likely R_e1A (r^2 = 0.3986, p = 0.000) and R_e2A (r^2 = 0.4119, p = 0.000) compared to geometric growth models, but still statistically significant, increasing and accounting for much more of the variation in growth by flood frequency in R_e1B (r^2 = 0.6276, p = 0.000) and R_e2A (r^2 = 0.5955, p = 0.000) in which colonies/sites 3 and 32 were excluded (Table 48).

The fitted regression in all other unlikely exponential models had lower rates of positive growth and lower rates of negative growth in response to flooding (Figures 16-19). For example, average growth rates decline in R_e3A more gradually (Figure 16), reaching 0 growth at the 1.6 year flood interval, and continuing to decline to the 4-year flood interval where the lowest growth rate (-0.0960) is reached, which remains constant.

Exponential growth (R_e) with flood frequencies determined from 1984-2003 and 1994-2003 PORs

Fifteen of the 48 models with the 1984-2003 POR and 1994-2003 POR were identified as likely based on Akaike's criteria and weights. Models with equations R_e1, R_e2, and R_e6 , which are the same as R_g1, R_g2, and R_g6, once again were the most frequent of these best models (Tables 49C.2, 49D.2, 50G.2, and 50H.2) with maximum growth rates. The flood frequency at zero colony/site growth was slightly less with flood frequencies determined from the 1984-2003 and 1994-2003 periods, but still very similar. Zero colony growth ranged from 1.9 – 2.6 years with these periods. During 1984-2003, it varied from 1.9 to 2.6 years in the best models (Table 51). For comparison, zero growth varied from 1.1 – 1.8 years in models with colony/site flood frequency data from the 1943-1997 POR. Model R_e1J with the 1994-2003 POR frequency data, outliers excluded, and without colonies/sites that did not flood during this period had the greatest regression coefficient, r^2 = 0.8133, p = 0.006 (Table 50J.1), accounting for a substantial part of the variation in colony/site growth in response to flood frequency.

Percent change growth (R_p) with the 1943-1997 POR

Models R_p4A (Figure 23) and R_p1A (Figure 20) were the most supported and likely (Table 48A.3), with positive colony/site growth requiring flooding more frequently than at least once on average every 1.1 years and 1.2 years respectively (Table 51). Zero colony/site growth occurred at 1.3 and 1.8 years (Table 51) in the companion best models R_p4B (Figure 23) and R_p1B (Figure 20) for the same POR, but with the exclusion of outlier colonies/sites 3 and 32. Average colony/site growth is maximized by these models, relative to all other exponential growth models with insufficient evidence. The declining average colony/site growth rates of R_p4A and R_p1A reach their lowest negative values, on average, at the 2-year flood interval, which remain constant with increasing flood intervals. The regression coefficients with the percent change growth models tended to be lower than the most likely exponential and geometric growth models, but they were still significant for the best models (R_p4A, r^2 = 0.3766, p = 0.0000; R_p4B r^2 = 0.6143, p = 0.000).

Percent change growth (R_p) with flood frequencies determined from 1984-2003 and 1994-2003 PORs

Ten models of colony/site growth were most likely during these periods (Table 51). Flood frequencies at zero growth were 2.0 to 3.3 years for the four best models with flood frequency data from 1994-2003, below which colony/site growth became negative. With the 1984-2003 POR, zero growth in the five most likely models varied from 1.9 to 3.9 years (Table 51). Here again, the best models had maximum colony/site growth (R_p1, R_p2, and R_p4). Model R_p1J with 1994-2003 frequency data and a zero growth flood frequency at 2.0 years explained most of the variation in colony/site growth in response to flooding (r^2 = 0.8133, p = 0.0006, Table 50J.1). Model R_p1C with 1984-2003 frequency data and a zero growth flood frequency of 1.9 years accounted for the least portion (r^2 = 0.4155, p = 0.0000, Table 49C.3) of growth variance.

Most likely models

Akaike's information criteria with the information-theoretic approach and maximum likelihoods is most effective at selecting the best models when the scientific question of interest has been critically considered, together with experimental designs to effectively measure and sample the populations of interest (Burnham and Anderson 2002). This is not quite the situation with the data on the number of pondberry in 2000 and 2005 from the selected colonies, the various measures of colony/site growth computed, and the relationships to flood frequency. However, AIC also is just as applicable in exploratory analysis or the assessment of data with other limitations: the difference is that model uncertainties will be greater and must be more carefully considered (Burnham and Anderson 2002). As previously described, models R_x1 and R_x2 for any measure of growth (geometric, exponential or percent change), and R_p4 share the same property of fitting the regression line for colony/site growth very near colonies/sites 54 and 56, which were the most frequently flooded colonies/sites with the greatest growth rates in the available data. This condition, mathematically, generates the least square residual difference between the observed growth and predicted growth, as well as the least AIC differences and greatest weights for these models. These models clearly would be favored without further considerations if none were warranted. However, the data for colony/site growth rates is limited at these most frequently flooded sites. Without more data, we are reluctant to conclude that a particular model within those that are most likely is the definite best, to the exclusion of all others.

The analytical approach to the nonlinear analysis involved different models with different sets of flood frequency periods. Also, we selected the equations from an even larger set for their various properties allowing rate changes to occur rapidly, and others more slowly, with the smallest number of parameters possible. This provided a framework of different model sets to evaluate colony/site growth response to flood frequency. The central feature shared in common by all of the most likely models within this framework is that the least squares solution is a curve with the greatest or near maximum positive colony/site growth rates. In contrast, virtually all other models without substantial supporting evidence had much lower growth rates. These generally unsupported models also tended to have greater flood frequency intervals at zero colony/site growth, which is the benchmark below which colonies/sites decline, on average, with negative growth. This could be the consequence of a small sample size for the most frequently flooded colonies/sites, essentially limited to colonies/sites 54 and 56. Whether additional frequently flooded colonies/sites would or would not change the relationships identified in the nonlinear models is unknown. This uncertainty, however, is further reason not to risk overfitting the models by selecting only a smaller set within the broader range of those most likely.

Model Conclusions

A total of 170 nonlinear, least squares regression models were evaluated for the relationships between geometric, exponential, and percent change growth at pondberry colonies/sites during 2000-2005 and their flood frequencies as computed from 1943-1997, 1984-2003, and 1994-2003. These comprised 30 separate sets of models. Within each set, the most likely models were evaluated by an information-theoretic approach based on computations for Akaike's criteria, weights, and evidence ratios (Burnham and Anderson 2002). Also, frequentist statistics for regression coefficients, F-statistics, error sum squares, residuals, and outliers were used to refine models and compare in a limited fashion the most likely models among different sets. A total of 56 nonlinear models were identified as most likely based on Akaike's information criterion.

Pondberry colony/site growth rates declined nonlinearly as the flood frequency interval increased (e.g. as flooding decreases). The rate and pattern of decline varied depending on the nonlinear regression model, but each of the most likely models had two distinctive nonlinear characteristics. The rate of positive colony/site growth decreased sharply from the most frequently flooded sites to the point of zero colony/site growth. From that point, negative growth rates increased at a much slower rate as flood the frequency interval increased (e.g. flooding decreased). The flood frequency at zero growth with the 1943-1997 frequency data ranged from 1.1 to 1.8 years for the 13 most likely models. With 1984-2003 POR flood frequencies, zero growth flood frequency intervals varied from 1.9 to 3.9 years for the 20 most likely models. The zero growth flood frequency in 18 of these 20 models ranged from 1.9 to 2.9 years. From the 22 regression models with the 1994-2003 flood frequency data, zero colony/site growth occurred at flood frequency intervals from 2.0 to 3.3 years.

These nonlinear regression models demonstrate a relationship between the frequency of flooding and colony/site growth rates during 2000 – 2005. The rates of growth or change in the number of pondberry during 2000-2005 may reflect a response to short-term periods of flooding and the lack of flooding during that 5-year period. The response also may reflect hydrological conditions in the recent past, as well as conditions from longer past periods. Results of the nonlinear regressions do not necessarily mean that flooding is the sole source or cause of these growth rates. More likely, flooding is one factor in association with others that directly and indirectly affect growth rates through their effects on pondberry, the structure and composition of the forest community at the site, the extent of interspecific and intraspecific competition with other plants for sunlight and other resources, and disease and dieback. Nevertheless, the nonlinear response to flood frequency interval reflects the same primary responses to categorical and class factors in the earlier analyses. Substantial variation exists among the change in number of plants at colonies/sites during 2000-2005, but the performance of pondberry and the ability of colonies/sites to persist and sustain are greater at the most frequently flooded and wetland sites.

Conclusions

Pondberry in the backwater area is known only from DNF, where there are at least 13 populations. The three largest populations are Colby, with at least 20,000 plants, Red Gum with at least 8,200 plants, and Spanish Fort with 3,800 or more plants. These three populations are part of the 12 largest remaining populations range wide, each with at least 3,000 plants.

There are 177 known colonies/sites distributed among these 13 populations. The 49 colonies/sites profiled by the Corps occur at sites with a wide range of flood frequencies. There are two primary sets of Corps data for flood frequencies at colonies/sites: 1) the FESM model and GIS for wetlands with flood frequencies determined from colony/site elevations by a 30-m DEM, and 2) flood frequencies at 49 profiled colonies/sites determined by ground-surveyed elevations from benchmarks. Overall, the flood frequencies determined from the ground surveyed elevations are greater (less frequent) than the frequencies from the FESM model. Flood frequencies from the ground-surveyed elevation data are considered more accurate than the FESM model with the 30-m DEM. From this data for the 49 profiled colonies/sites, 65 percent (32) of the colonies/sites are within the 5-year floodplain. This data was used as the most reliable. However, data from the FESM model also were used for spatial analysis.

Pondberry in DNF is not restricted to jurisdictional wetlands in areas that flood on average once every 5 years. Pondberry colonies/sites occur in jurisdictional wetlands with a hydrology established by overbank flooding, jurisdictional wetlands at sites with a local hydrology from rainfall independent of overbank flooding, jurisdictional wetlands where the hydrology may be established by a combination of overbank flooding and local hydrology, and nonwetland sites with a flood frequency ranging from 1 to 17 years. Most of the 49 profiled colonies/sites are in the 0 – 2 year floodplain (18.4 percent) and 2.1 – 5 year floodplain (47.0 percent), according to flood frequencies estimated by the Corps from ground surveyed elevations at each profiled colony site. Overall, about 32 percent (56) of the 177 colonies/sites are estimated to have a wetland hydrology, with 17 in FESM wetlands established by overbank flooding, and about 39 colonies with a local hydrology. About 121 colonies/sites (68 percent) lack a jurisdictional wetland hydrology from either overbank flooding or local hydrological factors. However, the status of pondberry at sites with different hydrologies is not the same.

Pondberry declined overall in DNF during 2000 and 2005 at 49 profiled colonies/sites by 42 percent, from 11,748 to 6,775. Most of these colonies were rated as in excellent or good health categories during 2000, but these ratings had no significant association or future predictive value since most also declined during this period. The average number of pondberry per colony/site declined significantly during that period, which was affected by the flood frequency class interval (Table 36). The average number of pondberry per colony in the 0 – 2 and 3 – 5 year floodplain was significantly greater than the average colony size in the less frequently flooded 6 – 10 and >11 year floodplains. Also, the average colony in the 0-2 year floodplain produced 3.7 times the number of pondberry as the average colony in the 11+ year floodplain. The total number of pondberry declined in every flood frequency class interval except the 0-2 year floodplain, where the total number of pondberry increased from 2000 to 2005, at a significantly different level (Table 39a).

The 13 wetland colonies/sites produced disproportionately and significantly more pondberry than the 34 nonwetland sites in 2000 and 2005 (Table 38). While pondberry declined in both wetland and nonwetland colonies, it also persisted at a greater rate in wetlands (Table 37). No significant statistical differences could be detected for colony growth rates in wetlands and nonwetlands, but colony growth rates declined in a statistically significant nonlinear response to a decrease in the frequency of flooding (Tables 48 - 50). The flood frequency intervals predicted by the most likely least squares regression models at which the average colony growth rates changed from positive to negative rates mostly occurred at 2 to 3 years. If the hydrology of pondberry for growth, survival, and persistence closely reflects the jurisdictional definition of hydrology, then the flood frequencies for 0 growth by these nonlinear models would indicate that habitat with frequent overbank flooding, at 3-year or more frequent intervals, as well as wetlands with a local hydrology wholly or partially dependent on overbank flooding are most important.

Historically, the hydrology of the backwater area from overbank flooding has been extensively altered by past flood control projects in the Yazoo Basin. Using the current 177 colonies/sites as reference locations, the extent and coverage of jurisdictional wetlands was greatest during the 1901-31 period, after which it declined to a low in 1958-78, from which it increased during 1979-97 – although not to the extent of the 1901-31 period. Sites with a local wetland hydrology independent of overbank flooding should not have been affected by these past flood control projects. Yet, the FESM models for the 1901-1931 period also indicate that not all colony reference sites historically would have been in wetlands.

The historical FESM analysis of these earliest periods is based on fewer river gages and less gage-stage data than the analysis for the 1943-97 POR. If the hydrology models are highly accurate, then this could be considered evidence that pondberry does not strictly require wetlands with a jurisdictional hydrology. Yet, we don't know of any method to test the accuracy of a historical hydrological analysis. To our knowledge, this is the first time FESM has been used to estimate historical conditions. Today, pondberry also occurs at nonwetland sites, even though most of the pondberry colonies and plants are produced at frequently flooded sites or in wetlands. And as previously reviewed, the number of pondberry, colony size, persistence, rates of decline, and growth rates are variously affected by flood frequency and wetland status. If the trends during 2000 – 2005 are average conditions, then pondberry would be unlikely to persist or even exist at sites that are not wetlands or flooded less frequently than about once every 3 years.

Is Pondberry and Obligate Wetland or Facultative Species?

Pondberry is classified as an obligate wetland species by the National List of Plant Species that Occur in Wetlands (Reed 1988). Obligate wetland plants are expected to occur almost always in wetlands under natural conditions. Wetlands in the backwater area are established by at least three factors: 1) overbank flooding, 2) rainfall at local sites with conditions from soils and topography that impede drainage or temporarily store rainfall in depressions, and 3) the storage of overbank floodwater in depressions --- with combinations of these three factors at different sites. The hydrology of a jurisdictional wetland for the purposes of the Clean Water Act is an area regularly inundated or saturated by water less than 5 percent of the growing season continuously, or areas that are inundated or saturated irregularly more than 12.5 percent of the growing season continuously. These conditions are further defined as occurring on average once every 2 years. The classification of obligate wetland species by the national review panel is not based on an empirical determination of the hydrology for each species, or the extent that their hydrology is known to match the hydrological definition for a jurisdictional wetland. Nevertheless, the ecology of hydrophytic vegetation and the fidelity of the occurrence of wetland species is sufficiently known that the National Research Council has concluded that the basis for classifying wetland species is scientifically credible and adequate.

Without baseline hydrological data for this species, it is reasonable to expect that the hydrology of pondberry, as an important habitat component, should reflect the jurisdictional definition of hydrology within the 2-year floodplain. Other information would suggest that the primary habitat for pondberry should at least occur within the 5-year floodplain. The potential importance of the 5-year floodplain is derived from the panel of pondberry experts convened by the Corps during 1991 to assess ecology of pondberry and potential impacts of projects in the Yazoo Basin. The panel was most concerned about the hydrology of the 5-year floodplain for pondberry, in comparison to less frequently flooded areas. Also, the HGM (hydrogeomorphic) approach developed by the Corps to assess wetland impacts and mitigation address different wetland functions and values in bottomland hardwoods subject to overbank flooding at frequencies of 5 years or less (e.g. Smith and Klimas 2002).

The Corps has contended during the later parts of this consultation that pondberry, at least in the bottomland hardwoods of the Yazoo Basin, is a facultative species, and not an obligate wetland species. Of the five basic categories of wetland indicator status the Service established (Tiner 2006), three are facultative. All of these categories reflect different frequencies of species occurrences in wetlands. The facultative group is between the obligate wetland indicator category and the obligate upland class. A facultative wetland (facultative wet) species usually occurs in wetlands, with an estimated frequency of 67 to 99 percent, and occasionally is found in nonwetlands. A facultative species is equally likely to occur in wetlands and nonwetlands, with an estimated probability of 34 – 66 percent. The facultative upland (facultative dry) category is for species that usually occur in nonwetlands, with an estimated probability of 67 – 99 percent, but occasional are in wetlands (1 – 33 percent). The categories reflect the fidelity or frequencies a species occurs in "wetlands." The Corps believes that pondberry would be better classified in the facultative group, including all three facultative categories.

We have considered the wetland classification of pondberry in this assessment of factors affecting the species because the classification also denotes categories of ecological performance. By definition for the wetland plant classification, wetlands species have a demonstrated ability to achieve maturity and reproduce where all or portions of the soil within the root zone become, periodically or continuously, saturated or inundated during the growing season (Reed 1988).

The Corps interpretation of the available pondberry data is that the current and historical distribution of pondberry in DNF in wetlands and nonwetlands is indicative of a species that is not fundamentally restricted to wetlands, as required for an obligate wetlands species. The data for the current distribution would include the jurisdictional field surveys with 13 profiled colonies/sites in wetlands and 34 colonies/sites in nonwetlands. The historical data is the Corps analysis of the stage-gage data with FESM modeling for the distribution of wetlands established by overbank flooding during 1901-1931, 1932-1957, and 1979-1997. Assuming that the current location and distribution of colonies/sites is a suitable reference to their historical occurrence, then colonies/sites were not historically restricted to wetlands.

To conclude that pondberry is not an obligate wetland species by these data also requires invoking alternative explanations or ad hoc theories to account for contradictory factors. The observed decline at colonies/sites during 2000-2005 and other associations of colony/site size, number of pondberry, persistence, and growth rates during this period by our analysis indicated the overall performance of pondberry in wetlands and the more frequently flooded sites was greater than in nonwetlands and less frequently flooded sites. The Corps has disagreed with most of our statistical and other analyses of these patterns and trends. The Corps also would claim that even if our analysis is accurate, the patterns and trends during 2000-2005 can be discounted or even disregarded because they could be unusual, infrequent, and aberrant conditions that are not representative of average long-term or future conditions. Similarly, a single 2000 – 2005 pondberry census is not sufficient to adequately demonstrate any pattern of environmental association and trend.

We would agree that the demographic dynamics and variation of pondberry growth and decline in association with environmental factors would be more accurately understood with more and long-term monitoring data. It is commonly recognized from studies on clonal plants that most demographic studies have been of relatively short duration, and the range of observed temporal variation in vital demographic rates indicates that short-term studies should be cautiously considered for understanding long-term dynamics (e.g.; Huenneke and Marks 1987; De Steven and Callaghan 1988; Menges 1991a; 1992; Eriksson 1993; Silverton et al. 1996; Damman and Cain 1998). And as we previously described in this assessment, the response of pondberry at permanent plots in the DNF Colby population during 1993, 1994, and 2006 indicated the short-term decline during 1993-1994 due to an acute episode of dieback from *Botryosphaeria* did not accurately predict the overall long-term trend measured in 2006. Nevertheless, pondberry in the more hydric pond plots recovered to a statistically significant greater number by 2006 than pondberry outside the vernal pools. If the overall decline during 2000-2005 from profiled colonies/sites is related to an acute or infrequent phase of dieback, then the predicted future trend from the Colby plot data would be that pondberry in wetlands and the most frequently flooded sites will recover within a decade, while the recovery of colonies/sites elsewhere is unlikely.

The range-wide classification of pondberry as an obligate wetland species is another factor that must be reconciled if pondberry is a facultative species. If pondberry is not an obligate wetland species in the bottomland hardwoods of the Yazoo Backwater Area, then either the entire range wide classification also must be incorrect, or the regional ecology of pondberry must be different for some reason from that elsewhere in the range. Outside of the bottomland hardwoods in the Mississippi alluvial valley in Mississippi and Arkansas, pondberry occurs in ecologically distinctive and geographically isolated wetlands, typically associated with depressions. To our knowledge, the ecology of pondberry as an obligate wetland species in geographically isolated wetlands has not been challenged or become the subject of any substantial scientific disagreement. Likewise, these wetland communities and habitats and have not been seriously considered as types other than wetlands.

The national classification of plant species in wetlands does not require that a species be classified in only one wetland indicator category throughout its entire range. Plants can have regional classifications that differ from other regions, and even different subregional classifications within regions. These geographic differences reflect ecologically and perhaps genetically differentiated populations with respect to wetland tolerances or other attributes (Tiner 2006). For example, the southeast region (Region 2) in the 1997 national review of proposed revisions to the national list consisted of Coastal Plain, Mountains, Florida, and Florida Keys subregions (Tiner 2006; Federal Register 1997. If pondberry is a facultative species, at least in the Yazoo Backwater Area, it would require a an additional sub-classification with the Coastal Plain subregion. To our knowledge, there are no species on the plant list with subdivided classifications among subregions in the southeast or elsewhere.

Alternative explanations or theories also are required to reconcile elements of the available pondberry data to its classification as an obligate wetland species in the Yazoo Backwater Area. The 2000-2005 trend and association data for pondberry in DNF is more indicative of a wetland species by our analysis, with poor overall performance in nonwetlands and sites with infrequent flooding. This pattern also generally would be expected by its classification as an obligate wetland species, consistent with such a classification for the entire geographic range of the species. However, the current and historical distribution of pondberry colonies in nonwetlands and infrequently flooded sites in DNF typically would not be expected by a strictly obligate wetland species. From the Corps historical analysis of wetlands with FESM for the 1901 – 1931 period, only 47 percent (84) of the currently known 177 colonies/sites were wetlands established by overbank flooding (Table 28). Even with our estimate of the number of colony/site reference locations that could be local wetlands (23) without depending on overbank flooding during this period, at most the historic analysis indicates there would be 107 wetland colonies sites, representing 61 percent of all colony reference locations during 1901-1931 (Table 28). If pondberry strictly conforms to the definition of an obligate wetland species, then there must an alternative explanation.

The historical FESM wetland analysis by the Corps for the 1901-1931 period was based on much less hydrological data than the analysis for the 1943-1997 POR. Only one river gage was available during the 1901-19931 period, and the FESM model was developed with a much smaller number of simulated nodes. The historical analysis from the 1901-1931 period to that today depicts a net decline in the coverage and extent of wetlands at pondberry colony reference locations (Table 28). The most difficult and unanswerable issue concerns the accuracy of the 1901-1931 model. Apparently, this is the first time such a historical analysis has been conducted with FESM or any similar methodology, and there currently is no estimate and perhaps no method to compare or determine historical accuracy. The ad hoc explanation required to reconcile the historical 1901 – 1931 data to the obligate wetland plant classification is that the historical coverage of wetlands is erroneously underestimated by this method, which were more extensive at pondberry colony reference sites.

By this alternative, then pondberry historically was prevalent in wetlands prior to the completion of extensive structural flood control measures, including stream channelization and diversions. The persistence of pondberry today in areas that no longer are wetlands or are not frequently flooded is due to its life history and ecology as a rhizomatous shrub, reproducing primarily by the asexual production of vegetative sprouts. There is ample ecological evidence that woody plants and predominately clonal shrubs with vegetative sprout production, which includes pondberry, are factors conferring greater survivorship and persistence relative to species with other life history attributes (Gilbert 1966; Tappeiner 1971; Schlesinger 1978; West et al. 1979; Huennecke 1987; Huenneke and Marks 1987). The life history and demography of pondberry and other clonal shrubby species would be characterized as stress tolerators, in contrast to other attributes and species that primarily are competitors by maximizing growth, and those that are ruderal by maximizing reproductive success or fecundity (Grime 1977; Grime et al. 1988; Silverton et al. 1992; Silverton and Mendoza 1993). Thus, pondberry colonies currently in nonwetlands and infrequently flooded sites in DNF have been persistent, but not necessarily stable or long-term viable, with attributes that were significantly different than those in wetlands and infrequently flooded sites.

The overall attributes of colonies in wetlands and frequently flooded sites during 2000-2005, in contrast to others, included their larger average size (Tables 34 and 36) and greater persistence (Table 37), number (Tables 38 – 40), and growth rates (Figures 9 – 25). If pondberry truly is a facultative species, then these differences either do not actually exist or they are the consequence of other environmental factors. If pondberry in these bottomland hardwoods is not an obligate wetland species as it is currently classified, then the proper procedure for changing the national classification is the 11-step process, including a scientific and technical review of the evidence by a regional or national panel of scientists with public review and comment (Reed 1997). The Service originally was the lead federal agency responsible for generating, maintaining, updating, and revising the national classification in coordination with the Corps, EPA, NRCS, regional and national scientific panels, and participating scientists. The 11-step procedure was intended to improve coordination among the federal agencies and participants. On December 12, 2006, this lead responsibility was transferred to the Corps, in accord with a Memorandum of Agreement among the Corps, Service, EPA and NRCS. The 11-step process and the continued establishment and operations of a national panel with regional panels of scientific review with science-based dispute resolutions are included in this agreement. Until the wetland indicator classification of pondberry is revised through this procedure, our analysis of the best available data continues to be that pondberry is an obligate wetlands species.

EFFECTS OF THE ACTION

The effects of the action are the direct and indirect impacts of the proposed federal action on the species and critical habitat, together with the effects of other activities that are interrelated or interdependent with the action, that will be added to the environmental baseline. Indirect effects are those that are caused by the proposed action and are later in time, but still reasonably certain to occur. Interrelated actions are those that are part of a larger action and depend on the larger action for their justification. Interdependent actions are those that have no independent utility apart from the action under consideration (50 CFR § 402.02).

The effects of the proposed Yazoo Backwater Area Reformulation project in this section are limited to direct and indirect effects. The proposed project is one of many flood control projects by the Corps in the lower Mississippi River Alluvial Valley, collectively known as Mississippi River and Tributary projects. However, the proposed project is not interdependent or interrelated to any other projects in the Yazoo River basin or elsewhere.

Factors to be considered

The proposed project is the construction and operation of facility that will pump flood water from behind the Steele Bayou structure when the gates are closed over the Yazoo Backwater levee, to discharge downstream into the Yazoo River near its confluence with the Mississippi River. The Steel Bayou structure is a set of flood gates that are closed to prevent backwater flooding from the Mississippi and Yazoo Rivers into the backwater area of the lower Yazoo basin. The pumps will operate when interior drainage from streams behind the gates accumulates to an elevation of 87' msl. The pumps will continue to operate until enough water is removed to lower the flood elevation to 87'.

In assessing the effects of the proposed action, the first factor considered is the extent that flooding will be reduced in the backwater area relative to baseline conditions. This is evaluated as the change in hydrology by altering the frequency and duration of backwater floods. The base data for this analysis is from the Corps. They used stage-gage data (1943-1997), hydrological models, rainfall and runoff models, routing models, pump discharge data, and other procedures to assess the extent that the Steele Bayou gates will be closed in the future, and how backwater flooding will be altered by the pumps (Figure 5). These were the same procedures used to estimate baseline conditions, except that baseline conditions are altered by gate and pump operations. The Corps computed the median 5 percent flood duration elevation at gages in the backwater as affected by operating the pumps. These project data were used with FESM, as in the baseline procedure, to spatially identify the coverage of the median 5 percent duration flood event in the backwater area. This represented the area of jurisdictional wetlands, hydrologically defined as 14 or more consecutive days of inundation on average once every two years. The Corps also used the data to estimate and spatially delineate the flood frequency stages in the backwater area under pumps operations.

The change in hydrology due to a reduction in backwater flood frequency is another factor considered. The Corps flood frequency data was generated by two methods. Both methods require a determination of elevation to assign flood frequency. Flood frequency is a function of the return interval that a site at a particular elevation will receive flooding, which is based on the stage-gage elevation data for the flood frequency event. The first method was based on GIS and the FESM model that spatially delineated areas by their flood frequency. The elevation was determined by a 30-m DEM. We used the Corps GIS shapefiles for the project-induced flood frequency in the backwater area to identify the frequency at each of the 177 known colonies/sites, which includes the 49 Corps-profiled colonies/sites. The other flood frequency data provided by the Corps was derived from the elevations determined at the profiled colonies/sites by a ground survey, with rod and instrument, from benchmarks. Both methods rely on the same POR and stage-elevation curves for the various flood frequency events. Thus, the flood frequency at any given site should be the same. One of the major differences by the two methods is the elevation assigned at the colony/site.

The second major factor analyzed is the extent that changes in backwater flooding by the project will alter the hydrology at the 177 known pondberry colonies/sites in the DNF. The backwater hydrology at these colonies/sites and respective pondberry populations is described in terms of the 5 percent duration flood (FESM) as well as flood frequency. The magnitude of the change caused by the project is compared to current baseline conditions as well as historical conditions. Also, the effects of reducing flood frequency are compared to the two methods and sets of data the Corps produced for flood frequency at colonies/sites.

Both of these factors are compared and added together with the historical changes from past projects to assess a net change.

The final factor is the response of pondberry to these hydrological changes. This is assessed relative to the nature of hydrology likely required by a species classified as an obligate wetland plant and compared to data on the patterns of growth and decline measured during 2000 and 2005 on different floodplains, flood frequencies, and by jurisdictional wetland status at sites. These patterns are expressed in terms of the total number of plants censused at selected colonies/sites, the percentage change in the total number at different flood frequencies, the rate of decline, and the statistics of change for the average number plants per colony/site as affected by year (2000 and 2005) and flood frequency. The performance of pondberry by these indicators is compared to the expected performance accompanying a reduction in overbank flooding, which changes the future flood frequency of colonies/sites. These and related response factors are assessed relative to all known colonies/sites and profiled colonies/sites, as well as the level of the three largest populations in DNF.

Species response

Project operations and hydrological change

The proposed project is not designed or intended to alter the 1-year floodplain. The closure of the Steele Bayou gates and operation of the pumps at a minimum elevation of 87' corresponds to the current 1-year floodplain under baseline conditions. Backwater flooding from the Mississippi River and Yazoo River cannot enter the backwater area when the gates are closed because the backwater area is protected by the Mississippi River mainline levee system, the backwater levee system, and other levees along the Yazoo River, the Whittington auxiliary channel, and the Holly Bluff cutoff. Additional interior flooding above the 1-year floodplain is the result of the accumulated and blocked drainage from Steele Bayou, Big Sunflower, Little Sunflower and other streams and tributaries behind the closed gates.

Flooding above 87' in the backwater area during these conditions is the difference between the pumps discharge and the inflow from backwater rivers and tributaries within the levee system. Flooding in the backwater still occurs because the pumps cannot instantaneously discharge all the inflow. The frequency and duration of flooding above 87'and the 1-year floodplain is reduced however, until the stage elevation is pumped down to 87' and the downstream elevation on the Yazoo River falls below 87'. At that time, the backwater flood gates are opened and the interior water is discharged by natural gravity flow. Alternatively, the Corps will open the gates at any time when interior flooding exceeds 87', but the downstream elevation is at a sufficient lower level so the discharge through the gates will exceed the pumps.

According to the Corps, the 1-year floodplain will not be reduced by this project. In the DNF, the 1-year floodplain covers 36,942 acres, or 60 percent of the forest. Operation of the project will reduce flooding above the 1-year floodplain. Data and GIS analysis from the Corps FESM model depict spatial changes in the reduction in backwater flood duration and the associated flood frequency intervals in the backwater area, as well as for each of the 177 known pondberry colonies/sites. Data from the ground survey of elevations for each of the 49 profiled colonies/sites characterize the change in flood frequency without the use of the 30-m DEM in the FESM model. The ground surveyed elevations and associated flood frequency data are specifically limited, however, to each of the 49 profiled colonies/sites. They do not spatially depict the project flood frequency at other sites. All of these data reveal a project-induced reduction in the duration and frequency of backwater flooding.

The project will reduce the acreage of land in the backwater area affected by the 0-2, 3-5, and 6-10 year flood event by, respectively, 22, 25, and 35 percent (Table 45). In the DNF, 55,579 acres currently on the 0-2 year floodplain will be reduced by 13 percent to 48,226 acres (Table 52, Plate 31). In contrast, the 3-5 year floodplain in DNF will increase by 86 percent, from 5,985 acres to 11,133 acres. Also, the 6-10 year floodplain will increase from 150 to 1,104 acres. Overall, these changes represent the shift from more frequently flooded to less frequently flood sites. Since the Corps FESM GIS data did not include baseline and project flood frequency events greater than the 10-year interval, we did not spatially assess such changes.

Wetlands by the 5 percent duration elevation definition (FESM) will be reduced in the backwater area and in DNF (Table 53). About 26,300 acres of wetlands will loose jurisdictional wetland hydrology from backwater flooding by the project. Any of these jurisdictional wetlands that also can function as wetlands because of a local hydrology independent of overbank flooding will not be affected. In DNF, current wetlands (43,596 acres) will be reduced to 38,638 acres, a decline of 11 percent (Plate 35). DNF forests loosing jurisdictional hydrology are located mostly along the edge and in the south.

Colonies/sites and population segments unlikely to be adversely or significantly affected

The proposed project is not designed or intended to hydrologically alter the 1-year floodplain. Fifteen of the 177 known pondberry colonies/sites occur in the 1-year floodplain, as identified by FESM, which should not be affected by the project. The only two colonies/sites (GSRC 54 and 56) in FESM wetlands selected by the Corps for the profile of 49 colonies/sites occur in the 1-year floodplain. From the profile data, these two colonies accounted for most all of the increase in total number of plants from profiled colonies/sites between 2000 and 2005. The total number of pondberry declined during this period by 42 percent. The colonies/sites on the 1-year floodplain are an important source for potential future growth, even though they are not associated with any of the large populations in DNF. Also, 28 other colonies/sites with a local wetland hydrology independent of overbank flooding will retain their wetland hydrology with the project. Overall, 43 (24.3 percent) of the 177 known colonies/sites are not likely to be adversely affected by a reduction in backwater flooding.

Of the 177 pondberry colonies/sites, 15 are in the 1-year floodplain where the frequency and duration of flooding will not be reduced (Table 54). These represent 8.4 percent of the 177 known colonies/sites in DNF. In the DNF, the 1-year floodplain covers 36,942 acres, or 60 percent of the forest. The 15 pondberry colonies/sites in the 1-year floodplain should not be affected by the normal, anticipated operation of the project.

Also, the 1-year floodplain includes the only two profiled colonies/sites (GSRC 54 and 56) in FESM wetlands, of the 49 selected colonies/sites. The Corps GIS data depicts a small change in the duration of growing season backwater flooding to three of these 15 colonies, even though they remain in the project

1-year floodplain (Table 54). The proposed project operational plan should not, in theory, alter the frequency or duration of backwater flooding in the 1-year floodplain. The GIS data for the flood duration intervals for these three colonies with the project is a Corps processing error (Johnston 2006, pers. comm.).

The Corps biological assessment tabulates the changes in flood duration to colonies/sites in wetlands in Appendix 14, Table 14-5, without special consideration of colonies/sites located in the 1-year floodplain. Colonies/sites in the 1-year floodplain that shifted in flood duration interval, by the FESM model for project conditions, are listed by the Corps in this table. We followed the same convention in Table 55, using the Corps FESM data for the project, even though the project is not designed to alter the 1-year floodplain. Assuming the operational plan of the pumps and gates will be implemented as intended, none of the 15 colonies/sites currently in wetlands in the 1-year floodplain will change to nonwetlands or other flood-duration interval classes with the project (Table 54), with any associated changes in growth, reproduction, and survival. Future conditions affecting pondberry in the 1-year floodplain will be those of the ambient environment where hydrology will not be altered by the project.

Wetlands by the 5 percent duration elevation definition (FESM) will be reduced in the backwater area and in DNF (Table 53). Of the 177 colonies/sites, the 17 (9.6 percent) colonies/sites that currently inhabit wetlands (Table 11) consist of 15 in the 1-year floodplain that will not be affected by the project, and the remaining two colonies/sites are in the 2-year floodplain. These two colonies/sites receive, on average, more than 34 days of growing season flood inundation every other year. Only one of the 17 FESM wetland colonies will loose a jurisdictional wetland hydrology according to the FESM model (Tables 55 and 56). However, this colony/site (GSRC 53) is located within a greentree reservoir, with levees, which is artificially flooded each year for waterfowl. The site actually is flooded more frequently than indicated by the FESM model, and the changes predicted by the model do not account for the Forest Service management at the site. Overall, the 17 FESM wetland colonies/sites will retain their hydrology with the project.

Only two of the 49 colonies/sites selected for the Corps pondberry profile occur in FESM wetlands, both of which are in the 1-year floodplain. This is the only set of data for the performance of pondberry in FESM wetlands. At 49 profiled colony sites in DNF from 2000 to 2005, the total number of pondberry plants decreased by 42 percent, from 11,748 to 6,775 plants (Table 57). Only 14 colonies/sites during this period did not decrease, of which 3 remained the same and 11 increased in the number of plants (Table 58). These two wetland (FESM) colonies/sites (GSRC 54 and 56), in the 1-year floodplain, accounted for 91 percent (1,697 plants) of the total increase (1,875 plants) from the 14 colonies/sites that did not decline during this period (Table 44). While this is a small sample size for the performance of colonies/sites in FESM wetlands, the data indicate the significant potential for pondberry growth in this environment. The duration or frequency of flooding for both of these colonies will not change according to the Corps GIS data.

In addition to pondberry in the 1-year floodplain, 11 of the 47 field surveyed colonies for jurisdictional wetlands are wetlands with a local hydrology either wholly or partially independent from backwater flooding (Table 21). Of these 11, eight are jurisdictional wetlands above the 2-year floodplain where the hydrology is established by local site conditions, independent of overbank flooding, by soils that are either saturated or inundated by local rainfall due to drainage and topography. Overbank flooding affects these eight colonies at a baseline frequency from 2.5 to 17 years (Table 21), which is inadequate to establish a jurisdictional hydrology solely from flooding. Regardless of the reduction to flood frequency or duration at these colonies/sites by the project, the edaphic and topographic factors responsible for establishing the current wetland hydrology from precipitation at these eight colonies will not be affected by the project. These local wetlands will remain intact.

In contrast, threé (Table 21: colonies/sites 2, 21, 42) of these eleven colonies are within the 2-year floodplain, but are not FESM wetlands, and have a jurisdictional wetland hydrology that is established by one of two conditions. The hydrology may be from a combination of local site conditions with backwater flooding. Or, the wetland hydrology may be established by local site factors and rainfall independently of any overbank flooding. Project induced alterations in the frequency and duration of backwater flooding will not affect these three wetland colonies if they have a local wetland hydrology, independent of overbank flooding. The baseline flood frequencies of colonies 2, 21, and 42 are, respectively, 1.5, 2.0, and 2.0 years. With the project, they are reduced and become, respectively, 3.5, 4.5, and 5.0 years (Table 59). Alternatively, a reduction in backwater flooding will affect these three colonies if their wetland hydrology depends at least partially on overbank flooding. Because the available data are inadequate to determine which of these two hydrologies is applicable, we are including both scenarios for comparison in the following analyses.

The extent that wetland colonies/sites are not hydrologically affected by the project also influences how a reduction in flood frequency and duration affects the remaining colonies/sites. This depends on such factors as the number and proportion of unaffected wetland colonies/sites relative to the other colonies/sites, and the number of pondberry produced in unaffected colonies/sites relative to their respective populations, and in the DNF.

To further assess these factors, we used GIS in combination with the data from the jurisdictional field surveys at 47 colonies to estimate the number and proportions of colonies/sites with a local wetland hydrology from the 177 known colonies. Data were processed to estimate the importance of pondberry production at wetland colonies/sites relative to nonwetland colonies/sites, among the major populations, and across the DNF.

In the Environmental Baseline, we used the proportion of colonies/sites with a local wetland hydrology from the Corps jurisdictional field survey of 47 colonies/sites to estimate the number colonies/sites with such a hydrology from the 177 known colonies/sites. The field-surveyed colonies/sites are a subset within the 177 colonies/sites. The field survey determined that 4.3 percent (2) of the 47 colonies/sites are in FESM wetlands (Table 59) maintained by the 5 percent duration flood once every two years on average. All remaining 45 sites in the jurisdictional field survey are not FESM wetlands. Seventeen of the 177 colonies/sites are FESM wetlands, as previously determined by the FESM model with GIS (Table 11), leaving 160 colonies/sites that are not FESM wetlands. From the jurisdictional field survey of 45 non-FESM wetland sites, 24.4 percent (11) are jurisdictional with a local hydrology established wholly or partially independent from overbank flooding.

In this section of analysis we assume that the wetland hydrology of the three non-FESM colonies/sites (GSRC 2, 21, and 42) that may be due to a combination of overbank flooding and local factors is, instead, entirely independent of overbank flooding. If the profiled colonies/sites are representative samples, then 24.4 percent of the 160 non-FESM wetlands, or up to 39 colonies/sites, are estimated to have a local wetland hydrology independent of overbank flooding. These are not likely to be directly and adversely affected by the project because their wetland hydrology does not depend on backwater flooding. As we also described in the Environmental Baseline, each of these colonies/sites may not represent random, independent samples of wetland sites because some are aggregated at what may be a single site. To some extent, the natural distribution of pondberry is clumped. Otherwise, it is not possible to quantify or measure the likelihoods that the selected colonies/sites are random and representative. If the profiled colonies/sites are not representative, then the estimated 39 colonies/sites with a local wetland hydrology independent of overbank flooding could be an overestimate or underestimate, depending on the nature of bias. Given this uncertainty, we consider this to be a maximum estimate of the proportion and number of colonies/sites with a local wetland hydrology. Of the 177 colonies/sites, there are an estimated 56 (31.6

percent) wetland colonies, with 17 FESM wetland colonies and 39 colonies with a local wetland hydrology.

The locations of the 17 FESM wetland colonies/sites, of the 177 colonies/sites, are known because the location of each colony/site was assessed relative to the area covered by FESM wetlands using the Corps GIS FESM coverage. It is not possible to identify the exact location of the estimated 39 colonies with a local wetland hydrology independent from overbank flooding because all were not jurisdictionally field-surveyed. The location of the 11 jurisdictionally surveyed colonies with a local wetland hydrology are known, but the identity of the remaining 28 predicted colonies within the set of 160 colonies that are not FESM wetlands can not be specified. To assess their locations relative to the delineated pondberry populations in DNF, we used GIS with the locations of the 45 jurisdictionally surveyed colonies to evaluate their association with depressions in a depressions GIS raster processed by USGS (O'Hara et al. 2000) from a 10-m DEM (Table 22). For example, 50 percent (6) of the field surveyed colonies in GIS-depressions (12) have a local hydrology independent of flooding, while only 15.2 percent (5) of the colonies in areas without GIS-depressions (33) have this local wetland hydrology.

With these associations and the proportions, we used GIS with the locations of the 160 colonies/sites in DNF that are not wetlands to estimate the number of colonies with a local hydrology in different populations (Table 23). Given the number of colonies/sites in depressions by GIS and the expected proportion of local hydrology wetlands (0.5000), we computed the expected number of wetland colonies in depressions in pondberry populations. Likewise, we estimated the number of wetland colonies in non-depressions, given the proportion of wetland colonies (0.1515) not in depressions and the total number of colonies/sites from GIS occurring in non-depressions.

The 39 wetland colonies with a local and independent wetland hydrology over the DNF are 24.3 percent of the 160 colonies that are not FESM wetlands (Table 23), and 22.0 percent of all 177 colonies/sites (Table 60). In the Colby, Red Gum, and Spanish Fort populations, most of the wetland colonies/sites are those with a local wetland hydrology, instead of FESM wetlands (Table 61). As a percent of all colonies/sites, those with a local wetland hydrology are similar among the three major populations and across the DNF, ranging from 23 to 28 percent, with most associated with the Spanish Fort population (Table 60). The Red Gum population would be the least affected of the major populations, where about 30.1 percent of all colonies are wetlands that will remain wetlands with the project (Table 61). Across DNF, about 32 percent of the 177 known colonies/sites will remain as wetlands (Table 61).

Wetland pondberry colonies/sites are more productive than nonwetland sites. Of the 47 profiled colonies/sites with jurisdictional wetland surveys, 28 percent (13) of the colonies/sites were in wetlands, which produced 60 percent (10,683) of all the pondberry (17,806) in 2000 and 2005 from 47 profiled and jurisdictionally field-surveyed colonies/sites (Table 38). The average wetland colony/site in 2005, with 101 pondberry, sustained 3.9 times more pondberry than the average nonwetland colony with 26 pondberry ($F = 6.0319$, $p = 0.0183$, Table 34). About 4 nonwetland colonies/sites are required, on average, to sustain the same number of pondberry as one wetland colony/site. Wetland colonies comprise less than one-third of all colonies in DNF (Table 61), but their relative importance for sustaining pondberry is greater.

We estimated the percentage of pondberry sustained in wetland and nonwetland colonies by multiplying the ratio of the average number of pondberry in wetland colonies to nonwetland colonies during 2005 (Table 34) by the ratio of pondberry in wetland:nonwetland colonies in the major populations and DNF (Table 61), and converting the ratio to a percentage. The pondberry in wetland to nonwetland colonies ratio is 3.8725. This is a maximum estimate from the 2000 – 2005 period because the dynamics in 2000 were not the same as 2005 (Table 34). The average number of pondberry in wetland colonies (84) was twice the number in nonwetland colonies (42) during 2000, but not statistically different. Biologically, this difference is still meaningful because pondberry populations in wetlands could be twice a large as nonwetlands. If these differences are real, they could have been statistically detected with a larger sample or survey of wetland colonies/sites. Nevertheless, environmental conditions in the period preceding the 2000 survey were such that the difference between wetland and nonwetland colonies were not as great as in 2005. We used the 2000 pondberry in wetland:nonwetland ratio of 2.0148 to include a different period and dynamic as a minimal estimate relative to the maximum difference observed during 2005. As a further minimal estimate, we assumed there was no actual difference between the average number of pondberry in wetlands and nonwetlands in 2000.

The simplest estimate of the number of pondberry sustained by wetland colonies/sites is the overall percentage of the total pondberry produced in wetlands from the jurisdictionally surveyed colonies/sites, which is 60 percent (Table 38). Refining this estimate for each population, as described above, adjusts for differences in the number and ratio of estimated wetland colonies. The maximum percentage of pondberry in wetlands within the three major populations ranges from 54 to 63 percent (Table 62a), with most in the Red Gum population, which is very similar to the Spanish Fort population. The intermediate estimate, based on the average wetland colony in 2000, is that pondberry can comprise 38 – 47 percent of the major populations, with 48 percent overall in DNF (Table 62b). The percentage of pondberry sustained by wetland colonies/sites according to the minimal estimate, based on an assumption that the number of pondberry is not different in wetlands, is from 30 to 43 percent in the major populations, with 46 percent overall in DNF (Table 62b).

The percentage of pondberry in the Colby population is underestimated by all of these methods. This is because the profiled colonies/sites are a small sample of this population, and the known colonies/sites do not include those associated with both vernal pools which capture, store, and hold precipitation into the spring growing season. The profiled colonies, as the source for this estimate, only include colonies from one of these depressional and seasonal pools. This is a large population, with at least 20,000 plants (Table 4). From our surveys and general reconnaissance through this population since 1991, we estimate that up to 75 percent of the population consists of colonies and plants in or on the edge of these seasonal woodland pools. The project will not alter the local hydrology of these two pools and most of this population.

The percentage is an estimate based on the overall number of pondberry per wetland and nonwetland colony from the combined profiled colonies across DNF. It is not based on the actual number for 2000 and 2005 for the colonies within each population. Thus, the estimate is a performance prediction from all data, on average, from the 2000 and 2005 period.

Wetland colonies that are FESM wetlands and those with a local wetland hydrology represent only about one-third of the 177 colonies/sites in DNF (Table 61), but can account for up to 64 percent of the pondberry (Table 62a). Most of the wetland colonies/sites are those with a local wetland hydrology, in contrast to FESM wetlands (Tables 60 and 61). Up to 63 percent of the pondberry in the Red Gum population and 60 percent of the pondberry in the Spanish Fort population can be derived from wetland colonies that will retain their wetland hydrology with the proposed project (Table 62a).

These estimates change when the three colonies/sites (2, 21, 42, Table 21) included as wetlands with a local hydrology are removed. In the following analysis, it is assumed these colonies depend on a combination of overbank flooding within the 2-year floodplain and local site conditions to establish a wetland hydrology. They are excluded because if they depend in part on the frequency of baseline flooding for a wetland hydrology, which ranges from 1.5 to 2.0 years, the project will alter this frequency to 2.5 – 5.0 years (Table 59), becoming insufficient for a jurisdictional wetland hydrology. The previously described procedures remain the same, except that the number and proportion of field surveyed colonies with a local wetland hydrology change, as well as the proportions of these colonies in depressions and non-depressions (Tables 22 and 63).

In the previous scenario, 24 percent of the non-FESM colonies are wetlands with a local hydrology, which comprise 50 percent of the colonies in depressions and 15.2 percent of the colonies in non-depressions. (Table 22). With the removal of these three colonies (2, 21, 42), 17.8 percent (8) of the jurisdictionally surveyed colonies that are not wetlands are wetlands with a local hydrology, comprising 50 percent (6) of the colonies in depressions, and 6.1 percent (2) of the colonies in non-depressions (Table 63). The two FESM wetland colonies established by overbank flooding remains the same, but the number and proportion of colonies with a local wetland hydrology is reduced in the major populations and across the DNF. Still, there are more wetlands with a local hydrology than FESM wetlands depending on overbank flooding. Of all 177 colonies, about 16 percent of colonies/sites in DNF are wetlands with a local hydrology, where the Spanish Fort population has the greatest population percentage (20.0) by these estimates (Table 65). About 25 percent of all colonies are wetland colonies/sites (FESM wetlands and wetlands with a local hydrology) in the DNF (Table 66), which is less than the 32 percent wetlands in DNF (Table 61) when these three colonies are not excluded.

In the DNF, up to 57 percent of the pondberry can be produced by wetland colonies (Table 66a), compared to 64 percent (Table 62a) when these three colonies are not excluded. Up to 54 percent of the pondberry in the Red Gum population and 50 percent of that in the Spanish Fort population can be produced by wetland colonies/sites (Table 66a). The intermediate estimates, based on the average number of pondberry in wetlands during 2000, reduce the percentage of pondberry sustained in wetlands in DNF, to 41 percent, with 27 – 33 percent in the major populations (Table 66b). By the lowest estimate, the number of pondberry is proportionate to the proportion of wetland and nonwetland colonies (Table 66b) if there is no difference between wetland and nonwetland colonies/sites In DNF, 34 percent of the pondberry would be produced by wetland colonies/sites, with 25 to 30 percent in the Spanish Fort and Red Gum populations, respectively (Table 66b). As before, these data underestimate the importance and proportion of pondberry in the Colby population from wetland colonies. Our estimates remain the same, that up to 75 percent of the pondberry in the Colby population are associated with two vernal pools, where the local hydrology will not be significantly affected by the project.

These estimates for greater relative pondberry production and persistence in wetland colonies/sites are derived from the average and number of pondberry from up to 13 wetland colonies/sites and 34 nonwetland colonies that were jurisdictionally surveyed. As samples, the number of wetland colonies/sites are small, with a highly variable number of pondberry from 2000 to 2005 (Table 67). The estimates of the number of pondberry at wetland colonies from the 177 known colonies/sites assume that, over time, pondberry production and persistence at wetland as well as nonwetland colony/sites varies within the magnitude measured during 2000 – 2005. The differences observed among wetland colonies/sites are not fixed over time, and will vary in response to the environment, genetic effects, and random demographic factors. The precise cause of the variation and differences among colonies/sites due to factors in addition to hydrology is not known, and could include variable site factors such as the incidence and severity of stem dieback and interspecific competition with other plants. The 2000 – 2005 data clearly reveal that a wetland hydrology is, alone, insufficient to establish positive growth rates for every wetland colony/site. Nevertheless, wetland colonies on average and by overall trend sustain more pondberry than nonwetland colonies. Since the wetland hydrology of these colonies will not be significantly altered by the project, their productivity, growth, persistence, mortality and other demographic factors as affected by a wetland hydrology also will not be adversely affected

Our minimal estimates, based on no differences between wetland and nonwetland colonies, are unlikely to be realistic because of the actual differences between wetland and nonwetland colonies by the 2000 and 2005 data. The wetland colonies which should not be hydrologically altered by the project comprise 25 –

32 percent of all 177 known colonies/sites in DNF (Tables 61 and 66), and can sustain from up to 40 – 64 percent of the remaining pondberry during the early phases of the project (Tables 61 and 66). This proportion will change in the future as nonwetland and less frequently flooded colonies slowly decline in response to long-term hydrological changes, as described in the next section.

Hydrological alterations and affected colonies/sites and populations

FESM

Based on the Corps GIS and FESM duration data, the reduction in flood frequency will shift 46 (26 percent) of the 177 colonies to less frequent flood interval classes (Table 59). Currently, there are 70 colonies/sites on the 2-year floodplain that do not occur in wetlands, but receive from 1 – 13 days of continuous backwater flooding in the growing season on average every other year (Table 11). With the reduction in backwater flooding by the project, 54 colonies will remain with this backwater hydrology, and 17 colonies/sites will shift from the 0-2 year floodplain to less frequently flooded sites (Table 55). Currently, 48 percent (85) and 52 percent (92) of the colonies currently occur in the 0-2 year and 3-5 year floodplain, without any colonies on the 5+ year floodplain (Table 68). With the project, the number of colonies on the 0-2 year and 3-5 year floodplains will be reduced, respectively, to 40 percent (70) and 48 percent (84). The sites for 23 (13 percent) of these colonies will be transformed to the 6+ year floodplain (Table 68).

Based on the Corps GIS and FESM data, the greatest hydrological change caused by the project occurs with colonies/sites above the 1-year floodplain. With this reduction in flood frequency, 46 (26 percent) of the 177 colonies will change to less frequent flood interval classes (Table 68). There are 70 colonies/sites on the 2-year floodplain that do not occur in wetlands, but receive from 1 – 13 days of continuous backwater flooding in the growing season on average every other year (Table 11). With the reduction in backwater flooding by the project, 54 colonies will remain with this backwater hydrology, and 17 colonies/sites will shift from the 0-2 year floodplain to less frequently flooded sites (Table 55). Currently, 48 percent (85) and 52 percent (92) of the colonies occur in the 0-2 year and 3-5 year floodplain, without any colonies on the 5+ year floodplain (Table 68). With the project, the number of colonies on the 0-2 year and 3-5 year floodplains will be reduced, respectively, to 40 percent (70) and 48 percent (84). The sites for 23 (13 percent) of these colonies will be transformed to the 6+ year floodplain.

As described in the previous section, up to 39 colonies/sites, or 24.4 percent of the 160 colonies/sites that are not in FESM wetlands are estimated to have a local wetland hydrology independent of overbank flooding. The location and identity of 11 of these colonies/sites are known from the Corps' jurisdictional wetland field survey of 47 colonies/sites. However, the location, identity, baseline flood frequency and change in frequency by the project for each of the remaining 28 colonies/sites that are estimated to have a local wetland hydrology are not known because these are predicted according to the 24.4 percent of the 160 non-FESM wetland colonies as a sample. Colonies/sites with a local wetland hydrology independent of overbank flooding will not be hydrologically affected by a reduction in the frequency and duration of backwater flooding by the project. These colonies/sites are included in the previously described hydrological changes, where the frequency of flooding will reduce the percentage of all colonies in the 0-2 year floodplain to 40 percent (70 colonies/sites), and increase those in the in the 3-5 year floodplain to 48 percent (84 colonies/sites), and 13 percent (23 colonies/sites) in the 6+ year floodplain. The changes based on the percentage of colonies/sites shifting in flood frequency class, according to Corps GIS and FESM data, overestimate the actual effect since these include up to 39 colonies/sites that will not be hydrologically affected.

The reduction in flood frequency will, overall, increase the rate of pondberry decline, based on the observed trend from 2000 to 2005. For the baseline, this trend was assessed according to the flood frequency assigned each profiled colony/site by the ground survey elevation, instead of the FESM GIS DEM. These were the frequencies used by the Corps to evaluate trend and relationships to flood frequency, as we also used in the baseline analysis (Environmental Baseline). The same declining trend is apparent also if the flood frequencies for the 49 profiled colonies or the 47 profiled colonies with a jurisdictional wetland field survey are determined according to the FESM GIS with a 30-meter DEM (Tables 69-70). The average annual rate of decline and the percentage decline is greater on the less frequently flooded 3 – 5 year floodplain than the 0-2 year floodplain from 2000 to 2005. Flood frequency and year interacted to affect the number of pondberry (repeated measures ANOVA, $p = 0.0333$), where the average number per colony/site in the 0-2 year floodplain increased from 49 to 56 during 2000 – 2005 ($p = 0.0000$), but declined from 50 to 29 plants per colony ($p = 0.0000$) in the 3-5 year floodplain (Table 69). From the net change in number of pondberry, 93.3% of the number in 2000 persisted and 6.7 percent were lost in the 0-2 year floodplain by 2005. The proportion persisting in the 0-2 year floodplain were 2.17 times that of the 3-5 year floodplain (relative risk ratio = 2.17, 95% confidence interval 2.1095 < R.R.< 2.2254), and the odds of persisting in the 0-2 year floodplain were13.9 times as that in the 3-5 year floodplain (Table 70b).

Data from the FESM GIS-DEM flood frequencies result in a greater negative overall rate of growth (R_e = -0.0138) and percentage (-6.8 percent) decline on the 0-2 year floodplain compared to that from ground-surveyed elevation flood frequency estimates (r = 0.1866, +9.8 percent) (Tables 57 and 70). These differences reflect the different colonies/sites that are included in the 0 – 2 year flood frequency interval by the two flood frequency classifications. The FESM GIS-DEM method included colonies/sites in the 0 – 2 year floodplain that are less frequently flooded than determined by ground surveyed elevations. These less frequently flooded colonies/sites also declined relative to the more frequently flooded sites in the classification.

Because the flood frequency estimates derived from the ground surveyed elevations at each profiled colony site are more accurate than those from the FESM-GIS with a 30-meter DEM, the primary analysis of effects will not be based on the reduction in flood frequencies estimated by FESM-GIS. The baseline differences in the FESM GIS-DEM and ground surveyed elevation frequencies can be substantial (Table 19, Figure 6), and the frequency differences with the project are even greater.

<u>Flood Frequency at Profiled Colonies/Sites– Ground Survey Elevation</u>

The flood frequency at 36 profiled nonwetland colonies will be reduced from a pre-project median of 4.0 years to 32.5 years with the project (Table 71). Under current (pre-project) conditions, most (23) of these colonies/sites (63.8 percent) are in the 0-5 year floodplain (Tables 71 and 72b) with four (11.1 percent) on the 0-2 and 19 (52.8 percent) on the 2-5 year floodplain. There will be three (8.3 percent) colonies/sites remaining in the 0-5 year floodplain with the project, with no colonies on the 0-2 and three colonies (8.3 percent) on the 2-5 year floodplain (Table 51b). With the project, most of these nonwetland colonies (14, 38.8 percent) will be in the much less frequently flooded 20 – 100+ year floodplain (Table 72b). Ten (27.8 percent) of these colonies will be inundated by flooding only once at intervals of more than 100 years.

The reduction in flood frequency will increase the decline of pondberry. This expectation is based on two factors. First, the performance of pondberry at profiled colonies during 2000 and 2005 was affected by and related to flood frequency, as described for the Environmental Baseline. For example, the average number of plants per colony was greater on the most frequently flooded sites, the only net growth or increase in pondberry among colonies/sites occurred in the 0-2 year floodplain, and the growth rates of colonies/sites declined in a nonlinear fashion as flood frequencies decreased, with negative average growth ensuing generally at a 2 – 3 year flood frequency, depending on the regression model. Secondly, most of the profiled colonies where flood frequency was determined by ground surveyed elevations will be flooded too infrequently to maintain a wetland hydrology or to provide wetland functions (5-year floodplain) regulating the structure and composition of the forest community.

Past and future trend

The relationship between overbank flooding to pondberry is directly and indirectly evident in several statistically significant tests and other data from profiled colonies/sites during 2000 and 2005. From the repeated measures ANOVA (Table 36), the number of plants per colony/site declined from 2000 to 2005 ($p = 0.013$), and flood frequency also affected the abundance of pondberry ($p = 0.085$). Site status affected the abundance of pondberry (Table 38, $p<0.001$), where the number in wetlands was greater than nonwetlands as otherwise compared if the number produced was proportionate to the number of colonies. The persistence of pondberry from 2000 to 2005 also was greater in wetlands (Table 37, $p = 0.000$) than nonwetlands. As the flood frequency interval increased (e.g. flooding decreased), colony/site growth rates declined significantly in a nonlinear fashion (Tables 48 – 50). Positive predicted growth by nonlinear regression analysis of the effect of flood frequency on colony/site growth rate occurred in the majority of the most likely models at a flood frequency interval of 3 years or less (Table 51). As the frequency of flooding decreased (e.g. flood frequency interval increased), negative colony growth rates either continued to decline, or the declining rates reached a lower most negative rate without declining further. By flood frequency class, the only net increase (10 percent) in the number of pondberry at profiled colonies/sites during 2000 - 2005 was in the 0-2 year floodplain (Table 39a). Otherwise, the total number of pondberry from profiled colonies at all other flood frequency classes declined by 50 or more percent.

These data are highly variable, illustrating that colonies with net positive growth were not restricted to sites in the 0-2 year floodplain or jurisdictional wetlands (Table 58). However, the declining overall trend during this period was definitive, with negative colony/site growth rates as the frequency of flooding decreased. If future environmental conditions reflect those during 2000 – 2005, then the nonlinear regression equations and models from the statistically significant relationships between the number of plants in 2000 and 2005 would predict on average an overall decline in the number of pondberry, with stable or net positive overall growth in the 0-3 year floodplain.

Colonies in the 1-year floodplain and colonies with a local wetland hydrology will not be directly and adversely affected by the project. Otherwise, the project is expected to increase the rate of pondberry decline, on average, since the number of nonwetland colonies/sites that will remain in the 0-2 and 3-5 year floodplain with the project will be reduced, and the number of nonwetland colonies at much less frequently flooded intervals will increase. Of 36 profiled nonwetland colonies, there currently are 23 colonies/sites in the 0 – 5 year floodplain. With the project, three colonies will remain in the 0-5 year floodplain (Table 72b). The least frequently flooded of the 47 jurisdictionally field surveyed colonies, based on the 1943 – 1997 POR, was colony/sites 4 and 27, both with a 16.0 year flood frequency (Table 99). With the project, the flood frequencies of 24 of the nonwetland colonies will be reduced to > 16 to > 100 years (Table 71).

These estimates of future decline are based on the performance of pondberry in relation to flood frequency and wetland conditions during 2000 – 2005. There are no data on the performance of pondberry colonies/sites during 2000-2005 to assess the response of pondberry at the highly infrequent flood intervals expected with the project. One approach to estimating the response of pondberry would be to use the nonlinear regression models of colony/site growth rate in response to flood frequency, and extend the fitted regression line from the 16-year floodplain to the 100-year flood frequency expected with the project. There were two basic pondberry responses to flood frequency in the most likely nonlinear regression models. Negative colony/site growth rates in one type reached a lowermost value below which growth rates no longer further declined as the flood frequency interval continued to decrease (Figure 32). The lowest negative colony/site growth rate generally is attained at a flood frequency interval of 2 – 3 years, depending on the model. By these models, a decrease in the flood frequency interval by the project, even extending to the 100-year interval, would not cause any further reduction to the lowest negative growth rates already achieved. The negative growth rates in the other type of the most likely nonlinear models continued to decline as the flood frequency interval also decreased (Figure 33). These models would predict that project-induced reductions in flood frequency intervals will increase negative colony/site growth rates, on average, and increase the rate of decline. By either type, the net long-term effect of average negative growth rates would be a decline in the number of pondberry, eventually leading to the extirpation of nonwetland colonies.

The difficulty with this approach is that the regression predictions and inferences of future colony/site growth rates at flood frequency intervals greater than 16 years with the project are outside the range of the growth rate response to flood frequency intervals during 2000-2005. Regression analysis frequently is used to make future predictions, including inferences for data outside the observed range for the regression model, but these predictions must be considered with extreme caution (e.g. Neter and Wasserman 1974). There is uncertainty whether the predicted average negative colony/site growth rates at flood frequency intervals greater than 16 years will reflect the observed response of colonies/sites to flood frequency intervals of 16 or less years.

According to the Corps, however, the baseline flood frequency intervals from the 55-year 1943 – 1997 POR do not closely reflect the actual frequency of overbank flooding during the recent 20-year 1984 – 2003 POR. As the Corps has evaluated (U.S. Army Corps of Engineers 2005b, Appendix 14, Biological Assessment), flooding at these colonies/sites during 1984 – 2003 occurred much less frequently than expected according to the flood frequencies for the 1943 – 1997 adjusted POR. This is because overbank flooding naturally is variable and cyclic over time, and is one reason the Corps typically requires a 50-year POR for hydrological analysis: flooding during any 20-year period is unlikely to occur at the exact frequency determined from a much longer POR (U.S. Army Corps of Engineers 2007).

In a related assessment, the Corps generally evaluated the sensitivity of the period of stage-gage data on estimates of the backwater 5 percent duration elevation for wetlands. They found significant variation in these flood stages from one year to the next, with a varying period from 3 to 9 years of increasing and decreasing flood stages (U.S. Army Corps of Engineers 2005a, Appendix 10, Assessment of Wetland Resources). Although the variation in the 5 percent duration backwater flood stage for wetlands is not the same hydrological event as the variation in flood frequency, the frequency of flooding also is expected to vary. The longer the POR, there will be less variation in the computed stage elevations.

Most importantly, however, the Corps compared the infrequent flooding during this recent 20-year period to the flooding that would be expected with the project (U.S. Army Corps of Engineers 2005b, Appendix 14 Biological Assessment: pgs 14-16 to 14-19).

> "On average, growing-season overbank flooding did not occur on 91.3 percent of the colonies from 1984 to 2003. . . With project conditions, growing-season overbank flooding would not have occurred on 93.5 percent of the colonies from 1984 to 2003. This was only a 1.8 percent increase in the average over the without-project conditions."

> "Approximately 88 percent of the colonies have been affected by growing-season overbank flooding in 2 years or less in the 20-year period. . . With-project conditions, approximately 96

percent of the colonies would have been affected by growing-season overbank flooding in 2 years or less in the 20-year period, an 8 percent increase."

From our assessment of this and related information from the Corps, the hydrological conditions from overbank flooding at profiled colonies/sites during the 10-year 1984-2003 period were more similar to conditions expected with the project than baseline conditions without the project. Furthermore, stage-gage data analyzed by the Corps at Holly Bluff during 2000 - 2005 indicated that the flooding was below the mean and median stage for four of these six years, the average annual stage was 2 feet less than the overall mean and 3 feet less than the overall median, and the 5 percent flood duration elevations was less than the median 5 percent duration flood elevation with the project (U.S. Army Corps of Engineers 2007).

These data indicate annual average stage elevation during this period are more representative of that expected with the project than the expected 1943 – 1997 POR baseline flood frequencies without the project. From base data on the number of flood events during 1984-2003 at each of the profiled colonies according to stage-gage elevation data provided by the Corps, we tallied the total number of flood events (dormant season and growing season) and growing season flood events. The number of infrequently flooded profiled colonies/sites during this period generally is more similar to that expected with the project than the baseline 1943 – 1997 average conditions (Table 74). One-half or more of the profiled colonies in the 0-2 and 2.1-5 year floodplain according to the 1943-1997 POR were functionally in a less frequently flooded interval during 1984-2003.

The ecological effects of hydrology and other factors are inherently expressed in changes in the number of pondberry between 2000 and 2005. The association and response of pondberry during 2000-2005 to flood frequency and hydrology can include short-term, intermediate, and long-term dynamics. The most prevalent type of response is not known. If it predominately is short-term, then the 2000-2005 trend would be intermediate or more indicative of project conditions than baseline conditions. If the response at the other extreme is mediated by more long-term dynamics, then the 2000-2005 trend would be more similar to conditions expected on average long-term. In any case, the data and evidence reveal a declining trend with negative growth rates, smaller colonies, and lower rates of persistence and pondberry production as flood frequency declines.

The future expectations of the number of pondberry based on the observed rates of growth or decline between 2000 and 2005 are not the same as a viability model with quantitative predictions of the change in population size, and the probabilities of future persistence or extirpation from demographic data. Population viability analysis (PVA) usually is based on vital demographic rates and the variation of such rates for survival, growth, and reproduction (e.g., Beissinger and Westphal 1998). These types of models generate estimates of future population size and fate depending upon the demographic values and variation for reproduction and survival (Groom and Pascual 1997, Reed et al.. 1998). The available pondberry data does not depict such demography in terms of plant mortality/survival and sexual or asexual reproductive rates. Instead, the pondberry data are direct measures of colony size or the number of plants in each selected colony/site, which we partitioned as populations and segments of populations at different flood frequencies.

Changes in the number of pondberry by the 2000 and 2005 surveys have been directly measured without requiring a generated population estimate from demographic parameters. The data represent a time series of measured changes in colony and population size. Time series data for changes in population size and the log change in population size ($\log P_f/P_i$) also are the subject of viability models and methods of analysis to predict the probabilities of persistence and extirpation (e.g. Boyce 1987; Dennis et al. 1991). However, the pondberry data consists of only a single time series interval, with the 2000 and 2005 census. More than one time series is required to generate an estimate of persistence or extinction probability by time-series methods. Population viability analysis in the broadest sense is an evaluation of the factors that can lead to population extinction (Soule 1987). Given that this is the best available data, our use of the rate of growth or decline in relation to flood frequency and hydrology is to evaluate the magnitude and direction of change as a general prediction of future trend.

The predicted decline of pondberry from the observed patterns indicates, on average, pondberry colonies/sites are not expected to be stable or increase except probably those that will remain in wetlands and others in the 0-3 year floodplain, perhaps even the 0-5 year floodplain. Only three (8.3 percent) of the 36 jurisdictionally nonwetland colonies/sites will remain in the 2.1 – 5.0 year floodplain. If this is a representative sample, then overall only about 8.3 percent of the nonwetland colonies would potentially retain sufficient flooding to persist for the long-term. If the profiled colonies/sites are generally representative of colonies/sites elsewhere, then the persistence of pondberry in DNF is related to the total number of colonies/sites and plants in DNF relative to the number remaining in wetlands and frequently flooded sites that will not be adversely affected. The greater the number, the longer the persistence for those projected with an average decline. Given the observed and highly variable average rate of change from 2000 to 2005, the overall decline with the project could last for decades, if not 100 or more years. Pondberry is relatively resilient because of the prevalence of vegetative and clonal reproduction. In a previous section we estimated the number and proportion of colonies/sites in wetlands with a local hydrology and pondberry that are not likely to be adversely affected by the project. We estimate that from 25 to 32 percent of all colonies/sites occur in wetlands with a local hydrology, which can produce 40 – 64 percent of all pondberry in DNF. With highly variable rates of future decline, eventually about 36 to 60 percent of the pondberry in DNF are expected to become extirpated.

Populations

Colby population

The Colby population is the largest and most concentrated in DNF, with at least 20,000 plants. With five profiled colonies/sites, it has the least number of selected colonies/sites than any of the largest populations. Three of these colonies/sites are in the 0-2 year floodplain, and two are in the 3-5 year floodplain. Only one of the profiled sites produced an increase in the number of plants during 2000 – 2005. All others declined. The overall annual exponential rate of decline was -0.2126 (Table 75). However, a different trend is evident from nine plots established in 1993, and monitored in 1994 and 2006 (McDearman 2006, unpub. data). Most of the pondberry in this population is associated with two woodland vernal pools that usually store winter rainwater into spring growing season, although at different levels depending on the weather, as well as overbank flood water. The population segment associated with the vernal pools increased from 1993 to 2006, with an average annual growth of 0.0234. Colonies in the non-ponded areas declined during this period (-0.0112). The net change from all plots in ponded and non-ponded areas was an increase from 1993 to 2006 (0.0104) due to the net growth from the ponded colonies.

The magnitude of the observed net decline at the profiled colonies/sites from 2000 to 2005 does not reflect the trend from the longer 1993 to 2006 period from nine other plots. Both periods are during the 1984 – 2003 interval of reduced flooding assessed by the Corps. The future trend in the Colby population probably isn't as stable as indicated by the nine permanent plots from 1993 – 2006, but not as vulnerable as the observed decline might indicate from the five profiled colonies/sites. Also, the change in flood frequency to the five profiled colonies/sites (Table 76) does not accurately portray the hydrology in the vernal woodland pools that will not be affected, with most of the population. The effects of the project are not as great in this population as others because most of the population is in or adjacent to annually, although variably, flooded woodland vernal pools from rainwater. The project will not reduce local hydrology from the capture, storage, inundation, or saturation by local rainfall. Alteration of the backwater flood frequency and duration by the project will reduce, however, the hydroperiod of these depressions by reducing the frequency of overbank flooding which is captured and stored in addition to precipitation.

From our surveys and general reconnaissance through this population since 1991, probably 75 percent of the population consists of colonies and plants in stands adjacent to the ponded areas. Most of the long-term decline in the population with the project probably will occur in these non-ponded population segments. The Colby population is expected be more resilient to the hydrological changes by the project primarily because of the local hydrology within these two depressions. However, the long-term change probably will involve a reduction in the number of pondberry associated with the woodland pools because its hydrology also will be reduced by overbank flooding. In contrast to the Red Gum and Spanish Fort populations, the Colby population is more stable.

Red Gum population

The Red Gum population is the only one of these three populations without any profiled colonies in the 0-2 year floodplain. Eight (47 percent) of the 17 profiled colonies are in the 2.1-5 year floodplain, with all others at less frequently flooded sites (Tables 75-76). Only two of the 17 profiled colonies produced an increase in the number of pondberry between 2000 and 2005. These two colonies are in the 2.1-5 year floodplain. The greatest rate of decline was in the 5.1-10 year floodplain (Table 76). We estimated the Red Gum population to minimally consist of 4,298 – 8,272 plants (Table 4). We also estimated that from 23 to 30 percent of DNF wetland colonies could occur in this population (Tables 61 and 66), capable of producing from 38 to 63 percent (Tables 62a and 66b) of all pondberry. Pondberry at other colonies/sites are expected to decline and eventually become extirpated, with a surviving population of 1,633 – 4,963 plants ([4,298 x 0.38] – [8,272 x 0.63]).

The disparity between the flood frequencies by the FESM GIS DEM elevations and the ground surveyed elevations at profiled colonies/sites is the greatest in the Red Gum population (Table 76). The FESM GIS DEM classified all of the profiled colony sites as within the 0-2 year floodplain, while the ground surveyed elevation flood frequencies ranged from the 2.1-5 to 15.1-20 year floodplains. The changes in flood frequency at colonies/sites by the project according to the FESM GIS DEM (Table 59) are much less than the frequency by elevations from the ground survey. Regardless of the 0-2 year FESM GIS DEM flood frequency classification, most of these colonies declined substantially during this period.

Spanish Fort population

In the Spanish Fort population, there are four profiled colonies/sites in the 0-2 year floodplain, one of which increased in the number of plants between 2000 and 2005 (Table 75). Only one other colony/site, located in the 2.1-5 year floodplain, experienced growth during this period. The remaining 19 colonies declined. The four colonies/sites in the 0-2 year floodplain represent 19 percent of the 21 profiled colonies in the population, three of which decreased during this period. The overall rate of decline was -0.1379, the lowest among the largest pondberry populations. However, the mean rate of decline, -0.1215 and its 95% confidence interval, -0.1889 - -0.0541, was the greatest. We previously estimated that the population consists of at least 3,880 plants, where 20 – 27 percent (Tables 61 and 67) of the colonies may have a wetland hydrology. While the overall trend at profiled colonies during 2000 – 2005 was a net decline, these did not include the predicted sites with a local wetland hydrology. Overall, the long term average, though highly variable, growth and production of pondberry at sites with a local hydrology is expected to sustain from 34 – 60 percent of this population (Tables 62a and 66b), while the remainder eventually becomes extirpated. No colonies/sites are predicted to remain in the 0-2 year floodplain (Table 76).

Other populations

The estimated size of the 9 remaining smaller populations is from 40 to 1,280 plants. These populations include six with at least one profiled colony/site in each (Table 4). Profiled colonies in two of these populations (Population 7, 12) declined during 2000 – 2005, with an average annual decline ranging from -0.1120 to -0.0033. The profiled colony/site in each of the other four small populations (Population 4, 8, 9, 10) either did not change (Population 8) or increased during this period. Colonies/sites with a positive average annual growth were in the 0-2 year floodplain. Declining colonies were in the 2.1 – 5 year floodplain. No trend data is available for the three remaining populations (Population 11, 12, 13) without any Corps profiled colonies/sites. Each of these is represented by just one known colony/sites (Table 4).

Eight of these nine smaller populations are not expected to persist because of a combination of hydrological changes with the project and the stochastic demographic and environmental effects in very small populations with, in most instances, a single colony. Population 10, with a single colony in the 0-2 year floodplain, increased from 94 to 1,280 plants from 2000 to 2005, at a greater rate than any of the other profiled colonies in DNF. This is the only small population located on the 1-year floodplain that would not be affected by the project. Also, it is the least likely of the small populations to become extirpated, but its persistence depends on an overall average positive growth rate, with little annual variation with negative rates. In all other small populations, the estimated size ranges from 40 to 780 plants (Table 2). These are much more vulnerable to variable growth rates which can drive such small populations to extirpation.

Cause-effect relationships

The data and statistics for profiled pondberry colonies/sites between 2000 and 2005 demonstrate a net declining trend, except on average for colonies in the 0-2 year floodplain and perhaps 0-3 year floodplain. The "effects" of overbank flooding and flood frequency are the mathematical relationships between different measures of flooding as a factor that is either related to or accounts for differences and variation in the number of pondberry, the average size of colonies/sites, and pondberry rates of growth/decline. Conclusions and inferences about the role of flooding to observed patterns of decline were not based on experimental studies in which all environmental factors that may possibly affect pondberry were controlled, or experimentally stratified or blocked by carefully designed field studies. This is not an uncommon factor in environmental survey studies. For example, as the flood frequency interval increased (less frequent flooding), the geometric growth rate of colonies/sites decreased in a statistically significant ($p < 0.01$) nonlinear fashion (Table 48A.1), in which flood frequency accounted for 50 percent of the variation in colony/site growth rate by the R_g1A model, and up to 75 percent of the variation in growth rate by the of the R_g1B regression (Table 48B.2). Flood frequency was just one environmental factor measured, and other factors directly or indirectly can affect growth.

Numerous authors have described the caution required to avoid improper inferences about cause and effect from data and statistics in environmental studies (e.g. Eberhardt 1970; Romesburg 1981; Holland 1986; Eberhardt and Thomas 1991). Overbank flooding does not account for 100 percent of the variation observed in the changes in pondberry at colonies/sites between 2000 and 2005. This is not unusual because there are no species known in which their distribution and abundance is regulated by a single environmental factor. Nevertheless, hydrology is important. For the proposed project, inferences and conclusions about the role of flooding as a factor affecting pondberry are supported by other science on the ecology and hydrology of wetland species, competition, and bottomland hardwood systems.

A stable environment for pondberry is expected to reflect the hydrological conditions of wetlands. The classification of pondberry as an obligate wetland species in the national wetland species plant list (Reed

1988) is not based on experimental studies. None of the wetland species on the national list are classified on such basis. Pondberry was classified as an obligate wetland plant according to the field surveys, observations, and opinions of experts, as for all other species, due to the high fidelity of its occurrence in habitats with characteristics ecologists have used for decades to identify wetlands. The National Research Council 1995) has found that the basis of these wetland plant classifications, as supported from other scientific studies, is scientifically reliable.

As a wetland plant, the essential hydrology of pondberry also reflects the hydrological definition of jurisdictional wetlands. This requires, on average, continuous inundation or saturation for 12.5 percent or more during the growing season, or from 5 – 12.5 percent with other evidence, once every two years. The data on pondberry performance and trend in relation to flooding during 2000 and 2005 resembles expectations based on its definition as an obligate wetland plant and the expected hydrology of wetland species. Profiled colonies/sites in the 0-2 year floodplain were the only ones with an overall average rate of positive growth. The average trend at all less frequent flood classes were declining, and by nonlinear regression analysis negative colony/site growth rates generally developed when the flood frequency interval was less than three years. Only three of the 49 profiled colonies/sites occur in wetlands based on the Corps FESM hydrology model, two of which (GSRC 54 and 56) had the greatest rate of growth and production of new plants than any other profiled colony/site. The third colony/site (GSRC 53) also increased from 91 to 308 plants from 2000 to 2005. However, this site is in a greentree reservoir in DNF that is annually flooded each year for waterfowl management, and the effects of artificial flooding could cause errors in the analysis.

These trends included substantial variation. Twelve of the 49 profiled colonies that did not decline between 2000 and 2005 occurred at sites with flood frequencies ranging from two to 14 years under baseline conditions. This pattern included the existence of colonies/sites with a local wetland hydrology independent of overbank flooding, as well as variation in the response to infrequent flooding. In any case, the expected long-term decline by the project also will be subject to substantial variation associated with periodic cycles of increasing and decreasing flooding, in conjunction with other stochastic environmental factors.

The decline of pondberry in association with a reduction in hydrology from overbank flooding probably is a response at two different scales; a physiological level and plant community-environment level, with interactions to pathogens. The physiological response involves the ability to tolerate drier conditions in habitats that, naturally, would have provided greater soil moisture. The plant community response concerns the nature of plant competition and long-term change following a reduction in hydrology, where the number of nonwetland and hydrologically intolerant species are expected to increase at sites that previously were wetlands. The interactions with *Botryosphaeria ribis*, the fungus causing stem-dieback, probably are exacerbated because plants experiencing soil moisture or other stress appear more susceptible to *Botryosphaeria* (Bacchus et al. 2000; Schoeneweiss 1978).

The reduction in the frequency of overbank backwater flooding will reduce soil water moisture and, at infrequently flooded sites, increase the risk of drought stress. Pondberry is susceptible to leaf wilt and loss during late summer drought stress even at sites with a natural hydrology (Wright 1989a). These responses during drought stress also include stem death. The ability of a plant to tolerate drought is partly related to the extent that leaf stomata regulate the rate of photosynthesis and transpiration. Stomata are the pores in leaves through which gases are exchanged and liquid water is transpired as water vapor during photosynthesis. Water is pulled from the soil through the vascular tissue of roots and stems to leaves as a result of the pressure or pull created in the water-tissue column during photosynthesis and transpiration. The size of stomata change in response to water turgor in leaves and other factors. As water availability in the soil decreases, the stomata will become constricted in most plants to reduce the rate of photosynthesis and water loss through transpiration.

Stomatal control, however, varies among different species of plants. As soil water becomes limited, the resistance of water to passage upward from the roots through vascular tissues increases, which also increases tension within the xylem tissue conducting the water. With unregulated stomata and photosynthesis during decreasing water availability, an excessive amount of conductance can lead to an irreversible collapse of the water conducting tissue (xylem) and/or blockage of the tissue with emboli by air-filled passages (e.g. Tyree and Sperry 1988; Jones and Sutherland 1991; Meinzer 1993), with subsequent die-back of stems and branches (Zimmerman 1983; Tyree et al. 1993.).

Studies of the ability of plants to tolerate water-saturated soils versus drought indicate a tradeoff between the ability of xylem to conduct water when it is readily available and to resist collapse caused by high water tension during drought. (e.g. Baruch 1994; ter Steege 1994; Loreti and Oesterheld 1996). The xylem is anatomically stronger and more resistant to collapse in plants inhabiting dry environments while plants in wet environments have xylem that may be more vulnerable to cavitation or emboli during periods of limited water availability (e.g. Alder et al. 1996). The resistance or adaptation to flooding is, generally, negatively associated with resistant to drought (e.g. Loreti and Oesterheld 1996). Thus obligate wetland plants such as pondberry that are tolerant of hydric wetland soils are not expected to be as tolerant to periods of low water availability or changes in hydrology that reduce the frequency of flooding and soil moisture.

With a reduction in soil moisture and an increase in stress, pondberry probably is more susceptible to stem die-back from the stem canker fungus, *Botryosphaeria ribis*, as observed from the response of other species to this pathogen (Schoeneweiss 1978; Bacchus et al. 2000) This mechanism involves structural damage by the pathogen to xylem and phloem, the plant conducting tissues, which further reduces the capacity of pondberry to conduct water to stems and leaves during limiting soil moisture conditions. Stem die-back also is a response to toxins produced by the fungus. In the Colby population, average annual growth following a severe outbreak of stem canker in 1993 was greater in colony plots within and on the edge of two woodland vernal pools that stored winter rainfall. Other colonies, on average, experienced a net decline over the short and long-term period through 2006. As the frequency of backwater flooding is further reduced at colonies/sites where wetland hydrology already doesn't exist, the incidence and severity of stem-canker is expected to increase, causing a greater overall decline.

Changes in hydrology also affect the structure and composition of bottomland hardwood forest and plant communities. Hydrology is a primary factor regulating the structure and plant species composition of bottomland hardwood forest communities (e.g. Wharton 1980; Clark and Benfardo 1981; Conner et al. 1981; Theriot 1988; Sharitz and Mitsch 1993; Smith 1996; King and Allen 1996; Mitsch and Gosselink 2000; Bledsoe and Shear 2000). These patterns reflect the tolerance of various species, including the dominants, to anaerobic gradients created by the variation in timing, duration, and frequency of flooding. The scientific data for these relationships is derived not only from studies of forest and communities affected by different patterns of overbank flooding. Changes in species composition also have occurred at impounded sites, such as green tree reservoirs, in bottomland hardwood systems where species less tolerant of flooding decreased and tolerant species increased (Frederikson 1979; Malecki et al. 1983; Schlaegel 1984; King 1994; Deller and Baldassarre 1998). Changes in hydrology, whether natural or man-made, have been found by these and other studies to be associated with an increase or decrease in the relative abundance, density, and growth of particular species.

As overbank backwater flooding is reduced at pondberry colony/sites, conditions become more suitable for other less tolerant native species to increase in relative abundance and cover. Changes in plant community structure, with an increase in the relative abundance of other species at pondberry colonies/sites, will alter actual and potential dynamics of competition. Pondberry experts at the Corps

1990 Pondberry Profile Workshop (U.S. Army Corps of Engineers 1990) recognized competition as an adverse consequence of reducing flood duration and frequency (e.g. Wright 1989a, 1989, 1990).

Interspecific plant competition occurs when plants compete for limited resources such as space, light and nutrients. Extensive studies and data reveals that plants interact or compete with other plants for these resources (e.g. Connell 1983, Schoener 1983, Fowler 1986, Tilman 1987, Grime 1987). The outcome of competitive interactions depends on the extent that individual plants or their populations can garner or deplete limited resources and suppress other plants (e.g. Tilman 1982, 1985, 1988). There are two situations when competition is an important factor affecting the structure and composition of plant communities (Goldberg 1990). In both situations, there is great potential for an increase in plant growth for the successful competitor in response to an increase in resource availability. The negative response to plants experiencing competitive exploitation of resources can involve a reduction in plant size or biomass, reproduction, and survival (e.g. Tilman 1988). Competition and resource gradients are considered the primary factors that regulate the distribution and abundance of species and the formation of plant communities (Austin 1985, 1990). Species are distributed in the environment with one or more optimal habitats or environments, the realized niche, and they decline and are less abundant in other conditions.

For pondberry, wetlands have been historically altered by past flood control projects, and flood frequencies will be further reduced by the proposed project. Most of the profiled colonies/sites currently exist at sites that are not wetlands, where they are declining on average. Infrequent flooding or even the absence of flooding, as identified at colonies/sites during 2000 – 2005, did not cause massive or widespread extirpation. Thus, pondberry is resilient, as generally expected from a woody plant with clonal vegetative reproduction from the base of stems near the ground and rhizomes. However, the 42 percent decline from 11,748 pondberry in 2000 to 6,775 by 2005 is substantial. Actual flooding during this period and in preceding years to 1984 was less than that normally expected, and could be a contributing factor for the magnitude of the observed decline. If so, the 2000-2005 response becomes similar to that expected by flood frequency conditions with the project. As the hydroperiod from backwater flooding will be further reduced by this project, the probabilities of short-term more acute effects of periodic cycles infrequent flooding become greater, with long-term effects of increasing interspecific plant competition within the bottomland hardwood forest community.

The effects of competition have not been experimentally measured in the action area. However, in South Carolina restoration management to reduce the cover of shrubs and other competing vegetation at pondberry sites has significantly increased pondberry plant size and growth, following a significant decline in the number of plants (Glitzenstein and Streng 2004). Plant size is a trait and general positive indicator of plant vigor, future mortality, and reproductive performance (Werner 1975; Solbrig 1981; Westoby 1982; Hutchings 1989). In DNF, pondberry in the Red Gum Research Natural Area occurs among heavy cover, as in other sites as described in the pondberry profile survey notes.

The effects of an increase in future interspecific plant competition with the project cannot be precisely forecast, but the overall effects will be negative. The magnitude and rate of change will depend on the current species composition, structure, and hydrology at each colony/site. Generally, changes in plant community composition and structure that increase competition are expected to be slow.

Project effects with historical past effects

Under current wetland conditions estimated by the FESM model, there are only 17 known colonies/sites in wetlands, representing 9.6 percent of the 177 known colonies/sites in DNF. The proposed project will alter the baseline wetland hydrology for one of the 17 colonies/sites currently in wetlands.

Of these 177 known colonies/sites, 49 are selected colonies/sites profiled by the Corps during 2000 and 2005. The proposed project will not alter the hydrology in the 0-1 year floodplain, where two profiled colonies/sites also will not be affected. Between 2000 and 2005, all of the profiled pondberry colonies/sites declined, on average, except those in the 0-1 year floodplain. The decline of six of the seven colonies in the 1.1-2 year floodplain probably is a response more indicative of the recent 20-year period of unexpectedly infrequent flooding, more representative of the expected flooding with the project, instead of baseline conditions predicted by the Corps 1943-1997 POR. It is possible that, under average baseline conditions, the frequency and duration of overbank flooding in the 0-2 year floodplain may have been adequate for pondberry to exist without an average overall decline. This is because much, but not all, of the 2-year floodplain by the FESM model is a wetland. If so, then the effects of the project would be to reduce the frequency of flooding to one (2 percent) of 49 profiled colonies that otherwise would have had a sufficient hydrology to avoid a net decline.

The FESM wetland classification and the profile data from 49 colonies/sites indicate that most of the pondberry colonies/sites under pre-project conditions are not in wetlands or at flood frequencies likely to be wetlands, and are declining. By the FESM wetlands estimate, 160 (90 percent) of the 177 known colonies currently are not in wetlands, and should be currently declining based on the data from the profiled colonies/sites. In comparison, 47 (96 percent) of the 49 profiled colonies/sites are outside the 0-1 year floodplain and are declining under current conditions. By the FESM estimate, 10 percent of known colonies/sites should be stable, while the profile colony data indicates that four percent should not be declining.

The two profiled colonies in the 0-1 year floodplain also are in FESM wetlands that will not change with the project. At most, it appears the project will eliminate the frequency and duration of backwater flooding for one colony/site, causing it to shift to a less frequently flooded interval where the average net change of other profiled colonies has declined. By the FESM estimate, this would reduce stable colonies/sites from 9.6 percent (17) to 9.0 percent (16).

The project will reduce the current average flood frequency at profiled colony sites, based on the 1943-1997 POR, from 6.6 years to 27.1 years. However, the available data from 2000 and 2005 indicates nonwetland colonies/sites likely have already been declining under baseline conditions, and would have continued to decline on average in the future even without the proposed project. These unsuitable hydrological conditions primarily are the consequence of past flood control projects. The proposed project, as added to historical changes, culminates in a condition where pondberry is expected to continue to decline, although probably at a faster rate, with a loss of from 40 to 64 percent of the pondberry in DNF. The Colby, Red Gum, and Spanish Fort populations are expected to persist, although at a reduced level. The smaller populations are likely to become extirpated.

Propagation and Stocking for Two New Populations

We recommended as a conservation measure during this consultation that the Corps propagate, stock, and establish two new populations in areas where the hydrology would not be adversely affected. On ??, the Corps and Service signed a MOA to further plan, develop, and implement this project (Appendix 3). By this agreement, the Corps committed as part of this proposed project to establish and monitor these populations for a 10-year period, as well as conduct additional conservation research on environmental factors affecting the species. This plan will increase the number of pondberry and populations, and reduce the adverse effects of accelerating the decline of pondberry DNF populations as backwater flooding is reduced by the project. These two populations, stocked with 20,000 plants in each, are expected to reestablish two large, and significant populations for recovery. The expectations for a successful project are based on ongoing pondberry conservation research funded by the Corps to the U.S. Forest Service's Center for Bottomland Hardwoods Research (CBHR).

In 2001, the Corps and U.S. Forest Service initiated a 7-year, $5 million interagency agreement to conduct conservation research assessing the effects of hydrology, sunlight, pathogens, competition, and ambient environmental conditions to pondberry, as well as characterizing the genetic diversity and structure of populations. In 2002, the Service entered this interagency agreement with the Corps and Forest Service.

The Mahannah WMA and Panther Swamp NWR are the currently designated locations to stock and establish these populations in the backwater area (Plate 7). Mahannah WMA is owned by the Corps and leased to the MS Department of Wildlife, Fisheries and Parks, where there are 12,539 acres of forest in the 1-year floodplain and 8,861 acres of FESM wetlands. Panther Swamp NWR, owned and managed by the Service, has 3,300 acres of forest habitat in the 1-year floodplain. As described in the MOA, the Corps and Service will further assess the suitability of these areas and forest for pondberry, which will include field surveys, site evaluations, and jurisdictional field determinations. Forest stand conditions will be selected to reflect those known to support pondberry. If for some unexpected reason these sites are determined unsuitable, the MOA provides that other sites will be evaluated and selected. Other potential areas with forests in the 1-year floodplain and wetlands that will not be adversely affected by the project include Twin Oaks WMA, Delta National Forest, as well as privately owned tracts.

The pondberry propagation phase of this conservation project is based on the methods successfully used by CBHR to propagate more than 10,000 plants required for the research implemented in 2001. It is a micropropagation protocol with pondberry shoot cultures (Hawkins et al. 2007), also used for conservation of other endangered species and species of concern (Godt et al. 1997; Hammatt and Evans 1985; Machon et al. 2001; Negash 2002). The technique is based on the laboratory propagation of multiple whole plants from vegetative shoots removed from stock plants. Sufficient stock plants are still available at CBHR for the propagation protocol. Also, these plants have been genotyped, and the genetic analysis of at least 40 stock plants indicates the presence of sufficient heterozygosity and polymorphism so that inbreeding genetic effects will not occur (Echt 2007, pers. comm.). At about eight weeks of age, potted plants are returned from the propagation facility, where they are placed in greenhouses at CBHR for further growth. The CBHR has successfully propagated and outplanted more than 3,500 pondberry at an experimentally controlled ponding facility, at different sun and shade treatments. Overall, pondberry has survived and grown well at these field sites. The sites are not within forests, but the survival and growth of pondberry in comparable sun and shade treatments indicate that with proper procedures, the outplanting phase should be successful.

A detailed stocking plan for each site will be developed, including the sites, planting densities, and dates. Pondberry propagation and stocking will be planned and conducted annually for at least four years to establish plants of different ages and cohorts.

During the next year, the Corps, Service and cooperators will develop the master plan for monitoring and managing this program. This plan will consist of measurable objectives and standards for evaluating the success of the project. These measures also will define the objectives and standards of the monitoring program to provide the performance data. Generally, we expect that a successful program will be demonstrated by the survival, growth, and reproduction of pondberry. Thus, monitoring protocols will be designed to measure these and related parameters, with the statistical ability to detect a change in each of these parameters, at the designated level which defines success. The monitoring program will continue for 10 years following the outplanting. The monitoring program also will be designed to provide performance data for adaptive management, identifying conditions when protocols or other measures of the program need to be modified – together with annual reports.

Research will be conducted in conjunction with the stocking program to assess effects of flooding, sunlight, competition, and pathogens to pondberry under forest conditions. The research and experimental designs will be developed within the next 12 months. Pondberry also will be propagated and stocked for these studies, which avoids any adverse experimental effects to resident populations. These studies will involve experimental manipulations of forest conditions, including thinning, as treatments with control conditions to assess response at plots in Delta National Forest, as approved by the Forest Service. Research with annual reports will conducted over a 10-year period. Scientists at the CBHR will be the principal investigators. The data are intended to supplement and assist in the evaluation of the response of pondberry to site conditions at the outplanted and stocked populations.

At the end of the 10-year monitoring and evaluation period, the Service and Corps will evaluate the success of the project and determine whether to continue, modify, or terminate the project. If the project fails, this would be new information the Service would consider in relation to the completed conservation research at CBHR to determine whether the Corps should reinitiate formal section 7 consultation on the effects of the Backwater Reformulation Project to pondberry.

Survival and recovery

Pondberry in DNF represents 13 of the 56 known potential populations in the species range. The Colby, Red Gum, and Spanish Fort populations in DNF currently are three of the 12 largest known populations in the species range, each with at least 3,000 plants (Table 3). Ten of these largest populations occur on federal or state lands with designated management and habitat protection for the species. In addition to the three in DNF, four of these populations occur in Francis Marion National Forest, South Carolina,; one is on state land managed by the Missouri Department of Conservation, and one is owned and managed by the North Carolina Plant Conservation Program. The largest population is in the St. Francis River floodway in Arkansas, which is on a mixture of private-public ownership by the Arkansas Game and Fish Commission, the Corps, and non-industrial private landowners. Public ownership and management is important, particularly on federal lands, because the Act does not protect pondberry or prohibit habitat destruction or other adverse management by private landowners for federally listed plants on their property.

The expected long-term decline of pondberry in the DNF, will eventually reduce the number of pondberry in the Red Gum and Spanish Fort populations to 3,000 or less, and reduce the number of large range-wide populations of 3,000 or more plants (Table 1). The Colby population should persist with 10,000 or more plants, and remain as a significant recovery population. The Red Gum and Spanish Fort populations will remain important for survival and recovery, but their value will be significantly diminished because populations of at least 3,000 plants appear necessary to avoid periodic short-term declines as observed in large South Carolina populations during drought and increased competition. The nine smaller populations in DNF, which range in size from 40 to 1,280 plants, will become more vulnerable with a reduction in flood frequency and colony/site growth rates. Eight of these are expected eventually to become extirpated. Population 10, located in the 1-year floodplain, will not be directly affected by reduced flooding, but will remain at risk due to its small population.

The limited and highly variable data from a single time series between 2000 and 2005 creates significant uncertainties for future estimates of the rate of decline, with periods of net growth and persistence during a longer period of overall decline. There are no other substantive data to indicate, otherwise, that pondberry throughout the DNF is stable, increasing, and potentially viable with an adequate hydrology under baseline conditions with or without the proposed project.

Successful sexual reproduction, with the production of seeds and seedlings, occurs rarely in pondberry. Local extirpation of small colonies and segments of populations will require long periods of time, if at all, for replacement from successful seed dispersal, followed by germination, growth, and survival. Large populations are required for survival and recovery under these conditions, in different environments where hydrology and other limiting factors vary asynchronously. According to the recovery plan, at least 15 self-sustaining and protected populations are required to downlist the species to threatened status, and 25 self-sustaining populations are required for recovery. Currently, there are only 12 populations of sufficient number to potentially be considered in the future as stable and self-sustaining. Hydrological changes by the proposed project as added to past projects will reduce these 12 to 10 populations. The effects of the propagation and stocking program to establish two populations, each with 20,000 plants, is expected to significantly reduce and compensate for the long-term decline and loss of perhaps up to 50 percent of the pondberry in DNF. These two populations in forest wetlands will become significant recovery populations due to their size, location, and resilience to periodic and variable growth rates.

CUMULATIVE EFFECTS

Cumulative effects are the effects of future State, tribal, local or private actions that are reasonably certain to occur in the action area considered in this biological opinion. Future federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation under section 7 of the Act (50 CFR § 402.02).

Pondberry in the action area is only known to occur in the DNF. There are no known or reasonably foreseeable future actions by non-federal entities that may affect pondberry in the action area.

CONCLUSION

After reviewing the current status of pondberry, the environmental baseline for the action area, and the effects of the proposed Yazoo Backwater Area Reformulation project, it is the Service's biological opinion that the proposed project is not likely to jeopardize the continued existence of pondberry. Critical habitat has not been designated for this species.

INCIDENTAL TAKE STATEMENT

Sections 7(b)(4) and 7(o)(2) of the Act generally do not apply to listed plant species. However, limited protection of listed plants is provided to the extent that the Act prohibits the removal and reduction to possession of Federally listed endangered plants or the malicious destruction of such plants on areas under Federal jurisdiction, or the destruction of endangered plants on non-Federal areas in violation of State law or regulation or in the course of any violation of State criminal trespass law.

CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the Act directs Federal agencies to use their authorities to further the purposes of the Act by carrying out conservation programs for the benefit of endangered and threatened species. Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of a proposed action on listed species or critical habitat, to help carry out recovery plans, or to develop information.

The Corps has established an important and ongoing pondberry conservation program, with research to assess the factors affecting the species, and projects to propagate, stock, and establish new populations. Long term monitoring is a vital element missing from these programs. Data currently are available on the number of pondberry censused during 2000 and 2005 at 49 colonies/sites in DNF. The Corps should evaluate the methods and benefits of continuing this element of a monitoring program, as well as modifying and expanding the program. More specifically, the Corps should statistically evaluate the available data from these sites to design a program capable of statistically detecting a change, whether positive or negative, at a specified magnitude of interest in the number and growth of pondberry. The monitoring program also should be designed to generate sufficient data on the variation in the growth and number of pondberry to, at a future date, stochastically model these dynamics as a likelihood prediction of the future persistence or decline of the species. These data will provide valuable information to assess the long term status of pondberry in the backwater area, and future effects of the proposed Backwater Reformulation.

During this consultation the Corps provided important information on the existence of a local hydrology, independent of overbank flooding, at certain colonies/sites. The question of the extent that colonies/sites and populations depend on a local hydrology is still important. Where a local wetland hydrology exists independently of flooding, projects affecting the frequency and duration of overbank flooding are not likely to adversely affect the species. The Corps should conduct surveys and hydrological studies to characterize the distribution and abundance depressions, vernal pools, or other sites with a local wetland hydrology, and where present , their physical characteristics and hydroperiods. Similarly, the Corps should consider fully implementing the HGM approach in the basin, particularly as it concerns the establishment of reference wetland standards for depressional classes, microdepressions, and vernal pools. These data will enable the Corps to more accurately assess impacts of past, ongoing, and future projects, while further documenting the status and trend of pondberry in the Yazoo Basin.

Important pondberry populations for recovery also occur in the St. Francis River floodway, within and near the St. Francis Sunken Lands WMA, managed by the Arkansas Game and Fish Commission. This probably is the largest single remaining population throughout its range, where flood releases regulated by the Corps and nearly annual flooding probably are important factors affecting the species. The Corps should conduct surveys to estimate the number and size of this population, with additional research and monitoring to assess population trends, the effects of flooding, and the extent that a local wetland hydrology exists at sites.

REINITIATION NOTICE

This concludes formal consultation for the proposed project. As required by 50 CFR §402.16, reinitiation of formal consultation is required where discretionary authority involvement or control over the action has been retained and if: (1) the amount or extent of incidental take is exceeded; (2) new information reveals the effects of the Corps action may affect listed species or critical habitat in a manner or to an extent not considered in this opinion; (3) the Corps action is later modified in a manner that causes an effect to listed species or critical habitat not considered in this opinion; or (4) a new species is listed or critical habitat designated that may be affected by the action.

We look forward to working with you and your staff to implement the pondberry conservation program.

Sincerely,

for Ray Aycock
Field Supervisor

cc: Dr. Sam Polles, Executive Director, MS Department of Wildlife, Fisheries and Parks
Mr. Antoine Dixon, Forest Supervisor, National Forests in Mississippi, U.S. Forest Service
Mr. Peter Nimrod, Chief Engineer, MS Levee Board

Literature Cited

Agresti, A. 2007. An introduction to categorical data analysis. 2nd edition. Wiley Interscience, John Wiley & Sons, Inc., Hoboken, New Jersey.

Aguilar, R., L. Ashworth, L. Galetto, and M.A. Aizen. 2006. Plant reproductive susceptibility to habitat fragmentation: review and synthesis through a meta-analysis. Ecology Letters 9:968-980.

Alabama Natural Heritage Program. 2004. Annual report. Montgomery, AL.

Aleric, K.M. and K.Kirkman. 2005. Seed germination observations of the federally listed *Lindera melissifolia*. Castanea 60:157-160.

Aleric, K.M. and L.K. Kirkman. 2005b. Growth and photosynthetic responses of the federally endangered shrub, *Lindera melissifolia* (Lauraceae), to varied light environments. American Journal of Botany 92:682-689.

Allee, W.C. 1951. The social life of animals. Beacon, Boston.

Anderson, D.R., K.P. Burnham, and W.L. Thompson. 2000. Null hypothesis testing: problems, prevalence, and an alternative. Journal of Wildlife Management 64:912-923.

Andreadis, K.M., E.A. Clark, A.W. Wood, A.F. Hamlet, and D.P. Letrtenmaier. 2005. Twentieth-century drought in the conterminous United States. Journal of Hydrometeorology 6:985-1001.

Austin, M.P. 1976. Non-linear species response models in ordination. Vegetatio 33:33-41.

Austin, M.P. 1985. Continuum concept, ordination methods, and niche theory. Annual Review of Ecology and Systematics 16:39-61.

Austin, M.P. 1990. Community theory and competition in vegetation. Pp. 215-238 *In* J.B. Grace and D. Tilman (eds.). Perspectives on Plant Competition. Academic Press, NY.

Bacchus, S.T., T. Hamazaki, K.O. Britton, and B.L. Haines. 2000. Soluble sugar composition of pond-cypress: A potential hydroecological indicator of ground water perturbations. Journal of the American Water Resources Association 36:55-64.

Barnett, V. and T. Lewis. 1984. Outliers in statistical data. John Wiley and Sons, New York.

Barrett, S.C.H. and J.R.K. Kohn. 1991. Genetic and evolutionary consequewnces of small population size in plants. Pp. 3031. In. D.A. Falk and K. Holsinger. Eds. Genetics and conservation of rare plants. Oxford University Press, New York.

Beck, D.E. 1970. Effect of competition on survival and height growth of red oak seedlings. USDA Forest Service, Southeastern Forest Experiment Station, Research Paper SE-56, Asheville, NC.

Beissinger, S.R. and M. I. Westphal. 1998. On the use of demographic models of population viability in endangered species management. Journal of Wildlife Management 62:821-841.

Belsley, D.A., E. Kuh, and R.E. Welsch. 1980. Regression diagnostics. Wiley, New York.

Bennett, S.H. and J.B. Nelson. 1991. Distribution and status of Carolina bays in South Carolina. Nongame and Heritage Trust Publication 1. South Carolina Wildlife and Marine Resources Department, Columbia, SC.

Bierzychudek, P. 1982. Life histories and demography of shade-tolerant termperate forest herbs: a review. New Phytologist 90:757-776.

Billups, S.E. and M.K. Burke. 1999. Influence of canopy density on ground vegetation in a bottomland hardwood forest. Pp. 195-200. USDA Forest Service, Southern Research Station, General Technical Report SRS-30, Asheville, NC.

Bledsoe, B.P. and T. H. Shear. 2000. Vegetation along hydrologic and edaphic gradients in a North Carolina Coastal Plain creek bottom and implications for restoration. Wetlands 20:126-147).

Bolton, S.C. and J.E. Metzger. 1998. The Vicksburg District 1977-1991. U.S. Army Corps of Engineers. Vicksburg District. Vicksburg, MS.

Boyce, M.S. 1987. Time-series analysis and forecasting of the Aransas/Wood Buffalo Whooping Crane population. Pp. 1-9. In. J.C. Lewis. Ed. Proceedings of the 1985 Crane Workshop, Platte River Whooping Crane Habitat Maintenance Trust, Grand island, Nebraska.

Braun, E.L. 1950. Deciduous forests of Eastern North America. Hafner Press. New York, NY.

Brinson, M.M. 1990. Riverine forests. Pp. 87-141. In. A.E. Lugo, M.M. Brinson, and S. Brown. Eds. Ecosystems of the world 15: forested wetlands. Elsevier Scientific Publishing. New York.

Brinson, M.M. 1993. A hydrogeomorphic classification for wetlands. Technical report WRP-DE-4. U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS.

Brook, B.W., D.W. Tonkyn, J.J. O'Grady, and R. Frankham. 2002. Contribution of inbreeding to extinction risk in threatened species. Conservation Ecology 6:16.

Brooks, R.T. 2004. Weather-related effects on woodland vernal pool hydrology and hydroperiod. Wetlands 24:104-114.

Brooks, R.T. 2005. A review of basin morphology and pool hydrology of isolated ponded wetlands: implication for seasonal forest pools of the northeastern United States. Wetlands Ecology and Management 13:335-348.

Bryant, R.M. 2007. Laurel wilt disease: an ecological disaster, extinction of red bay trees in the southeast. Workshop summary, on rapid decline of red bay, January 18, 2007, Jekyll Island, GA. International Paper Company, Southlands Experimental Forest, Bainbridge, GA.

Burdick, D.M. and I.A. Mendelssohn. 1990. Relationship between anatomical and metabolic responses to soil waterlogging in the coastal grass *Spartina patens*. Journal of Experimental Botany 41:223-228.

Burke, M.K., S.L. King, D. Gartner, and M.H. Eisenbies. 2003. Vegetation, soil, and flooding relationships in a blackwater floodplain forest. Wetlands 23:988-1002.

Burrough, P.A. 1986. Principles of geographical information systems for land resource assessment. Wiley Interscience, New York.

Butterwick, M. 1998. The hydrogeomophic approach and its use in vernal pool functional assessment. Pp. 50-55. In. C.W. Witham, E.t. Bauder, D. Belk, W.R. Ferren, Jr., and R. Ornduff. eds. Ecology, Conservation, and Management of Vernal Pool Ecosystems. California Native Plant Society, Sacramento, CA.

Campbell, D. 1985. Pollen and gene dispersal: the influences of competition for pollination. Evolution 39:418-431.

Chmielewski, R.M. 1966. Hydrological analysis of Carolina bay wetlands at the Savannah River Site, South Carolina. M.S. Thesis. University of Wisconsin-Milwaukee, Milwaukee, WI.

Christensen, N.L. 1988. Vegetation of the southeastern Coastal Plain. Pp. 317-363. *In* M.G. Barbour and W.D. Billings (eds.). North American Terrestrial Vegetation. Cambridge University Press. Cambridge, England.

Clairain, E.J., Jr. 2002. Hydrogeomorphic approach to assessing wetland functions: guidelines for developing regional guidebooks. Chapter 1. Introduction and overview and overview of the hydrogeomophic approach. ERDC/EL TR-02-3, U.S. Army Research and Development Center, Vicksburg, MS.

Clatterbuck, W.K. and J.S. Meadows. 1993. Regenerating oaks in the bottomlands. Pp. 184-195. *In* D.L. Loftis and C.E. McGee. (eds.). Oak regeneration: serious problems, pratical recommendations. USDA Forest Servcie Southeastern Forest Experiment Station, General Technical Report SE-84, Asheville, NC.

Cohen, J. 1988. Statistical power analysis for the behavioral scienc3es. Academic Press, New York.

Cohen, J. 1990. Things I have learned so far. American Psychologist 45:1304-1312.
Colegrave, D. and G.D. Ruxton. ??. Confidence intervals are a more useful compliment to nonsignificant tests than are power calculations. Behavioral Ecology 14:446-450.

Comer, P., D. Faber-Langendoen, R. Evans, S. Gawler, C. Josse, G. Kittel, S. Menard, M. Pyne, M. Reid, K. Schulz, K. Snow, and J. Teague. 2003. Ecological systems of the United States: A working classification of U.S. terrestrial systems. NatureServe, Arlington, VA.

Conner, W. and J.W. Day, Jr. 1982. The ecology of forested wetlands in the southeastern United States. Pp. 69-87. *In* B. Gopal, R. Turner, R. Wetzel, and D. Whigham (eds.). Wetlands: Ecology and Management. International Science Publishers, Jaipur, India.

Connor, K.F., G.M. Schafer, J. Donahoo, M. Devall, E. Gardiner, T. Leininger, D. Wilson, N. Schiff, P. Hamel, and C. Echt. 2006. A study of the early fruit characteristics of pondberry. Pp. 564-568. In. K. Connor. Ed. Proceedings of the 13th Biennial Southern Silviculture Research Conference. General Technical Report SRS-92. Southern Research Station, USDA Forest Service. Asheville, NC.

Corner, P., K. Goodin, A. Tomainao, G. Hammerson, G. Kittel, S. Menard, C. Nordman, M. Pyne, M. Reid, L. Sneddon, and K. Snow. 2005. Biodiversity values of geographically isolated wetlands in the United States. NatureServe, Arlington, VA.

Crawford, R.M. and P.D. Tyler. 1969. Organic acid metabolism in relation to flooding tolerance in roots. Journal of Ecology 57:235-244.

Cronk, J.K. and M.S. Fennessy. 2001. Wetland plants: biology and ecology. Lewis Publishers, New York.

Damman, H. and M.L. Cain. 1998. Population growth and viability analyses of the clonal woodland herb, *Asarum canadense*. Journal of Ecology 86:13-26.

Daubenmire, R. 1968. Plant communities: a textbook of plant synecology. Harper and Row, New York.

Dayton, P.K. 2001. Reversal of the burden of proof in fisheries management. Science 279:821-822.

Dennis, B. 1989. Allee effects: population growth, critical density, and the chance of extinction. Natural Resource Modeling 3:481-538.

Dennis, B., P.L. Munholland, and J.M. Scott. 1991. Estimation of growth and extinction parameters for endangered species. Ecological Monographs 61:115-143.

De Steven, D. 1989. Genet and ramet demography of *Oenocarpus mapora* ssp. *mapora*, a clonal palm of Panamanian tropical moist forest. Journal of Ecology 77:579-596.

De Steven, D. and M. M. Toner. 2004. Vegetation of upper coastal plain depression wetlands: environmental templates and wetland dynamics within a landscape network. Wetlands 24:23-42.

Devall, M.S. 2006. Personal communication with Will McDearman, U.S. Fish and Wildlife Service, regarding status of Shelby population. USDA Forest Service, Southern Research Station, Center for Bottomland Hardwoods Research. Stoneville, MS.

Devall, M.S., N. Schiff, and D. Boyette. 2001. Ecology and reproductive biology of the pondberry, *Lindera melissifolia* (Walt.) Blume. Natural Areas Journal 21:250-258.

Devall, M.S., N. Schiff, and P. Hamel. 2002. Ecosystem dynamics and the sustainability of native pondberry (*Lindera melissifolia* [Walt.] Blume) colonies in Mississippi. Study Plan Summary (June). FS-SRS-4155-02. Problem 4. USDA Forest Service, Southern Research Station, Center for Bottomland Hardwoods Research. Stoneville, MS.

Devall, M.S., N.M. Schiff, and S.A. Skojac. 2003. Introduction of the endangered pondberry (*Lindera melissifolia* [Walt.] Blume) to new sites in Mississippi. Abstract. Botany 203 Conference, Botanical Society of America.

Devall, M.S., N. Schiff, and S. A. Skojac. 2004. Reproductive biology of pondberry (*Lindera melissifolia* [Walt.] Blume). Abstract. Botany 2004 Conference. Botanical Society of America. Salt Lake City, UT.

Dewey, J.C., S.H. Schoenholtz, J.P. Shepard, and M.G. Messina. 2006. Issues related to wetland delineation of a Texas, USA bottomland hardwood forest. Wetlands 26:410-429.

Diaz-Ramos, S., D. L. Stevens, Jr., and A.R. Olsen. 1996. EMAP statistical methods manual. EPA/620/R-96/002. Office Research and Development, NHEERL-Western Ecology Division.U.S. Environmental Protection Agency, Corvalis, OR.

Didham, R.K., J. Ghazouil, N.E. Stork, and A.J. Davis. 1996. Insects in fragmented forest: a functional approach. Trends in Ecology and Evolution 11:255-260.

Dudash, M.R. 1990. Relative fitness of selfed and outcrossed progeny in a self-compatible, protandrous species, *Sabatia angularis* L. (Gentianaceae); a comparison in three environments. Evolution 44:1129-1139.

Eberhardt, L.L. and J.M. Thomas. 1991. Designing environmental field studies. Ecological Monographs 61:53-73.

Echt, C. 2003. Genotyping of *Lindera melissifolia* populations on the Delta National Forest. Preliminary findings. Report for pondberry investigator's meeting. USDA Forest Service, Southern Forest Experiment Station. Stoneville, MS.

Echt, C. 2006. Personal communication with Will McDearman, U.S. Fish and Wildlife Service, and unpublished data, regarding status of genetic and DNA microsattelite studies with pondberry. USDA Forest Service, Southern Research Station, Center for Bottomland Hardwoods Research. Stoneville, MS.

Echt, C. 2007. Personal communication with Will McDearman, U.S. Fish and Wildlife Service, regarding status of pondberry at the Shelby Site, Bolivar County, Mississippi. USDA Forest Service, Southern Research Station, Center for Bottomland Hardwoods Research. Stoneville, MS.

Echt, C. 2007. Personal communication with Will McDearman, U.S. Fish and Wildlife Service, regarding genotypes and genetic status of pondberry stock plants at CBHR. USDA Forest Service, Southern Research Station, Center for Bottomland Hardwoods Research. Stoneville, MS.

Echt, C., D. Deemer, D. Gustafson, K. Connor, M. Devall, P. Hamel, E. Gardiner, T. Hawkins, B. Lockhart, T. Leininger, N. Schiff, and D. Wilson. 2007. Genetic differences among populations of the engendered pondberry. Draft abstract prepared for meeting of pondberry researchers. USDA Forest Service, Southern Research Station, Center for Bottomland Hardwoods Research. Stoneville, MS.

Ellstrand, N.C. and D.R. Elam. 1993. Population genetic consequences of small population size: implications for plant conservation. Annual Review of Ecology and Systematics 24:217-242.

Erdfelder, E., F. Faul, and A. Buchner. 1996. G*Power: a general power analysis program. Behavior Research Methods, Instruments, and Computers 28:1-11.

Eriksson, O. 1993. Dynamics of genets in clonal plants. Trends in Ecology and Evolution 8:313-316.

Ernst, W.H.O. 1990. Ecophysiology of plants in waterlogged and flooded environments. Aquatic Botany 38:73-90.

Eudaly, E.M. 2005. Pondberry (*Lindera melissifolia*) monitoring, Marine Corps Air Station, Beaufort, South Carolina. U.S. Fish and Wildlife Service, Charleston, SC.

Everitt, B.S. 1992. The analysis of contingency tables: monographs on statistics and applied probability 45. Chapman & Hall, New York.

Fahrig, L. 2002. Effect of habitat fragmentation on the extinction threshold: a synthesis. Ecological Applications 12:346-353.

Fairweather, P.G. 1991. Statistical power and design requirements for environmental monitoring. Australian Journal of Marine and Freshwater Research 42:555-567.

Federal Register. 1997. Revision of the National List of Plant Species That Occur in Wetlands. Notice of availability and request for comments. January 17, 1997. Federal Register 62(12): 2680-2681.

Fenster, C. and M. Dudash. 1994. Genetic considerations for plant population restoration and conservation. Pp. 34-62. In. M. Bowles and C. Whelan. Eds. Restoration of endangered species: conceptual issues, planning, and implementation. Cambridge University Press, Cambridge, UK.

Fischer, M. and D. Matthies. 2000. Effects of population size on performance in the rare plant *Gentianella germanica*. Journal of Ecology 86:195-204.

Fischer, M. and D. Matthies. 1998. RAPD variation in relation to population size and plant performance in the rare *Gentianella germanica*. American Journal of Botany 85:811-819.

Foti, T. 1992. Correspondence to Allan Mueller, U.S. Fish and Wildlife Service, Vicksburg, MS. Comments on pondberry profile workshop. Arkansas Natural Heritage Program, Little Rock, AR.

Fraedrich, S.W. 2005. Association of *Xyleborus glabratus* and an *Ophiostoma* sp. With mortality of red bay (*Persea borbonia*) in Georgia and South Carolina. Poster. Annual Meeting of the American Phytopathological Society, July 30-August 3, 2005, Austin, TX.

Fraedrich, S.W. T.C. Harrington, and R.J. Rabaglia. 2006. An *Ophiostoma* species and *Xyleborus glabratus* threaten red bay (*Persea borbonia*) and other members of the Lauraceae in the southeastern United States. Poster. Conference on Advances in Threat Assessment and Applications to Forest and Rangeland Management. July 18-20, U.S. Forest Service, Boulder, CO.

Galen, C. and R.C. Plowright. 1984. The effects of nectar level and flower development on pollen carryover in inflorescences of fireweed (*Epilobium angustifolium*) (Onagraceae). Canadian Journal of Botany 63:488-491.

Galloway, G.E. 1980. Ex-post evaluation of regional water resources development: the case of the Yazoo-Mississippi Delta. Report No. IWR-80-D1. U.S. Army Corps of Engineers, Water Resources Support Center, Institute for Water Resources.

Gausch, H.G. and T.R. Wentworth. 1976. Canonical correlation analysis as an ordination technique. Vegetatio 33:17-22.

Gausch, H.G. 1982. Multivariate analysis in community ecology. Cambridge University Press, Cambridge.

Geber, M. 1985. The relationship of plant size to self-pollination in *Mertensia cliata*. Ecology 66:762-72.

Geo-Marine, Inc. 1991. Pondberry profile, endangered specie study. Contract No. DACW38-90-D-0003. Report prepared for U.S. Army Corps of Engineers, Vicksburg District. Baton Rouge, LA.

Gilbert, E.F. 1966. Structure and development of sumac clones. American Midland Naturalist 75:432-445.

Gittins, R. 1979. Ecological applications of canonical analysis. Pp. 309-535. In. L. Orloci, C.R. Rao, and W.M. Stiteler. Eds. Multivariate methods in ecological work. Statistical Ecology, No. 7. Fairland, MD.

Glitzenstein, J. and D. Streng. 2004. Francis Marion National Forest pondberry (*Lindera melissifolia*) monitoring report. Francis Marion National Forest, Columbia, SC.

Glitzenstein, J., J. Brubaker, D. Streng, R. Roecker, D. Giordano, and D. Carlson. Undated. South Carolina Native Plant Society pondberry final report. South Carolina Native Plant Society, Columbia, SC.

Godfrey, R.K. and J.W. Wooten. 1981. Aquatic and wetland plants of southeastern United States. University of Georgia Press, Athens, GA.

Godt, M.J. and J.L. Hamrick. 1996. Allozyme diversity in the endangered shrub *Lindera melissifolia* (Lauraceae) and its widespread congener *Lindera benzoin*. Canada Journal of Forest Research. 26:2080-2087.

Godt, M.J.W., T. Race, and J.L. Hamrick. 1997. A population genetic analysis of *Ziziphus celata*, an endangered Florida shrub. Journal of Heredity 88:53-55.

Goodman, D. 1987. The demography of chance extinction. Pp. 11-34. In. M.E. Soulé. Ed. Viable populations for conservation. Cambridge University Press, Cambridge, UK.

Gosselink, J.G., L.C. Lee, and T.A. Muir. 1990. Ecological processes and cumulative impacts: illustrated by bottomland by bottomland hardwood wetland ecosystems. Lewis Publishers, Chelsea, MI.

Gosselink, J.G., B.A. Touchet, J. Van Beek, D. Hamilton, with Panel. 1990b. Bottomland hardwood forest ecosystem hydrology and the influence of human activities: the report of the hydrology workgroup. Pp. 348-387 *In* J.G. Gosselink, L.C. Lee, and T.A. Muir (eds.). Ecological Processes and Cumulative Impacts: Illustrated by Bottomland Hardwood Wetland Ecosystems. Lewis Publishers. Chelsea, Michigan.

Goodman, D. 1987. The demography of chance extinction. Pp. 13-34. In. M.E. Soule. Ed. Conservation biology: the science of scarcity and diversity. Sinauer.

Goodman, S.N. and J.A. Berlin. 1994. The use of predicted confidence intervals when planning experiments and the misues of power when interpreting results. Annals of Internal Medicine 121:200-206.

Grime, J.P. 1977. Evidence or the existence of three primary strategies in plants and its relevance to ecological and evolutionary theory. American Naturalist 111:1169-1194.

Grime, J.P., J.G. Hodgson, and R. Hunt. 1988. Comparative plant ecology. Allen & Unwin, London.

Groom, M.J. 1998. Allee effects limit population viability of an annual plant. The American Naturalist 151:487-496.

Groom, M.J. 2001. Consequences of subpopulation isolation for pollination, herbivory, and population growth in *Clarkia concinna concinna* (Onagraceae). Biological Conservation 100:55-63.

Groom, M.J. and M. A. Pascual. 1997. The analysis of population persistence: an outlook on the practice of viability analysis. Pp 1-27 In P.L. Fiedler and P.M. Karieva. Eds. Conservation biology for the coming decade. Chapman and Hall, New York.

Gulf South Biological Surveys. 2001. Hydrology and habitat evaluation of fifty-one selected colonies of pondberry in Delta National Forest, MS. Report to U.S. Fish and Wildlife Service, Jackson, Mississippi Field Office. Wiggins, MS.

Gulf South Research Corporation. 2000. Final survey report: reevaluation of pondberry in Mississippi. Prepared for U.S. Army Corps of Engineers, Vicksburg District. Baton Rouge, LA.

Gulf South Research Corporation. 2001. Revised final report: survey report, re-evaluation of pondberry in Mississippi. Prepared for U.S. Army Corps of Engineers, Vicksburg District. Baton Rouge, LA.

Gulf South Research Corporation. 2005. Final survey report: re-evaluation of pondberry (*Lindera melissifolia*) in Big Sunflower River and Yazoo River Backwater Areas. Attachment 6 In. Appendix 14: Endangered and threatened species biological assessment. U.S. Army Corps of Engineers, Vicksburg, MS. .

Hammatt, N. and P.K. Evans. 1985. the in vitro propagation of an endangered species: *Centaurea junoniana* Svent. (Compositae). Journal of the Horticulture Society 60:93-97.

Hawkins, T.S., B. R. Lockhart, M.S. Devall, N.M. Schiff, and P. Hamel. 2005. Bottomland hardwood forest composition and structure associated with occurrence of the federally endangered species *Lindera melissifolia* (Lauraceae) in Mississippi. ??????

Hawkins, T.S., D.D. McCowan, N.M. Schiff, E. S. Gardiner, T. Leininger, M.S. Devall, D. Wilson, and P. Hamel. 2007. Micropropagation of the endangered shrub pondberry (*Lindera melissifolia* [Walt.] Blume). HortScience. In Press.

Hamrick, J.L. 1987. Gene flow and distribution of genetic variation in plant populations. Pp. 53-57. In K.M. Urbanska. ed. Differentiation patterns in higher plants. Academic Press, London.

Hamrick, J.L., M.J.W. Godt, D.A. Murawski, and M.D. Loveless. 1991. Correlations between species traits and allozyme diversity: Implications for conservation biology. Pp. 75-86. In. D.A. Falk and K.E. Holsinger. Eds. Genetics and Conservation of Rare Plants. Oxford University Press, New York.

Hanes, T. 1998. Hydrology of vernal pools on non-volcanic soils in the Sacramento Valley. Pp. 38-49. In. C.W. Withan. E.T. Baudner, D. Belk, W.R. Ferren, Jr., and R. Ornduff. eds. Ecology, conservation, and management of vernal pool ecosystems. Proceedings from the 1996 Conference. California Native Plant Society, Sacramento, CA.

Hara, T. 1984. A stochastic model and the moment dynamics of the growth and size distribution in plant populations. Journal of Theoretical Biology 109:173-190.

Heineke, T.E. 1987. The flora and plant communities of the middle Mississippi River Valley. Ph.D. dissertation. Southern Illinois University, Carbondale, IL.

Heinrich, B. 1975. Energetics of pollination. Annual Reviews of Ecology and Systematics 6:139-170.

Hendricks, E.L. and M.H. Goodwin. 1952. Water-level fluctuations in limestone sinks in southwestern Georgia. U.S. Geological Survey Water Supply Paper 1110-E.

Heschel, M.S. and K. N. Paige. 1995. Inbreeding depression, environmental stress, and population size variation in scarlet gilia (*Ipompsis aggregate*). Conservation Biology 9:126-133.

Hill, M.O. and H.g. Gauch. 1980. Detrended correspondence analysis, an improved ordination technique. Vegetatio 42:47-48.

Hodges, J.D. and E.S. Gardiner. 1993. Ecology and physiology of oak regeneration. Pp. 54-65d. *In*. D. Loftis and C.E. McGee. (eds.). Oak regeneration: serious problems, practical recommendations. USDA Forest Service, Southeastern Forest Experiment Station, General Technical Report SE-84, Asheville, NC.

Hoenig, J.M. and D. M. Heisey. 2001. The abuse of power: the pervasive fallacy of power calculations for data analysis. American Statistical Association 55:1-6.

Hook, D.D. and C.L. Brown. 1973. Root adaptations and relative flood tolerance of fine hardwood species. Forest Science 19:225-229.

Huenneke, L.F. 1987. Demography of a clonal shrub, *Alnus incana* ssp. *rugosa* (Betulaceae). American Midland Naturalist 117:43-55.

Huenneke, L.F. and P.L. Marks. 1987. Stem dynamics of the shrub *Alnus incanna* ssp. *rugosa*: a transition matrix. Ecology 68:1234-1242.

Huffman R. T., S. W. Forsythe. 1981. Bottomland hardwood communities and their relation to anaerobic soil conditions. P. 187–196. *In* J. R. Clark and J. Benforado (eds.) Wetlands of Bottomland Hardwood Forests. Elsevier Scientific Publishing Company, New York, NY, USA.

Hutchings, M.J. 1989. The structure of plant populations. Pp. 97-136. *In* M.J. Crawley (ed). Plant Ecology. Blackwell. Oxford, UK.

James, F.C. and C.E. McCulloch. 1990. Multivariate analysis in ecology and systematics: panacea or Pandora's box? Annual Review of Ecology and Systematics 21:129-166.

Janzen, G.C. and J.D. Hodges. 1987. Development of advanced oak regeneration as influenced by removal of mistory and under-story vegetation. Pp. 455-461. *In*. Proceedings of the Fourth Southern Silvicultural Research Conference, November 4-6, 1986, Atlanta, GA. USDA Forest Service, Southeastern Forest Experiment Station, Technical Report SE-42. Asheville, NC.

Johnson, D.E. 1998. Applied multivariate methods for data analysis. Duxbury Press.

Johnson, D.H. 1999. The insignificance of statistical significance testing. Journal of Wildlife Management 63:763-772.

Johnson, D. 2006. Personal communication with Will McDearman, U.S. Fish and Wildlife Service, Jackson, MS, regarding GIS data, flood frequency, and other changes by the project in the 1-year floodplain. U.S. Army Corps of Engineers, Vicksburg, MS.

Johnson, R.L. 1975. Natural regeneration and development of Nuttall oak and associated species. USDA Forest Service, Southern Forest Experiment Station, Research Paper SO-104, New Orleans, LA.

Johnson, R.L. 1981. Wet silvicultural systems. Pp. 63-79. *In* Proceedings, Hardwood Regeneration Symposium, January 29, Atlanta, GA. Southeastern Lumber Manufacturing Association, Forest Park, GA.

Karron, J.d. 1989. Breeding systems and levels of inbreeding depression in geographically restricted and widespread species of *Astragalus* (Fabaceae). American Journal of Botany 76:331-340.

Kearns, C.A. D.W. Inouye, and N.M. Waser. 1998. Endangered mutualisms: the conservation of plant-pollinator interactions. Annual Review of Ecology and Systematics 29:83-112.

Keiding, N. 1975. Extinction and exponential growth in random environments. Theoretical Population Biology 8:49-63.

Keller, L.F. and D.M. Waller. 2002. Inbreeding effects in wild populations. Trends in Ecology and Evolution 17:230-241.

Kendall, B.E. 1998. Estimating the magnitude of environmental stochasticity in survivorship data. Ecological Applications 8:184-1993.

Kery, M., D. Matthies, and H. Spillman. 2000. Reduced fecundity and offspring performance in small populations of the declining grassland plants *Primula veris* and *Gentiana lutea*. Journal of Ecology 88:17-30.

Kienzle, S. 2004. The effect of DEM resolution on first order, second order, and compound terrain derivatives. Transactions in GIS 8:83-11.

Kirk, R. 1996. Practical significance: a concept whose time has come. Educational and Psychological Measurement 56:746-759.

Kirkman, L.K. and R.R. Sharitz. 1994. Vegetation disturbance and maintenance of diversity in intermittently flooded Carolina bays in South Carolina. Ecological Applications 4:177-188.

Kirkman, L.K., S.W. Golladay, L. Laclaire, and R. Sutter. 1999. Biodiversity in southeastern, seasonally ponded, isolated wetlands: management and policy perspectives for research and conservation. Journal of the American Benthological Society 18:553-562.

Kirkman, L.K., P.C. Goebel, L. West, M.B. Drew, and B.J. Palik. 2000. Depressional wetland vegetation types: a question of plant community development. Wetlands 20:373-385.

Klimas, C.V., E.O. Murray, J. Pagan. H. Langston, and T. Foti. 2004. A regional guidebook for applying the hydrogeomorphic approach to assessing wetland functions of forested wetlands in the Delta region of Arkansas, Lower Mississippi River Alluvial Valley. ERDC/EL TR-04-16.
Environmental Laboratory, Engineer Research and Development Center, U.S. Army Corps of Engineers. Vicksburg, MS

Klimas, C.V., E.O. Murray, J. Pagan, H. Langston, and T. Foti. 2005. A regional guidebook for applying the hydrogeomorphic approach to assessing wetland functions of forested wetlands in the West Gulf Coastal Plain region of Arkansas. ERDC/EL TR-05-2. Environmental Laboratory, Engineer Research and Development Center, U.S. Army Corps of Engineers. Vicksburg, MS

Kolb, C.R., W.B. Steinriede, Jr., E.L. Krinitzsky, R.T. Saucier, P. R. Mabry, F.L. Smith, and A.R. Fleetwood. 1968. Geological investigations of the Yazoo Basin, Lower Mississippi Valley. Technical Report TR-3-480 (map folio). U.S. Army Engineer Waterways Experimehnt Station, Vicksburg, MS.

Kramer, P.J. and T.T. Kozlowski. 1979. Physiology of woody plants. Academic Press, New York.

Lacy, R.C. 1993. Vortex: a computer simulation model for population viability analysis. Wildlife Research 20:45-65.

Lande, R. 1987. Extinction thresholds in demographic models of terrestrial populations. Oecologia 130:624-635.

Lande, R. 1993. Risks of population extinction from demographic and environmental stochasticity and random catastrophes. American Naturalist 142:911-927.

LeBlond, R. 2006. Personal communication with Will McDearman, U.S. Fish and Wildlife Service, Jackson, MS, regarding the status of pondberry at Big Pond Bay, White Woods, and Bladen Co., NC. North Carolina Natural Heritage Program, Raleigh, NC.

Lennartsson, T. 2002. Extinction thresholds and disrupted plant-pollinator interactions in fragmented plant populations. Ecology 83:3060-3072.

Lennartsson, T. and J.G.B. Oostermeijer. 2001. Demographic variation and population viability in *Gentianella campestris*: effects of grassland management and environmental stochasticity. Journal of Ecology 89:451-463.

Leonard, S.W. 1995. Monitoring, management, and restoration of pondberry (*Lindera melissifolia*) in North Carolina. Report to the Plant Protection Section, North Carolina Department of Agriculture. Raleigh, NC.

Levin, D.A. 1981. Dispersal versus gene flow in plants. Annals of the Missouri Botanical Garden 68:233-253.

Levin, D.A. and H.W. Kerster. 1971. Neighborhood structure in plants under diverse reproductive methods. American Naturalist 195:345-354.

Levin, D.A. and H.W. Kerster. 1974. Gene flow in seed plants. Evolutionary Biology 7:139-220.

Li, Z. 1992. Variation of the accuracy of digital terrain models with sampling interval. Photogrammetric Record 14:113-128.

Lide, R.F., V.G. Meentemeyer, J .E. Pinder, III, and L.M. Beatty. 1995. Hydrology of a Carolina bay located on the upper Coastal Plain of western South Carolina. Wetlands 15:47-57.

Loftis, D.L. 1983. Regenerating red oak on productive sites in the southern Appalachians: a research proposal. Pp. 144-150. *In*. Proceedings of the Secon Bennial Southern Silviculture Research Conference, November 4-5, 1982., Atlanta, GA. USDA Forest Service, Southeastern Forest Experiment Station, Technical Report SE-24. Asheville, NC.

Loftis, D.L. 1988. Regenerating oaks on high-quality sites; an update. Pp. 207-209. *In*. C. Smith, A.W. Perkey, and W.E. Kidd, Jr. (eds.). Workshop on Guidelines for regenerating Appalachian hardwood stands, May 24-26, 1988. Society of American Foresters Publication 88-03. Morgantown, WV.

Loftis, D.L. 1990. A shelterwood method of regenerating red oak in the southern Appalchians. Forest Science 36:917-929.

Machon, N., J.M. Guillon, G. Dobigny, S. Le Cadre, and J. Moret. 2001. Genetic variation in the horsetail *Equisetum variegatum,* Schleich., an endangered species in the Parisian region. Biodiversity and Conservation 10:1543-1554.

Mackie, R. 2006. Personal communication with Will McDearman, U.S. Fish and Wildlife Service, Jackson, MS, regarding habitat and limiting factors for pondberry Francis Marion National Forest, South Carolina. U.S. Forest Service, Clemson, SC.

MacMannon, M. and R.M. Crawford. 1971. A metabolic theory of flooding tolerance: the significance of enzyme distribution and behavior. New Phytology 10:299-306.

MacDonald, P.O., W.E. Frayer, and J.K. Clausser. 1979. Documentation, chronology, and future projections of bottomland hardwood habitat loss in the Lower Mississippi Alluvial Plain. U.S. Fish and Wildlife Service. Vicksburg, MS.

Mansell, R.S., S.A. Bloom, and F. Sun. 2000. A model for wetland hydrology: description and validation. Soil Science 165:384-397.

Mayfield, A.E. and M. C. Thomas. 2006. Pest alert: the redbay ambrosia beetle, *Xylegborus glabratus* Eichoff (Scolytinae: Curculionidae). Florida Department of Agriculture and Consumer Services, Division of Plant Industry. Gainesville, FL.

McDearman, W. 1994a. Unpublished data. Number of pondberry flowers, stem length, and plant size. U.S. Fish and Wildlife Service, Jackson, MS.

McDearman, W. 1994b. Unpublished data. Stem canker presence, absence, dieback, and plant size in Delta National Forest study plots. U.S. Fish and Wildlife Service, Jackson, MS.

McDearman, W. 2006. Unpublished data. Permanent plot data from 2006, Colby population, Delta National Forest. U.S. Fish and Wildlife Service, Jackson, MS.

McGarigal, K., S. Cushman, and S. Stafford. 2000. Multivariate statistics for wildlife and ecology research. Springer Verlag.

McGoun, D. undated. Review of Appendix 14: Pondberry biological assesssent. Attachment 5 In. U.S. Army Corps of Engineers. 2005. Appendix 14: Endangered Threatened Species Biological Assessment. (revised). Yazoo Backwater Area, Mississippi, Reformulation Report. Flood Control, Mississippi River and Tributaries, Yazoo Basin. Draft Supplemental Environmental Impact Statement. Vickburg, MS.

Meadows, J.S. 1994. Stand development and silviculture in bottomland hardwoods. Pp. 12-16. *In*. W.P. Smith and D.N. Pashley. (eds.). Proceedings of the Workshop to Resolve Conflicts in the Conservation of Migratory Landbirds in Bottomland Hardwood Forests, August 9-10, Tallulah, LA. USDA Forest Service, Southern Forest Experiment Station, General Technical Report, New Orleans, LA.

Meadows, J.S. and J.A. Stanturf. 1997. Silvicultural systems for southern bottomland hardwood forests. Forest Ecology and Management 90:127-140.

Mendelssohn, I.A., K.L. McKee and M.L.Postek. 1982. Sublethal stresses controlling *Spartina alterniflora* productivity. Pp. 223-242 *In* B. Gopal, R.E. Turner, R.G. Wetzel, and D.F. Whigham (eds.). Wetlands Ecology and Management. National Institute of Ecology and International Science Publications, Jaipur, India.

Menges, E.S. 1990. Population viability analysis of a rare plant. Conservation Biology 4:52-62.

Menges, E.S. 1991a. The application of minimum viable population theory to plants. Pp. 45-61. In. D.A. Falk and K.E. Holsinger. Eds. Genetics and Conservation of Rare Plants. Oxford University Press, New York.

Menges, E.S. 1991b. Seed germination percentage increases with population size in a fragmented prairie species. Conservation Biology 5:158-164.

Menges, E.S. 1992. Stochastic modeling of extinction in plant populations. Pp. 253-275. In. P.L. Fiedler and S. K. Jain. Eds. Conservation biology: the theory and practice of nature conservation, preservation, and management. Chapman and Hall, New York, New York.

Menges, E.S. 2000. Population viability analyses in plants: challenges and opportunities. Trends in Ecology and Evolution 15:51-56.

Mentis, M.T. 1988. Hypothetico-deductive and inductive approaches in ecology. Functional Ecology 2:5-14.

Middleton, B.A. 2002. Flood pulsing in the regeneration and maintenance of species in riverine forested wetlands of the southeastern United States. Pp. 223-294. In. B.A. Middleton. Ed. Flood pulsing in wetlands: Restoring the natural hydrological balance. John Wiley & Sons, Inc.

Mississippi River Commission. 1959. Comprehensive review of the Mississippi River and Tributaries Project. Submitted in response to a resolution by the Committee on Public Works of the United States Senate, Adopted 12 June 1954. Mississippi River Commission and U.S. Army Corps of Engineers.

Mitsch, W.J. and J.G. Gosselink. 1993. Wetlands. 2nd edition. Van Nostrand Reinhold, New York.

Mitsch, W.J. and J.G. Gosselink. 2000. Wetlands. 3rd edition. John Wiley & Sons, New York.

Middleton, B.A. 2002. Flood pulsing in the regeneration and maintenance of species in riverine forested wetlands of the southeastern United States. Pp. 223-294. In. B.A. Middleton. Ed. Flood pulsing in wetlands: Restoring the natural hydrological balance. John Wiley & Sons, Inc.

Morgan, J. 1999. Effects of population size on seed production and germinability in an endangered, fragmented grassland plant. Conservation Biology 13:266-273.

Morgan, S. 1983. *Lindera melissifolium*: a rare southeastern shrub. Natural Areas Journal 3:62-67.

Morris, W.F. and D.F. Doak. 2002. Conservation biology: theory and practice of population viability analysis. Sinauer Associates.

Morris, W.F., M. Mangel, and F.R. Adler. 1995. Mechanisms of pollen dispersal by insect pollinators. Evolutionary Ecology 9:304-317.

Morris, W.F., M.V. Price, N.M. Waser, J.D. Thompson, B. Thompson, and D.A. Stratton. 1994. Systematic increase in pollen carryover and its consequences for geitonogamy. Oikos 71:431-440.

Mulhouse, J.M., Diane De Steven, R.F. Lide, and R.R. Sharitz. 2005. Effects of dominant species on vegetation change in Carolina bay wetlands following a multi-year drought. Journal of the Torrey Botanical Society 132:411-420.

Murphy, D.D. and B.D. Noon. 1991. Coping with uncertainty in wildlife biology. Journal of Wildlife Management 55:773-782.

Murray, E.O. 2006. Personal communication to Cary Norquist, U.S. Fish and Wildlife Service, Jackson, MS, regarding the jurisdictional wetland status of sand ponds, relative to recent Supreme Court rulings, and other conversation with Corps staff involved in preparing guidance relative to these rulings. Coordinator, Arkansas Multi-Agency Wetland Planning Team, Arkansas Game and Fish Commission, Little Rock, AR.

National Research Council. 1995. Wetlands: characteristics and boundaries. Committee on Characterization of Wetlands. Water Science and Technology Board, Board on Environmental Studies and Toxicology, and Commission on Geosciences, Environment, and Resources. National Academy Press. Washington, D.C.

National Research Council. 1995b. Science and the Endangered Species Act. Committee on Scientific Issues in the Endangered Species Act, Board on Environmental Studies and Toxicology, and Commission on Life Sciences. National Academy Press. Washington, D.C.

National Research Council 2007. Elevation data for floodplain mapping. Committee on Floodplain Mapping Technologies, Board on Earth Sciences and Resources, Division of Earth and Life Science. National Academies Press, Washington, DC.

NatureServe. www.natureserve.org/explorer. Arkansas lowland little bluestem-switchgrass sand prairie. CEGL003974. NatureServe. Arlington, VA.

Negash, L. 2002. Successful vegetative propagation techniques for the threatened African pencil cedar (*Juniperus procera* Hoechst. Ex. Endl.). Forest Ecology and Management 161:53-64.

Netter, J. and W. Wasserman. 1974. Applied linear statistical models. Irwin, Inc., Homewood, IL.

Newman, D. and D. Pilson. 1997. Increased probability of extinction due to decreased genetic effective population size: experimental populations of *Clarkia pulchella*. Evolution 52:342-362.

Nix, L.E. and S.K. Cox. 1987. Cherrybark oak enrichment plantings appear successful after seven years in South Carolina bottomlands. *In*. D.R. Phillips. (ed.). Proceedings of the fourth biennial southern silviculture research conference. USDA Forest Service, Southeastern Forest Experiment Station, General Technical Report SE42. Asheville, NC.

Norquist, C. 2006. Personal communication, to Will McDearman, U.S. Fish and Wildlife Service, Jackon, MS, regarding the 1990 pondberry profile workshop, and the conclusions of pondberry experts concerning hydrology. U.S. Fish and Wildlife Service, Jackson, MS.

North Carolina Natural Heritage Program. 2005. Biennial protection plan. Office of Conservation and Community Affairs, Department of Environment and Natural Resources, Raleigh, NC.

O'Hara, C.G., A.A. Davis, and B.A. Kleiss. 2000. A decision support system for prioritizing forested wetland restoration in the Yazoo Backwater Area, Mississippi. U.S. Geological Survey, Water-Resources Investigatios Report 00 4199. Prepared in cooperation with the U.S. Environmental Protection Agency. Pearl, MS.

Omer, C.R., N.E. James, and A.K. Zundel. 2003. Impact of varied data resolution on hydraulic modeling and floodplain delineation. Journal of the American Water Resources Association 39:

Oostermeijer, J.G.B. 2000. Population viability analysis of the rare *Gentiana penumonanthe*: the importance of genetics, demography, and reproductive biology. Pp 313-334. In. A.G. Young and G.M. Clarke. Eds. Genetics, Demography and Viability of Fragmented Populations. Cambridge University Press, Cambridge, UK.

Oostermeijer, J.G.B., M.W. Van Eijck, and J.C.M. den Nijs. 1994. Offspring fitness in relation to population size and genetic variation in the rare perennial plant species *Gentiana pneumonanthe* (Gentianaceae). Oecologia 97:289-296.

Oostermeijer, J.G.B., M.W. Van Eijck, N.C. Van Leeuwen, and J.C.M. den Nijs. 1995. Analysis of the relationship between allozyme heterozygosity and fitness in the rare *Gentiana pneumonanthe* L. Journal of Evolutionary Biology 8:739-757.

Oostermeijer, J.G.B., S.H. Luijten, and J.C.M. den Nijs. 2003. Intergrating demographic and genetic approaches in plant conservation. Biological Conservation 113:389-398.

Orr, J.M., P.R. Sackett, and C.L.Z. DuBois. 1991. Outlier detection and treatment in I/O Psychology: researcher beliefs and an empirical illustration. Personnel Psycology 44:473-486.

Osborne, C. 2006. Personal communication with Cary Norquist, U.S. Fish and Wildlife Service, concerning status of pondberry in Arkansas sand ponds. Arkansas Natural Heritage Commission. Little Rock, AR.

Pagan, J.B. and T.L. Foti. In preparation. A comprehensive floristic inventory and distribution model of unique wetland communities on terraces along the Quachita River in southern Arkansas. Arkansas Natural Heritage Commission and USDA Natural Resource Conservation Service, Little Rock, AR.

Paschke, M., C. Abs, and B. Schmid. 2002. Relationship between population size, allozyme variation, and plant performance in the narrow endemic *Cochleari bavarica*. Conservation Genetics 5:145-156.

Penfound, W.T. 1952. Southern swamps and marshes. Botanical Review 18:413-446.

Pezeshki, S.R., S.W. Matthews, and R.D. Delaune. 1991. Root cortex structure and metabolic responses of *Spartina patens* to soil redox conditions. Environmental and Experimental Botany 31:91-97.

Platt, J.R. 1964. Strong inference. Science 146:347-353.

Pluess, A.R., and J. Stocklin. 2004. Genetic diversity and fitness in *Scabiosa columaria* in the Swiss Jura. Conservation Genetics 5:145-156.

Putnam, J.A. and H.Bull. 1932. The trees of the bottomlands of the Mississippi River Delta Region. Occasional Paper 27:1-207. U.S. Forest Service, Southern Forest Experiment Station. New Orleans, LA.

Price, M.V. and N.M. Waser. 1982. Experimental studies of pollen carryover: hummingbirds and *Ipomopsis aggregate*. Oecologia 54:353-358.

Proffer, T.J. 1989. *Botryospaeria* cankers and dieback. Plant Pathology Circular No. 325. Division of Plant Industry, Florida Department of Agriculture and Consumer Service.

Pyke, G.H. 197. Optimal foraging: movement patterns of bumblebees between inflorescences. Theoretical Population Biology13:72-98.

Pyke, G.H. 1980. Optimal foraging in nectar-feeding animals and coevolution with their plants. In. A.C. Kamil and T.D. Sargent. eds. Foraging behavior: ecological, ethological, and phychological approaches,. Garland, New York.

Pyke, G.H., H.R. Pulliam, and E.L. Charnov. 1977. Optimal foraging: a selective review of theory and tests. Quarterly Review of Biology 52:137-154.

Price, M.V. and N.M. Waser. 1979. Pollen dispersal and optimal outcrossing in *Delphinium nelsonii*. Nature 277:294-296.

Rayner, D.A. and D.P. Ferral. 1988. Honey Hill lime-sinks final report. South Carolina Natural Heritage Program. Columbia, SC.

Riekerk, H. and L.V. Korhnak. ? The hydrology of cypress wetlands in Florida pine flatwoods. Wetlands 20f:448-460.

Reed, P.B. 1988. National list of plant species that occur in wetlands: national summary. Biological Report 88(24). U.S. Fish and Wildlife Service, Washington, DC.

Reed, P.B. (compiler). 1997. Revision of the National List of Plant Species that Occur in Wetlands. In Cooperation with the National and Regional Interagency Review Panels: U.S. Fish and Wildlife Service, U.S. Army Corps of Engineers, U .S. Environmental Protection Agency, and Natural Resources Conservation Service. Department of Interior, U.S. Fish and Wildlife Service, Washington, DC.

Reed, J.M. and A.R. Blaustein. 1995. Assessment of nondeclining amphibian populations using power analysis. Conservation Biology 9:1299-1300.

Reed, J.M., D. Murphy, and P.F. Brussard. 1998. Efficacy of population viability analysis. Wildlife Society Bulletin 26:244-251.

Richards, C.M. 2000. Inbreeding depression and genetic rescue in a plant metapopulation. American Naturalist 155:383-394.

Ridley, H.N. 1930. The dispersal of plants throughout the world. L. Reeve and Company. Ashford, Kent, England.

Robertson, A.W. 1992. The relationship between floral display size, pollen carryover, and geitonogamy in *Myosotis colensoi* (Kirk) Macbride (Boraginaceae). Biological Journal of the Linnean Society 46:333-349.

Roecker, R. 2001. Pondberry (*Lindera melissifolia*) monitoring in Honey Hill Limesinks, Francis Marion National Forest. USDA Forest Service, Clemson, SC.

Romesburg, H.C. 1981. Wildlife science: gaining reliable knowledge. Journal of Wildlife Management 45:293-313.

Saccheri, I., M. Kuussaari, M. Kankare, P. Vikman, W. Fortelius, and I. Hanski. 1998. Inbreeding and extinction in a butterfly metapopulation. Nature 392:491-494.

Sander, I.L. 1972. Size of oak advance reproduction: key to growth following harvest cutting. USDA Forest Service, North Central Forest Experiment Station, Research Paper NC-79, St. Paul, MN.

Sander, I.L. and F.B. Clark. 1971. Reproduction of upland hardwood forests in the Central States. USDA Forest Service, Agricultural Handbook 405. Washington, DC.

Sanderson, H. and K.R. Solomon. 2003. Precautionary limits to environmental science and risk management: three types of errors. The Journal of Transdisciplinary Environmental Studies 2:1-5.

Saucier, R.L. 1978. Sand dunes and related eolian features of the lower Mississippi River alluvial valley. Geoscience and Man 19:23-40.

Saucier, R.L. 1994. Geomorphology and quaternary geologic history of the Lower Mississippi Valley. Vol. I and II. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
U.S. Army Corps of Engineers. 2000. Yazoo Backwater Area, Mississippi, Reformulation Report. Flood Control, Mississippi River and Tributaries Project. Volume 1. Main Report. Supplement No.: 1 to The 1982 Yazoo Area Pump Project. Final Environmental Impact Statement Flood Control, Mississippi River and Tributaries, Yazoo Basin, Mississippi. Vicksburg District. Vicksburg, MS.

Saucier, R.T. and A.R. Fleetwood. 1970. Origin and chronological significance of late Quarternary terraces, Ouachita River, Arkansas and Louisiana. Geological Society of America Bulletin 81:869-890.

Schaal, B.A. 1980. Measurement of gene flow in *Lupinus texensis*. Nature 284:450-451.

Schafale, M.P. and A.S. Weakley. 1990. Classification of the natural communities of North Carolina. Third Approximation. North Carolina Department of Environment, Health, and Natural Resources, Raleigh, NC.

Schalles, J.F. and D.J. Shure. 1989. Hydrology, community structure, and productivity patterns of a dystrophic Carolina bay wetland. Ecological Monographs 59:365-385.

Schemske, D.W., B.C. Husband, M.H. Ruckelshause, C. Goodwillie, I. Parker, and J. G. Bishop. 1994. Evaluating approaches to the conservation of rare and endangered plants. Ecology 75:584-606.

Schiff, N., M. Devall, and D. Webb. 2003. A partial list of insects associated with pondberry (*Lindera melissifolia* [Walt.] Blume). Poster. Annual meeting of the Entomological Society of America. Cincinnati, OH.

Schleisinger, W.H. and D.S. Gill. 1978. Demographic studies of the chaparral shrub, *Ceanothus megacarpus*, in the Santa Ynez Mountains, California. Ecology 59:1256-1263.

Schmidt, K. and K. Jensen. 2000. Genetic structure and AFLP variation of remnant populations in the rare plant *Pedicularis palustris* (Scrophulariaceae) and its relation to population size and reproductive components. American Journal of Botany 87:678-689.

Schnabel, A. and J.L. Hamrick. 1995. Understanding the population genetic structure of *Gleditsia triacanthos* L.: the scale and pattern of pollen flow. Evolution 49:921-931.

Schoeneweiss, D.F. 1978. Water stress as a predisposing factor in plant disease. Pp. 61-99. In. T.T. Kozlowski. Ed. Water deficits and plant growth. Academic Press, New York.

Scott, M.L., W.L. Slauson, C.A. Segelquist, and G.T. Auble. 1989. Correspondence between vegetation and soils in wetlands and nearby wetlands. Wetlands 9:41-60.

Scott, M.L., B.A. Kleiss, W.H. Patrick, C.A. Segelquist with Panel. 1990. The effect of developmental activities on water quality functions of bottomland hardwood ecosystems: the report of the water quality workgroup. Pp. 411-453. *In* J.G. Gosselink, L.C. Lee, and T.A. Muir (eds.). Ecological Processes and Cumulative Impacts: Illustrated by Bottomland Hardwood Wetland Ecosystems. Lewis Publishers. Chelsea, Michigan.

Shabel, A.B. and D.R. Peart. 1994. Effects of competition, herbivory and substrate disturbance on growth and size structure in pin cherry (*Prunus pennsylvanica* L.) seedlings. Oecologia 98:150-158.

Shartiz, R.R. 2003. Carolina bay wetlands: unique habitats of the southeastern United States. Wetlands 25:550-562.

Sharitz, R.R. and J.W. Gibbons. 1982. The ecology of southeastern shrub bogs (pocosins) and Carolina bays: a community profile. FWS/OBS-82/04. U.S. Fish and Wildlife Service, Division of Biological Services, Washington, DC.

Sharitz, R.R. and W.J. Mitsch. 1993. Southern floodplain forests. Pp. 311-372. *In* W.H. Martin, S.G. Boyce, and A.C. Echternacht (eds.). Biodiversity of the Southeastern United States: Lowland Terrestrial Communities. John Wiley & Sons. New York, NY.

Shelford, V.E. 1954. Some lower Mississippi Valley floodplain biotic communities: their age and elevation. Ecology 35:126-142.

Silverton, J., M. Franco, and K. McConway. 1992. A demographic interpretation of Grime's triangle. Functional Ecology 6:130-136.

Silverton, J., M. Franco, I. Pisanty, and A. Mendoza. 1993. Comparative plant demography – relative importance of life-cycle components to the finite rate of increase in woody and herbaceous perennials. Journal of Ecology 81:465-476.

Silverton, J., M.Franco, and E. Menges. 1996. Interpretation of elasticity matrices as an aid to the management of plant populations for conservation. Conservation Biology 10:591-597.

Smith, T.E. 2003. Observations on the experimental planting of *Lindera melissifolia* (Walter) Blume in southeastern Missouri after ten years. Castanea ??

Smith, T.E. 2006. Personal communication with Cary Norquist, U.S. Fish and Wildlife Service, on the status of pondberry in Missouri. Missouri Department of Conservation. Jefferson City, MO.

Smith, R.D. 2006. E-mail to Will McDearman, U.S. Fish and Wildlife Service, in response to questions about HGM or other data on the hydrology and characteristics of microdepressions, vernal pools, or other features in the Yazoo Basin where wetlands could exist independent of flooding. U.S. Army Corps of Engineers Research and Development Center, Vicksburg, MS.

Smith, A.M. and ap Rees, T. 1979. Pathways of carbohydrate fermentation in the roots of marsh plants. Planta 146:327-334.

Smith, A.M., C.M. Hylton, L. Koch and H.W. Woolhouse. 1986. Alcohol dehydrogenase activity in the roots of marsh plants in naturally waterlogged soils. Planta 168:130-138.

Smith, R.D. and J.S. Wakeley. 2001. Hydrogeomorphic approach to assessing wetland functions: guidelines for developing regional guidebooks. Chapter 4. Developing assessment models. ERDC?EL TR-01-30, U.S. Army Research and Development Center, Vicksburg, MS.

Smith, R.D. and C.V. Klimas 2002. A regional guidebook for applying the hydrogeomorphic approach to assessing wetland functions of selected regional wetland subclasses, Yazoo Basin, Lower Mississippi River Alluvial Valley. ERDC/EL TR-024. Environmental Laboratory, Engineer Research and Development Center, U.S. Army Corps of Engineers. Vicksburg, MS.

Smith, C.G., P.B. Hamel, M.S. Devall, and N.M. Schiff. 2004. Hermit thrush is the first observed dispersal agent for pondberry (*Lindera melissifolia*). Castanea 69:1-8.

Smith, W.P., P.B. Hamel, and R.P. Ford 1993. Mississippi Alluvial Valley forest conversion: implications for eastern North American avifauna. Proceedings of the Annual Conference of Southeastern Fish and Wildlife Agencies 47:460-469.

Solbrig, O.T. 1981. Studies on the population biology of the genus *Viola* II. The effect of plant size on fitness in *Viola sororia*. Evolution 35: 1080-1093.

Sokal, R.R. and F.J. Rohlf. 1981. Biometry: the principles and practice of statistics in biological research. W.H. Freeman and Company. San Francisco, CA.

Soule, M.E. Viable populations for conservation. Cambridge University Press, New York.

Soule, P.T. 1990. Spatial patterns of multiple drought types in the contiguous United States: a seasonal comparison. Climate Research 1:13-21.

Stahle, D.W., M.K. Cleaveland, and J.G. Hehr. 1988. North Carolina climate changes reconstructed from tree rings; A.D. 372-1985. Science 240:1517-1519.

Stanturf, J.A. and J.S. Meadows. 1994. Natural regeneration of southern bottomland hardwoods. Pp. 6-11. *In*. A.F. Egan (ed.). Proceedings of the Southern Regional Council on Forest Engineering, Annual Meeting. March 15-17, 1994, Vicksburg, MS. Office of Agricultural Communications, Mississippi State University, Mississippi State, MS.

StatSoft. 1995. Statistica for Windows. Volume I. General Conventions and Statistics. Tulsa, OK.

Steffan-Dewenter, I., U. Munzenbert, C. Burger, C. Thies, and T. Tscharntke. 2002. Scale dependent effects of landscape context on three pollinator guilds. Ecolgy 83:1421-1432.

Steidl, R.J., J.P. Hayes, and E. Schauber. 1997. Statistical power in wildlife research. Journal of Wildlife Management 61:270-279.

Stevens, D.L., Jr., and A.R. Olsen. 2003. Variance estimation for spatially balanced samples of environmental resources. Environmetrics 14:593-610.

Stevens, D.L., Jr., and A.R. Olsen. 2004. Spatially-balanced sampling of natural resources in the presence of frame imperfections. Journal of the American Statistical Association ?

Streng, D.R., J.S. Glitzenstein, and P.A. Harcombe. 1989. Woody seedling dynamics in an east Texas floodplain forest. Ecological Monographs 59:117-204.

Suiter,, D. 2006. Personal communication with Will McDearman, U.S. Fish and Wildlife Service, regarding the status of pondberry at Big Pond Bay, NC. U.S. Fish and Wildlife Service, Charleston Field Office, SC.

Tabachnick, B.G. and L.S. Fidell. 1989. Using multivariate statistics. 2nd edition. Harper Collins Publishers, New York.

Tappeiner, J.C. 1971. Invasion and development of beaked hazel in red pine stands in northern Minnesota. Ecology 52:514-519.

Ter Braak, D.J.F. 1987-1992. CANOCO-A FORTRAN program for canonical community ordination. Versions 2.1. Microcomputer Power, Ithaca, New York.

Teskey, R.O. and T.M. Hinkley. 1977. Impact of water level changes on woody riparian and wetland communities. Vol. II. The southern forest region. FWS/OBS-77/59. U.S. Fish and Wildlife Service. Washington, DC.

Thieken, A.H., A. Lucke, B. Diekkruger, and O. Richter. 1999. Scaling input data by GIS for hydrological modeling. Hydrological Processes 13:611-630.

Thomas, L. and F. Juanes. 1996. The importance of statistical power analysis: an example from Animal Behaviour. Animal Behaviour 52:856-859.

Thomas, D.R. and C.M. Allen. 1998. Atlas of the vascular flora of Louisiana. Volume III. Louisiana Department of Wildlife, Fisheries, and Parks, Natural Heritage Program, Baton Rouge, LA.

Thomson, J.D. 1986. Pollen transport and deposition of bumble bees in *Erythronium*: influences of floral nectar and bee grooming. Journal of Ecology 74:329-341.

Thomson, J.d. and R.C. Plowright. 1980. Pollen carryover, nectar rewards, and pollinator behavior with special reference to *Diervilla lonicera*. Oecologia 46:68-74.

Thomson, J.D., M.V. Price, N.M. Waser, and D.A. Stratton. 1986. Comparative studies of pollen and fluorescent dye transport by bumble bees visiting *Erythronium grandiflorum*. Oecologica 69:561-566.

Tiner, R.W. 1991. The concept of hydrophyte for wetland identification. BioScience 41:236-247.

Tiner, R.W. 1993. Geographically isolated wetlands of the United States. Wetlands 23:494-516.

Tiner, R.W., H.C. Berquist, G.P. DedAlessio, and M.J. Starr. 2002. Geographically isolated wetlands: a preliminary assessment of their characteristics and status in selected areas of the United States. U.S. Fish and Wildlife Service, Hadley, MA. (http:/wetlands.fws.gov/Pubs_Reports/isolated/report.htm).

Touchet, B.A., S. Faulkner, R. Heeren, D. Kovacic, W. Patrick, and C. Segelquist. 1990. The use of soil classes to delineate transition zones in bottomland hardwood forests: the report of the soils workgroup. Pp. 390-408 *In* J.G. Gosselink, L.C. Lee, and T.A. Muir (eds.). Ecological Processes and Cumulative Impacts: Illustrated by Bottomland Hardwood Wetland Ecosystems. Lewis Publishers. Chelsea, Michigan.

Tucker, G.E. 1984. Status report on *Lindera melissifolia*. Contract report to U.S. Fish and Wildlife Service. Atlanta, GA.

Tucker, G.E. 2006. Personal communication with Will McDearman, U.S. Fish and Wildlife Service, regarding status of pondberry population in the St. Francis River sunken lands. FTN Associates. Little Rock, AR.

Tucker, G.E. 2006b. Personal communication with Will McDearman, U.S. Fish and Wildlife Service, regarding the 1990 pondberry profile workshop, and the conclusions of the pondberry experts regarding ponding and hydrology. FTN Associates. Little Rock, AR.

U.S. Army Corps of Engineers. 1977. Yazoo River Basin, Mississippi, feasibility report and plan of study. Vicksburg District. Vicksburg, MS.

U.S. Army Corps of Engineers. 1990. Minutes of the Pondberry Profile Workshop, December 19, 1990. Vicksburg District, Vicksburg, MS.

U.S. Army Corps of Engineers. 1991. Biological assessment of pondberry (*Lindera melissifolia*), Upper Steele Bayou Project, Mississippi. Vicksburg District, Vicksburg, MS.

U.S. Army Corps of Engineers. 1996. 1996. Final biological assessment of impacts to pondberry (*Lindera melissifolia*) resulting from the Big Sunflower River Maintenance Project. Vicksburg Distric, Vicksburg, MS.

U.S. Army Corps of Engineers. 2000. Yazoo Backwater Area, Mississippi, Reformulation Report. Flood Control, Mississippi River and Tributaries, Yazoo Basin. Draft Supplemental Environmental Impact Statement. Vickburg, MS.

U.S. Army Corps of Engineers. 2001. Revised final report: Survey report re-evaluation of pondberry in Mississippi. Vicksburg District, Vicksburg, MS.

U.S. Army Corps of Engineers. 2005a. Appendix 10: Assessment of wetland resources (revised). To Endangered Threatened Species Biological Assessment. Revised draft to 2000. Yazoo Backwater Area, Mississippi, Reformulation Report. Flood Control, Mississippi River and Tributaries, Yazoo Basin. Draft Supplemental Environmental Impact Statement. Vickburg, MS.

U.S. Army Corps of Engineers. 2005b. Appendix 14: Endangered Threatened Species Biological Assessment. (revised). Yazoo Backwater Area, Mississippi, Reformulation Report. Flood Control, Mississippi River and Tributaries, Yazoo Basin. Draft Supplemental Environmental Impact Statement. Vickburg, MS.

U.S. Army Corps of Engineers. 2005c. Attachment 2: Pondberry profile. Final report prepared by GeoMarine, Inc. for U.S. Army Corps of Engineers, April 1991. In Appendix 14: Endangered Threatened Species Biological Assessment. (revised). Yazoo Backwater Area, Mississippi, Reformulation Report. Flood Control, Mississippi River and Tributaries, Yazoo Basin. Draft Supplemental Environmental Impact Statement. Vickburg, MS.

U.S. Army Corps of Engineers. 2005d. Attachment 3: Survey report, reevaluation of pondberry in Mississippi. In, Appendix 14: Endangered Threatened Species Biological Assessment. (revised). Yazoo Backwater Area, Mississippi, Reformulation Report. Flood Control, Mississippi River and Tributaries, Yazoo Basin. Draft Supplemental Environmental Impact Statement. Vickburg, MS.

U.S. Army Corps of Engineers. 2005e. Attachment 5: Review of Appendix 14 (2000) pondberry biological assessment. Applied Research and Analysis. In Appendix 14: Endangered Threatened Species Biological Assessment. (revised). Yazoo Backwater Area, Mississippi, Reformulation Report. Flood Control, Mississippi River and Tributaries, Yazoo Basin. Draft Supplemental Environmental Impact Statement. Vickburg, MS.

U.S. Army Corps of Engineers. 2006. Review and response to the U.S. Fish and Wildlife Service's September 25, 2006 draft biological opinion for the proposed Yazoo Backwater Area Reformulation Project. U.S. Fish and Wildlife Service, Jackson Field Office, Jackson, MS.

U.S. Army Corps of Engineers. 2007. Comments on U.S. Fish and Wildlife Service's draft pondberry biological opinion, Yazoo Backwater Reformulation Project. U.S. Fish and Wildlife Service, Jackson Field Office, Jackson, MS.

U.S. Department of Interior. 1988. The impact of federal programs on wetlands. Volume I. The lower Mississipi Alluvial Plain and the Prairie Pothole Region. A report to Congress by the Secretary of the Interior. Washington, D.C.

U.S. Fish and Wildlife Service. 1982.Yazoo Area Pump Study, Yazoo Backwater Project, Mississippi. Fish and Wildlife Coordination Act Report to U.S. Army Corps of Enginners, Vicksburg District. Jackson, MS.

U.S. Fish and Wildlife Service and National Marine Fisheries Service. 1988. Endangered Species Act consultation handbook: procedures for conducting section 7 consultations and conferences. Washington, DC.

U.S. Fish and Wildlife Service. 1993. Recovery plan for pondberry (*Lindera melissifolia*). Atlanta, GA.

U.S. Fish and Wildlife Service. 2000. Correspondence from Ray Aycock, Mississippi Field Office, to Col. Robert Crear, U.S. Army Corps of Engineers, Vicksburg District. Mississippi Field Office technical review and comment on the 2000 draft Appendix 14: Endangered and Threatened Species Biological Assessment of the Draft Yazoo Backwater Area, Mississippi Reformulation Report. Jackson, MS.

U.S. Geological Survey. 1997. Standards for digital elevation models. Department of the Interior, Washington, DC.

Vanderpool, S., W. Reed, and J. Jackson. 2004. Organization, distribution, and sex ratio of an extensive population of pondberry (*Lindera melissifolia*) in Arkansas. Abstract. Botany 2004 Conference, Botanical Society of America, Salt Lake City, UT.

Wagenius, S. 2006. Scale dependence of reproductive failure in fragmented *Echinacea* populations. Ecology 2006:931-941.

Waser, N.M. 1988. Comparative pollen and dye transfer by pollinators of *Delphinium nelsonii*. Functional Ecology 2:41-48.

Waser, N.M. and M.V. Price. 1982. A comparison of pollen and fluorescent dye carry-over by natural pollinators of *Ipomopsis aggregate* (Polemoniaceae). Ecology 63:1168-1172.

Waser, N.M. and M.V. Price. 1983. Optimal and actual outcrossing in plants, and the nature of plant-pollinator interaction. Pp. 341-359. In. C.E. Jones and R.J. Little. Eds. Handbook of experimental pollination biology. Van Nostrand Reinhold, New York.

Wechsler, S.P. 2003. Perceptions of digital model uncertainty by DEM users. Urban and Regional Information Systems Association Journal 15:57-64.

Wechsler, S.P. 2006. Uncertainties associated with digital elevation models for hydrologic applications: a review. Hydrology and Earth System Sciences – Discussions 3:2343-2384.

Wechsler, S.P. and C. Kroll. 2006. Quantifying DEM uncertainty and its effect on topographic parameters. Phtogrammetric Enginering and Remote Sensing 72:1081-1090.

Weiner, J. 1988. Variation in the performance of individuals in plant populations. Pp. 59-81. *In*. A.J. Davy, M.J. Hutchings, and A.R. Watkinson. (eds.). Plant population ecology. Blackwell Scientific Publications, Oxford.

Weiner, J. and S.C. Thomas. 1986. Size variability and competition in plant monocultures. Oikos 47:211-222.

Weiner, J. and S.C. Thomas. 1992. Competition and allometry in three species of annual plants. Ecology 73:648-656.

Weiner, J. and L. Fishman. 1994. Competition and allometry ni *Kochia scoparia*. Annals of Botany 73:648-656.

Werner, P.A. 1975. Predictions of fate from rosette size in teasel (*Dipascus fullonum* L.). Oecologia 20:197-201.

West, N.E. K.H. Rhea, and R.O. Harniss. 1979. Plant demographic studies in sagebrush-grass communities of southeastern Idaho. Ecology 60:376-388.

Westoby, M. 1982. Frequency distributions of plant size during competitive growth of stands: the operation of distribution modifying functions. Annals of Botany 50:733-735.

Wharton, C.H., W.M. Kitchens, E.C. Pendleton, and T.W. Snipe. 1982. The ecology of bottomland hardwood swamps of the southeast: a community profile. U.S. Fish and Wildlife Service, Biological Services Program FWS/OBS-81/37.

Whitlow, T.H. and R.W. Harris. 1979. Flood tolerance in plants: a state-of-the-art review. U.S. Army Engineers Waterways Experiment Station Technical Report E-79-2. Vicksburg, MS.

Widen, B. 1993. Demographic and genetic effects on reproduction as related to population size in a rare, perennial, herb, *Senecio integrifolius* (Asteraceeae). Biological Journal of the Linnean Soceity 50:179-195.

Wilcock, C. and R. Neiland. 2000. Pollination failure in plants: why it happens and why it matters. Trends in Plant Science 7:270.

Williams, C. 2006. Personal communication with Will McDearman, U.S. Fish and Wildlife Service, regarding ownership, conservation, and management of Big Pond Bay. Sandhills Area Land Trust, Cumberland County Field Office, Fayetteville, NC.

Wilson, A.D., N.M. Schiff, M.S. Devall, K.F. Connor, P.B. Hamel, E.S. Gardiner, and T. Leininger. 2004. Incidence and severity of *Botryosphaeria* stem canker and dieback of pondberry (*Lindera melissifolia*) in Mississippi. Phytpathology 94(6).

Wilson, A.D., N. Schiff, T. Leininger, P. Hamel, E. Gardiner, K. Connor, and M. Devall. 2005. Black twig borer exacerbates damage caused by *Bortyospheria* stem canker and dieback of pondberry in Delta National Forest of Mississippi. Phytopathology 95(6).

Wise, S. 1998. The effect of GIS interpolation errors on the use of digital elevation models in geomorphology. *In*. S.N. Lane, K.S. Richards, and J.H. Chandler. (eds.). Landorm monitoring, modeling and analysis. John Wiley and Sons, New York.

Wise, S. 2000. Assessing the quality for hydrological applications of digital elevation models derived from contours. Hydrological Processes 14:1909-1929.

With, K.A. and T.O. Christ. 1995. Critical thresholds in species' responses to landscape structure. Ecology 7:2446-2459.

Wright, R.D. 1988. Pondberry in Arkansas: an environmental analysis. Preliminary report of a study for the Arkansas Department of Natural Heritage. Little Rock, AR.

Wright, R.D. 1989a. Reproduction of *Lindera melissifolia* in Arkansas. Proceedings of the Arkansas Academy of Science 43:69-70.

Wright, R.d. 1989b. Species biology of *Lindera melissifolia* (Walt.) Blume in northeast Arkansas. Pp. 176-179. R.S. Mitchell, C.J. Sheviak, and D.J. Leopold. Eds. Ecosystem management: rare species and significant habitats. Proceedings of the 15th Natural Areas Association Conference, New York State Museum Bulletin 471. Albany, NY.

Wright, R.D. 1990. Photosynthetic competence of an endangered shrub, *Lindera melissifolia*. Proceedings of the Arkansas Academy of Science 44:118-120.

Wright, R.D. 1991. Correspondence to Cary Norquist, U.S. Fish and Wildlife Service, Jackson, MS. Comments on pondberry profile workshop, hydrology, and pondberry surveys. University of Central Arkansas, Conway.

Wright, R.D. 1994. Sex ratio and success, an assessment of *Lindera melissifolium* in Arkansas. Proceedings of the Arkansas Academy of Science 48:230-233.

Yoccoz, N.G. 1991. use, overuse, and misuse of significance testing in evolutionary biology and ecology. Bulletin of the Ecological Society of America 72:106-111.

Table 1. Number of extant pondberry populations and estimated population size.[1]

State	Populations	Number of Populations by Size-class (number of pondberry)				
		> 20,000	10,000-20,000	3,000-10,000	500-3,000	< 500
AR	19	1	0	0	5	13
AL	2	0	0	1	0	1
GA	7	0	0	0	1	4
MS	16	1	1	2	4	8
MO	1	0	0	1	0	0
NC	2	0	0	1	0	1
SC	7	1	0	3	1	1
Total	54	3	1	8	11	28

[1] The total number of populations tallied by size class (45) is less than the total number of extant populations (56) because sufficient information was not available to generally estimate size for 11 populations.

Table 2. List of 54 range wide pondberry populations.

State	Range Rank[3]	State Rank[2]	Population Name	Population Size Class[4]	Ownership	Estimated Pop. Size	Population Data[1]	Comment
AR	1	1	St. Francis WMA	>20,000	State-Fed-Private	>20,000		St. Francis River floodway, flooded annually by Corps.
	17	2	Hwy 67 Sand Ponds	500-3,000	Private	1,280	Limited	Sand ponds: 8 ponds, 20 and 5 plants in 2 ponds. Fragmented by Hwy 67, ponds in ROW and either side.
	18	3	Stateline Sand Ponds	500-3,000	State	1,000	Limited	2 ponds, 25 colonies, with hundreds of plants.
	19	4	AR Pop. 14	500-3,000	Private	800	Limited	1 sand pond with 20 colonies, partially drained
	21	5	AR pop. 12	500-3,000	Private	640	Limited	4 sand ponds. 20 plants in 1 pond.
	22	6	AR Pop. 15	500-3,000	Private	600	Limited	1 sand pond, 15 colonies, site partially logged.
	25	7	AR pop. 13	<500	Private	480	None	3 sand ponds.
	27	8	AR pop. 19	<500	Private	320	Limited	2 sand ponds, with 20 plants at one site.
	28	9	AR pop. 11	<500	Private	320	None	2 sand ponds
	30	10	AR Pop. 3	<500	Private	280	Limited	1 sand pond, 7 colonies, all male plants.
	33	11	AR Pop. 16	<500	Private	225	Limited	1 small sand pond, 0.5 acres, 225 plants
	35	12	AR Pop. 4	<500	Private	200	Limited	1 sand pond, 5 colonies, site ditched, drained, and logged.
	36	13	AR Pop. 17	<500	Private	160	None	1 sand pond.
	37	14	AR Pop. 7	<500	Private	160	None	1 sand pond.
	38	15	AR Pop. 6	<500	Private	160	None	1 sand pond.
	39	16	AR Pop. 5	<500	Private	160	None	1 sand pond.
	40	17	AR Pop. 1	<500	Private	160	None	1 sand pond.
	41	18	AR Pop. 9	<500	Private	160	None	1 sand pond, 1 colony.
	50	19	Coffee Prairie	<500	State	25	Surveyed	25 plants sand prairie pond.
		Extirpated	FWS 2		Private			Sand pond drained, cleared, converted to agriculture.
		Extirpated	FWS 3		Private			2 colonies 1980, drained-converted to agriculture.

State	Range Rank	State Rank	Population Name	Population Size Class	Ownership	Estimated Pop. Size	Population Data	Comment
AR		Extirpated	FWS 4		Private			Sand pond, 1 colony, drained-converted to agriculture.
		Extirpated	FWS 5		Private			Sand pond, 5 colonies, converted to agriculture.
		Extirpated	FWS 9		Private			Sand pond, 1 colony, converted agriculture.
		Extirpated	FWS 14		Private			Sand pond, 5 colonies, ditched and drained.
		Extirpated	FWS 15		Private			Sand pond, 1 colony, heavily logged.
		Extirpated	FWS 16		Private			Sand pond, 5 colonies, drained, converted to agriculture.
		Extirpated	FWS 17		Private			Sand pond, 1 colony.
		Extirpated	FWS 18					Sand pond, 1 colony.
		Extirpated	FWS 19					Sand pond, 1 colony.
		Extirpated	FWS 20					Sand pond, 1 colony.
		Extirpated	FWS 21					Sand pond, drained, converted to agriculture.
AL	12	1	1	3,000-10,000	Private	3,000	Limited	Part of pond site bedded for timber production
	26	2	2	<500	Private	350	Limited	Threatened by intensive management for timber.
GA	15	1	Jones Ecological Ctr	500-3,000	Private/protected	1,500	Limited	1 limesink, managed by research center.
	34	2	TNC	<500	Private/protected	200	Limited	1 depression, 2 colonies, probably all male plants.
	44	3	3	<500	Private	100	Limited	1 cypress dome, on timber company land.
	45	4	4	<500	Private	<100	Limited	1 depression, 3 colonies, less than 100 plants, timber company.
	24	5	5	<500	Private	500	Limited	1 disturbed pond, clearcut and site-preped for timber.
	51	6	6	?	Private	?	None	1 small cypress pond, < 1acre.
	52	7	7	?	Private	?	None	1 sandhill pond, timber company, by excavated pit.
		Extirpated	Ocmulgee Park		State			Extirpated by 1990, mowing and golf course mgt.

State	Range Rank	State Rank	Population Name	Population Size Class	Ownership	Estimated Pop. Size	Population Data	Comment
GA		Extirpated	Ocmulgee Park		State			Extirpated by 1990, mowing and golf course mgt.
		extirpated			Private			1 sinkhole, affected by hogs and livestock.
MS	3	1	Shelby	>20,000	Private	>20,000	Surveys	1 site, 2 landowners, about 25% of pop protected by conservation easement, no overbank flooding, affected by local ponding and overflow from adjacent rice fields.
	4	2	DNF Colby	10,000-20,000	Federal	20,000	Surveys	DNF, includes 2 vernal pools.
	6	3	DNF Red Gum	3,000-10,000	Federal	8,200	Surveys	DNF, declining, 75+ colonies
	10	4	DNF Spanish Fort	3,000-10,000	Federal	3,900	Surveys	DNF, declining, 65+ colonies
	16	5	DNF 10	500-3,000	Federal	1,280	Surveys	DNF, 1 colony.
	23	6	DNF 9	500-3,000	Federal	560	Surveys	DNF, 1 colony.
	20	7	DNF 4	500-3,000	Federal	780	Surveys	DNF, 5 colonies.
	32	8	DNF 5	<500	Federal	240	No data	DNF, 6 colonies.
	42	9	DNF 6	<500	Federal	160	No data	DNF, 4 colonies.
	43	10	DNF 7	<500	Federal	130	Surveys	DNF, 3 colonies.
	29	11	DNF 8	<500	Federal	300	Surveys	DNF, 1 colony.
	47	12	DNF 11	<500	Federal	40	No data	DNF, 1 colony.
	48	13	DNF 12	<500	Federal	40	No data	DNF, 1 colony.
	49	14	DNF 13	<500	Federal	40	No data	DNF, 1 colony.
	14	15	Merigold	500-3,000	Private	1,600	Limited	2 sites, 1 depressional, fragmented woodland patches, affected by adjacent farming.
	53	16	MDOT		Private		No data	New site, found during highway ROW survey.
		Extirpated	Merigold 59		Private			1 colony, 500 plants in 2000, extirpated 2005.

State	Range Rank	State Rank	Population Name	Population Size Class	Ownership	Estimated Pop. Size	Population Data	Comment
MO	9	1	Sand Ponds CA	3,000-10,000	State/TNC	5,000	Limited	5 sand ponds, protected by MO Dept. Conservation & TNC. Part of pop. Across state line in AR with Stateline Sand Ponds.
NC	8	1	Big Pond Bay	3,000-10,000	State	5,000	Limited	1 site, Carolina bay, recently purchased.
	31	2	White Woods	<500	Private	250	Limited	1 site, pond cypress bay, declining.
SC	2	1	Brick Church-Hoover Rd.	>20,000	Federal	50,000	Limited	Francis Marion National Forest, 6 sites, most of pop in 1 bay, encroaching shrubs and fire needed at most sites.
	7	2	Whiddon Bay	3,000-10,000	Federal	8,100	Surveys	FMNF, shrubs encroaching, needs fire.
	5	3	Marine Air Base	3,000-10,000	Federal	8,600	Surveys	Marine Corps Air Base, annual monitoring during past 5 years, no flowering, restoration plan in progress to control encroaching vegetation.
	13	4	Conifer Rd	500-3,000	Federal	2,000	Surveys	FMNF, 1 site, restoration with fire probably too frequent, reducing pondberry.
	11	5	Honey Hill	3,000-10,000	Federal	3,500	Surveys	FMNF, declined from more than 10K plants in 1988, restoration treatments in progress to control competing vegetation.
	46	6	Echaw Rd	<500	Federal	<500	Surveys	<100 plants, severe competition, restoration fire treatments probably too frequent.
	54	7	7		Private		No data	1 depression, in residential area.
	54	7	7		Private		No data	1 depression, in residential area.

1 – Limited population data refers to general surveys in all or parts of sites and population segments, where estimates of population size are based on reconnaissance. Surveys refer to population estimates from plots or transects in parts or all of the site or population.
2 – State rank is the population size rank order within a state.
3 – Range rank is the population size rank order range wide.
4 – Population size classes: >20,000; 10,000-20,000,;3,000-10,000,; 500-3,000; and <500.

Table 3. Largest pondberry populations (>3,000 plants), by range wide rank order.

State	Range Rank	State Rank	Population Name	Population Size Class	Ownership	Estimated Pop. Size	Population Data	Comment
AR	1	1	St. Francis WMA	>20,000	State-Fed-Private	>20,000	Limited	St. Francis River floodway, flooded annually by Corps.
SC	2	1	Brick Church-Hoover Rd.	>20,000	Federal	50,000	Limited	Francis Marion National Forest, 6 sites, most of pop in 1 bay, encroaching shrubs, restoration and fire needed at most sites.
MS	3	1	Shelby	>20,000	Private	>20,000	Surveys	1 site, 2 landowners, about 25% of pop protected by conservation easement, no overbank flooding, affected by local ponding and overflow from adjacent rice fields.
MS	4	2	DNF Colby	10,000-20,000	Federal	20,000	Surveys	DNF, includes 2 vernal pools.
SC	5	3	Marine Air Base	3,000-10,000	Federal	8,600	Surveys	Marine Corps Air Base, annual monitoring during past 5 years, no flowering, restoration needed to control encroaching vegetation.
MS	6	3	DNF Red Gum	3,000-10,000	Federal	8,200	Surveys	DNF, declining, 75+ colonies
SC	7	2	Whiddon Bay	3,000-10,000	Federal	8,100	Surveys	FMNF, shrubs encroaching, needs fire.
NC	8	1	Big Pond Bay	3,000-10,000	State	5,000	Limited	1 site, Carolina bay, recently purchased.
MO	9	1	Sand Ponds CA	3,000-10,000	State/TNC	5,000	Limited	5 sand ponds, protected by MO Dept. Conservation & TNC.
MS	10	4	DNF Spanish Fort	3,000-10,000	Federal	3,900	Surveys	DNF, declining, 65+ colonies
SC	11	5	Honey Hill	3,000-10,000	Federal	3,500	Surveys	FMNF, declined from more than 10K plants in 1988, restoration treatments in progress to control competing vegetation
AL	12	1	1	3,000-10,000	Private	3,000	Limited	Part of pond site bedded for timber production, threatened.

Table 4. Pondberry populations in Delta National Forest, with number of known colonies/sites, profiled colonies/sites, and estimated population ize.

Population	Known Colonies/ Sites[1]	GSRC Sites- Reference[2]	GSRC Number of Plants[3]		Pop Estimate-Site Data[4]		Pop Estimate- All Site Data[5]	Minimum Pop Estimate[6]
			2000	2005	95% CI	Number		
1 – Colby	13	5 (39-43)	5,918	2,048	1.9 - 40.0	25 - 520	348 – 776	20,000
2 – Red Gum	75	17 (22-38)	3120	1,205	17.3 - 70.3	4,298 – 8,272	5,010 – 7,477	8,272
3 – Spanish Ft.	65	21 (1-21)	1,688	847	9.7 – 33.6	630 – 2,184	1,742 – 3,880	3,880
4	5	2 (45-46)	656	657	--		135 – 300	780
5	6	0	--	--	--	--	162 – 360	240
6	4	0	--	--	--	--	108 – 240	160
7	3	1 (55)	153	130	--	--	80 – 180	130
8	1	1 (53)	91	308	--	--	27 - 60	308
9	1	1 (54)	47	558	--	--	27 – 60	558
10	1	1 (56)	94	1,280	--	--	27 – 60	1,280
11	1	0	--	--	--	--	27 – 60	40
12	1	1 (44)	21	12	--	--	27 – 60	12
13	1	0	--	--	--	--	27 – 60	40

1 – Colonies/sites tallied and mapped by the Corps, including profiled (GSRC) sites, and colonies/sites from U.S. Forest Service data.
2 – Selected colonies/sites in the Corps pondberry profile, with colony/site reference numbers.
3 – Number of plants at profiled colonies/sites in the 2000 and 2005 census.
4 – Total estimated number of pondberry based on the computed mean and 95% confidence interval from log-transformed data (expressed as back-transformed values) for profiled colonies/sites in the population, extrapolated (multiplied by) to the total number of known colonies/sites.
5 – Total estimated number ofpondberry based on the computed mean and 95% confidence interval from log-transformed data (listed as back-transformed values) from all profiled colonies/sites in DNF, extrapolated to the total number known colonies/sites in the population.
6 – Minimum estimated number of plants, including other sources of information or data.

Table 5. Nearest colony neighbor distances within DNF pondberry populations with more than one colony/site, for 177 colonies/sites.

Populations	Colonies/sites	Nearest Colony Neighbor Distances (feet)		
		Range (min-max)	Mean (Median)	95% C.I.[1]
1	75	13.2 – 3303.8	349.2	257.2 – 472.0
2	65	17.9 – 289.9	58.0	49.7 – 68.0
3	13	16.1 – 281.7	79.8	39.4 – 163.7
4	6	50.1 – 461.9	(380.0)	
5	5	104.7 – 204.7	(107.9)	
6	5	18.1 – 43.9	(33.6)	
7	4	657.1 – 1027.8	(658.4)	
8	3	108.1 – 127.6	(108.1)	

1 – 95% confidence interval for the computed mean nearest neighbor distance.

Table 6. Change in total number of pondberry plants in permanent plots[1], at colonies in the Colby population, Delta National Forest, in depressional ponds (vernal pools) and without ponding, with estimated average annual change in number of plants.[2] Changes during 1993 – 1994 were due to rapid leaf wilt, death, and stem dieback, with and without resprouting during a severe episode of fungal-caused stem die-back and late summer drought stress.

Plot	Site	N[3] (Quads)	Total Plants			Exponential growth, 1993-2006	Percent Change, 1993-2006
			1993	1994	2006		
1	Pond	84	104	83	37	-0.0795	-64.4
2	Pond	36	70	64	62	-0.0093	-11.4
3	Pond	72	121	75	151	0.0170	+24.8
4	Pond	78	67	52	145	0.0594	+116.4
5	No Pond	100	134	87	56	-0.0671	-58.2
6	No Pond	36	28	12	17	-0.0384	-39.3
7	No Pond	110	78	91	124	0.0357	+59.0
8	No Pond	25	33	23	37	0.0088	+12.1
9	Pond	36	67	42	175	0.0739	+161.2
Total			702	529	804	0.0104	+14.5

1- Plots established and sampled in 1993-1994 by MS Department of Wildlife, Fisheries and Parks-MS Museum of Natural Science, and resampled in 2006 by U.S. Fish and Wildlife Service, Jackson Field Office.
2- Average annual change computed as exponential growth rate, $r = 1/t(log(P_f/P_i))$, *where* t = *time*, P_i = *number of plants in 1993, and* P_f = *number of plants in 2006.*
3- Number of 0.25 m^2 quadrats.

Table 7. Total number of pondberry plants in 1994 and 2006, in depressional ponds (vernal pools) and at sites other than ponds (No-pond), from nine permanent plots in the Colby population, Delta National Forest, with expected number of plants based on an extrinsic hypothesis of the proportion of plants in ponds (0.6111) and not in ponds (0.3889) during 1993 if the frequency of occurrence is independent of site (Pond and No-pond) since 1993.

a. Contingency table.

Year	Site				Total
	No-pond		Pond		
	Observed	Expected	Observed	Expected	
1993	273	-----	429	-----	702
1994	213	205.7	316	323.3	529
2006	234	312.7	570	491.3	804
Total	447	518.4	886	814.6	1,333

b. Total *G* partitioned by year ($\chi^2_{0.0001,1}$=15.1367).

Year	df	*G*
1994	1	0.4190
2006	1	33.6788*
Total	4	34.0978*

Table 8. Total number of pondberry during 1994 and 2006, in depressional ponds (vernal pools) and at sites other than ponds (No-pond), from nine permanent plots in the Colby population, Delta National Forest. The expected number if the abundance of pondberry is independent of site was computed as an extrinsic hypothesis, based on the proportion of the area surveyed in plots at non-pond sites (0.5303) and pond sites (0.4697), and the expected proportionate number of pondberry from the total each year.

a. Contingency table.

Year	Site				Total
	No-pond		Pond		
	Observed	Expected	Observed	Expected	
1993	273	372.3	429	329.7	702
1994	213	280.5	316	248.5	529
2006	234	426.4	570	377.6	804
Total	447	1079.2	886	955.8	2,035

b. Total *G* partitioned by year ($\chi^2_{0.0001,1}$=15.1367, ($\chi^2_{0.0001,2}$=18.4207).

Year	df	*G*
1993	1	56.5*
1994	1	35.1*
2006	1	188.6*
Total	2	280.2*

Table 9. Acres of potential jurisdictional wetlands in backwater area estimated by three methods, and compared by three strata. Data from Table 10-15, 2005 revised draft wetland appendix (Appendix 10) (U.S. Army Corps of Engineers 2005).

Method	Acres of Jurisdictional Wetlands			
	Tier 1	Tier 2	Tier 3	Total
FLOOD	120,786	27,870	28,456	177,112
FESM	164,921	1,294	3,251	169,466
EMAP	130,914	66,091	15,279	212,284

Table 10. Acres of potential jurisdictional wetlands from FESM, based on a 30-meter DEM and 10-meter DEM, and the difference in the estimates as affected by the DEM. Data from August 15, 2006 Corps correspondence to Service.

DEM	Tier 1	Tier 2	Tier 3	Total
30-meter	189,522	0	0	189,522
10-meter	146,317	9,994	17,290	173,601
Difference	-43,205	+9,994	+17,290	-15,921

Table 11. Number and proportion of known pondberry colonies/sites in non-jurisdictional and jurisdictional wetlands in Delta National Forest, as determined by the 5 percent flood duration elevation (FLOOD) Determinations at GSRC colonies (Corps profile colonies) based on a physical survey of the elevation at each site. Elevations at 177 known pondberry colonies derived from 30-meter digital elevation model, and determined by FESM.

Determination	%Duration Interval	Flood Duration Days	Pondberry Colonies[1]		GSRC Colonies	
			Number	%	Number	%
Above 5% duration wetland elevation	3-5yr floodplain	<1	90	50.8	29	59.2
	<2.5	1 – 6	64	36.2	17	34.7
	2.5-5.0	7 – 13	6	3.4	0	0.0
Jurisdictional wetlands	5.0-7.5	14 – 19	2	1.1	1	2.0
	7.5-10.0	20 – 26	12	6.8	2	4.1
	10.0-12.5	27 – 33	1	0.6	0	0.0
	>12.5	> 34	2	1.1	0	0.0
Total			177	100.0	49	100.0

Table 0. Known pondberry colonies/sites from DNF stand data acquired by Corps and the 49 GSRC colonies.

Table 12. Reproduced Table 14-2, from Corps Appendix 14, Biological Assessment. Summary of comprehensive stand surveys in DNF by U.S. Forest Service staff for pondberry in relation to areas above and below the FESM 1-year flood frequency.

Item	Above 1-yr flood frequency		At or below 1-yr flood frequency		Total	
	Acres	Percent	Acres	Percent	Acres	Percent
DNF	25,061	40.4	36,906	59.6	61,967	100.00
Surveyed	10,806	43.1	8,977	24.3	19,783	31.9
Colonies	159	87.4	23	12.6	182	100.0

Table 13. Stands surveyed (acres) on Delta National Forest for pondberry, above and below the 1-year floodplain, and expected acres surveyed. H_0: Acres surveyed are proportionate to the total forest available above and below the 1-year floodplain. G=1624, χ^2=1662, $\chi^2_{(1,0.05)}$=3.84, $p<0.0001$.

Hydrology	Total Forest Acres	Proportion	Stands (Acres) Surveyed	H_0: Expected Survey Acres
Above 1-yr floodplain	25,061	0.404	10,806	7,992
Below 1-yr floodplain	36,906	0.596	8,977	11,791
TOTAL	61,967	1.000	19,783	19,783

Table 14. Actual and expected acres of stands in DNF surveyed for pondberry and number of pondberry colonies/sites, in wetlands (FESM) and non-wetlands. Expected values are based on the independence of two factors, survey status and wetland status. The expected number of pondberry colonies/sites is an extrinsic hypothesis of independence, that the number of colonies is the expected proportion according the proportion of acres surveyed.

Wetlands	Stands Comprehensively Surveyed				Stands Not Comprehensively Surveyed			
	Acres		Pondberry		Acres		Pondberry	
	Actual	Expected	Actual	Expected	Actual	Expected	Actual	Expected
Not Wet	6,497	5,756	96	35	11,747	12,486	61	19
Wet	13,016	13,757	10	71	30,580	29,841	7	41
Total	19,513	19,513	106	106	42,327	42,327	68	68

Total pondberry colonies/sites = 174, from 2005 Corps data, which exludes three colonies/sites in DNF that became extirpated between 2000-2005. Total acres of DNF stands = 61,840. Jurisdictional wetlands are those determined by FESM, located on or below the elevation of the 5 percent duration backwater flood, occurring once every two years on average.

Table 15. Acres in DNF stands comprehensively surveyed for pondberry, with 5% duration wetlands (FESM) and nonwetlands. Expected acres based on independent or homogeneous distribution by survey type and class (contingency of marginal row and column totals).

Class	Surveyed Acres		Not Surveyed Acres		Total Acres
	Actual	Expected	Actual	Expected	
Not Wet	6,497	5,756	11,747	12,486	18,244
Wet	13,016	13,757	30,580	29,841	43,396
Total	19,513	19,513	42,327	42,327	61,840

Table 16. Number of pondberry colonies/sites in DNF stands by stand comprehensive survey type and wetland class. Expected number based on hypothesis from extrinsic data, that pondberry occurrences are independent (proportionate) to the acres comprehensively surveyed/not surveyed by land class (not wetland/wetland).

Class	Surveyed		Not Surveyed		Total	
	Actual	Expected	Actual	Expected	Actual	Expected
Not Wet	96	35	61	19	157	54
Wet	10	71	7	49	17	120
Total	106	106	68	68	174	174

Table 17. Flood frequencies (return interval years) in DNF by acres and number of pondberry colonies/sites, determined by FESM-GIS with a 30-meter DEM.

Flood Frequency	Acres	All Colonies/Sites		GSRC Colonies/sites	
		No.	%	No.	%
0 – 2	55,579	85	48.0	19	38.8
3 – 5	5,985	92	52.0	30	61.2
Total	61,564	177	100.0	49	100.0

Table 18. Number and proportion of 49 profiled pondberry colonies/sites in Delta National Forest by flood frequency class, according to two methods. Flood frequencies by physical survey were determined from site elevations by a rod and instrument survey from established benchmarks. Flood frequencies by GIS were determined from the FESM-GIS data with a 30-meter digital elevation model (DEM).

Flood Frequency	Physical Survey		GIS-DEM	
	Sites	Percent	Sites	Percent
0 – 2	9	18.4	19	38.8
2.1 – 5	23	47.0	30	61.2
5.1 – 10	8	16.3	0	0
10.1 – 15	6	12.2	0	0
15.1 – 20	3	6.1	0	0
Total	49	100.0	49	100.0

Table 19. Flood frequencies at Corps profiled (GSRC sites) pondberry colonies, determined from elevations physically surveyed at sites and a GIS 30-meter DEM.

GSRC Site	Physical Survey-Flood Frequency	GIS-DEM Flood Frequency	GSRC Site	Physical Survey-Flood Frequency	GIS-DEM Flood Frequency
56	0.7	1	46	4.0	3
54	0.8	1	55	4.0	3
2	1.5	3	29	4.5	2
3	1.5	3	1	4.5	3
19	2.0	3	45	4.5	3
21	2.0	3	5	5.0	3
42	2.0	3	37	6.0	2
40	2.0	4	38	6.0	2
41	2.0	4	8	6.0	3
16	2.5	3	28	7.0	2
18	2.5	3	7	7.0	3
43	2.5	3	11	7.5	3
39	2.5	4	12	7.5	3
35	3.0	2	6	9.0	3
20	3.0	3	13	11.0	3
44	3.0	3	25	14.0	2
34	3.5	2	23	15.0	2
14	3.5	3	24	15.0	2
15	3.5	3	26	15.0	2
17	3.5	3	9	15.0	3
30	4.0	2	27	16.0	2
31	4.0	2	4	16.0	3
32	4.0	2	22	17.0	2
33	4.0	2			
10	4.0	3			
36	4.0	3			

Table 20. Number of Corps profiled pondberry colonies/sites where flood frequencies as determined from physical ground-surveyed elevations are equal or less than, or greater than the flood frequency determined from the FESM-GIS 30-m DEM.

GIS-DEM Flood Frequency	Number of Physical Survey Sites		
	Site Freq. ≥ GIS	Site Freq. < GIS	Total
1	2	0	2
2	0	16	16
3	8	20	28
4	3	0	3
Total	13	36	49

Table 21. Jurisdictional wetland colonies/sites, as determined by jurisdictional field surveys, with flood frequencies according to FESM-GIS with a 30-m DEM and ground surveyed elevations at each site, and wetland hydrology type. Wetland conditions by Flooding are established by overbank flooding of sufficient frequency and duration; Flooding-Local: sustained by either overbank flooding and local site conditions, or local site conditions without flooding; and Local: established by local precipitation, drainage, and site conditions independent of flooding.

Colony/Site	Flood Frequency		Wetland Hydrology
	FESM	Ground-survey	
56	1	0.7	Flooding
54	1	0.8	Flooding
2	3	1.5	Flooding - Local
21	3	2.0	Flooding - Local
42	3	2.0	Flooding - Local
43	3	2.5	Local
35	2	3.0	Local
44	3	3.0	Local
30	2	4.0	Local
25	2	14.0	Local
23	2	15.0	Local
24	2	15.0	Local
22	2	17.0	Local

Table 22. Number of profiled pondberry colonies/sites, with and without a local wetland hydrology[1], in GIS-depressions and areas outside of GIS-depressions, and the expected number in the absence of any association. Depressions identified from a 10-m DEM raster by USGS. Wetlands determined by jurisdictional field survey. Chi-square = 5.79, p=0.0161. Odds ratio = 5.6, 95% C.I.= 1.28<O.R.<24.56.

Feature	Jurisdictional wetlands		Not wetlands		Total
	Observed	Expected	Observed	Expected	
Depressions	6	2.9	6	9.1	12
Not depressions	5	8.1	28	24.9	33
Total	11	11.0	34	34.0	45

1 – Excludes sites 54 and 56 that are FESM wetlands established by overbank flooding. Local hydrology refers to colonies/sites where wetland conditions are established entirely or partially by local precipitation and site factors, independent from overbank flooding. Includes three wetland colonies/sites where the wetland hydrology may be established by the combined effects of overbank flooding, site precipitation, and local conditions.

Table 23. Number of colonies/sites (n=160) estimated[1] with a local wetland hydrology in GIS-depressions and not associated with depressions, for major populations and the entire DNF.

Population	Depressions			Not Depressions			All Colonies/sites		
	W	NW	Total	W	NW	Total	W	NW	Total
Colby	1	1	2	2	9	11	3	10	13
Red Gum	9	9	18	8	42	50	17	51	68
Spanish Fort	10	10	20	8	37	45	18	47	65
All DNF[2]	21	20	41	18	101	119	39	121	160[3]

1 – Estimated from the proportion (0.2438) of colonies/sites determined as jurisdictional wetlands with a local hydrology, and not wetlands from 47 field surveyed colonies/sites.2 – Numbers from rows above to do not necessarily add to the sum because not all populations are listed. 3 – 160 colonies/sites that are not FESM wetlands.

Table 24. Number and area of GIS-depressions (Dep.) and non-depressional areas (Ndep.), from GIS with a 10-m DEM, in the three largest DNF population areas and the entire DNF, with number of known pondberry colonies/sites as of 2000 in each.

Population	Area (acres)					Pondberrry Colonies/sites				
	Dep.	%	Ndep.	%	Total	Dep.	%	Ndep.	%	Total
Colby	13	22.8	44	77.2	57	2	15.4	11	84.6	13
Red Gum	1,910	33.5	3,799	66.5	15,709	21	28.8	52	71.2	73
Spanish Fort	211	32.5	438	67.5	649	20	30.8	45	69.2	65
Entire DNF	19,656	31.8	42,184	68.2	61,840	47	26.5	130	73.4	177

Table 25. Number of colonies/sites in DNF GIS-depressions, with size of each depression. Depressions identified from depression GIS raster prepared by USGS from a 10-m DEM.

Depression ID	Number of Colonies/Sites	Depression Size (Acres)
21258	1	0.4
21309	1	1.5
21283	3	1.9
21056	2	1.9
20864	1	2.5
14926	1	2.7
20935	1	3.4
14910	2	4.2
21499	1	4.9
20863	2	7.4
21422	2	13.8
16544	2	19.5
21306	6	29.6
14315	1	37.2
14820	2	49.5
14681	1	101.5
21975	1	103.8
20492	1	147.3
14446	5	180.0
14877	2	356.4
16057	7	556.8
18072	1	1039.2
21359	1	1331.6
Total	47	3996.8

Table 26. Historical change in FESM wetland acres in Delta National Forest and FESM wetland colonies/sites referenced to 177 known pondberry colonies/sites as of 2000.

Period	Delta National Forest (acres)				Delta National Forest Colonies/Sites			
	Wetland	Percent	NonWet	Percent	Wetland	Percent	NonWet	Percent
1901-31	56,993	92.2	4,847	7.8	84	47.5	93	52.5
1932-57	42,749	69.1	19,091	30.9	26	14.7	151	85.3
1958-78	19,673	31.8	42,167	68.2	4	2.3	173	97.7
1979-97	44,870	72.6	16,970	27.4	22	12.4	155	5.6
Baseline[1]	43,596	70.5	18,244	29.5	17	9.6	160	90.4

1 – Baseline is the FESM wetland acres under current conditions from the 1943-1997 POR, and pondberry colonies/sites in 2000.

Table 27. Historical change in FESM wetland (Wet) and other (not-FESM, Nwet) acres in the three largest DNF pondberry populations, and referenced to the known-mapped pondberry colonies/sites as of 2000 in each population.

Population-Period	Population Area (acres)					Pondberrry Colonies/sites				
	Wet	%	Nwet	%	Total	Wet	%	Nwet	%	Total
Colby 1901-31	198	35.1	37	64.9	57	4	30.8	9	69.2	13
1932-57	0	0	57	100.0	57	0	0	13	100.0	13
1958-78	0	0	57	100.0	57	0	0	13	100.0	13
1979-97	0	0	57	100.0	57	0	0	13	100.0	13
Baseline[1]	0	0	57	100.0	57	0	0	13	100.0	13
Red Gum 1901-31	4,681	96.0	1,028	18.0	5,709	54	74.0	19	26.0	73
1932-57	826	14.5	4,883	85.5	5,709	9	12.3	64	87.7	73
1958-78	21	0.4	5,688	99.6	5,709	0	0.0	0	0.0	73
1979-97	736	12.9	4,973	87.1	5,709	5	6.8	68	93.2	73
Baseline	905	15.9	4,804	84.1	5,709	5	6.8	68	93.2	73
Spanish Ft1901-31	89	13.7	560		649	8	12.3	57	87.7	65
1932-57	18	2.8	631	97.2	649	6	9.2	59	90.8	65
1958-78	0	0.0	649	100.0	649	0	0.0	65	100.0	65
1979-97	21	3.2	628	96.8	649	6	9.2	59	90.8	65
Baseline	0	0.0	649	100.0	649	0	0.0	65	100.0	65

1 – Baseline is the FESM wetland acres under current conditions, and pondberry colonies/sites in 2000

Table 28. Historical change in total number of wetland colonies/sites, referenced to the location of 177 colonies/sites as of 2000, where total wetland colonies/sites are the number of FESM wetland sites plus the number of sites estimated with a local wetland hydrology either wholly or partially independent of overbank flooding.

Period	FESM Wetland	Not FESM Wetland	Local Wetland[1]	Total			
				Wetland	Percent	Not Wet	Percent
1901-31	84	93	23	107	60.5	70	39.5
1932-57	26	151	37	63	35.6	114	64.4
1958-78	4	173	42	46	26.0	131	77.0
1979-97	22	155	38	60	33.9	117	66.1
Baseline	17	160	39	56	31.6	121	68.4

1 – Number of colonies/sites with a local wetland hydrology estimated as 0.244 x Non-FESM wetland colonies/sites.

Table 29. Comparison of pondberry colony health rating, for 49 profiled (GSRC) sites, in Delta National Forest, 2000 and 2005.

Year		Pondberry Colony Health				Total
		Excellent	Good	Fair	Poor	
2000		22	25	2	0	49
2005	Excellent	6	1	0	0	7
	Good	13	18	1	0	32
	Fair	2	3	0	0	5
	Poor	1	1	0	0	2
	Extirpated	0	2	1	0	3

Table reproduced from Table 1407, Corps biological assessment, Appendix 14, U.S. Army Corps of Engineers (2005).

Table 30. Health rank score assigned to selected pondberry profile colonies in 2000 in Delta National Forest compared to the change (increase or decline) in the number of plants from 2000 and 2005.

Heath Score	Change in Number of Plants				Total Colonies
	Increase (+)	%	Decrease(-)	%	
Excellent – 4	3	15.8	16	84.2	19
Good – 3	7	28.0	18	72.0	25
Fair – 2	0	0.0	2	100.0	2
Poor – 1	0	0.0	0	0.0	0
Total	10	21.7	36	78.3	46

3 colonies with no net change, positive or negative, not included.

Table 31. Health rank score for selected pondberry profile colonies/sites in 2000 in Delta National Forest compared to the percent change categories in the number of plants at each colony/site from 2000 and 2005.

Health Score	Change in Number of Plants			Total Colonies
	> 10%	+/- 10%	<10%	
Excellent – 4	3	4	15	22
Good – 3	5	5	15	25
Fair – 2	0	0	2	2
Poor – 1	0	0	0	0
Total	8	9	32	49

Table 32. Change in the total number of pondberry plants in profiled colonies/sites in DNF, grouped by colony health score, between 2000 and 2005.

Health Score	Number of plants by Year		Percent Change
	2000	2005	
Excellent – 4	10,485	5,296	-49.5
Good – 3	1,107	1,349	+21.9
Fair – 2	156	130	-16.7
Poor – 1	0	0	0.0
Total	11,748	6,775	-42.3

Table 33. Rank change in number of plants in colonies from 2000 and 2005, relative to the change in the health scores for 2000 and 2005 in Delta National Forest.

2000 Health Score	2005 Change in Health Score	Number of Colonies with Rank Change in Number of Plants			Total Colonies
		> 10%	+/- 10%	<10%	
Excellent	-	2	4	10	16
	0	1	0	5	6
	+	0	0	0	0
	Total	3	4	15	22
Good	-	0	0	6	6
	0	4	5	9	18
	+	1	0	0	1
	Total	5	5	15	25

Table 34. Effect of site (wetland and non-wetland) and year (2000 and 2005) on the mean number of pondberry per colony, by repeated measures ANOVA. Number of pondberry are log-transformed. Wetlands (W) are FESM wetlands and sites with a local wetland hydrology wholly are partially independent of overbank flooding.

Site	2000			2005			Site		
	Mean	SE	Back-transformed	Mean	SE	Back-transformed	Mean	SE	Back-transformed
Wet	4.4356	0.5218	84.4028	4.6233	0.4774	101.8295	4.5294	0.4752	92.7029
NWet	3.7351	0.3012	41.8922	3.2694	0.2756	26.2956	3.5022	0.2744	33.1884
Year	4.0855	0.3012	59.4717	3.9463	0.2756	51.7436			

Effect	df	F	P
Site	**1**	**3.5047**	**0.0682**
Year	1	0.5971	0.4402
Site x Year	**1**	**3.2977**	**0.0765**

Effect	Mean	SE	Back Transformed Values	
			Mean	95% Confidence Interval
Site NW	3.5022	0.2744	33.1884	19.0792 – 57.7371
Site W	4.5294	0.4752	92.7029	35.5308 – 241.8699
Year 2000	4.0855	0.3012	59.4717	32.3754 – 109.2130
Year 2005	3.9463	0.2756	51.7436	29.6689 – 90.2515
2000 NW	3.7351	0.3012	41.8922	22.8100 – 77.0150
2005 NW	3.2694	0.2756	26.2956	15.0759 – 45.8603
2000 W	4.4356	0.5218	84.4028	29.4472 – 241.8941
2005 W	4.6233	0.4774	101.8295	38.8536 – 266.8802

Effect	F	P
2000NW x 2005NW	**6.7013**	**0.0132**
2000W x 2005W	0.3628	0.5502
2000W x 2000NW	1.3518	0.2515
2005W x 2005NW	**6.0319**	**0.0183**

Table 35. The 17 basic nonlinear models for pondberry colony/site growth in response to flood frequency, where y is colony/site growth during 2000-2005, and x is colony/site flood frequency.

Growth Measure	Growth Equation	Model	Colony/site Growth (y) – Flood Frequency (x) Model
Geometric	$R_g: \; r = (e^{[(\log(P_f / P_i))/n]}) - 1$; where P_f = the number of pondberry at a colony/site in 2005, P_i = the number of pondberry in 2000, and n = 5, the number of years.	R_g1	$y = a + b(\exp^{-cx})$
		R_g2	$y = a + b(\exp^{1/x})$
		R_g3	$y = a^x - b$
		R_g4	$y = x^a - b$
		R_g5	$y = a - b(\log x)$
		R_g6	$y = a^{\log x} - b$
Exponential	$R_e: \; r = \frac{[\log(P_f / P_i)]}{n}$	R_e1	$y = a + b(\exp^{-cx})$
		R_e2	$y = a + b(\exp^{1/x})$
		R_e3	$y = a^x - b$
		R_e4	$y = x^a - b$
		R_e5	$y = a - b(\log x)$
		R_e6	$y = a^{\log x} - b$
Percent change	$R_p: \; r = \log(P_f / P_i)$	R_p1	$y = a + b(\exp^{-cx})$
		R_p2	$y = a + b(\exp^{1/x})$
		R_p3	$y = a^x - b$
		R_p4	$y = x^a - b$
		R_p5	$y = a - b(\log x)$

Table 36. Effect of flood frequency class (0-2, 3-5, 6-10, 11-20 years) and year (2000 and 2005) on the mean number of pondberry per colony/site, by repeated measures ANOVA. Number of pondberry per colony/site were transformed as log10(x + 1). Means are also reported as back-transformed values.

Flood Freq.	2000			2005			Flood Frequency		
	Mean	SE	Back-transformed	Mean	SE	Back-transformed	Mean	SE	Back-transformed
0-2	1.7810	0.2427	59.4	1.7116	0.2427	50.5	1.7463	0.2289	54.8
3-5	1.8649	0.1518	72.3	1.7448	0.1518	54.6	1.8048	0.1432	62.8
6-10	1.4237	0.2574	25.5	1.1871	0.2574	14.4	1.3054	0.2428	19.2
11-20	1.3732	0.2427	22.6	1.0165	0.2427	9.4	1.1948	0.2289	14.7
Year	1.6107	0.1138	39.8	1.4150	0.1138	25.0			

Effect	F	p
Flood Frequency	**2.35**	**0.0847**
Year	**6.69**	**0.0130**
Flood x Year	0.71	0.5529

Effect	Mean	SE	Back-Transformed Mean
Flood 0-2	1.7463	0.2289	54.8
Flood 3-5	1.8048	0.1432	62.8
Flood 6-10	1.3054	0.2428	19.2
Flood 11-20	1.1948	0.2289	14.7
Year 2000	1.6107	0.1138	39.8
Year 2004	1.4150	0.1138	25.0
Year 2000 Flood 0-2	1.7810	0.2427	59.4
Year 2000 Flood 3-5	1.8649	0.1518	72.3
Year 2000 Flood 6-10	1.4237	0.2574	25.5
Year 2000 Flood 6-10	1.3732	0.2427	22.6
Year 2005 Flood 0-2	1.7116	0.2427	50.5
Year 2005 Flood 3-5	1.7448	0.1518	54.6
Year 2005 Flood 6-10	1.1871	0.2574	14.4
Year 2005 Flood 11-20	1.0165	0.2427	9.4

Effect	t	P
Flood 0-2 x 3-5	-0.22	0.8295
Flood 0-2 x 6-10	1.32	0.1930
Flood 0-2 x 11-20	**1.70**	**0.0953**
Flood 3-5 x 6-10	**1.77**	**0.0832**
Flood 3-5 x 11-20	**2.26**	**0.0287**
Flood 6-10 x 11-20	0.33	0.7419

Table 37. Number of pondberry that persisted and were lost from 2000 to 2005 at 47 colonies/sites with field determinations for wetland status. Number expected is the null hypothesis of no association between number of pondberry and site status. Pearson $\chi^2 = 188.4$, $p = 0.0000$. Odds ratio = 1.6976, 95% confidence interval $1.5737 < O.R. < 1.8313$.

Site	Persist		Loss		Total
	Actual	Expected	Actual	Expected	
Wetland	4,127	3,771	2,429	2,785	6,556
Non-wetland	2,375	2,731	2,373	2,017	4,648
Total	6,502	6,502	4,802	4,802	11,304

Table 38. Association of wetland status to the number of pondberry at 47 colonies/sites during 2000 and 2005, relative to that expected by an extrinsic null hypothesis that the number of pondberry is proportionate (no effect) to the number of wetland and non-wetland colonies/sites, by *G* tests.

Site Status	N	Percent	No. Pondberry 2000		No. Pondberry 2005		Total	
			Actual	Expected	Actual	Expected	Actual	Expected
Wetland	13	27.66	6,556	3,127	4,127	1,798	10,683	4,925
Non-wetland	34	72.34	4,748	8,177	2,375	4,704	7,123	12,881
Total	47	100.00	11,304	11,304	6,502	6,502	17,806	17,806

Tests	df	G	$\chi^2_{.001}$
Pooled	1	8104.4*	10.828
Heterogeneity	1	51.8*	10.828
Total	2	8156.2*	13.816

Table 39. Change in the number of pondberry at 49 profiled colonies/sites by flood frequency, between 2000 and 2005 in Delta National Forest, with 4 x 2 test *G*-test of the null hypothesis of no independence or no association, with expected number based on hypothesis intrinsic to data. The change in number of pondberry by flood frequency classes with the same letter are not significantly different, by G_H test.

a. Number of pondberry at 49 profiled colonies/sites, including all wetland colonies/sites. (G_H = 726.6, $\chi^2_{(.001,3)} = 16.27$).

N	Flood Frequency	2000		2005		Total	Percent Change	Exponential growth
		Actual	Expected	Actual	Expected			
4	0 – 2.0	2,454	3,265	2,694	1,884	5,148[a]	+09.8	0.0187
12	2.1 – 5.0	8,467	7,714	3,696	4,449	12,163[b]	-56.3	-0.1658
6	5.1 – 10.0	328	312	164	180	492[b]	-50.[b]	-0.1386
18	10.1 – 20.0	499	457	221	263	720[b]	-55.7	-0.1629
49	Total	11,748	11,748	6,775	6,776	18,523	-42.3	-0.1101

b. Data'for 39 profiled colonies sites, without 8 colonies above the 2-year floodplain, with a local wetland hydrology. ($G_H = 427.7$, $\chi^2_{(.001,3)} = 16.27$; G_H for flood frequency classes 2-4 = 1.94, $\chi^2_{(.05,2)} = 5.991$).

N	Flood Frequency	2000		2005		Total	Percent Change	Exponential growth
		Actual	Expected	Actual	Expected			
8	0 – 2.0	2,434	2,985	2,661	2,110	5,095[a]	+9.3	0.0178
18	2.1 – 5.0	3,855	3,410	1,966	2,411	5,821[b]	-49.0	-0.1347
8	5.1 – 10.0	328	288	164	204	492[b]	-50.0	-0.1386
5	10.1 – 20.0	444	378	200	266	644[b]	-54.9	-0.1595
39	Total	7,061	7,061	4,991	4,991	12,052	-29.3	-0.0694

Table 40 . Association of flood frequency interval class to the number of pondberry colonies/sites during 2000 and 2005, relative to that expected by an extrinsic null hypothesis that the number of pondberry in each flood frequency class is proportionate (no effect) to the number the number of colonies/sites (N) in the class by *G* tests.

a. Data for 49 profiled colonies/sites, including all wetland colonies/sites. (G_H= 748.3, $\chi^2_{(.001,3)}$ = 16.27).

Flood Frequency	N	Percent	No. Pondberry 2000		No. Pondberry 2005		Total	
			Actual	Expected	Actual	Expected	Actual	Expected
1. 0 – 2.0	9	18.37	2,454	2,158	2,694	1,245	5,148	3,402
2. 2.1 – 5.0	23	46.94	8,467	5,515	3,696	3,180	12,163	8,695
3. 5.1 – 10.0	8	16.33	328	1,917	164	1,106	492	3,025
4. 10.1 – 20.0	9	18.37	499	2,158	221	1,245	720	3,402
Total	49	100.00	11,748	11,748	6,775	7,466	18,523	18,523

b. Summary of *G* tests and significance.

Tests	df	G	$\chi^2_{.001}$
Pooled	1	1,574.2*	10.828
Heterogeneity	3	748.3*	16.266
Total	4	16,491*	18.467

c. Total *G* partitioned by each flood frequency class interval, for the number of pondberry in 2000 and 2005.

Flood Frequency Class	df	*G*
1. 0 – 2.0	1	1,0322.2*
2. 2.1 – 5.0	1	3,459.6*
3. 5.1 – 10.0	1	1,157.0*
4. >10.0	1	1,552.2*
Total	4	16,491.0*

Table 41. Median colony/site growth rates, 2000-2005, from wetland (n=11) and nonwetland (n = 33) colonies/sites that persisted from 2000 – 2005. R_e is average annual exponential growth, R_g is average annual geometric growth, and R_p is percent (log) change.

Growth Rate	Habitat	Median	Range	Mean
Re	Wetland	-0.1176	-0.2181 – 0.5222	0.0375
	Non-wetland	-0.1098	-0.5724 – 0.4755	-0.0932
	All	-0.1109	-0.5724 – 0.5223	-0.0605
R_g	Wetland	-0.1109	-0.1960 – 0.6858	-0.0834
	Non-wetland	-0.1040	-0.4359 – 0.6088	-0.0759
	All	-0.1049	-0.4359 – 0.6858	-0.0360
R_p	Wetland	-0.5878	-1.0904 – 2.6113	0.1877
	Non-wetland	-0.5491	-2.8622 – 2.3445	-0.4658
	All	-0.5543	-2.8622 – 2.6113	-0.3024

Table 42 . Pondberry colony/site data for least squares nonlinear regression models, with reference to the predicted flood frequency upon completion of the project (Project Flood Freq). Models did not include colonies/sites that were jurisdictional wetlands established by local hydrological factors (Local Wetland=1, shaded rows), instead of overbank flooding, if the flood frequency interval from the 1943-1997 POR was greater than 2 years..

Colony/ Site	Local Wetland	Plants 2000	Plants 2005	R_g[1]	R_e[2]	R_p[3]	Flood Freq. 1943-1997	Flood Freq. 1984-2003	Flood Freq. 1999-2003	Project Flood Freq.
56	1	94	1280	0.6858	0.5223	2.6113	0.7	1.3	1.3	0.7
54	1	47	558	0.6402	0.4948	2.4742	0.8	1.3	1.1	0.8
3	0	70	4	-0.4359	-0.5724	-2.8622	1.5	2.9	2.5	4.0
2	1	36	14	-0.1721	-0.1889	-0.9445	1.5	2.9	2.5	3.5
41	0	46	41	-0.0228	-0.0230	-0.1151	2.0	6.7	5.0	4.5
21	1	72	45	-0.0897	-0.0940	-0.4700	2.0	2.9	2.5	4.5
42	1	2064	719	-0.1902	-0.2109	-1.0545	2.0	6.7	5.0	5.0
16	0	40	40	0.0000	0.0000	0.0000	2.5	10.0	11.0	8.5
39	0	12	14	0.0313	0.0308	0.1542	2.5	10.0	10.0	7.0
43	1	3791	1274	-0.1960	-0.2181	-1.0905	2.5	10.0	10.0	4.5
20	0	218	57	-0.2353	-0.2683	-1.3414	3.0	20.0	11.0	15.0
35	1	25	63	0.2030	0.1849	0.9243	3.0	10.0	10.0	13.0
44	1	72	40	-0.1109	-0.1176	-0.5878	3.0	10.0	10.0	6.5
14	0	13	27	0.1574	0.1462	0.7309	3.5	20.0	11.0	20.0
15	0	143	39	-0.2288	-0.2599	-1.2993	3.5	20.0	11.0	19.0
17	0	262	133	-0.1268	-0.1356	-0.6780	3.5	20.0	11.0	17.0
34	0	10	11	0.0192	0.0191	0.0953	3.5	10.0	10.0	20.0
10	0	11	6	-0.1142	-0.1212	-0.6061	4.0	20.0	11.0	25.0
31	0	1800	565	-0.2069	-0.2317	-1.1587	4.0	10.0	10.0	25.0
32	0	9	97	0.6088	0.4755	2.3775	4.0	10.0	10.0	27.0
33	0	22	16	-0.0617	-0.0637	-0.3185	4.0	10.0	10.0	27.0
36	0	11	10	-0.0189	-0.0191	-0.0953	4.0	10.0	10.0	37.0
46	0	258	266	0.0061	0.0061	0.0305	4.0	20.0	11.0	35.0
55	0	153	130	-0.0321	-0.0326	-0.1629	4.0	10.0	10.0	30.0
30	1	300	113	-0.1774	-0.1953	-0.9764	4.0	10.0	10.0	25.0
1	0	2	2	0.0000	0.0000	0.0000	4.5	20.0	11.0	70.0
29	0	485	148	-0.2113	-0.2374	-1.1869	4.5	10.0	10.0	37.0
45	0	398	401	0.0015	0.0015	0.0075	4.5	20.0	11.0	15.0
5	0	8	4	-0.1294	-0.1386	-0.6931	5.0	20.0	11.0	45.0
8	0	6	3	-0.1294	-0.1386	-0.6931	6.0	21.0	11.0	55.0
37	0	161	43	-0.2321	-0.2640	-1.3202	6.0	20.0	11.0	100.0
38	0	31	29	-0.0133	-0.0133	-0.0667	6.0	20.0	11.0	100.0
7	0	14	12	-0.0304	-0.0308	-0.1542	7.0	21.0	11.0	85.0
28	0	48	43	-0.0218	-0.0220	-0.1100	7.0	20.0	11.0	100.0
11	0	37	19	-0.1248	-0.1333	-0.6665	7.5	21.0	11.0	85.0
12	0	21	12	-0.1059	-0.1119	-0.5596	7.5	21.0	11.0	100.0
6	0	10	3	-0.2140	-0.2408	-1.2040	9.0	21.0	11.0	100.0

Table 43. Outlier evaluation of selected residuals by standardized residual and Z score, with probability (p) of a greater Z, from least squares regression of $y = a + b(\exp^{-cx})$, where y = colony/site growth rate, R, by three different measures, in response to flood frequency (x) for all colonies/sites that persisted from 2000 – 2005. Flood frequencies from 19943-1997 POR.

Measure and Model	Colony/ Site	R	Residual	Standardized Residual	Z	p
Exponential R_e1A	54	0.3362	0.1586	0.2998	0.9738	0.4612
	56	0.5223	-0.0854	-0.1614	-0.5241	0.3001
	32	0.4755	0.5735	1.0838	3.5205	0.0002
	3	-0.5724	-0.4889	-0.9240	-3.0015	0.0013
Geometric R_g1A	54	0.6402	0.1713	0.3236	1.0526	0.01463
	56	0.6858	-0.0956	-0.1807	-0.5878	0.2783
	32	-0.4359	-0.3780	-0.7143	-2.323	0.0101
	3	0.6088	0.6904	1.3046	4.2431	0.0000
Percent Change R_p1A	54	2.4742	0.7941	0.9484	0.9751	0.1648
	56	2.6113	-0.4274	-0.5104	-0.5248	0.2999
	32	-2.8622	-2.4445	-2.9192	-3.0015	0.3313
	3	2.3775	2.8674	3.4243	3.5209	0.0002

Table 44. Outlier evaluation of selected residuals by standardized residual and Z score, with probability (p) of a greater Z, from least squares regression of $y = a + b(\exp^{1/x})$, where y = colony/site growth rate, R, by three different measures, in response to flood frequency (x) for all colonies/sites that persisted from 2000 – 2005. Flood frequencies from 1943-1997 POR.

Measure	Colony/ Site	R	Residual	Standardized Residual	Z	p
Exponential R_e2A	54	0.4948	0.1770	0.9954	1.0094	0.1564
	56	0.5223	0.0761	0.4283	0.4343	0.3320
	32	0.4755	0.5722	3.2190	3.2643	0.0005
	3	-0.5724	-0.6004	-3.3777	-3.4252	0.0003
Geometric R_g2A	54	0.6402	0.1901	1.0591	1.0738	0.1415
	56	0.6858	0.0714	0.3981	0.4036	0.3423
	32	0.6088	0.6088	3.8430	3.8961	0.0000
	3	-0.4359	-0.4359	-2.8688	-2.9084	0.0018
Percent Change R_p2A	54	2.4742	0.8848	0.9956	1.0093	0.1564
	56	2.6113	0.3807	0.4284	0.4343	0.3320
	32	2.3775	2.8611	3.2196	3.2639	0.0005
	3	-2.8622	-3.4248	-3.3784	-3.4248	0.0003

Table 45. Outlier evaluation of selected residuals by standardized residual and Z score, with probability (p) of a greater Z, from least squares regression of $y = a^x - b$, where y = colony/site growth rate, R, by three different measures, in response to flood frequency (x) for all colonies/sites that persisted from 2000 – 2005. Flood frequencies from 1943-1997 POR.

Measure	Colony/ Site	R	Residual	Standardized Residual	Z	p
Exponential R_e3A	54	0.4948	0.2840	1.5358	1.5563	0.0598
	56	0.5223	0.2626	1.4200	1.4389	0.0751
	32	0.4755	0.5702	3.0834	3.1245	0.0009
	3	-0.5724	-0.5851	-3.1686	-3.2058	0.0007
Geometric R_g3A	54	0.6402	0.3498	1.7993	1.8239	0.0308
	56	0.6858	0.3465	1.7823	1.8067	0.0354
	32	0.6088	0.6870	3.5333	3.5816	0.0002
	3	-0.4359	-0.5100	-2.6232	-2.6591	0.0039
Percent Change R_p3A	54	2.4742	2.3166	2.2857	2.3166	0.0103
	56	2.6113	2.4176	2.3854	2.4176	0.0078
	32	2.3775	2.7536	2.7469	2.7536	0.0029
	3	-2.8622	-2.8150	-2.7775	-2.8150	0.0024

Table 46. Outlier evaluation of selected residuals by standardized residual and Z score, with probability (p) of a greater Z, from least squares regression of $y = x^a - b$, where y = colony/site growth rate, R, by three different measures, in response to flood frequency (x) for all colonies/sites that persisted from 2000 – 2005.

Measure	Colony/ Site	R	Residual	Standardized Residual	Z	p
Exponential R_e4A	54	0.4948	0.3631	1.8339	1.8601	0.0314
	56	0.5223	0.3723	1.8803	1.9072	0.0282
	32	0.4755	0.5400	2.7276	2.7666	0.0028
	3	-0.5724	-0.6225	-3.1443	-3.1893	0.0007
Geometric R_g4A	54	0.6402	0.3945	1.8894	2.9151	0.0018
	56	0.6858	0.4118	1.9722	1.9991	0.0228
	32	0.6088	0.6510	3.1176	3.1601	0.0008
	3	-0.4359	-0.5580	-2.8723	-2.7087	0.0034
Percent Change R_p4A	54	2.4742	0.7529	0.8957	0.9080	0.1819
	56	2.6113	-0.4916	-0.5848	-5.928	0.0000
	32	2.3775	2.8845	3.4313	3.4787	0.0003
	3	-2.8622	-2.5803	-3.0694	-3.1118	0.0009

Table 47. Outlier evaluation of selected residuals by standardized residual and *Z* score, with probability (*p*) of a greater *Z*, from least squares regression of $y = a + b(log(x))$, where y = colony/site growth rate, *R*, by three different measures, in response to flood frequency (x) for all colonies/sites that persisted from 2000 – 2005.

Measure	Colony/ Site	*R*	Residual	Standardized Residual	*Z*	*p*
Exponential R_e5A	54	0.4948	0.3964	1.9894	2.0162	0.0222
	56	0.5223	0.4106	2.0605	2.0883	0.0188
	32	0.4755	0.5367	2.6983	2.7301	0.0033
	3	-0.5724	-0.6085	-3.0541	-3.0952	0.0010
Geometric R_g5A	54	0.6402	0.4669	2.1962	2.2266	0.0132
	56	0.6858	0.4952	2.3293	2.3615	0.0091
	32	0.6088	0.6440	3.0292	3.0711	0.0011
	3	-0.4359	-0.5277	-2.4823	-2.5166	0.0060
Percent Change R_p5A	54	2.4742	1.9819	1.9883	2.0879	0.0188
	56	2.6113	2.0528	2.0594	2.0158	0.0222
	32	2.3775	2.6837	2.6923	2.7296	0.0032
	3	-2.8662	-3.0426	-3.0524	-3.0946	0.0010

N = 38 colonies/sites with wetland field determinations, excluding colonies/sites with a local jurisdictional hydrology above the 2-year floodplain.

Table 48. Nonlinear and linear regression models for three measures of colony/site growth during 2000-2005 in response to flood frequency (1943-1997 POR). Model # is the model number and growth measure, where R_g is geometric growth rate, R_e = exponential growth rate, and R_p = percent change growth. Model is the regression equation, x = flood frequency, n = number of colonies/sites, K=number of model parameters, SSE = sum squares error, AIC = Akaike's Information Criterion, AIC_c = AIC corrected for small sample size, ΔAIC_c = the difference in AIC_c for the model relative to the model with the minimum AIC_c value, w_i = normalized AIC_c weight, and r^2 = coefficient of determination. Wetland colonies/sites included only if located in the 0-2 year floodplain.

No.	Model	n	K	SSE	AIC	AIC_c	ΔAIC_c	w_i	r^2
A. Models with 1943-1997 POR, with no deletions.									
A.1. Geometric growth R_g									
R_g1A	$y = -0.0815 + 20.0310e^{-4.4925x}$	38	4	0.9791	-131.0309	-129.8188	0.0000	0.8705	0.5033
R_g2A	$y = -0.3898 + 0.2407e^{1/x}$	38	3	1.1593	-126.6113	-125.9054	3.9134	0.1230	0.4119
R_g3A	$y = 0.2945^x - 0.0857$	38	3	1.3610	-120.5159	-119.8100	10.0088	0.0058	0.3096
R_g4A	$y = -0.8000 + x^{-0.2001}$	38	3	1.5708	-115.0680	-114.3622	15.4566	0.0004	0.2032
R_g5A	$y = 0.1444 - 0.1296*\log x$	38	3	1.6278	-113.7136	-113.0077	16.8111	0.0002	0.1744
A.2. Exponential growth R_e									
R_e1A	$y = -0.0980 + 21.1263e^{-4.8596x}$	38	4	0.9817	-130.9301	-129.7180	0.0000	0.7861	0.3986
R_e2A	$y = -0.3380 + 0.1879e^{1/x}$	38	3	1.1371	-127.3460	-126.6401	3.0779	0.1687	0.3034
R_e3A	$y = 0.2248^x - 0.0975$	38	3	1.2317	-124.3093	-123.6034	6.1146	0.0370	0.2455
R_e4A	$y = -0.8980 + x^{-0.1314}$	38	3	1.4000	-119.4423	-118.7364	10.9816	0.0032	0.1364
R_e6A	$y = 0.8768^{\log x} - 0.8979$	38	3	1.4097	-119.1800	-118.4741	11.2439	0.0028	0.1364
R_e5A	$y = 0.0763 - 0.0992*\log x$	38	3	1.4308	-118.6154	-117.9095	11.8085	0.0021	0.1235
A.3. Percent change growth R_p									
R_p4A^*	$y = -0.51 + x^{3.4982}$	38	3	25.4405	-9.2473	-8.5414	0.0000	0.5924	0.3766
R_p1A	$y = -0.5166 + 35.1920e^{-3.3178x}$	38	4	24.5428	-8.6124	-7.4002	1.1412	0.3348	0.3986
R_p2A	$y = -1.8917 + 1.0831e^{1/x}$	38	3	28.4286	-5.0272	-4.3214	4.2200	0.0718	0.3034
R_p5A	$y = 0.1243 - 0.1304*\log x$	38	3	35.7688	3.7006	4.4065	12.9479	0.0009	0.1235
B. Models with 1943 – 1997 2004 POR, colonies 3 and 32 deleted as statistical outliers.									
B.1. Geometric growth R_g									
R_g1B	$y = -0.0939 + 8.3457e^{-3.2568x}$	36	4	0.3459	-159.2244	-157.9341	0.0000	0.8705	0.7512
R_g2B	$y = -0.4330 + 0.2674e^{1/x}$	36	3	0.4081	-155.2714	-154.5214	3.4127	0.1580	0.7065
R_g3B	$y = 0.3831^x - 0.1118$	36	3	0.5940	-141.7582	-141.0082	16.9259	0.0002	0.7568
R_g4B	$y = -0.7109 + x^{-0.2971}$	36	3	0.8043	-130.8468	-130.0968	27.8373	0.0000	0.4222
R_g5B	$y = 0.1799 - 0.1558*\log x$	36	3	0.9209	-125.9732	-125.2232	32.7109	0.0000	0.3378
B.2. Exponential growth R_e									
R_e1B	$y = -0.1033 + 7.0524e^{-3.0265x}$	36	4	0.4032	-153.7062	-152.4159	0.0000	0.5431	0.6276
R_e2B	$y = -0.3784 + 0.2166e^{1/x}$	36	3	0.4378	-152.7424	-151.9924	0.4235	0.4394	0.5955
R_e3B	$y = 0.3335^x - 0.1171$	36	3	0.5238	-146.2859	-145.5359	6.8801	0.0174	0.5161
R_e4B	$y = -0.8207 + x^{-0.2000}$	36	3	0.7004	-135.8264	-135.0764	17.3396	0.0001	0.3530
R_e5B	$y = 0.1243 - 0.1304*\log x$	36	3	0.7534	-133.2004	-132.4504	19.9656	0.0000	0.3040
B.3. Percent change growth R_p									
R_p4B	$y = -0.5138 + x^{-3.6041}$	36	3	10.4381	-38.5700	-37.8200	0.0000	0.5121	0.6143
R_p1B	$y = -0.4899 + 106.0830e^{-4.8619x}$	36	4	10.0787	-37.8314	-36.5411	1.2789	0.2702	0.7512
R_p2B	$y = -1.6901 + 0.9396e^{1/x}$	36	3	10.9459	-36.8599	-36.1099	1.7101	0.2178	0.5955
R_p5B	$y = 0..3816 - 0.4961*\log x$	36	3	18.8354	-17.3201	-16.5701	21.2499	0.0000	0.3040
R_p3B	$y = 0.5808^x - 0.4899$	36	3	21.4059	-12.7147	-11.9647	25.8553	0.0000	0.2090

Table 49. Nonlinear regression models for three measures of colony/site growth during 2000 - 2005, in response to flood frequency (1984-2003 POR). No. is the model number and code, where R_g is geometric growth rate, R_e = exponential growth rate, and R_p = percent change growth. Model is the regression equation, y=colony/site growth rate, x = flood frequency at colony/site, n = number of colonies/sites, K=number of model parameters, SSE = regression sum squares error, AIC = Akaike's Information Criterion, AIC_c = AIC corrected for small sample size, ΔAIC_c = the difference in AIC_c for the model relative to the model with the minimum AIC_c value, w_i = normalized AIC_c weight, and r^2 = coefficient of determination. Wetland colonies/sites included only if located in the 0-2 year floodplain. Most likely models shaded.

No.	Model	n	K	SSE	AIC	AIC_c	ΔAIC_c	w_i	r^2	p
C. Models for 1984-2003 POR.										
C.1. Geometric growth R_gC										
R_g1C	$y = -0.0820 + 27.0983e^{-2.8268x}$	38	4	0.9505	-132.1574	-130.9453	0.0000	0.7841	0.5179	0.0000
R_g6C	$y = 0.0925^{\log x} - 0.0801$	38	3	1.0952	-128.7727	-128.0668	2.8785	0.1859	0.4445	0.0000
R_g2C	$y = -0.6727 + 05442e^{1/x}$	38	3	1.2181	-124.7312	-124.0253	6.9200	0.0246	0.3822	0.0001
R_g3C	$y = 0.5011^x - 0.0762$	38	3	1.3271	-121.4744	-120.7685	10.1768	0.0048	0.3269	0.0004
R_g4C	$y = x^{-0.2367} - 0.6081$	38	3	1.5310	-116.0433	-115.3374	15.6079	0.0003	0.2234	0.0056
R_g5C	$y = 0.2778 - 0.1290*\log x$	38	3	1.5844	-114.7405	-114.0346	16.9107	0.0002	0.1964	0.0104
C.2. Exponential growth R_eC										
R_e1C	$y = -0.0988 + 31.0215e^{-3.0603x}$	38	4	0.9541	-132.0138	-130.8017	0.0000	0.5218	0.4155	0.0000
R_e6C	$y = 0.0525^{\log x} - 0.0962$	38	3	1.0303	-131.0940	-130.3881	0.4136	0.4243	0.3688	0.0000
R_e2C	$y = -0.5525 + 0.4194e^{1/x}$	38	3	1.1850	-125.7780	-125.0722	5.7295	0.0297	0.2741	0.0005
R_e3C	$y = 0.4365^x - 0.0928$	38	3	1.2030	-125.2052	-124.4993	6.3024	0.0223	0.2630	0.0007
R_e4C	$y = x^{-0.1311} - 0.7931$	38	3	1.4123	-119.1099	-118.4040	12.3976	0.0011	0.1348	0.0123
R_e5C	$y = 0.1645 - 0.0932*\log x$	38	3	1.4304	-118.6260	-117.9201	12.8815	0.0008	0.1237	0.0154
C.3. Percent change growth R_pC										
R_p1C	$y = -0.4937 + 155.1920e^{-3.0975x}$	38	4	23.8528	-9.6960	-8.4839	0.0000	0.9419	0.4155	0.0000
R_p2C	$y = -2.7623 + 2.0968e^{1/x}$	38	3	29.6249	-3.4609	-2.7550	5.7289	0.0537	0.2741	0.0005
R_p4C	$y = x^{-1.4391} - 0.4090$	38	3	35.1983	3.0896	3.7955	12.2794	0.0020	0.1375	0.0166
R_p5C	$y = 0.8225 - 0.4658*\log x$	38	3	35.7598	3.6911	4.3969	12.8808	0.0015	0.1238	0.0154
R_p3C	$y = 0.7043^x - 0.4107$	38	3	36.8581	4.8406	5.5465	14.0304	0.0008	0.0968	0.0266
D. Models for 1984-2003 POR, colonies 3 and 32 excluded as statistical outliers.										
D.1. Geometric growth R_gD										
R_g1D	$y = -0.0930 + 11.4780e^{-2.1194x}$	36	4	0.3340	-160.4848	-159.1945	0.0000	0.9419	0.7598	0.0000
R_g4D	$y = x^{-1.9032} - 0.0981$	36	3	0.4141	-154.7460	-153.9960	5.1985	0.0700	0.7022	0.0000
R_g6D	$y = 0.1490^{\log x} - 0.0981$	36	3	0.4174	-154.4603	-153.7103	5.4842	0.0607	0.7022	0.0000
R_g2D	$y = -0.7582 + 0.6149e^{1/x}$	36	3	0.4560	-151.2761	-150.5261	8.6683	0.0124	0:6721	0.0000
R_g3D	$y = 0.5882^x - 0.0930$	36	3	0.5725	-143.0854	-142.3354	16.8591	0.0002	0.5883	0.0000
R_g5D	$y = 0.3619 - 0.1628*\log x$	36	3	0.8315	-129.6495	-128.8995	30.2949	0.0000	0.4020	0.0000
D.2. Exponential growth R_eD										
R_e6D	$y = 0.0931^{\log x} - 0.1052$	36	3	0.4174	-154.4603	-153.7103	0.0000	0.4930	0.6144	0.0000
R_e1D	$y = -0.1027 + 10.3924e^{-2.2072x}$	36	4	0.3912	-154.7940	-153.5037	0.2066	0.4446	0.6387	0.0000
R_e2D	$y = -0.6399 + 0.4965e^{1/x}$	36	3	0.4732	-149.9432	-149.1932	4.5170	0.0515	0.5629	0.0000
R_e3D	$y = 0.5326^x - 0.1032$	36	3	0.5161	-146.8191	-146.0691	7.6412	0.0108	0.5233	0.0000
R_e4D	$y = x^{-0.2386} - 0.6251$	36	3	0.6645	-137.7206	-136.9706	16.7396	0.0001	0.3862	0.0000
R_e5D	$y = 0.2668 - 0.1323*\log x$	36	3	0.7130	-135.1845	-134.4345	19.2757	0.0000	0.3414	0.0000
D.3. Percent change growth R_pD										
R_p1D	$y = -0.5137 + 51.7207e^{-2.2035x}$	36	4	9.7792	-38.9174	-37.6271	0.0000	0.8963	0.6387	0.0000
R_p2D	$y = -3.1996 + 2.4827e^{1/x}$	36	3	11.8307	-34.0616	-33.3116	4.3155	0.1036	0.5629	0.0000
R_p3D	$y = 0.8145^x - 0.4665$	36	3	17.8248	-19.3054	-18.5554	19.0717	0.0001	0.2277	0.0011
R_p4D	$y = x^{-1.0528} - 0.4545$	36	3	20.9025	-13.5714	-12.8214	24.8057	0.0000	0.2497	0.0007
R_p5D	$y = 1.3341 - 0.6617*\log x$	36	3	20.3070	-14.6119	-13.8619	23.7652	0.0000	0.3414	0.0000

Table 49. continued

No.	Model	n	K	SSE	AIC	AIC_c	ΔAIC_c	w_i	r^2	p
E. Models for 20-year 1984-2003 POR, colonies/sites without any flooding excluded.										
E.1. Geometric growth R_gC										
R_g1E	$y = -0.0754 + 28.5950e^{-2.8529x}$	30	4	0.9149	-96.7041	-95.1041	0.0000	0.6527	0.5191	0.0001
R_g6E	$y = 0.0877^{\log(x)} - 0.0721$	30	3	1.0582	-94.3388	-93.4158	1.6884	0.2806	0.4437	0.0002
R_g2E	$y = -0.6703 + 0.5429e^{1/x}$	30	3	1.1879	-90.8703	-89.9472	5.1569	0.0495	0.3756	0.0012
R_g3E	$y = 0.4938^x - 0.0674$	30	3	1.2883	-88.4362	-87.5131	7.5910	0.0147	0.3228	0.0037
R_g4E	$y = x^{-0.2534} - 0.5925$	30	3	1.4973	-83.9260	-83.0029	12.1012	0.0015	0.2129	0.0301
R_g5E	$y = 0.2817 - 0.1318*\log x$	30	3	1.5531	-82.8283	-81.9053	13.1989	0.0009	0.1836	0.0502
E.2. Exponential growth R_eC										
R_e6E	$y = 0.0508^{\log(x)} - 0.0911$	30	3	0.9896	-96.3496	-95.4265	0.0000	0.4825	0.3710	0.0007
R_e1E	$y = -0.0946 + 31.3984e^{-3.3265x}$	30	4	0.9143	-96.7238	-95.1238	0.3027	0.4147	0.4188	0.0009
R_e2E	$y = -0.5520 + 0.4191e^{1/x}$	30	3	1.1473	-91.9136	-90.9905	4.4360	0.0525	0.2707	0.0055
R_e3E	$y = 0.4313^x - 0.0867$	30	3	1.1610	-91.5575	-90.6344	4.7921	0.0439	0.2620	0.0065
R_e4E	$y = x^{-0.1354} - 0.7882$	30	3	1.3737	-86.5107	-85.5876	9.8389	0.0035	0.1268	0.0686
R_e5E	$y = 0.1668 - 0.0948*\log x$	30	3	1.3923	-86.1072	-85.1841	10.2423	0.0029	0.1150	0.0828
E.3. Percent change growth R_pC										
R_p1E	$y = -0.4730 + 156.6660e^{-3.0826x}$	30	4	22.8575	-0.1575	1.4425	0.0000	0.8708	0.4188	0.0009
R_p2E	$y = -2.7601 + 2.0956e^{1/x}$	30	3	28.6831	4.6533	5.5764	4.1339	0.1102	0.2707	0.0055
R_p4E	$y = x^{-1.5263} - 0.3570$	30	3	33.9608	9.7203	10.6434	9.2009	0.0087	0.0935	0.0587
R_p5E	$y = 0.8351 - 0.4742*\log x$	30	3	34.8076	10.4592	11.3822	9.9398	0.0060	0.1365	0.0828
R_P3E	$y = 0.6669^x - 0.3548$	30	3	35.6508	11.1772	12.1003	10.6578	0.0042	0.0935	0.1158
F. Models for 1984-2003 POR, colonies without any flooding excluded, and colonies 3 and 32 removed as statistical outliers.										
F.1. Geometric growth R_gD										
R_g1F	$y = -0.0930 + 8.3457e^{-3.2568x}$	28	4	0.3024	-118.7899	-117.0507	0.0000	0.8481	0.7726	0.0000
R_g6F	$y = 0.7426^{\log(x)} - 0.7105$	28	3	0.3829	-114.1812	-113.1812	3.8695	0.1225	0.7120	0.0000
R_g2F	$y = -0.4328 + 0.2674e^{1/x}$	28	3	0.4251	-111.2538	-110.2538	6.7969	0.0283	0.6802	0.0000
R_g3F	$y = 0.3831^x - 0.1118$	28	3	0.5409	-104.5083	-103.5083	13.5424	0.0010	0.5932	0.0000
R_g5F	$y = 0.1799 - 0.1558*\log x$	28	3	0.7917	-93.8418	-92.8418	24.2089	0.0000	0.4045	0.0009
R_g4F	$y = x^{-0.2971} - 0.7109$	28	3	0.8348	-92.3575	-91.3575	25.6932	0.0000	0.3721	0.0017
F.2. Exponential growth R_eD										
R_e6F	$y = 0.8187^{\log(x)} - 0.8206$	28	3	0.3789	-114.4752	-113.4752	0.0000	0.5302	0.6330	0.0000
R_e1F	$y = -0.1033 + 7.1524e^{-3.3203x}$	28	4	0.3524	-114.5054	-112.7663	0.7089	0.3719	0.6559	0.0000
R_e2F	$y = -0.3784 + 0.2167e^{1/x}$	28	3	0.4352	-110.5963	-109.5963	3.8789	0.0762	0.5750	0.0000
R_e3F	$y = 0.3335^x - 0.1171$	28	3	0.4773	-108.0108	-107.0108	6.4644	0.0209	0.5339	0.0000
R_e4F	$y = x^{-0.2000} - 0.8207$	28	3	0.6176	-100.7953	-99.7953	13.6799	0.0006	0.3962	0.0005
R_e5F	$y = 0.1243 - 0.1304*\log x$	28	3	0.6691	-98.5527	-97.5527	15.9225	0.0002	0.3466	0.0014
F.3. Percent change growth R_pD										
R_p1F	$y = -0.5166 + 35.1920e^{-3.3168x}$	28	4	8.8088	-24.3807	-22.6416	0.0000	0.8297	0.6559	0.0000
R_p2F	$y = -1.8917 + 1.0831e^{1/x}$	28	3	10.8793	-20.4696	-19.4696	3.1720	0.1699	0.5750	0.0000
R_p5F	$y = 0.6216 - 0.6520*\log x$	28	3	16.7281	-8.4232	-7.4232	15.2184	0.0004	0.3466	0.0014
R_p4F	$y = x^{-1.0971} - 0.4035$	28	3	19.1249	-4.6740	-3.6740	18.9676	0.0001	0.2530	0.0079
R_P3F	$y = 0.6426^x - 0.5331$	28	3	19.8219	-3.6717	-2.6717	19.9699	0.0000	0.2257	0.0127

Table 50. Nonlinear regression models for three measures of colony/site growth during 2000 - 2005, in response to flood frequency (1994-2003 POR). No. is the model number and code, where R_g is geometric growth rate, R_e = exponential growth rate, and R_p = percent change growth. Model is the regression equation, y=colony/site growth rate, x = flood frequency at colony/site, n = number of colonies/sites, K=number of model parameters, SSE = regression sum squares error, AIC = Akaike's Information Criterion, AIC_c = AIC corrected for small sample size, ΔAIC_c = the difference in AIC_c for the model relative to the model with the minimum AIC_c value, w_i = normalized AIC_c weight, and r^2 = coefficient of determination. Wetland colonies/sites included only if located in the 0-2 year floodplain. Most likely models shaded.

No.	Model	n	K	SSE	AIC	AIC_c	ΔAIC_c	w_i	R^2	p
G. Models for 10-year 1994-2003 POR.										
G.1. Geometric growth R_gC										
R_g6G	$y = 0.0412^{\log(x)} - 0.0796$	38	3	1.0522	-130.2947	-129.5888	0.0000	0.5009	0.4663	0.0000
R_g1G	$y = -0.0819 + 15.9266e^{-2.6494}$	38	4	0.9876	-130.7024	-129.4903	0.0985	0.4768	0.4991	0.0000
R_g2G	$y = -0.6094 + 0.4717e^{1/x}$	38	3	1.2550	-123.5971	-122.8912	6.6976	0.0176	0.3634	0.0002
R_g3G	$y = 0.4558^x - 0.0760$	38	3	1.3525	-120.7540	-120.0481	9.5407	0.0042	0.3140	0.0006
R_g4G	$y = x^{-0.2876} - 0.5992$	38	3	1.5628	-115.2621	-114.5562	15.0326	0.0003	0.2073	0.0082
R_g5G	$y = 0.2824 - 0.1548 * \log x$	38	3	1.6229	-113.8281	-113.1222	16.4666	0.0001	0.1768	0.0161
G.2. Exponential growth R_eC										
R_e6G	$y = 0.0182^{\log(x)} - 0.0973$	38	3	1.0115	-131.7938	-131.0879	0.0000	0.6369	0.3804	0.0000
R_e1G	$y = -0.0984 + 17.2523e^{-2.8969}$	38	4	0.9814	-130.9417	-129.7296	1.3583	0.3230	0.3988	0.0000
R_e2G	$y = -0.5020 + 0.3621e^{1/x}$	38	3	1.2102	-124.9784	-124.2725	6.8153	0.0211	0.2586	0.0008
R_e3G	$y = 0.3917^x - 0.0927$	38	3	1.2214	-124.6284	-123.9225	7.1654	0.0177	0.2517	0.0009
R_e4G	$y = x^{-0.7955} - 0.1531$	38	3	1.4426	-118.3033	-117.5974	13.4905	0.0007	0.1163	0.0179
R_e5G	$y = 0.1593 - 0.1077 * \log x$	38	3	1.4634	-117.7593	-117.0534	14.0345	0.0006	0.1035	0.0232
G.3. Percent change growth R_pC										
R_p1G	$y = -0.4912 + 86.1357e^{-2.8565}$	4	24.5343	0.6456	-8.6255	-7.4134	0.0000	0.9316	0.3988	0.0000
R_p2G	$y = -2.5010 + 1.8106e^{1/x}$	3	30.2552	0.7962	-2.6609	-1.9550	5.4584	0.0608	0.2586	0.0008
R_p4G	$y = x^{-2.0804} - 0.3928$	3	34.6041	0.9106	2.4427	3.1486	10.5620	0.0047	0.1520	0.0085
R_p5G	$y = 0.7966 - 0.5387 * \log x$	3	36.5853	0.9628	4.5583	5.2642	12.6776	0.0016	0.1035	0.0232
R_p3G	$y = 0.6176^x - 0.3985$	3	37.1261	0.9770	5.1159	5.8218	13.2352	0.0012	0.0902	0.0303
H. Models for 1994-2003 POR, colonies 3 and 32 deleted as statistical outliers.										
H.1. Geometric growth R_gD										
R_g1H	$y = -0.0937 + 7.6877e^{-1.9906}$	36	4	0.3577	-158.0169	-156.7265	0.0000	0.3844	0.7428	0.0000
R_g4H	$y = x^{-2.5331} - 0.0956$	36	3	0.3928	-156.6471	-155.8971	0.8295	0.2539	0.7175	0.0000
R_g6H	$y = 0.0796^{\log(x)} - 0.0956$	36	3	0.3928	-156.6471	-155.8971	0.8295	0.2539	0.6089	0.0000
R_g2H	$y = -0.6982 + 0.5482e^{1/x}$	36	3	0.4120	-154.9290	-154.1790	2.5475	0.1076	0.6605	0.0000
R_g3H	$y = 0.5453^x - 0.0934$	36	3	0.5952	-141.6856	-140.9356	15.7910	0.0001	0.5720	0.0000
R_g5H	$y = 0.4125 - 0.2172 * \log x$	36	3	0.7731	-132.2712	-131.5212	25.2054	0.0000	0.4440	0.0000
H.2. Exponential growth R_eD										
R_e6H	$y = 0.0371^{\log(x)} - 0.1044$	36	3	0.4234	-153.9464	-153.1964	0.0000	0.5956	0.6089	0.0000
R_e1H	$y = -0.1033 + 6.6804e^{-2.0602}$	36	4	0.4067	-153.3951	-152.1048	1.0916	0.3451	0.6243	0.0000
R_e2H	$y = -0.5903 + 0.4367e^{1/x}$	36	3	0.4866	-148.9379	-148.1879	5.0085	0.0487	0.5505	0.0000
R_e3H	$y = 0.4900^x - 0.1034$	36	3	0.5306	-145.8216	-145.0716	8.1249	0.0102	0.5099	0.0000
R_e4H	$y = x^{-0.3037} - 0.6022$	36	3	0.6410	-139.0168	-138.2668	14.9296	0.0003	0.4078	0.0000
R_e5H	$y = 0.3021 - 0.1739 * \log x$	36	3	0.6869	-136.5271	-135.7771	17.4194	0.0001	0.3655	0.0000
H.3. Percent change growth R_pD										
R_p1H	$y = -0.5163 + 33.4648e^{-2.0618}$	36	4	10.1680	-37.5138	-36.2235	0.0000	0.8761	0.6243	0.0000
R_p2H	$y = -2.9512 + 2.1836e^{1/x}$	36	3	12.1654	-33.0572	-32.3072	3.9163	0.1236	0.5505	0.0000
R_p5H	$y = 1.5106 - 0.8695 * \log x$	36	3	17.1719	-20.6488	-19.8988	16.3247	0.0002	0.3655	0.0000
R_p4H	$y = x^{-1.4343} - 0.4330$	36	3	19.8793	-15.3782	-14.6282	21.5953	0.0000	0.2655	0.0005
R_p3H	$y = 0.7541^x - 0.4620$	36	3	21.3563	-12.7982	-12.0482	24.1753	0.0000	0.2109	0.0016

Table 50. Continued.

No.	Model	n	K	SSE	AIC	AIC_c	ΔAIC_c	w_i	r^2	p
I. Models for 10-year 1994-2003 POR, colonies without any flooding excluded.										
I.1. Geometric growth R_gC										
R_g6I	$y = 0.0330^{[illegible]} - 0.0510$	15	3	0.8100	-37.7816	-35.5998	0.0000	0.6368	0.4904	0.0115
R_g1I	$y = -0.0588 + 17.0911e^{[illegible]}$	15	4	0.7505	-36.9260	-32.9260	2.6738	0.1673	0.5279	0.0233
R_g2I	$y = -0.6010 + 0.4676e^{1/x}$	15	3	1.0281	-34.2051	-32.0232	3.5765	0.1065	0.3532	0.0543
R_g3I	$y = 0.4260^x - 0.0382$	15	3	1.1014	-33.1720	-30.9902	4.6095	0.0635	0.3071	0.0851
R_g4I	$y = x^{0.3149} - 0.5788$	15	3	1.3351	-30.2857	-28.1038	7.4959	0.0150	0.1600	0.2970
R_g5I	$y = 0.2738 - 0.1442*\log x$	15	3	1.3932	-29.6467	-27.4649	8.1349	0.0109	0.1235	0.3917
I.2. Exponential growth R_eC										
R_e6I	$y = 0.158^{[illegible]} - 0.0829$	15	3	0.7361	-39.2166	-37.0348	0.0000	0.6327	0.4234	0.0277
R_e1I	$y = -0.0861 + 17.7846e^{-2.9428x}$	15	4	0.7071	-37.8195	-33.8195	3.2153	0.1268	0.4461	0.0609
R_e2I	$y = -0.5030 + 0.3626e^{1/x}$	15	3	0.9389	-35.5664	-33.3846	3.6501	0.1020	0.2645	0.1349
R_e3I	$y = 0.3716^x - 0.0681$	15	3	0.9394	-35.5585	-33.3766	3.6581	0.1016	0.2642	0.1354
R_e4I	$y = x^{0.1445} - 0.8023$	15	3	1.1707	-32.2567	-30.0749	6.9599	0.0195	0.0830	0.5662
R_e5I	$y = 0.1502 - 0.0965*\log x$	15	3	1.1887	-32.0278	-29.8460	7.1887	0.0174	0.0689	0.6252
I.3. Percent change growth R_pC										
R_p1I	$y = -0.4301 + 89.2019e^{-2.9456x}$	15	4	17.6775	10.4636	14.4636	0.0000	0.4151	0.4461	0.0609
R_p2I	$y = -2.5150 + 1.8131e^{1/x}$	15	3	23.4736	12.7174	14.8992	0.4356	0.3338	0.2645	0.1349
R_p4I	$y = x^{-2.4070} - 0.1613$	15	3	26.6368	14.6137	16.7955	2.3318	0.1294	0.1654	0.3069
R_p3I	$y = 0.5338^x - 0.1563$	15	3	29.2075	15.9956	18.1774	3.7138	0.0648	0.0849	0.5586
R_p5I	$y = 0.7511 - 0.4823*\log x$	15	3	29.7183	16.2557	18.4375	3.9739	0.0569	0.0688	0.6252
J. Models for 1994-2003 POR, colonies without any flooding excluded, and colonies 3 and 32 deleted as statistical outliers.										
J.1. Geometric growth R_gD										
R_g4J	$y = x^{[illegible]} - 0.0925$	13	3	0.1660	-50.6893	-48.0227	0.0000	0.6096	0.8401	0.0000
R_g1J	$y = -0.09190 + 7.7417e^{[illegible]}$	13	4	0.1309	-51.7775	-46.7775	1.2451	0.3271	0.8739	0.0000
R_g2J	$y = -0.7509 + 0.5678e^{1/x}$	13	3	0.2374	-46.0385	-43.3718	4.6509	0.0596	0.7713	0.0003
R_g3J	$y = 0.5400^x - 0.0870$	13	3	0.3680	-40.3401	-37.6734	10.3492	0.0034	0.6455	0.0032
R_g5J	$y = 0.4343 - 0.2454*\log x$	13	3	0.5272	-35.6666	-33.0000	15.0227	0.0003	0.4921	0.0228
R_e6J	$y = 0.8187^{\log(x)} - 0.8206$	13	3	0.1520	-51.8347	-49.1680	0.0000	0.7148	0.7900	0.0002
R_e1J	$y = -0.1033 + 7.1524e^{[illegible]}$	13	4	0.1352	-51.3573	-46.3573	2.8107	0.1753	0.8133	0.0006
R_e2J	$y = -0.3784 + 0.2167e^{1/x}$	13	3	0.2117	-47.5279	-44.8613	4.3068	0.0830	0.7076	0.0012
R_e3J	$y = 0.3335^x - 0.1171$	13	3	0.2589	-44.9114	-42.2447	6.9233	0.0224	0.6423	0.0035
R_e4J	$y = x^{-0.2000} - 0.8207$	13	3	0.3493	-41.0181	-38.3514	10.8167	0.0032	0.5175	0.0181
R_e5J	$y = 0.1243 - 0.1304*\log x$	13	3	0.4064	-39.0498	-36.3831	12.7849	0.0012	0.4386	0.0417
R_p1J	$y = -0.4943 + 34.2324e^{[illegible]}$	13	4	3.3794	-9.5143	-4.5143	0.0000	0.6743	0.8133	0.0006
R_p2J	$y = -3.1305 + 2.2706e^{[illegible]}$	13	3	5.2922	-5.6833	-3.0166	1.4976	0.3189	0.7076	0.0012
R_p5J	$y = 1.5866 - 0.9674*\log x$	13	3	10.1594	2.7949	5.4615	9.9758	0.0046	0.4386	0.0417
R_p4J	$y = x^{-1.6435} - 0.1884$	13	3	12.0723	5.0375	7.7042	12.2185	0.0015	0.3329	0.1078
R_p3J	$y = 0.7093^x - 0.2258$	13	3	13.7701	6.7482	9.4148	13.9291	0.0006	0.2391	0.2222

Table 51. Flood frequency at zero (0) pondberry colony/site growth rates, below which negative growth is predicted according to the fitted least squares nonlinear regression line for various models of colony/site growth rate during 2000-2005, in response to flood frequencies computed from the 1943-1997, 1984-2003, and 1994-2003 periods at each colony/site. A full (Full) model includes all colonies/sites (n=38); part (Part) models consist of colonies/sites in the full model for the respective period, but without colonies/sites that were not flooded during the period[1]; and models with outliers removed (Outliers Removed) consist of all colonies/sites in the respective full or part model, but with colonies/sites 3 and 32 removed as statistical outliers[2]. Most likely models by AIC (Tables 48 - 50) shaded.

Model	1943-1997 POR		1984 – 2003 POR				1994 – 2003 POR			
	Full R_xA	Full Outliers Removed R_xB	Full R_xC	Full Outliers Removed R_xD	Part R_xE	Part Outliers Removed R_xF	Full R_xG	Full Outliers Removed R_xH	Part R_xI	Part Outliers Removed R_xJ
R_g1	1.2	1.4	2.1	2.3	2.1	2.3	2.0	2.2	2.1	2.2
R_g2	2.0	2.1	4.7	4.8	4.7	4.7	3.9	4.0	---[3]	3.6
R_g3	2.0	2.0	3.7	4.5	3.8	4.5	3.3	3.9	---	4.0
R_g4	3.0	3.1	8.1	3.4	7.9	9.2	5.9	2.5	---	2.5
R_g5	3.0	3.2	8.6	9.2	8.5	8.9	6.2	6.7	---	5.9
R_g6	3.0	3.2	2.9	3.4	2.9	3.4	2.2	2.5	2.4	2.5
R_e1	1.1	1.3	1.9	2.1	1.9	2.1	1.8	2.0	---	2.0
R_e2	1.7	1.8	3.6	3.9	3.6	3.9	3.1	3.3	---	3.1
R_e3	1.6	1.4	2.9	3.6	2.9	3.6	2.5	3.2	---	3.2
R_e4	2.3	2.7	5.9	7.2	2.0	6.8	4.5	5.3	---	4.5
R_e5	2.1	2.6	5.8	7.5	5.8	7.3	4.4	5.7	---	5.2
R_e6	2.3	2.7	2.2	2.6	2.2	2.6	1.8	2.0	1.8	2.0
R_p1	1.1	1.3	1.9	2.1	1.9	2.1	1.8	2.0	---	2.0
R_p2	1.7	1.8	3.6	3.9	3.6	3.9	3.1	3.3	---	3.1
R_p3	1.3	1.2	2.5	3.7	2.6	3.9	1.9	2.7	---	---
R_p4	1.2	1.2	1.9	2.1	2.0	2.3	1.6	1.8	---	---
R_P5	2.2	2.6	5.8	7.5	5.8	7.3	4.4	5.7	---	5.2

1-Colonies/sites that did not flood were coded with a flood frequency of 21 years for the Full model for the 20-year 1984-2003 POR, and 11 years for the 10-year 1994-2003 POR.

2-Z-scores for colonies/sites 3 and 32 for respective nonlinear models, when removed, were 2.0000 or greater, with a probability of 0.025 or less of greater Z.

3-Results from model not reported and included, where P>0.05 for the model coefficient of determination (r^2).

Table 52. Acres affected by different flood frequency events under current (baseline) and proposed project conditions, and the percentage change, according to an analysis of Corps GIS data.

Flood Frequency	Baseline Conditions		Project Conditions		Percent Change	
	Total area	DNF	Total area	DNF	Total area	DNF
0-2	325,682	55,579	254,741	48,226	-21.8	-13.2
3-5	222,846	5,985	166,598	11,133	-25.2	+86.0
6-10	81,067	150	52,483	1,104	-35.3	+636.0

Data processed in GIS from shapefiles provided by Corps.

Table 53. Acres of wetlands (FESM) and other (non-wetland) lands during current (baseline) and proposed project conditions, and the percentage change.

Class	Baseline Conditions		Project Conditions		Percent Change	
	Total area	DNF	Total area	DNF	Total area	DNF
Wetland	189,722	43,596	163,121	38,639	-13.7	-11.4
Other	735,876	18,244	762,477	23,201	+3.6	+27.2

Table 54. Number of known pondberry colonies/sites and profiled colonies (GSRC Colonies) in Delta National Forest in the 1-year floodplain, under current (pre-project) and project conditions, with project changes in flood duration interval.

Class	%Duration Interval	Duration Days	All colonies/sites		GSRC Colonies	
			Pre-project	Project	Pre-project	Project
Not-wetlands	<2.5	1 – 6	1	3	0	0
	2.5-5.0	7 – 13	2	1	0	1
Wetlands (FESM)	5.0-7.5	14 – 19	1	1	1	0
	7.5-10.0	20 – 26	10	10	2	2
	10.0-12.5	27 – 33	1	0	0	0
	>12.5	> 34	0	0	0	0
Total			15	15	3	3

Table 55. Number and proportion of known pondberry colonies/sites in non-jurisdicational and jurisdictional (FESM) wetlands in Delta National Forest, by proposed project conditions.

Determination	%Duration Interval	Duration Days	Pondberry Colonies[1]		GSRC Colonies[1]	
			Number	%	Number	%
Above 5% duration wetland elevation	3-5yr floodplain	<1	107	60.4	31	63.3
	<2.5	1 – 6	53	29.9	16	3.3
	2.5-5.0	7 – 13	1	0.6	0	0.0
Jurisdictional wetlands	5.0-7.5	14 – 19	4	2.3	0	0.
	7.5-10.0	20 – 26	10	5.6	2	4.1
	10.0-12.5	27 – 33	0	0	0	0.0
	>12.5	> 34	2	1.1	0	0.0
Total			177	100.0	49	100.0

1- GSRC colonies are the selected colonies for the Corps pondberry profile.

Table 56. Number of colonies/sites by population, in wetlands (FESM) by baseline (current) conditions and with the proposed project.

Population	Total Colonies	Base Wetland Colonies	Project Colonies		
			FESM Wetlands	0-1 Floodplain	1-2 Floodplain
Colby	13	0	0	0	0
Red Gum	75	5	5	3	2
Spanish Fort	65	0	0	0	0
4	5	0	0	0	0
5	6	4	4	4	0
6	4	4	4	3	1
7	3	0	0	0	0
8[1]	1	1	0	0	0
9	1	1	1	1	0
10	1	1	1	1	0
11	1	1	1	1	0
12	1	0	0	0	0
13	1	0	0	0	0
Total	177	17	16	13	3

1 – Located in greentree reservoir, which is artificially flooded each year.

Table 57. Change in the total number of pondberry at 49 Corps profiled colonies/sites and average annual percent growth R_p, by flood frequency, between 2000 and 2005 in Delta National Forest. Flood frequency determined from ground-surveyed elevations at each colony/site.

Flood Frequency	Total Number of Plants		Percent Change	R_p
	2000	2005		
0-2	2,454	2,694	+09.8	0.1866
3-5	8,467	3,696	-56.3	-0.1658
6-10	328	164	-50.0	-0.1386
11+	499	221	-55.7	-0.1629
Total	11,748	6,775	-42.3	-0.1101

Average annual exponential change computed as $r = 1/t(\log(P_f/P_i))$, *where* t = *time*, P_i = *number of plants in 1993, and* P_f = *number of plants in 2006.* Flood frequency determined from ground surveyed elevations at each colony site.

Table 58. Ponberry colonies/sites (14) with no net decrease from 2000 to 2005, from 49 profiled colonies/sites in Delta National Forest.

Flood Frequency Class	Flood Frequency	Number of Pondberry 2000	Number of Pondberry 2005	Exponential growth rate	GSRC Colony/Site
0 – 2	0.7	94	1,280	0.5223	56
0 – 2	0.8	47	558	0.4948	54
0 – 2	2.0	20	33	0.1002	19
2.1 – 5	2.5	12	14	0.0301	39
2.1 – 5	2.5	40	40	0.0000	16
2.1 – 5	3.0	25	63	0.1849	35
2.1 – 5	3.5	13	27	0.1462	14
2.1 – 5	3.5	10	11	0.0191	34
2.1 – 5	4.0	9	97	0.4755	32
2.1 – 5	4.0	258	266	0.0061	46
2.1 – 5	4.5	398	401	0.0015	45
2.1 – 5	4.5	2	2	0.0000	1
10.1 – 20	11.0	2	13	0.3744	25
10.1 – 20	14.0	6	6	0.0000	13
	Overall	936	2,811	0.2199	

Table 59. Flood frequencies at Corps profiled (GSRC sites) pondberry colonies, determined from elevations physically surveyed at each colony/site, by pre-project (baseline) and project conditions. Colonies/sites in bold did not decrease in the number of plants between 2000 and 2005.

GSRC Site	Flood Frequency		GSRC Site	Flood Frequency	
	Pre-project	Project		Pre-project	Project
56	0.7	0.7	**46**	4.0	35.0
54	0.8	0.8	55	4.0	30.0
2	1.5	3.5	29	4.5	37.0
3	1.5	4.0	**1**	4.5	70.0
19	2.0	5.5	**45**	4.5	15.0
21	2.0	4.5	5	5.0	45.0
42	2.0	5.0	37	6.0	>100.0
40	2.0	4.5	38	6.0	>100.0
41	2.0	4.5	8	6.0	55.0
16	2.5	8.5	28	7.0	>100.0
18	2.5	8.5	7	7.0	85.0
43	2.5	4.5	11	7.5	85.0
39	2.5	7.0	12	7.5	>100.0
35	3.0	13.0	6	9.0	>100.0
20	3.0	15.0	**13**	11.0	>100.0
44	3.0	6.5	**25**	14.0	>100.0
34	3.5	20.0	23	15.0	>100.0
14	3.5	20.0	24	15.0	>100.0
15	3.5	19.0	26	15.0	>100.0
17	3.5	17.0	9	15.0	>100.0
30	4.0	25.0	27	16.0	>100.0
31	4.0	25.0	4	16.0	>100.0
32	4.0	27.0	22	17.0	>100.0
33	4.0	27.0	Average[1]	6.6	27.1
10	4.0	25.0	95% CI	5.7 – 7.7	19.4 – 38.0
36	4.0	37.0	Log(x+1) transformed, reported back-transformed.		

1 – Average flood frequency is log(x + 1) transformed data, expressed as back-transformed value, with 95% confidence intervals. Shapiro-Wilk (W) statistics: pre-project = 0.94126, p=0.0168, project=0.8971, p=0.0004.

Table 59. Wetland and non-wetland colonies/sites, as determined by Corps jurisdictional (JD) field surveys at 47 profiled colonies/sites, compared to the FESM 5 percent duration wetland classifications.

FESM Percent Flood Duration	FESM Days Inundated	Wetland Colonies/sites		Non-wetland Colonies/sites	
		JD	FESM	JD	FESM
Non-wetland	<1	4	0	23	29
	1 – 6	7	0	11	18
	7 – 13	0	0	0	0
Wetland	14 – 19	0	0	0	0
	20 – 26	2	2	0	0
	27 – 33	0	0	0	0
	>34	0	0	0	0
Total		13	2	34	47

Table 60. Estimated number and percent of all colonies/sites for FESM wetlands, wetlands with a locally hydrology independent of overbank flooding, and non-wetlands.

Population	FESM		Local Hydrology[1]		Not Wetland		Total
	Number	Percent	Number	Percent	Number	Percent	
Colby	0	0.0	3	23.1	10	76.9	13
Red Gum	5	6.8	17	23.3	51	69.9	73
Spanish Fort	0	0.0	18	27.7	47	72.3	65
All DNF[2]	17	9.6	39	22.0	121	68.4	177

1 – Includes colonies sites 2, 21 and 42 (Table 67), assuming their hydrology is independent – and not partially dependent – of overbank flooding.

Table 61. Estimated number and percent of wetland and non-wetland colonies, of 177 colonies/sites, in major populations and DNF.

Population	Wetland			Wetland Percent	Not Wet	Not Wet Percent	Total	Wet:NW Ratio
	FESM	Local[1]	Total					
Colby	0	3	3	23.08	10	76.92	13	0.3000
Red Gum	5	17	22	30.14	51	69.86	73	0.4317
Spanish Fort	0	18	18	26.92	47	72.30	65	0.3829
All DNF[2]	17	39	56	31.6	121	68.40	177	0.4628

1 – Wetlands with a local hydrology, wholly or partially independent of overbank flooding.

2 – Rows in columns above do not add because other populations in DNF are not listed.

Table 62. Estimated percentage of pondberry in wetland and non-wetland colonies/sites, with project, based on ratio of the number of pondberry produced per wetland and non-wetland colonies/sites as adjusted by the ratio of wetland:non-wetland colonies in each population, from 47 profiled colonies in 2000 and 2005.

a. Maximum estimates, based on average number of pondberry in wetland and non-wetland colonies in 2005, with 3.8725 wetland plants for 1 non-wetland plant.

Population	Pondberry W[2]:NW Ratio[3]	Percent of Total Pondberry[4]	
		Wetland	Not Wetland
Colby	1.1612	53.7	46.3
Red Gum	1.6738	62.6	37.4
Spanish Fort	1.4821	59.7	40.3
All DNF[1]	1.7914	64.2	35.8

b. Minimum estimates, based on average number of pondberry in wetland and non-wetland colonies in 2000, with 2.0148 wetland plants for 1 non-wetland plant in the first example, and a 1:1 ratio for the second.

	2.0148:1 pondberry W:NW ratio			1:1 pondberry W:NWratio		
	Pondberry	Percent of Total Pondberry[4]		Pondberry	Percent of Total Pondberry[4]	
Population	W:NW Ratio	Wetland	Not Wetland	W:NW Ratio	Wetland	Not Wetland
Colby	0.6044	37.7	62.3	0.3000	30.0	60.0
Red Gum	0.8698	46.5	53.5	0.4317	43.2	56.8
Spanish Ft	0.7715	43.5	56.5	0.3829	38.3	61.7
All DNF[1]	0.9324	48.3	51.7	0.4628	46.3	53.7

1 – Rows in columns above do not add because other populations in DNF are not listed. 2 – Wetlands are FESM wetlands by overbank flooding and those with a local hydrology wholly or partially independent of flooding. 3 – Ratio of the average number of pondberry in wetland colonies to non-wetland colonies, adjusted by the ratio of wetland:non-wetland colonies in each population, representing the number of pondberry produced on average from all wetland colonies to non-wetland colonies. 4 – Computed by converting pondberry W:NW ratio to percentage.

Table 63. Number of profiled pondberry colonies/sites with project and a local wetland hydrology independent of overbank flooding, relative to colonies/sites that are not FESM wetlands or wetlands with a local hydrology affected by a combination of overbank flooding (0-2 year floodplain) and local hydrology, with associations in GIS depressions. Expected is the number of colonies if they occur independently of wetland status and depressions. Depressions identified from a 10-m DEM raster by USGS. Wetlands determined by jurisdictional field survey. Baseline wetland colonies/sites 2, 21, and 42 are excluded as wetlands with the project due to flood frequency changes, assuming their hydrology depends at least partially on overbank flooding. Chi-square = 12.8, p=0.0003. Odds ratio = 17.0, 95% C.I.= 2.78<O.R.<104.90).

	Jurisdictional wetlands[2]		Not wetlands[1]		
Feature	Observed	Expected	Observed	Expected	Total
Depressions	6	2.1	6	9.9	12
Not depressions	2	5.9	31	27.1	33
Total	8	8.0	37	37.0	45

1 – Excludes sites 54 and 56 that are FEAT wetlands established by overbank flooding. Local hydrology independent of overbank flooding refers to colonies/sites where jurisdictional wetland conditions are established by local precipitation and site factors entirely independent of backwater flooding, at sites where the overbank flood frequency interval is greater than 2 years. 2 – Excludes colonies/sites 2, 21 and 42, assumed to partially depend on overbank flooding.

Table 64. Number of colonies/sites (n=160) estimated[1] with a local wetland hydrology, independent of overbank flooding, in depressions and not associated with depressions, for major populations and the entire DNF with project. Excludes colonies/sites 2, 21, and 42 as wetlands.

Population	Depressions			Not Depressions			Total			
	W	NW[4]	Total	W	NW[4]	Total	W	NW[4]	Total	W Percent
Colby	1	1	2	1	10	11	2	11	13	15.3
Red Gum	9	9	18	3	47	50	12	56	68	17.6
Spanish Fort	10	10	20	3	42	45	13	52	65	20.0
All DNF[2]	21	20	41	7	112	119	28	132	160[3]	17.5

1 – Estimated from the proportion of colonies/sites determined as jurisdictional wetlands, with a local hydrology independent of overbank flooding, and colonies not wetlands from 47 field surveyed colonies/sites, with GIS of 160 colonies sites and a USGS prepared depressions raster from a 10-m DEM.
2 – Numbers from rows above to do not necessarily add to the sum because not all populations are listed.
3 – 160 colonies/sites that are not FESM wetlands.
4 - Colonies that are not FESM wetlands and do not occur at sites with a local hydrology independent of overbank flooding.

Table 65. Estimated number and percent of all colonies/sites for FESM wetlands, wetlands with a local hydrology independent of overbank flooding, and non-wetlands with project. Excludes colonies/sites 2, 21, and 42 as wetlands.

Population	FESM		Local Hydrology[1]		Not Wetland		Total
	Number	Percent	Number	Percent	Number	Percent	
Colby	0	0.0	2	15.4	11	84.6	13
Red Gum	5	6.8	12	16.4	56	76.7	73
Spanish Fort	0	0.0	13	20.0	52	80.	65
All DNF[2]	17	9.6	28	15.8	132	74.6	177

1 – Excludes colonies sites 2, 21 and 42 (Table 67), assuming their hydrology is partially dependent upon – and not independent of -- overbank flooding. 2 – Rows in columns above do not add because other populations in DNF are not listed.

Table 66. Estimated number and percent of wetland and non-wetland colonies, of 177 colonies/sites, in major populations and DNF, with project where three wetlands with a local hydrology dependent on backwater flooding and local conditions become non-wetlands.

Population	Wetland			Wetland Percent	Not Wet	Not Wet Percent	Total	Wet:NW Ratio
	FESM	Local[1]	Total					
Colby	0	2	2	15.38	11	84.62	13	0.1818
Red Gum	5	12	17	23.29	56	76.71	73	0.3036
Spanish Fort	0	13	13	20.00	52	80.00	65	0.2500
All DNF[2]	17	28	45	25.42	132	74.58	177	0.3409

1 – Wetlands with a local hydrology, wholly independent of overbank flooding.
2 – Rows in columns above do not add because other populations in DNF are not listed.

Table 66. Estimated percentage of pondberry in wetland and non-wetland colonies/sites with project, based on ratio of the number of pondberry produced per wetland and non-wetland colonies/sites from 47 profiled colonies in 2000 and 2005, with project and conversion of wetlands with a local hydrology dependent on backwater flooding and local factors to non-wetlands.

a. Maximum estimates, based on average number of pondberry in wetland and non-wetland colonies in 2005, with 3.8725 wetland plants for 1 non-wetland plant.

Population	Pondberry W[2]:NW Ratio[3]	Percent of Total Pondberry[4]	
		Wetland	Not Wetland
Colby	0.6921	59.1	40.9
Red Gum	1.1558	53.6	46.4
Spanish Fort	0.9518	48.8	51.2
All DNF[1]	1.2978	56.5	43.5

b. Minimum estimates, based on average number of pondberry in wetland and non-wetland colonies in 2000, with 2.0148 plants in wetlands for 1 non-wetland plant, and 1:1 ratio.

Population	2.0148:1 pondberry W:NW ratio			1:1 pondberry W:NWratio		
	Pondberry W:NW Ratio	Percent of Total Pondberry[4]		Pondberry W:NW Ratio	Percent of Total Pondberry[4]	
		Wetland	Not Wetland		Wetland	Not Wetland
Colby	0.3663	26.8	73.2	0.1818	18.2	81.8
Red Gum	0.6117	38.0	62.0	0.3036	30.4	69.6
Spanish Ft	0.5037	33.5	66.5	0.2500	25.0	75.0
All DNF[1]	0.6868	40.7	59.3	0.3409	34.1	65.9

1 – Rows in columns above do not add because other populations in DNF are not listed. 2 – Wetlands are FESM wetlands by overbank flooding and those with a local hydrology wholly or partially independent of flooding. 3 – Ratio of the average number of pondberry in wetland colonies to non-wetland colonies, adjusted by the ratio of wetland:non-wetland colonies in each population, representing the number of pondberry produced on average from all wetland colonies to non-wetland colonies. 4 – Computed by converting pondberry W:NW ratio to percentage.

Table 67. Number of pondberry at wetland colonies/sites, 2000 and 2005, with change and geometric (R_g), exponential (R_e), and percent change (R_p) growth rates.

Colony	Number of Pondberry		Absolute Change	R_g	R_e	R_p
	2000	2005				
56	94	1,280	1,186	0.5226	0.6858	2.6113
54	47	558	511	0.4948	0.6402	2.4742
35	25	63	38	0.1849	0.2030	0.9243
25	2	13	11	0.3744	0.4541	1.8718
23	3	0	-3			
24	16	8	-8	-0.1386	-0.1294	-0.6931
2	36	14	-22	-0.1889	-0.1721	-0.9445
21	72	45	-27	-0.0940	-0.0897	-0.4700
44	72	40	-32	-0.1176	-0.1109	-0.5878
22	34	0	-34			
30	300	113	-187	-0.1953	-0.1774	-0.9764
42	2,064	719	-1,345	-0.2109	-0.1902	-1.0545
43	3,791	1,274	-2,517	-0.2181	-0.1959	-1.0905
Total	6,556	4,127	-2,429			

Table 68. Flood frequency at 177 pondberry colonies/sites during pre-project conditions and the changes with the proposed project. Flood frequency at each colony/site determined using GIS and elevation data from a 30-m DEM and the FESM model.

Flood	Pre-project (baseline)		Project	
Frequency (yrs)	Colonies/sites	Percent	Colonies/sites	Percent
0 – 2	85	48.0	70	39.5
3 – 5	92	52.0	84	47.5
6+	0	0.0	23	13.0
Total	177	100.0	177	100.0

Table 69. Effect of flood frequency class (0-2 and 3-5) determined by FESM-GIS with a 30-meter DEM and year (2000 and 2005) on the number of pondberry per colony, for 47 field-surveyed colonies, by repeated measures ANOVA. Number of pondberry are log-transformed.

	2000-Frequency			2005-Frequency			Frequency		
Site	Mean	SE	Back-transformed	Mean	SE	Back-transformed	Mean	SE	Back-transformed
0-2	3.8840	0.4395	48.6183	4.0277	0.4155	56.1317	3.9559	0.4083	52.2427
3-5	3.9252	0.3322	50.6632	3.3679	0.3141	29.0175	3.6466	0.3087	38.3440
Year	3.9046	0.2755	49.6302	3.6978	0.2604	40.3584			

Effect	df	F	P
Flood frequency	1	0.3651	0.5489
Year	1	1.6861	0.2012
Frequency x Year	**1**	**4.8434**	**0.0333**

Effect	Mean	SE	Back Transformed Values	
			Mean	95% Confidence Interval
Flood freq 0-2	3.9559	0.4083	52.2427	22.9152 – 119.0924
Flood freq 3-5	3.6466	0.3087	38.3440	20.5652 – 71.4859
Year 2000	3.9046	0.2755	49.6302	28.4657 – 86.5308
Year 2005	3.6978	0.2604	40.3584	23.8599 – 68.2584
Freq 0-2, 2000Year	3.8840	0.4395	48.6183	20.0274 – 118.0254
Freq 0-2, 2005Year	4.0277	0.4155	56.1317	24.2714 – 129.8266
Freq 3-5, 2000Year	3.9252	0.3322	50.6632	25.9144 – 99.0575
Freq 3-5, 2005Year	3.3679	0.3141	29.0175	15.3959 – 54.6910

Effect	F	P
0-2, 2000 x 0-2, 2005	**78.1016**	**0.0000**
3-5, 2000 x 3-5, 2005	**139.5933**	**0.0000**
0-2, 2000 x 3-5, 2000	0.0056	0.9407
0-2, 2005 x 3-5, 2005	1.6050	0.2122

Table 70. Change in number of pondberry plants from 2000 to 2005 at profiled colonies in Delta National Forest by flood frequency class. Flood frequency at each colony/site determined by FESM-GIS.

a. Percent change and average annual exponential growth R_p at 49 profiled colonies/sites.

Frequency	Total Pondberry		Percent Change	R_p
	2000	2005		
0 – 2	3,250	3,033	-06.8	-0.0138
3 – 5	8,498	3,742	-56.1	-0.1640
Total	11,748	6,775	-42.3	-0.1101

Growth computed as $r = 1/t(log(P_f/P_i)$, *where* t = *time*, P_i = *number of plants in 2000, and* P_f = *number of plants in 2005.*

b. Number of pondberry that persisted and were lost from 2000 to 2005 at 47 colonies/sites with field determinations for wetland status. Number expected is the null hypothesis of no association between number of pondberry and flood frequency. Pearson $\chi^2 = 2393.056$, $p = 0.0000$. Odds ratio 18.4734, 95% confidence interval 15.9860<O.R.<21.3479.

Flood Frequency	Persist		Loss		Total
	Actual	Expected	Actual	Expected	
0 – 2	3,033	1,869	217	1,381	3,250
3 – 5	3,469	4,633	4,585	3,421	8,054
Total	6,502	6,502	4,802	4,802	11,304

Table 71. Flood frequencies at non-wetland Corps-profiled (GSRC sites) pondberry colonies, determined from elevations physically surveyed at each colony/site, by pre-project (baseline) and project conditions. Colonies/sites in bold did not decrease in the number of plants between 2000 and 2005.

GSRC Site	Flood Frequency		GSRC Site	Flood Frequency	
	Pre-project	Project		Pre-project	Project
3	1.5	4.0	55	4.0	30.0
19	2.0	5.5	1	4.5	70.0
40	2.0	4.5	29	4.5	37.0
41	2.0	4.5	45	4.5	15.0
16	2.5	8.5	**5**	5.0	45.0
18	2.5	8.5	8	6.0	55.0
39	2.5	7.0	37	6.0	>100.0
20	3.0	15.0	38	6.0	>100.0
14	3.5	20.0	**7**	7.0	85.0
15	3.5	19.0	28	7.0	>100.0
17	3.5	17.0	11	7.5	85.0
34	3.5	20.0	**12**	7.5	>100.0
10	4.0	25.0	**6**	9.0	>100.0
31	4.0	25.0	13	11.0	>100.0
32	4.0	25.0	9	15.0	>100.0
33	4.0	27.0	26	15.0	>100.0
36	4.0	37.0	4	16.0	>100.0
46	4.0	35.0	27	16.0	>100.0
			Median	4.0	32.5
			95% CI	5.7 – 7.7	19.4 – 38.0

Table 72. Current (baseline) flood frequency class profiled colonies in Delta National Forest, and change with the project. Flood frequencies determined from ground-surveyed elevation data at each colony/site.

a. Baseline and change for 49 profiled colonies.

Baseline		Project Flood Frequency						
Colonies	Frequency	0 -2.0	2.1-5.0	5.1-10.0	10.1-15.0	15.1-20.0	20.0-100	>100
9	0-2.0	2	6	1	0	0	0	0
23	2.1-5.0	--	1	4	3	4	11	0
8	5.1-10.0	--	--	0	0	0	8	0
6	10.1-15.0	--	--	--	0	0	0	6
3	15.1-20.0	--	--	--	--	0	0	3
0	20.1-100	--	--	--	--	0	0	0
0	>100	--	--	--	--	--	--	0
49	Total	2	7	5	3	4	19	9

b. Baseline and change for 36 profiled colonies, excluding wetland colonies/sites

Baseline		Project Flood Frequency						
Colonies	Frequency	0 -2.0	2.1-5.0	5.1-10.0	10.1-15.0	15.1-20.0	20.0-100	>100
4	0-2.0	0	3	1	0	0	0	0
19	2.1-5.0	--	0	2	1	5	11	0
8	5.1-10.0	--	--	0	0	0	3	5
3	10.1-15.0	--	--	--	0	0	0	3
2	15.1-20.0	--	--	--	--	0	0	2
0	20.1-100	--	--	--	--	.0	0	0
0	>100	--	--	--	--	--	--	0
36	Total	0	3	3	1	5	14	10

Table 73. Flood frequency at 177 pondberry colonies/sites during pre-project conditions and the changes with the proposed project. Flood frequency at each colony site determined from a ground survey of the elevation with instrument and rod from established benchmarks.

Flood Frequency	Pre-project		Project	
	Colonies	Percent	Colonies	Percent
0 – 2	9	18.4	2	4.1
2.1 – 5	23	46.9	7	14.3
5.1 – 10	8	16.3	5	10.2
10.1 – 15	6	12.2	3	6.1
15.1 – 20	3	6.1	4	8.2
20.1 – 100	0	0.0	14	28.6
100	0	0.0	14	28.6
Total	49	100.0	49	100.0

Table 74. Number of profiled pondberry colonies/sites by flood frequency interval according to stage-gage data for two periods-of record, at sites where the elevation was determined by a ground surveys from benchmarks. The adjusted 1943-1997 POR is the standard used by the Corps to estimate baseline conditions without the project. The 1984-2003 period is a recent POR with less frequent observed flooding relative to that expected by the 1943 – 1997 POR. With project conditions are the expected frequencies by the proposed project.

Flood Frequency	1943-1997	1984-2003		With Project Conditions
		Total[1]	Growing Season[2]	
0 – 2	9	4	2	2
2.1 – 5	23	12	4	7
5.1 – 10	8	6	12	5
10.1 – 15	6	0	0	3
15.1 – 20	3	18	22	4
> 20	0	9	9	28

1 – Represents all flooding, dormant and growing season, during the 1984-2003 period.
2 – Represents only growing season flood events.

Table 75. Number of pondberry and overall annual exponential growth rates (R_e) in three Delta National Forest Populations, during 2000 and 2005, at Corps profiled colonies/sites, by flood frequency data from the 1943 – 1997 POR.

Flood Freq.	Colby Population				Red Gum Population				Spanish Fort Population			
	N	2000	2005	R_e	N	2000	2005	R_e	N	2000	2005	R_e
0-2	3	2,115	760	-0.2047	0	0	0	0	4	198	96	-0.1448
2.1-5	2	3,813	1,288	-0.2165	8	2,662	1,023	-0.1913	9	1,121	548	-0.1431
5.1-10	0	0	0	0	3	240	115	-0.1471	5	88	49	-0.1171
10.1+	0	0	0	0	6	218	67	-0.2360	3	281	154	-0.1203
Total	5	5,928	2,048	-0.2126	17	3,120	1,205	-0.1903	21	1,688	847	-0.1379

Table 76. Number of profiled pondberry colonies/sites by flood frequency class in three populations, by current (Base) and project (Proj.) conditions, relative to flood frequencies determined from the elevations by a 30-m DEM with FESM GIS (GIS DEM), and elevations by a ground survey with instrument and rod from benchmarks (Ground Survey).

Flood Freq.	Colby Population				Red Gum Population				Spanish Fort Population			
	GIS-DEM		Ground Survey		GIS-DEM		Ground Survey		GIS-DEM		Ground Survey	
	Base	Proj.	Base	Proj.	Base	Proj.	Base	Proj.	Base	Proj.	Base	Proj.
0-2	0	0	3	0	17	16	0	0	0	0	4	0
2-5	5	2	2	4	0	1	8	0	21	21	9	3
5-10	0	3	0	1	0	0	3	0	0	0	5	3
10-15	0	0	0	0	0	0	4	1	0	0	2	1
15-20	0	0	0	0	0	0	1	1	0	0	1	3
20-100	0	0	0	0	0	0	0	6	0	0	0	6
>100	0	0	0	0	0	0	0	9	0	0	0	5
Total	5	5	5	5	17	17	17	17	21	21	21	21

Flood frequency class intervals are 0-2, 2.1-5, 5.1-10, etc.

Table 77. Mean number of pondberry plants per colony/site for 2000 and 2005 at different flood frequency class intervals, from repeated measures ANOVA, with raw effect size between means.

Mean No. Plants/colony[1]	Flood Frequency	Effect Difference between Flood Frequency Classes			
		0 – 2	3 – 5	6 – 10	11+
54.5[ab]	0 – 2	---	---	---	---
62.8[a]	3 – 5	8.3[2] (0.86)[2]	---	---	---
19.2[bc]	6 – 10	35.3 (2.84)	43.6 (3.27)	---	---
14.7[c]	11+	39.8 (3.71)	48.1 (4.27)	4.5 (1.3)	---

1 – any pair of means with the same letter are not significantly different ($\alpha = 0.10$).
2 – The first number in the pair is the arithmetic difference between the two means being compared. The second number in parenthesis is the relative difference, computed as (mean value 1/mean value 2).

Table 78. Summary of single-factor ANOVA for pondberry attributes (variable) at four flood frequency intervals in Delta National Forest from profiled colonies in 2000, from Applied Research and Analysis report, Attachment 5, Appendix 14, Pondberry Biological Assessment (U.S. Army Corps of Engineers 2005)

Variable	F	P	Minimum Detectable Difference	Power
Number of clumps	0.6494	0.5877	0.4331	0.8911
Number of plants	1.7019	0.1825	5.5556	0.9852
Number of dead stems	2.7525	0.0555	2.0100	0.9996
Number of females	0.9450	0.4267	1.2152	0.9324
Number of fruit	0.7241	0.5428	2.2381	0.9626
Average plant height	1.3596	0.2669	5.6778	0.9980
Average stem diameter	0.6277	0.6008	0.0916	0.8819

Table 79. Least square mean number of pondberry per colony and 95% confidence intervals at four flood frequency intervals in Delta National Forest from profiled colonies in 2000, from single factor ANOVA.

Flood Frequency	Mean	Back-transformed	SE	Confidence Interval		N
				-95%	+95%	
0-2	1.7810	61.39	0.2415	1.2946	2.2674	9
3-5	1.8649	74.25	0.1511	1.5606	2.1692	23
6-1[b]	1.4237	27.53	0.2561	0.9078	1.9396	8
11+	1.3732	24.60	0.2415	0.8868	1.8956	9

Computed from transformed data, $X = \log_{10}(X + 1)$, where X = number of pondberry in each colony. Back-transformed are the transformed means converted to original values.

Table 80. Number plants per profiled colony/site in Delta National Forest in 2000, from Table 2 of Applied Research and Analysis report, Attachment 5, Appendix 14, Pondberry Biological Assessment (U.S. Army Corps of Engineers 2005).

Flood Frequency	N	Untransformed Mean	Standard Deviation	Transformed Mean
0-2	6	41.50	26.786	6.0949
2-5	19	216.68	412.629	10.9364
5-10	9	37.33	48.539	5.3809
>10	9	55.44	64.977	6.1551

Transformed data are the square-root of original data.

Table 81. Retrospective and prospective power calculations, for a single factor ANOVA of effects of flood frequency class interval to the mean number of pondberry per colony/site. Data reproduced from U.S. Army Corps of Engineers 2006. LSN is the least significant number, the smallest sample size to detect the given effect size.

Effect Size	Power	LSN	Power when N = LSN
0.21430	0.35712[1]	92	0.64157
0.50504	0.98535[2]	50	0.63650
0.61855	0.99932[2]	15	0.64006
0.71424	0.99998[2]	15	0.67133

1 – Retrospective power. 2 – Prospective power.

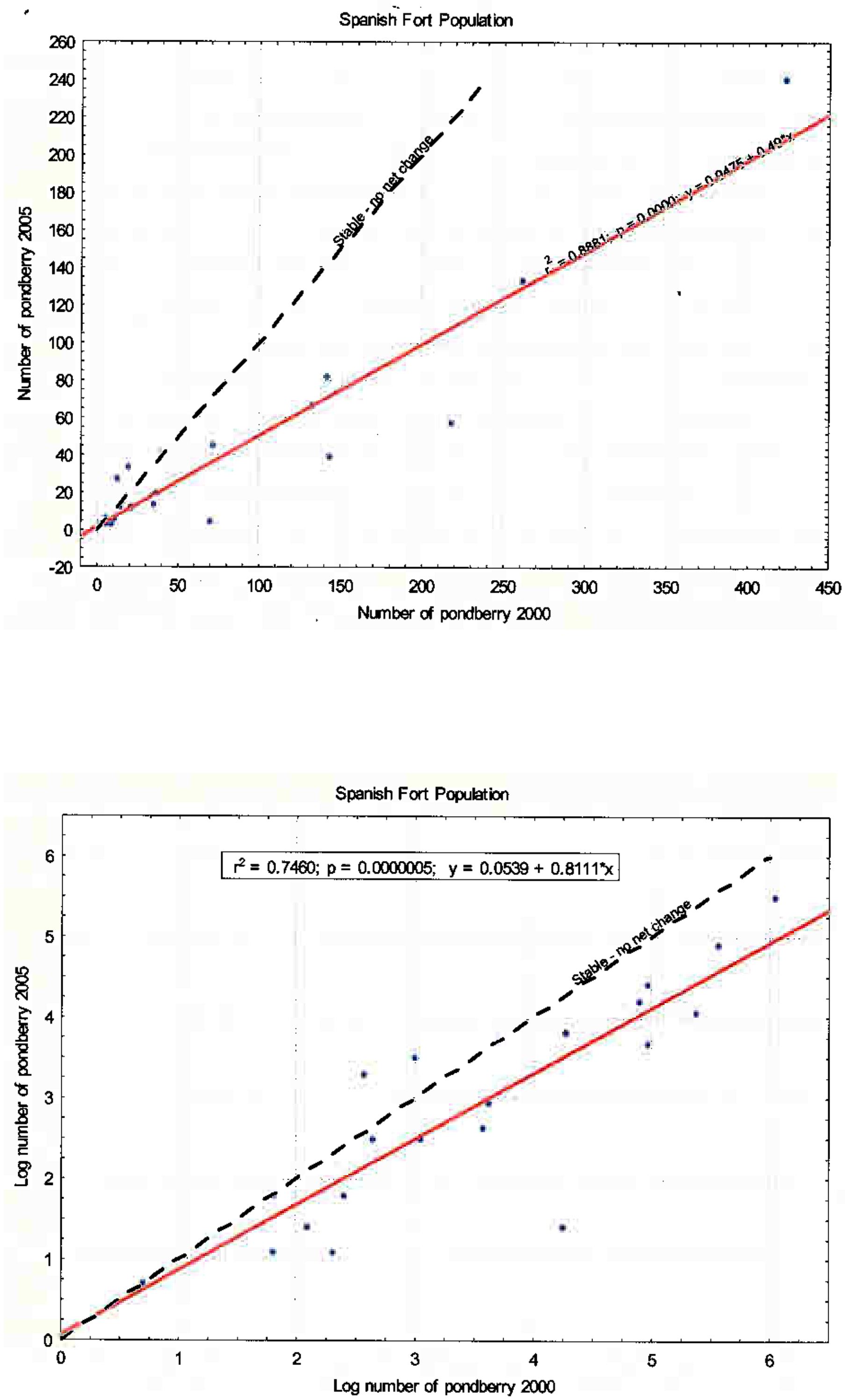
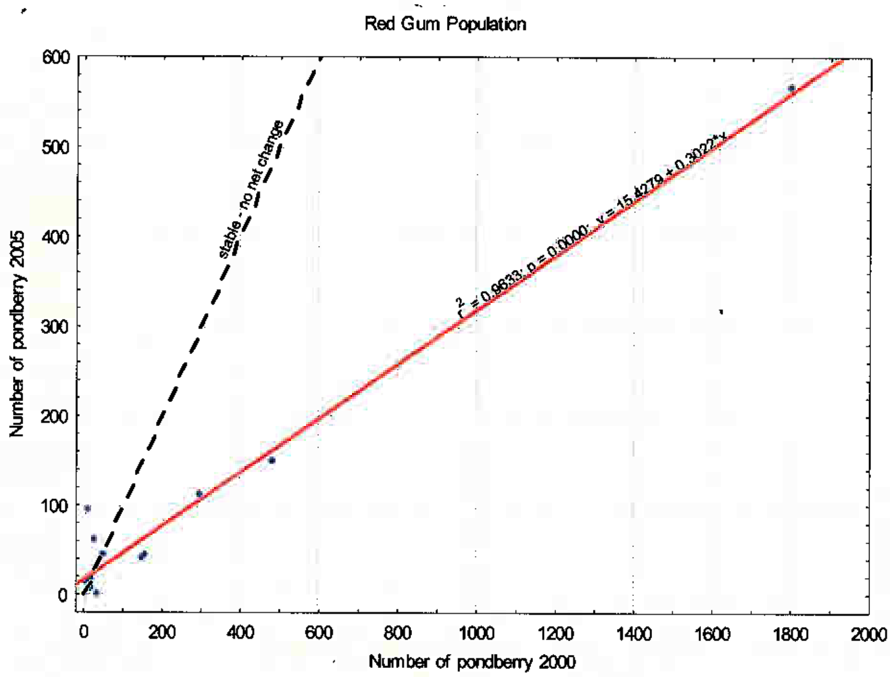


Figure 1. Change in the number of pondberry at profiled colonies/sites (n=21), 2000 and 2005, in the Spanish Fort population.



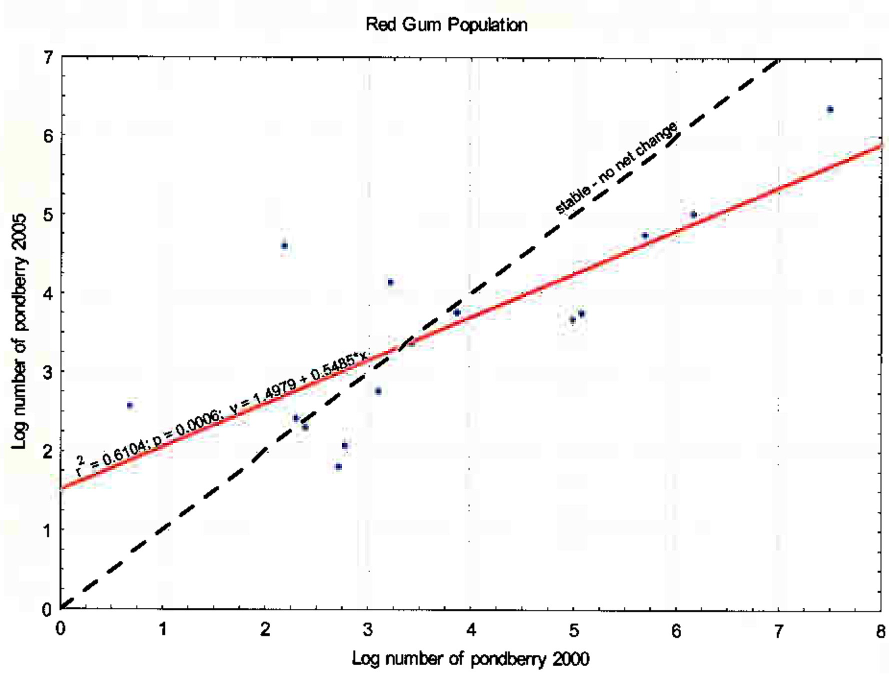


Figure 2. Change in the number of pondberry at profiled colonies/sites (n=17), 2000 and 2005, in the Red Gum population.

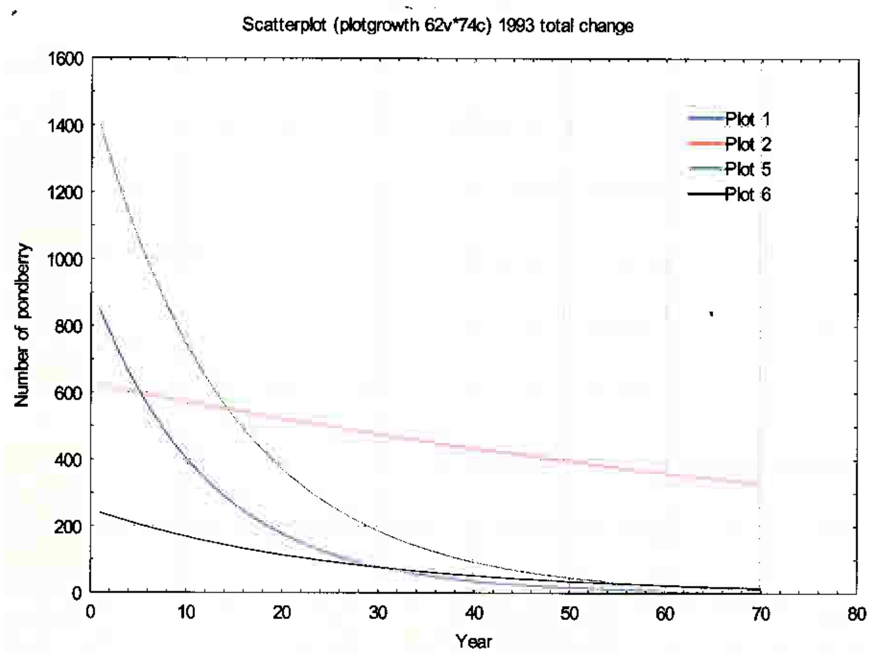


Figure 3. Number of pondberry, from four declining plots in the Colby population, computed from 1993 (Year 0) to 2006, with future projection based on 1993-2006 exponential growth rate. Number of plants in each plot in 1993 and 2006 extrapolated as the total number, from a 10% sample in each plot with 0.25 m^2 quadrats.

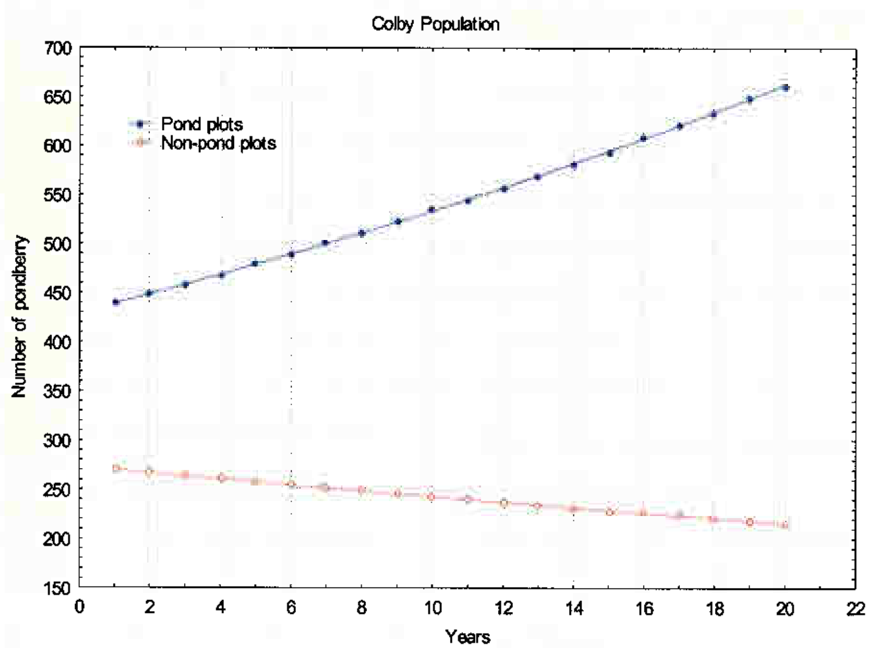


Figure 4. Number of pondberry from ponded and non-pond plots, computed from 1993 and 2006 plot data for exponential growth rate since 1993 (Year 0), with future projection based on 1993-2006 exponential growth rate.

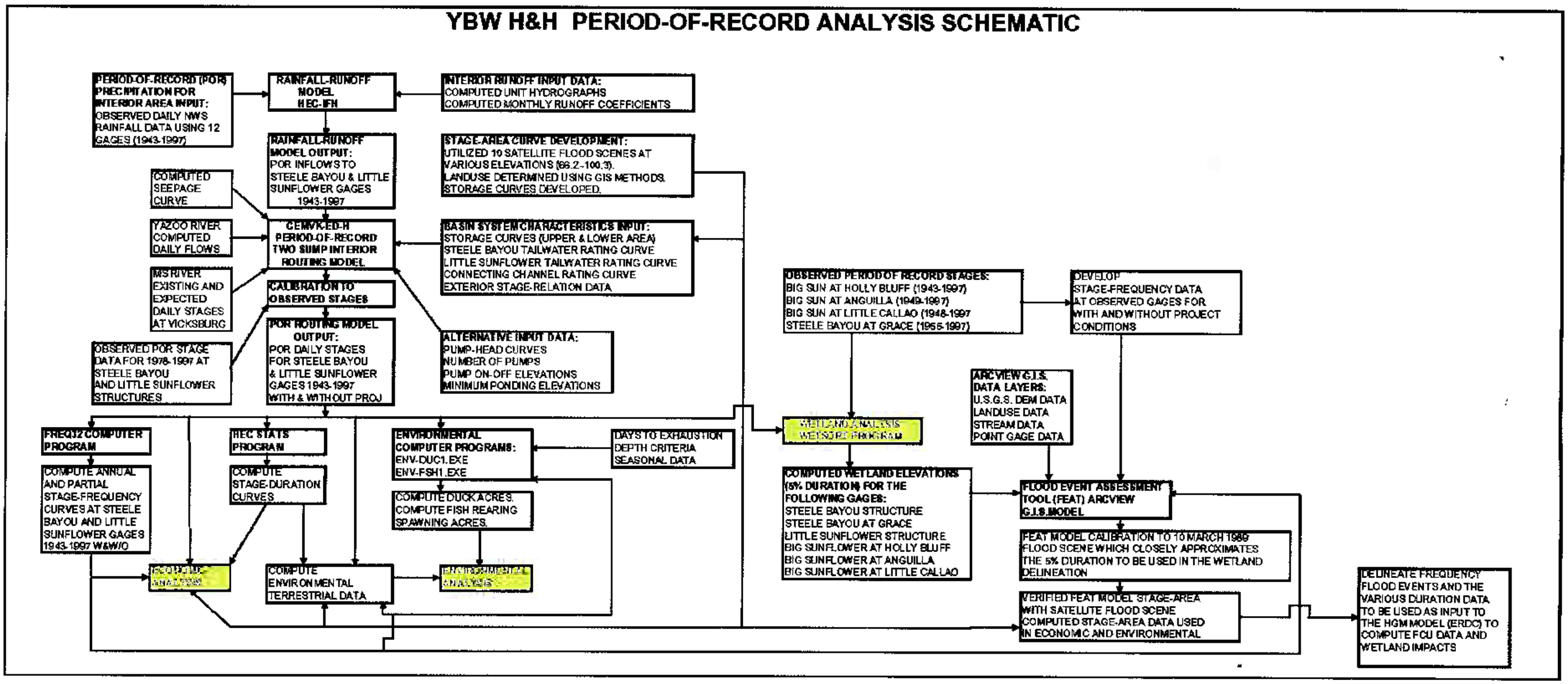


Figure 5. Corps hydrology and hydraulics analysis procedure, Yazoo Backwater Area.

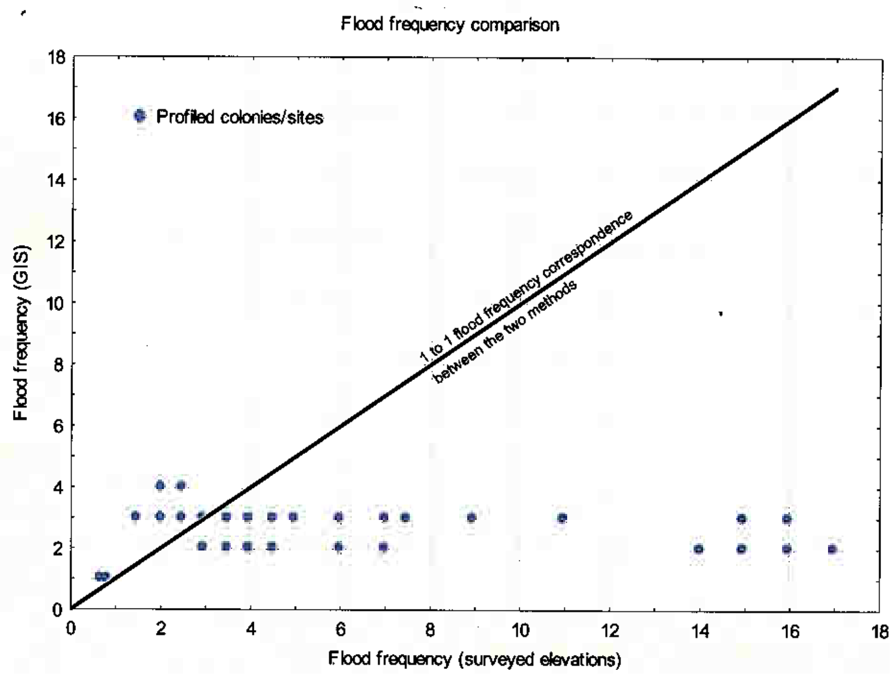


Figure 6. Flood frequency correspondence at profiled colonies/sites, based on elevations from ground surveys and elevations from GIS with 30-meter DEM.

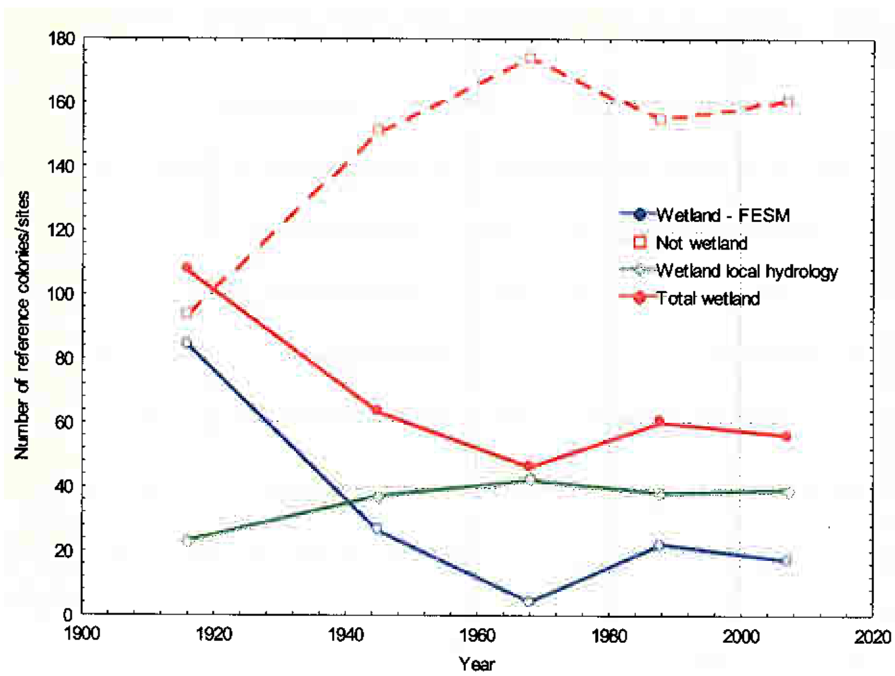


Figure 7. Historical change in wetlands (FESM) at locations for 177 pondberry colonies/sites in 2000. Year plotted as mid-point for the periods 1901-31, 1932-57, 1958-78, 1979-97. Baseline=2007.

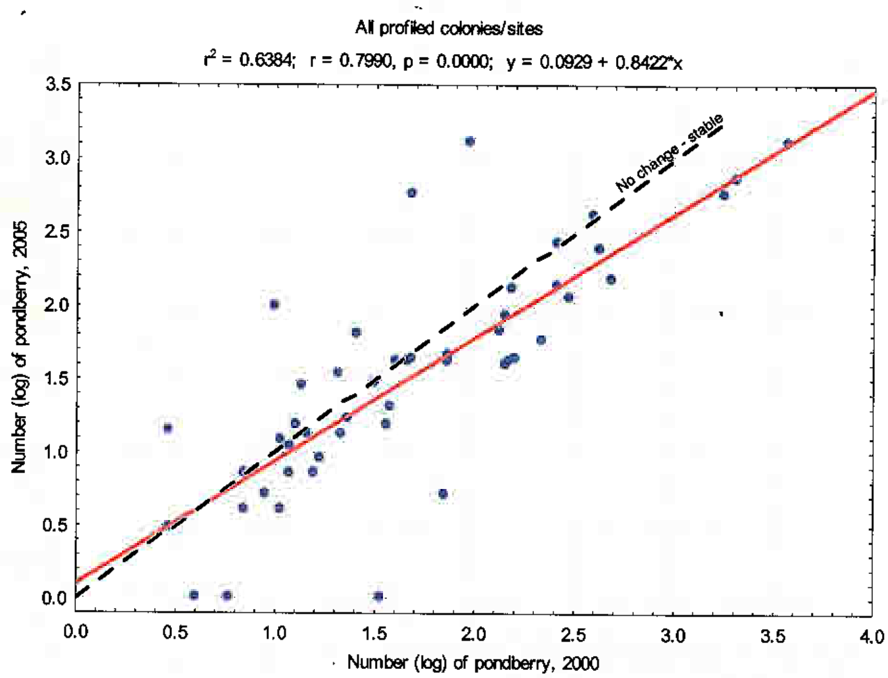


Figure 8. Number of pondberry at profiled colonies/sites in 2005 in response to number in 2000.

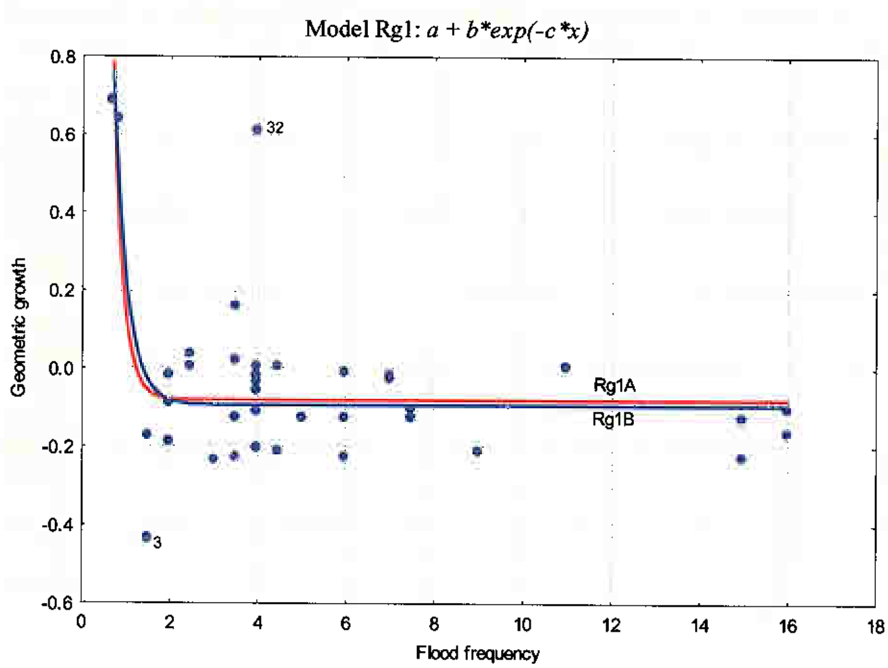


Figure 9. Nonlinear regression of flood frequency on colony/site geometric growth rate, model R_g1A $r^2 = 0.5033$, $p = 0.0000$; model R_g1B $r^2 = 0.7512$, $p = 0.0000$ with colonies/sites 3 and 32 removed.

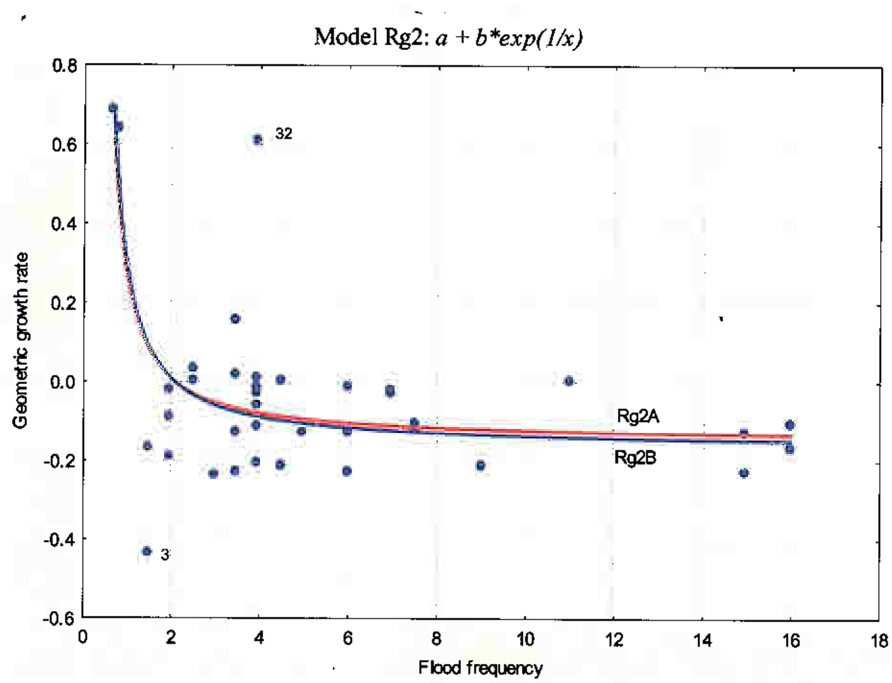


Figure 10. Nonlinear regression of flood frequency on colony/site geometric growth rate, model R_g2A $r^2 = 0.4119$, $p = 0.0000$; model R_g2B $r^2 = 0.7065$, $p = 0.0000$ with colonies/sites 3 and 32 removed.

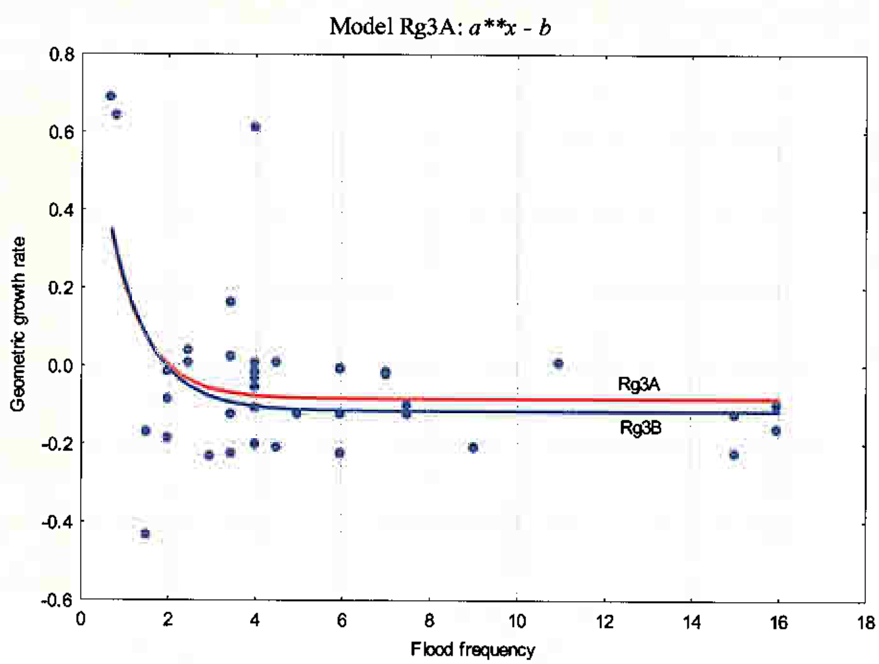


Figure 11. Nonlinear regression of flood frequency on colony/site geometric growth rate, model R_g3A $r^2 = 0.3096$, $p = 0.0007$; model R_g3B $r^2 = 0.7568$, $p = 0.0000$ with colonies/sites 3 and 32 removed.

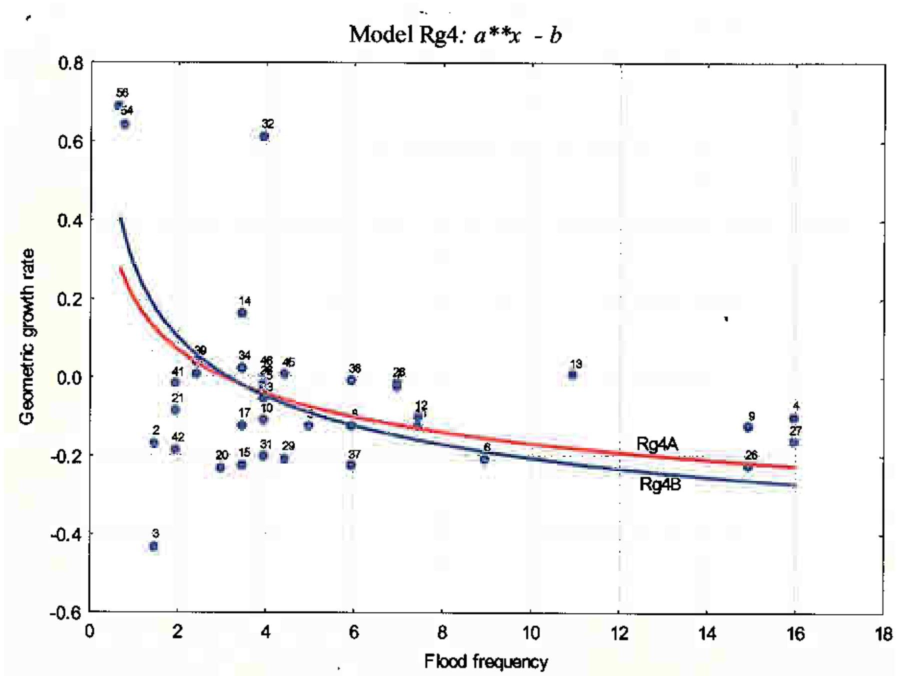


Figure 12. Nonlinear regression of flood frequency on colony/site geometric growth rate, model R_g4A $r^2 = 0.2032, p = 0.0089$; model R_g4B $r^2 = 0.4222, p = 0.0000$ with colonies/sites 3 and 32 removed.

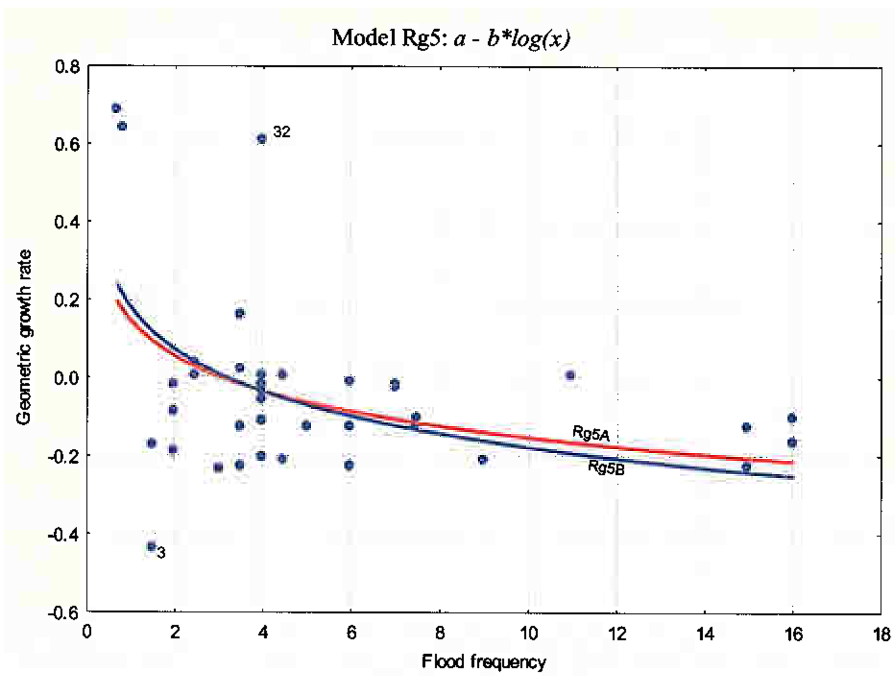


Figure 13. Nonlinear regression of flood frequency on colony/site geometric growth rate, model R_g5A $r^2 = 0.1744, p = 0.0170$; model R_g5B $r^2 = 0.3378, p = 0.0003$ with colonies/sites 3 and 32 removed.

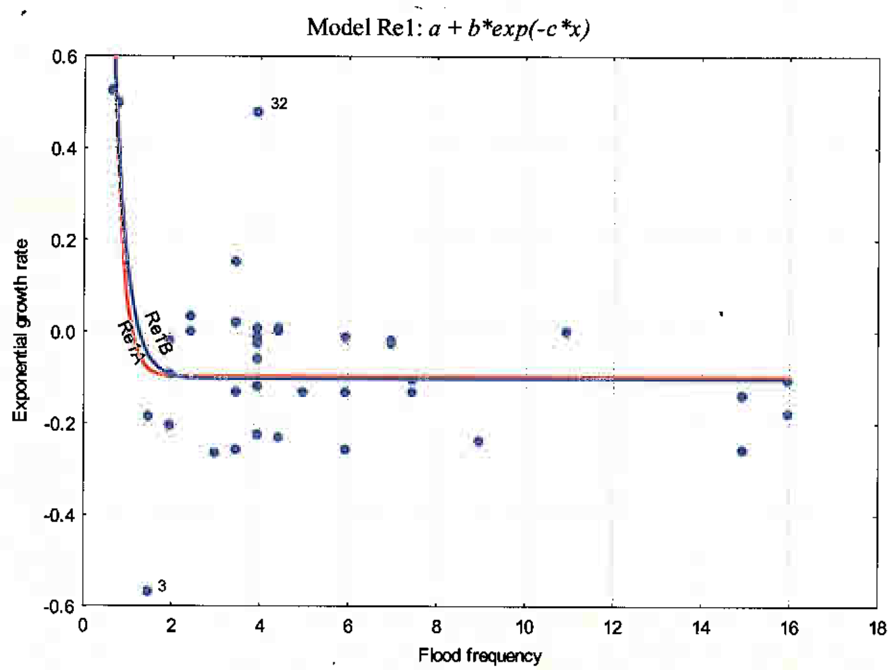


Figure 14. Nonlinear regression of flood frequency on colony/site exponential growth rate, model R_e1A $r^2 = 0.3986$, $p = 0.0000$; model R_e1B $r^2 = 0.6276$, $p = 0.0000$ with colonies/sites 3 and 32 removed.

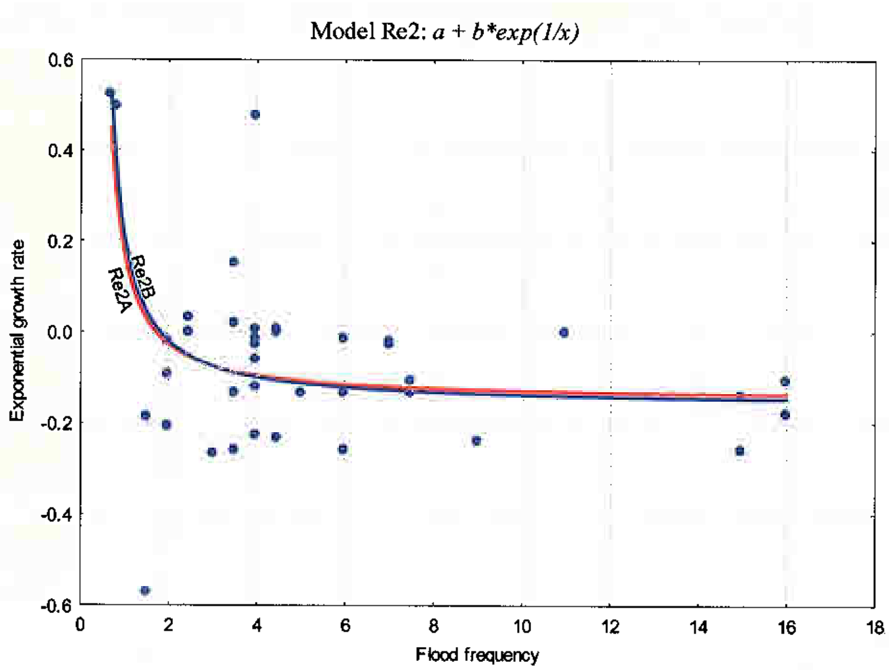


Figure 15. Nonlinear regression of flood frequency on colony/site exponential growth rate, model R_e2A $r^2 = 0.3034$, $p = 0.0002$; model R_e2B $r^2 = 0.5955$, $p = 0.0000$ with colonies/sites 3 and 32 removed.

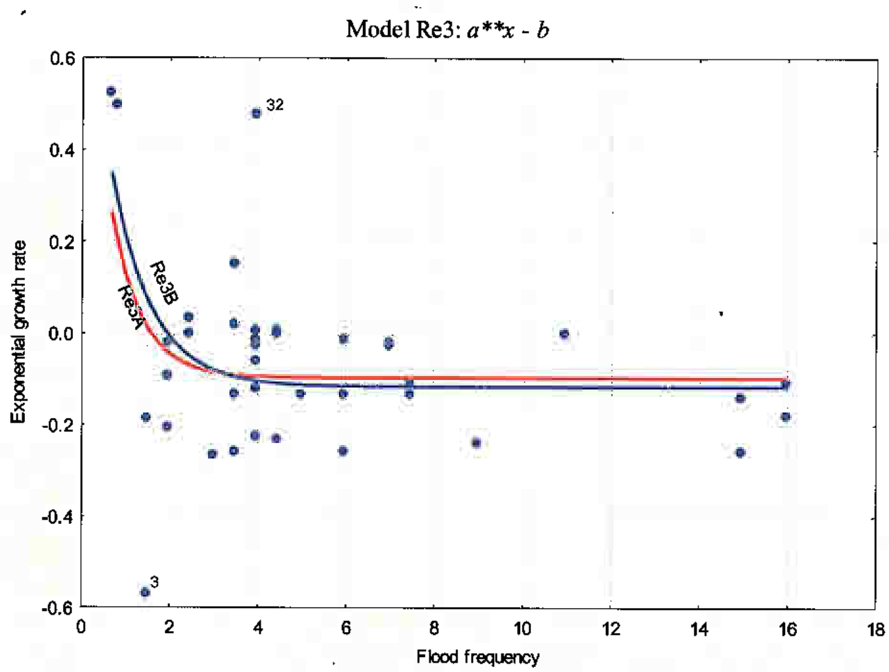


Figure 16. Nonlinear regression of flood frequency on colony/site exponential growth rate, model R_e3A $r^2 = 0.2455$, $p = 0.0010$; model R_e3B $r^2 = 0.5160$, $p = 0.0000$ with colonies/sites 3 and 32 removed.

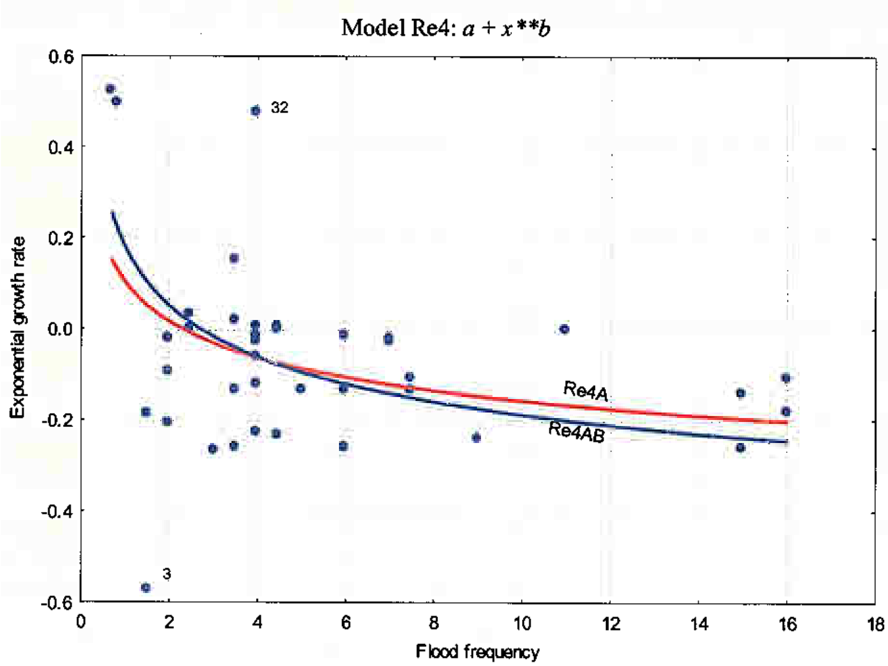


Figure 17. Nonlinear regression of flood frequency on colony/site exponential growth rate, model R_e4A $r^2 = 0.1364$, $p = 0.0119$; model R_e4B $r^2 = 0.3530$, $p = 0.0001$ with colonies/sites 3 and 32 removed.

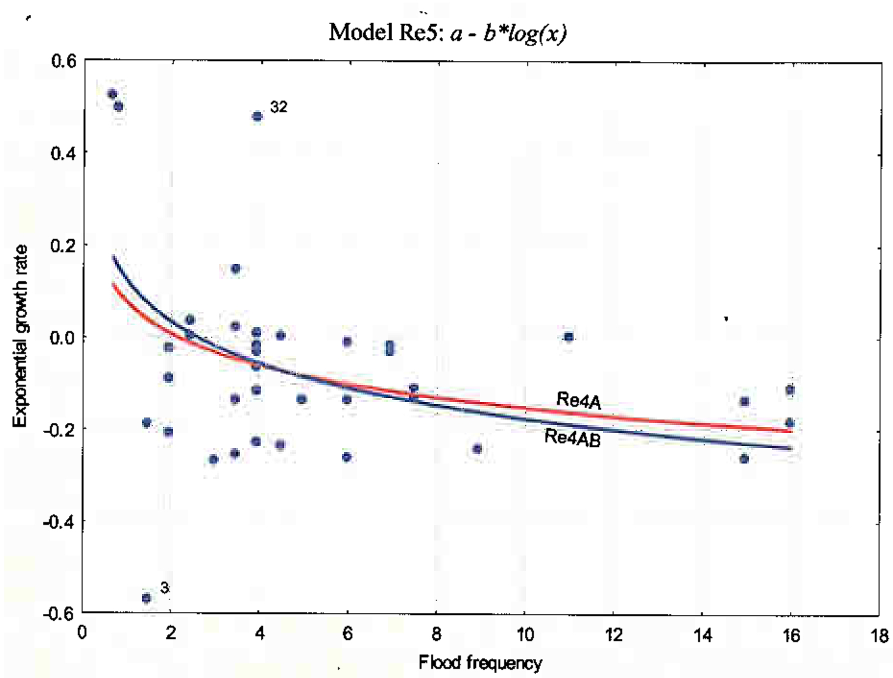


Figure 18. Nonlinear regression of flood frequency on colony/site exponential growth rate, model R_e5A $r^2 = 0.1235$, $p = 0.0155$; model R_e5B $r^2 = 0.3040$, $p = 0.0002$ with colonies/sites 3 and 32 removed.

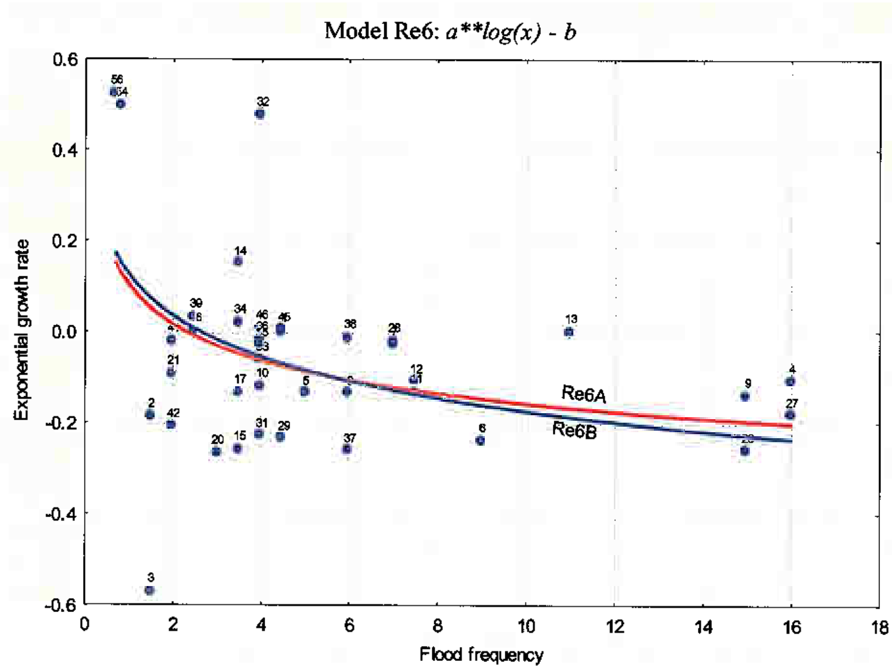


Figure 19. Nonlinear regression of flood frequency on colony/site exponential growth rate, model R_e6A $r^2 = 0.1364$, $p = 0.0119$; model R_e6B $r^2 = 0.3530$, $p = 0.0000$ with colonies/sites 3 and 32 removed.

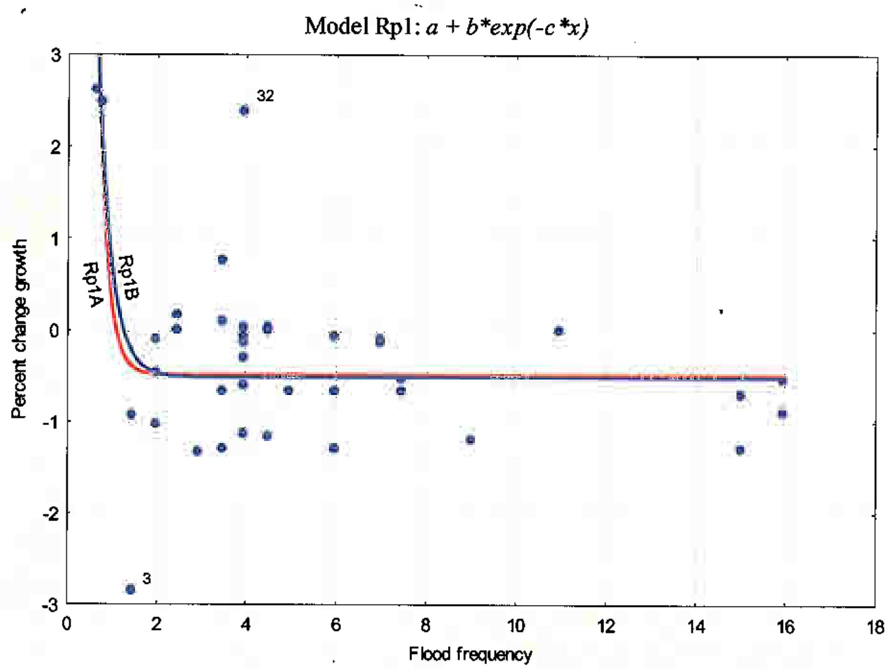


Figure 20. Nonlinear regression of flood frequency on colony/site percent change growth rate, model R_p1A $r^2 = 0.3986$, $p = 0.000$; model R_p1B $r^2 = 0.6276$, $p = 0.0000$ with colonies/sites 3 and 32 removed.

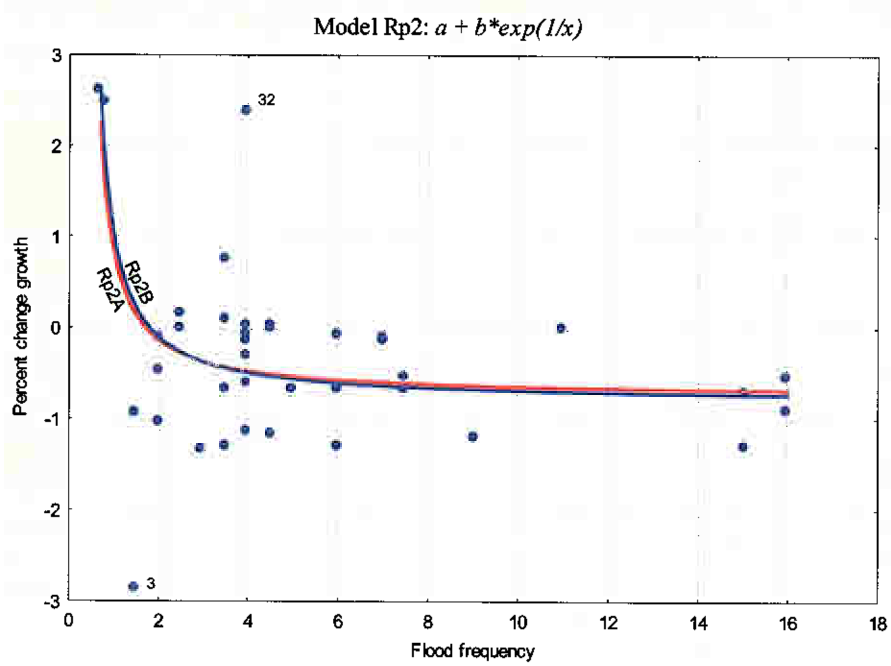


Figure 21. Nonlinear regression of flood frequency on colony/site percent change growth rate, model R_p2A $r^2 = 0.3034$, $p = 0.0000$; model R_p2B $r^2 = 0.5955$, $p = 0.0000$ with colonies/sites 3 and 32 removed.

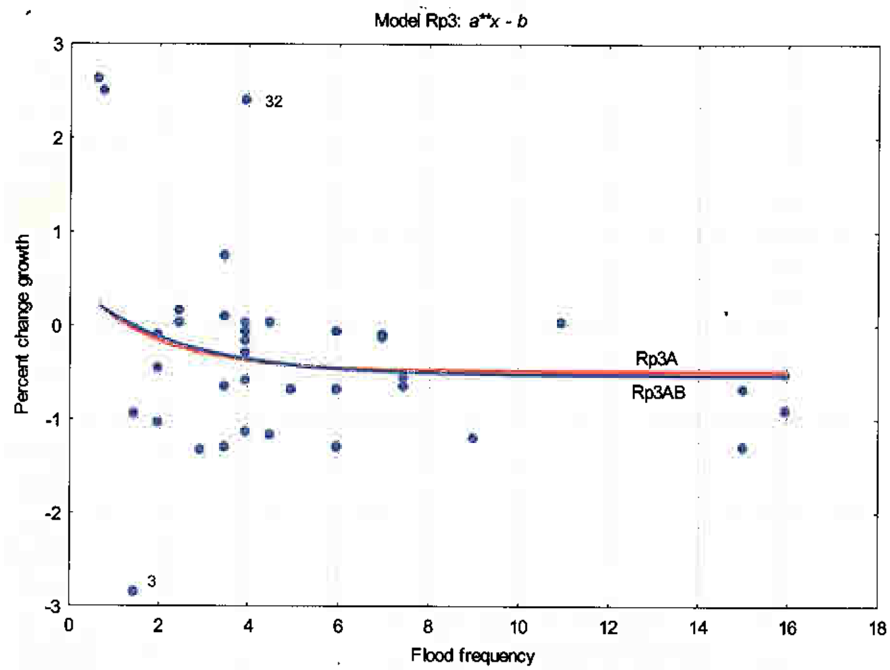


Figure 22. Nonlinear regression of flood frequency on colony/site percent change growth rate, model R_p3A $r^2 = 0.0939, p = 0.0282$; model R_p3B $r^2 = 0.2090, p = 0.0016$ with colonies/sites 3 and 32 removed.

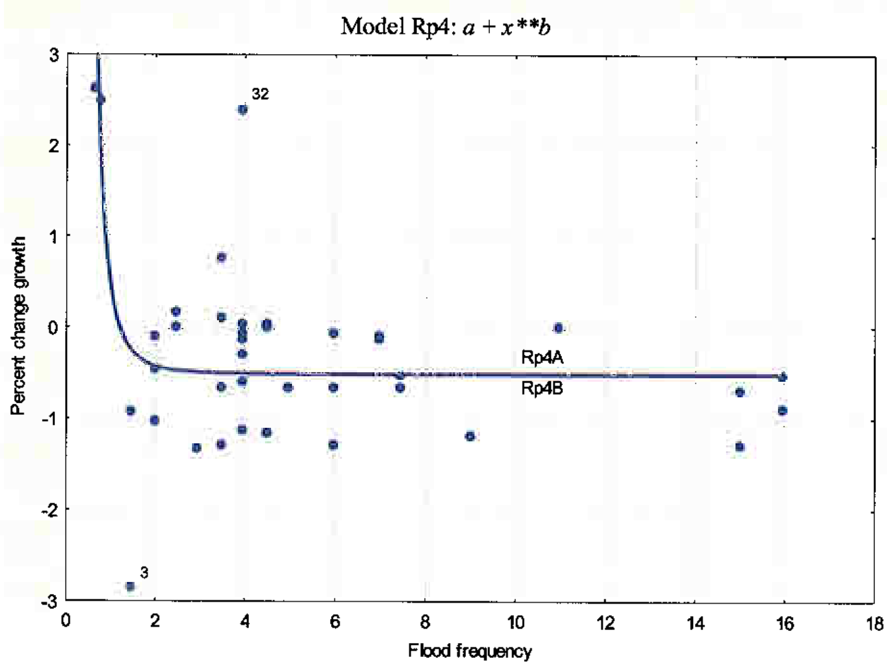


Figure 23. Nonlinear regression of flood frequency on colony/site percent change growth rate, model R_p4A $r^2 = 0.3766, p = 0.0000$; model R_p4B $r^2 = 0.6143, p = 0.0000$ with colonies/sites 3 and 32 removed.

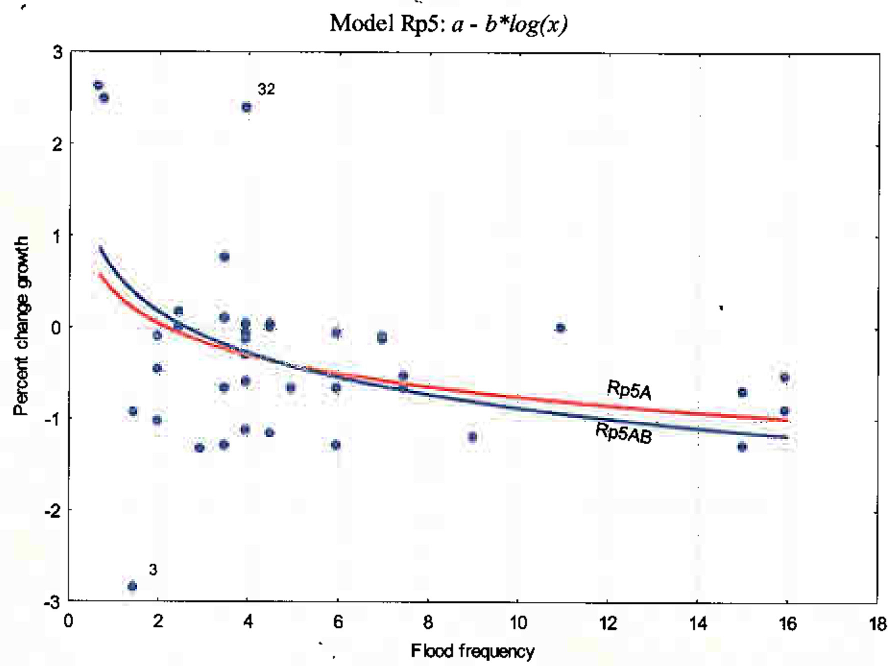


Figure 24. Nonlinear regression of flood frequency on colony/site percent change growth rate, model R_p5A $r^2 = 0.1235$, $p = 0.0155$; model R_p5B $r^2 = 0.3040$, $p = 0.0002$ with colonies/sites 3 and 32 removed.

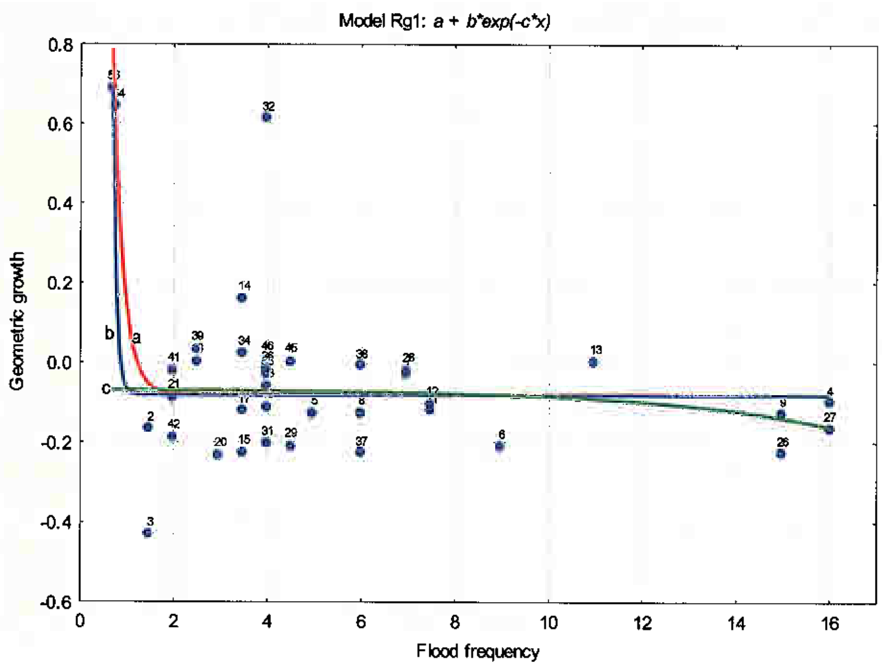


Figure 25. Nonlinear regression of flood frequency on colony/site geometric growth rate, model R_g1A with a) all data, $r^2 = 0.5032$, $p = 0.0000$, b) colony/site 54 removed, $r^2 = 0.3845$, $p = 0.0002$, and c) colonies/sites 54 and 56 removed, $r^2 = 0.240$, $p = 0.341$.

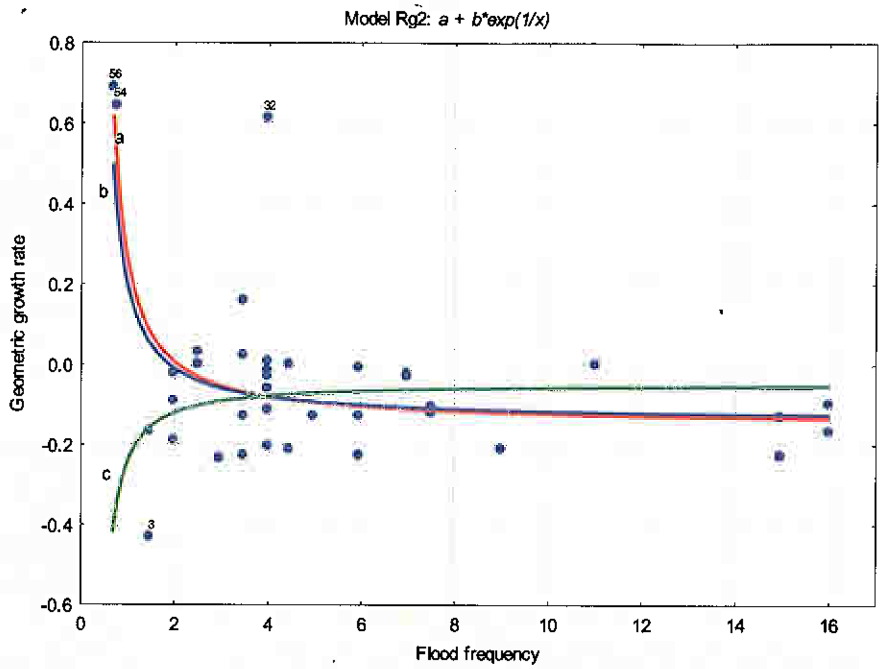


Figure 26. Nonlinear regression of flood frequency on colony/site geometric growth rate, model R_g2A with a) all data, $r^2 = 0.4119, p = 0.0000$, b) colony/site 54 removed, $r^2 = 0.2590, p = 0.0001$, and c) colonies/sites 54 and 56 removed, $r^2 = 0.0258, p = 0.0120$.

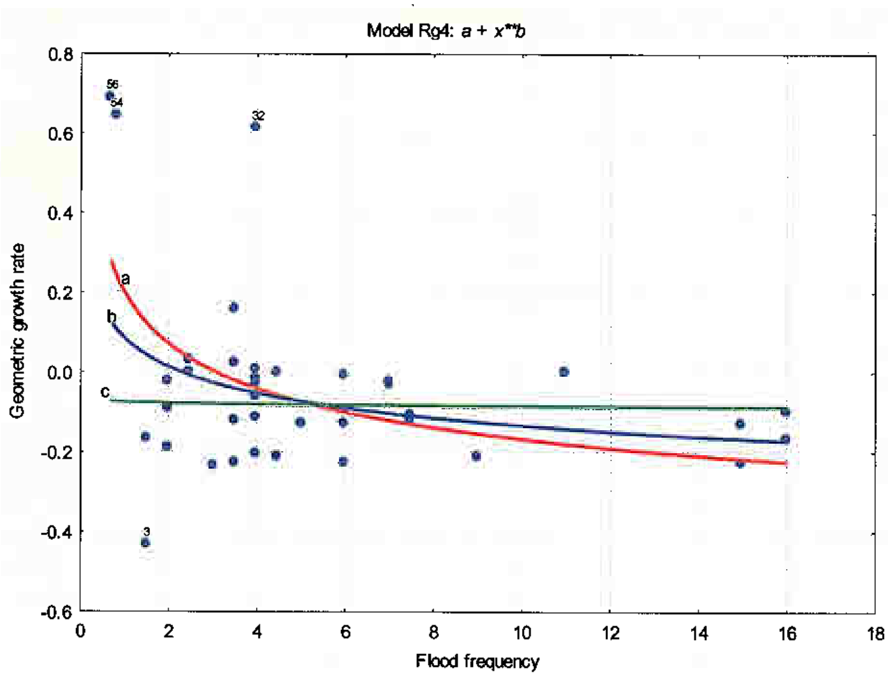


Figure 27. Nonlinear regression of flood frequency on colony/site geometric growth rate, model R_g4A with a) all data, $r^2 = 0.2032, p = 0.0089$, b) colony/site 54 removed, $r^2 = 0.0908, p = 0.0397$, and c) colonies/sites 54 and 56 removed, $r^2 = 0.0003, p = 0.0185$.

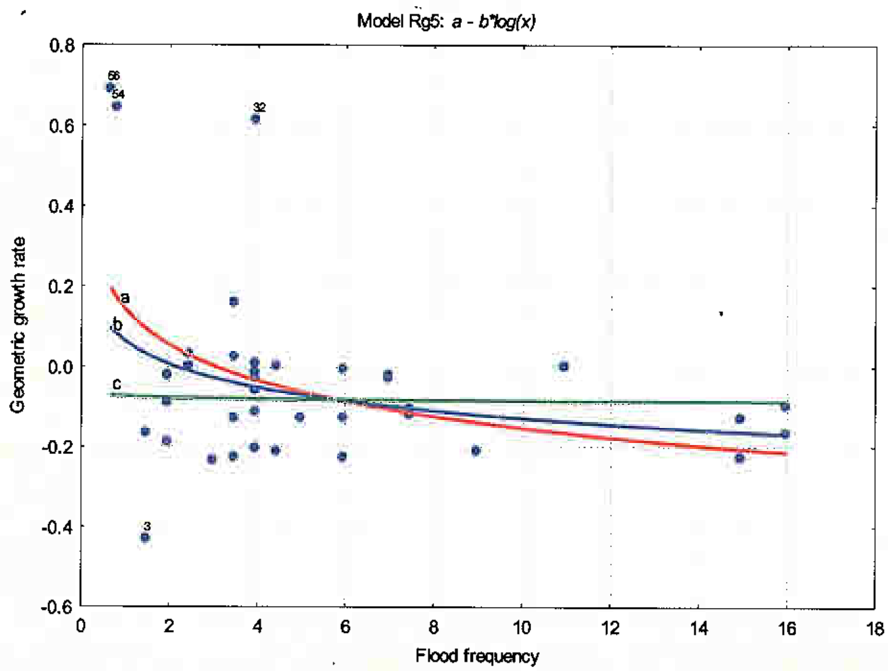


Figure 28. Nonlinear regression of flood frequency on colony/site geometric growth rate, model R_g5A with a) all data, $r^2 = 0.1744, p = 0.0170$, b) colony/site 54 removed $r^2 = 0.0836, p = 0.0456$, and c) colonies/sites 54 and 56 removed $r^2 = 0.0003, p = 0.0185$.

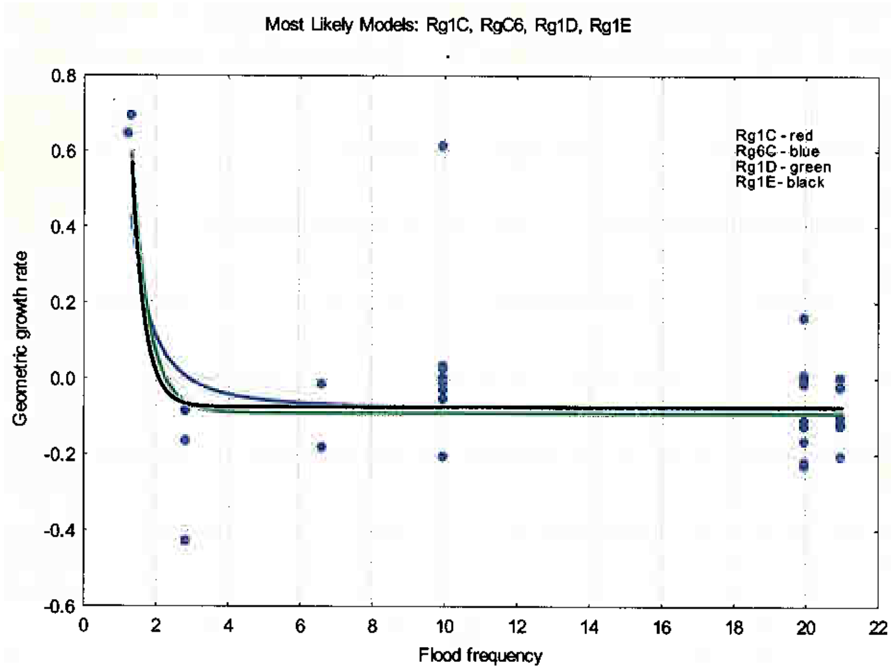


Figure 29. Most likely nonlinear regression geometric growth models, R_g1C, R_g6C, R_g1D, and R_g1E, with flood frequencies from 1984-2003.

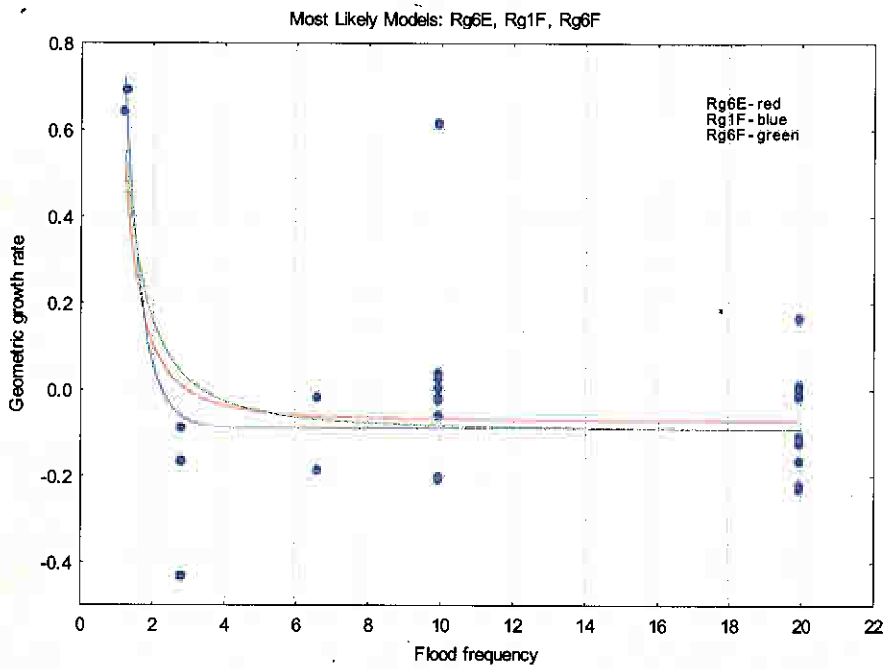


Figure 30. Most likely nonlinear regression geometric growth models, R_g6E, R_g1F, and R_g6F with flood frequencies from 1984-2003.

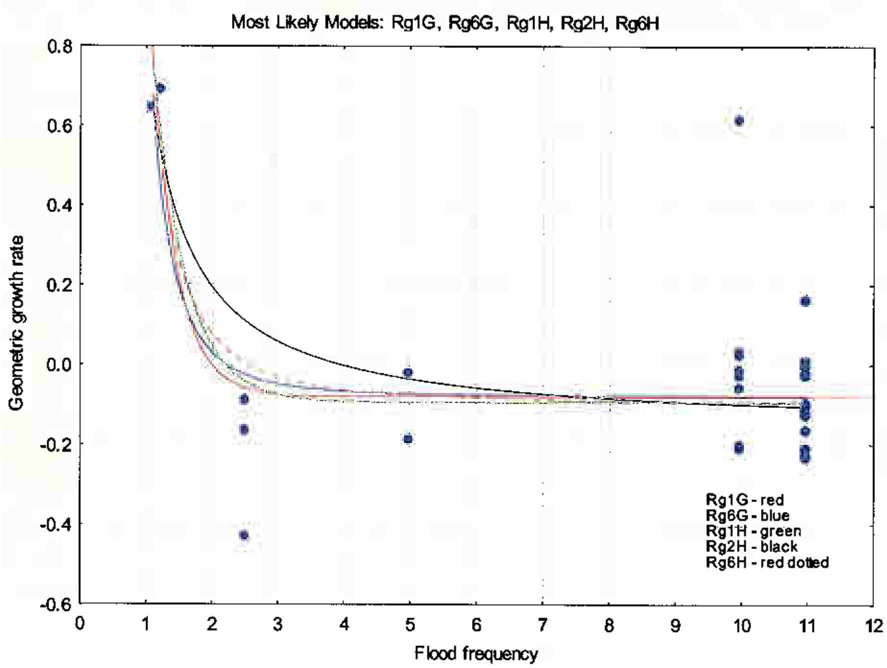


Figure 31. Most likely nonlinear regression geometric growth models, R_g1G, R_g6G, R_g1H, R_g2H, and R_g4H, with flood frequencies from 1994-2003.

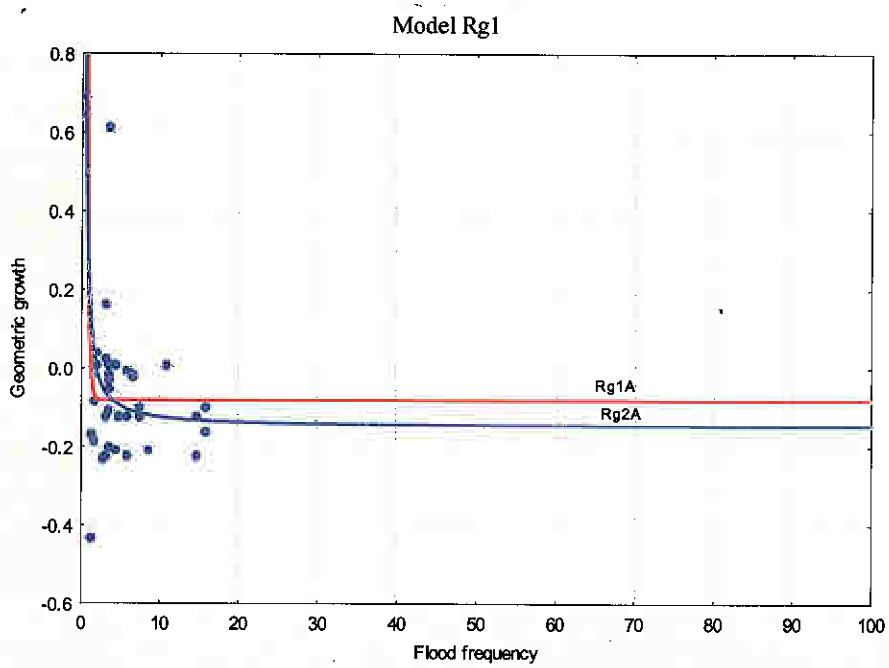


Figure 32. Colony/site geometric growth in response to flood frequency, by nonlinear regression model R_g1A and R_g1B, based on flood frequency data from the 1943-1997 POR, with regression line extended from the data with 16-year flood frequency to 100-year frequency, the maximum expected with the project.

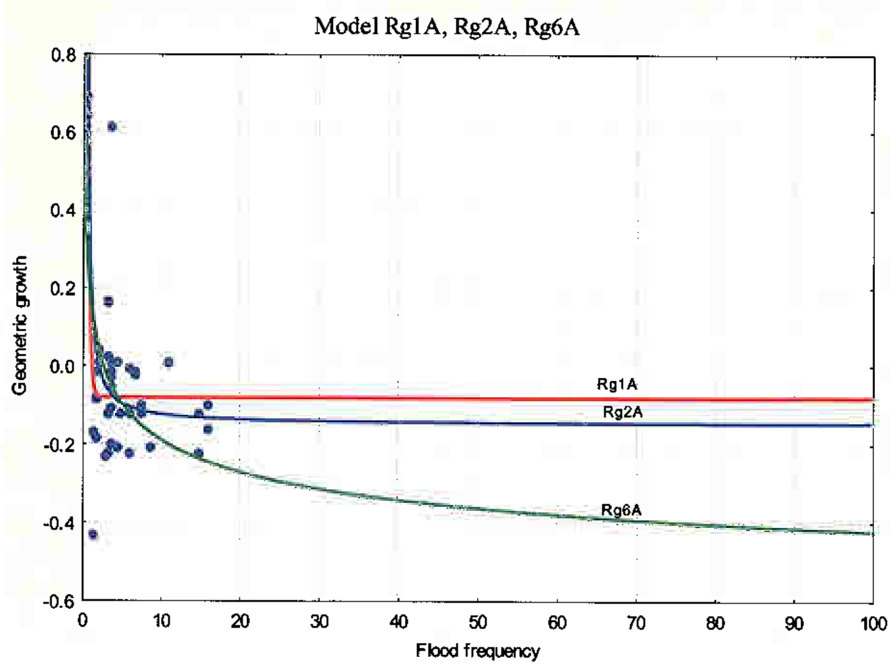


Figure 33. Nonlinear regression of colony/site growth in response to flood frequency, with 1947-1993 POR, and response by fitted regression extended to 100-year flood interval.

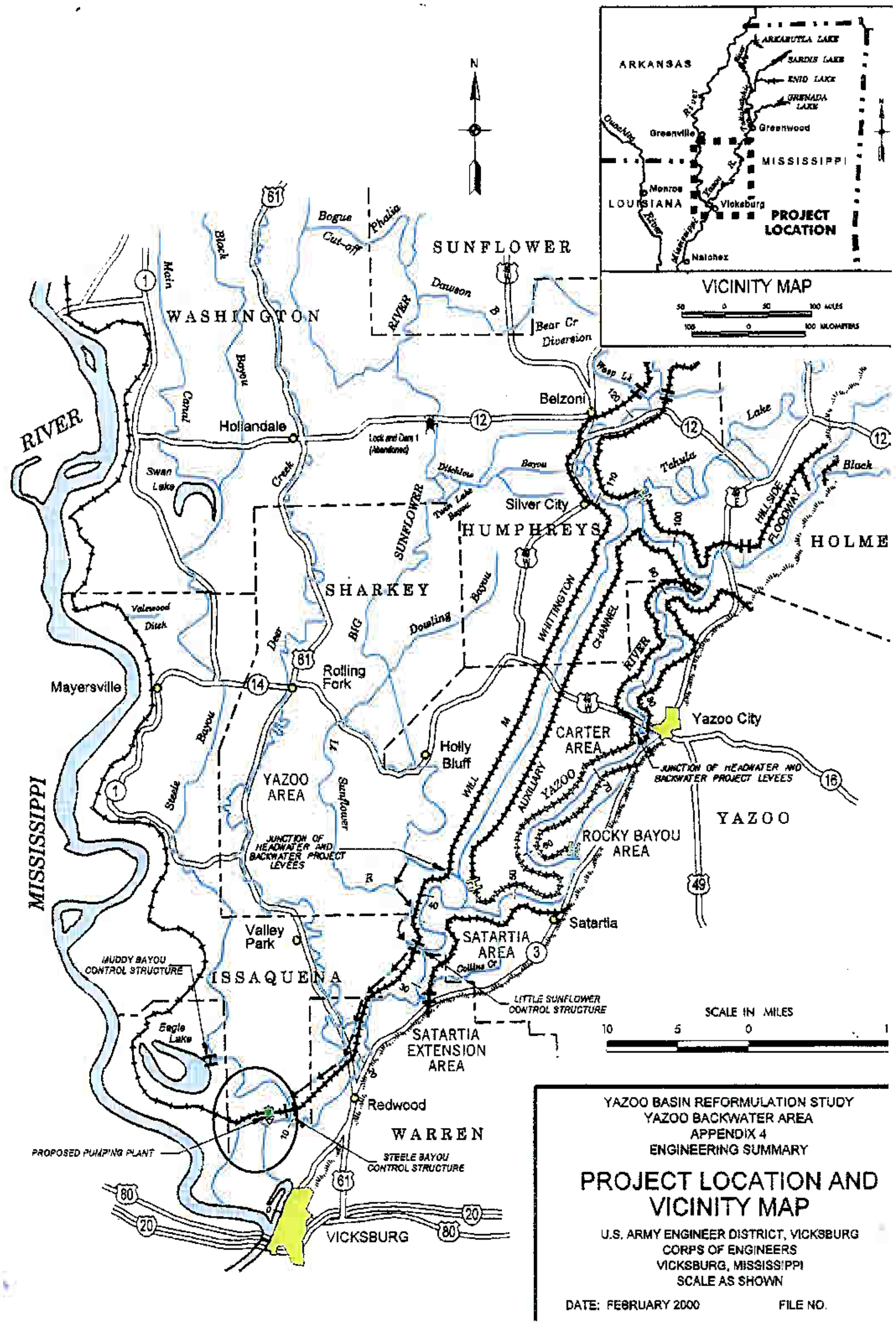


Plate 1. Yazoo Backwater Area, and location of the proposed pumping facility at the Steele Bayou Structure.

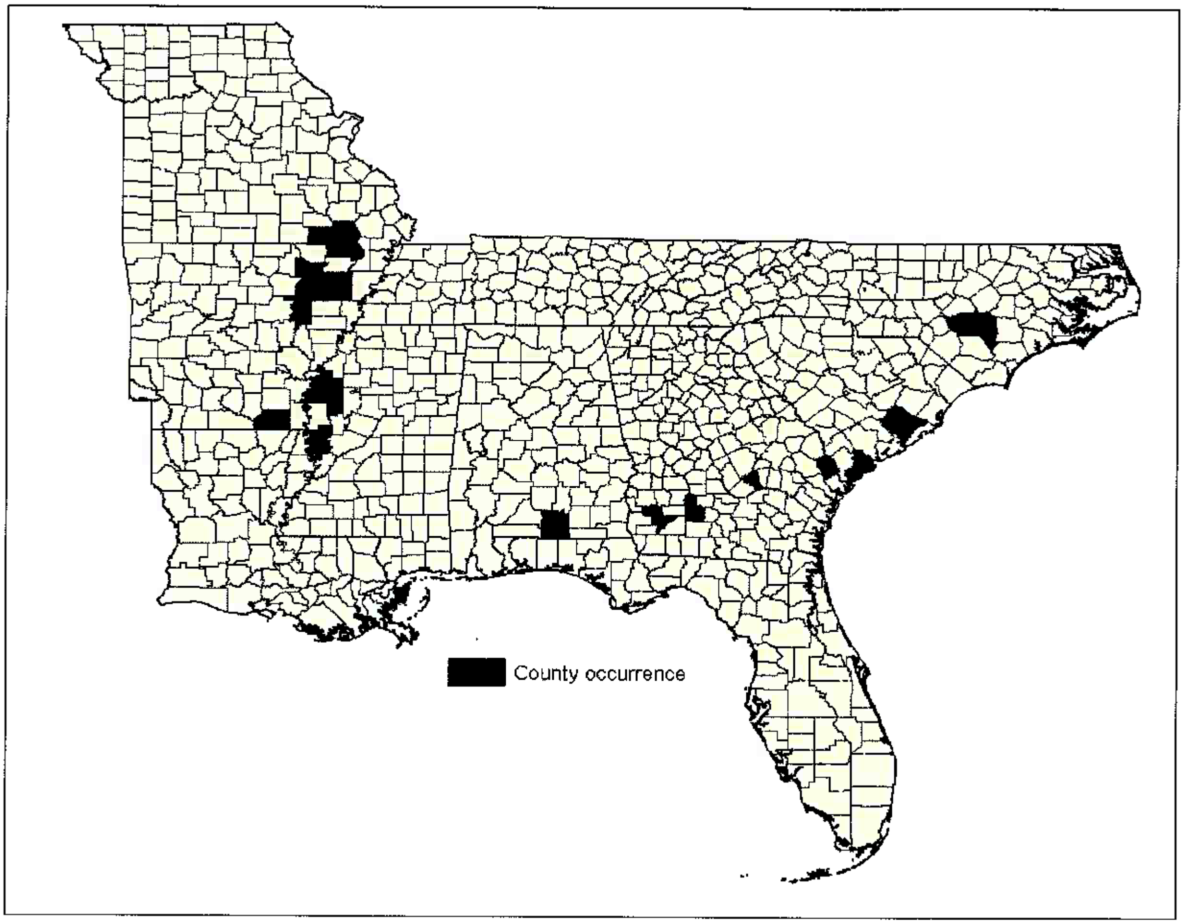


Plate 2. Distribution of extant occurrences of pondberry, by state and county.

Plate 3. Yazoo Backwater Area location and action area.

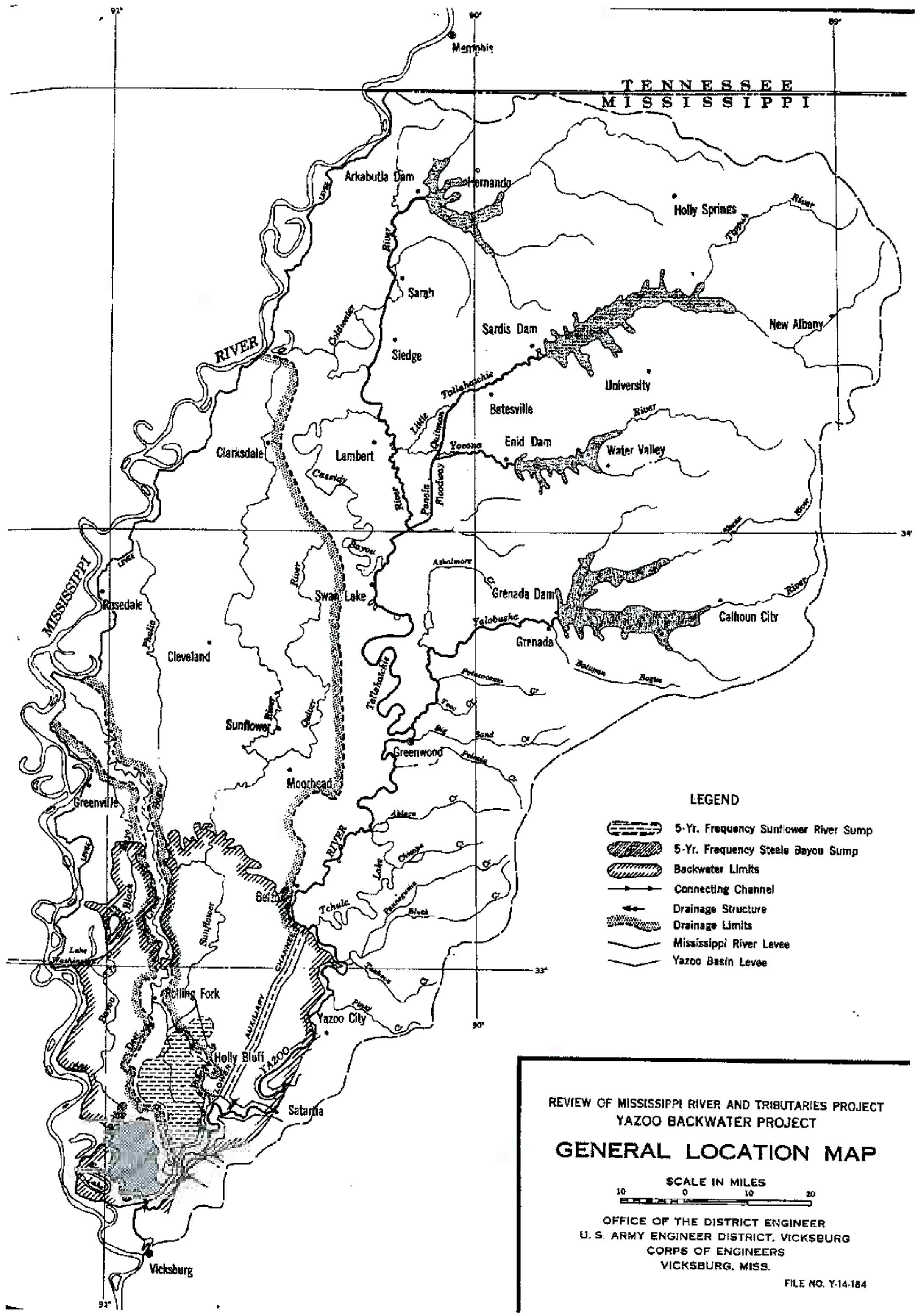


Plate 4. Yazoo River Basin, with headwater and backwater area.

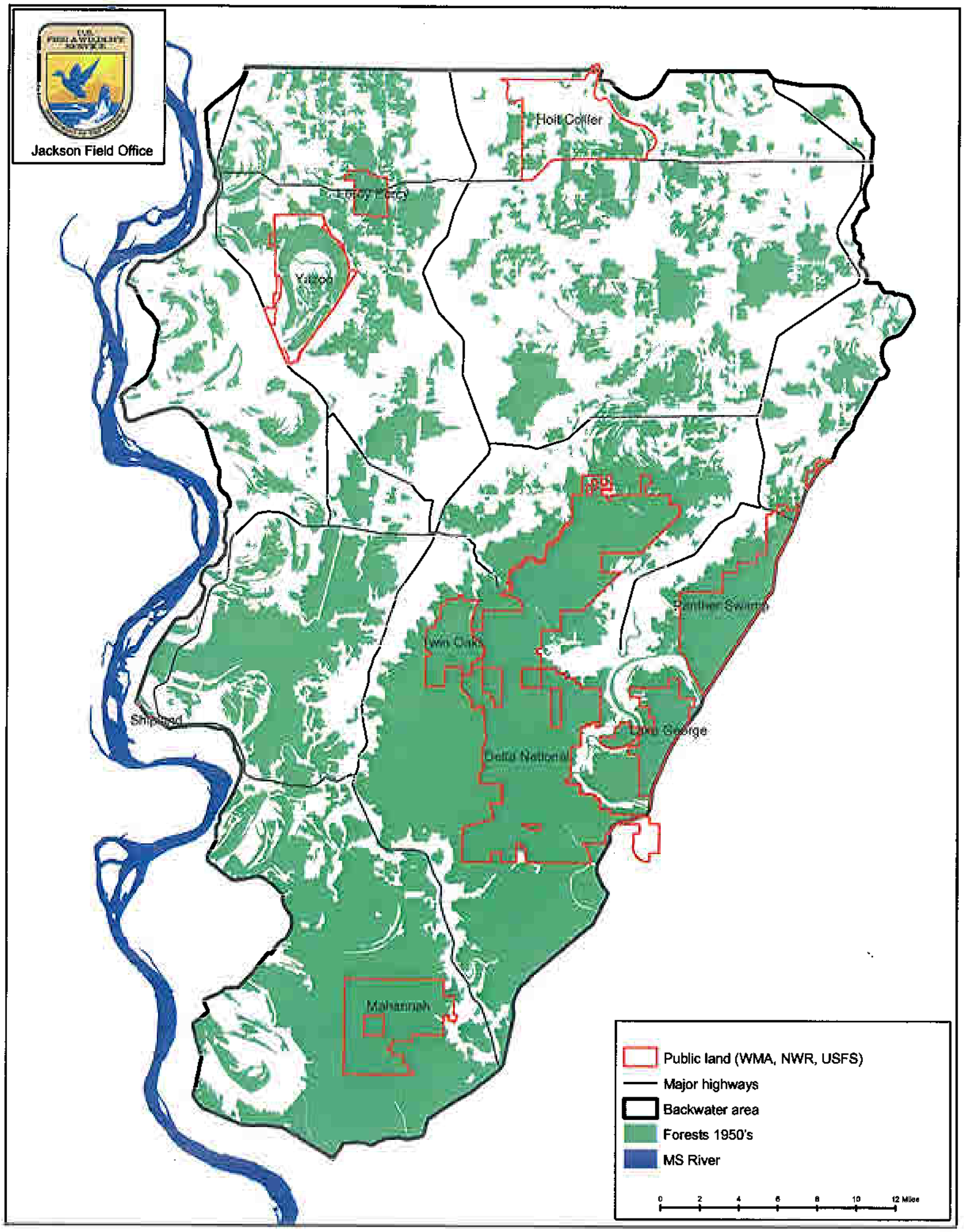


Plate 5. Forest cover, 1950's, in the Yazoo Backwater Area.

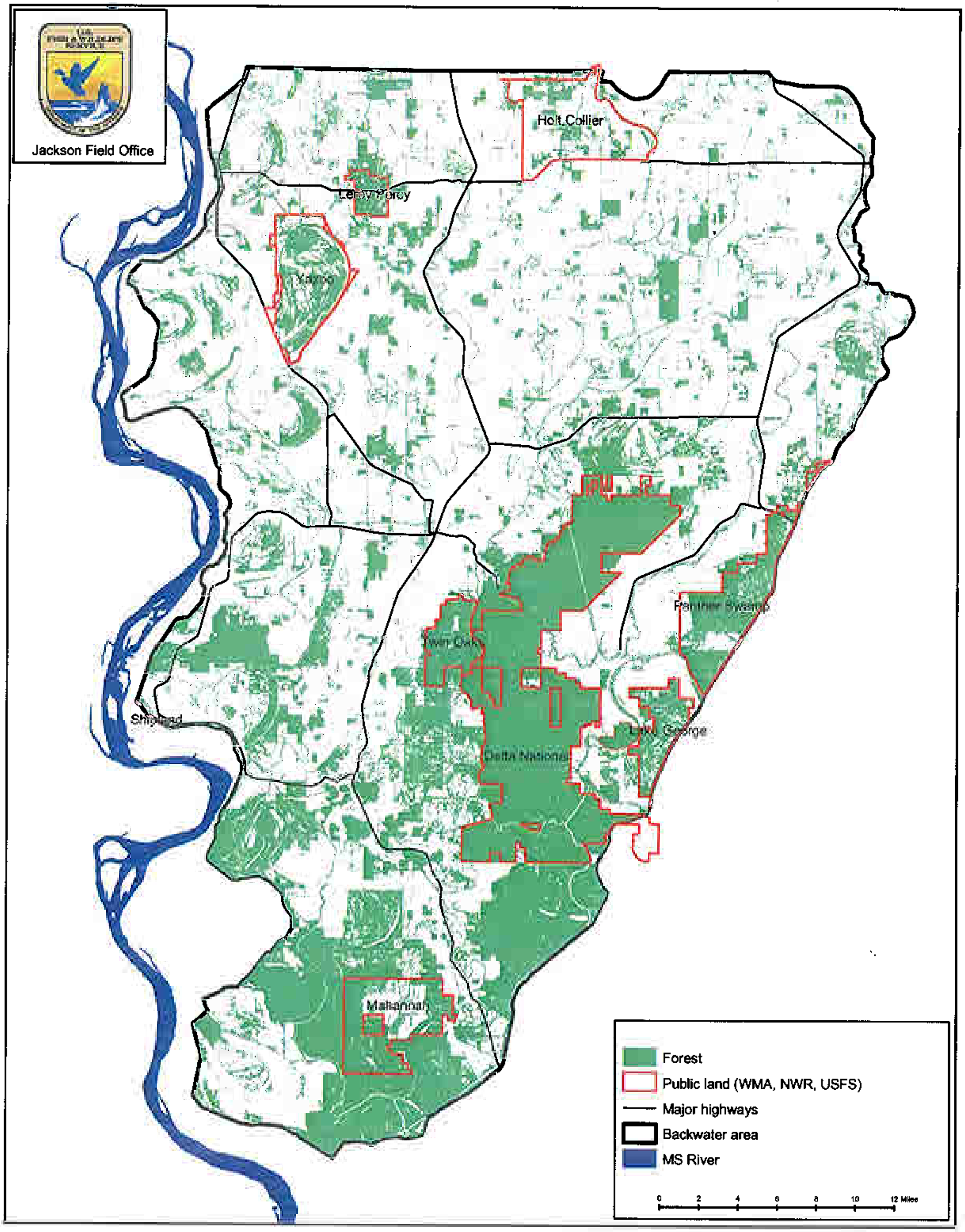


Plate 6. Current forest cover, Yazoo Backwater Area.

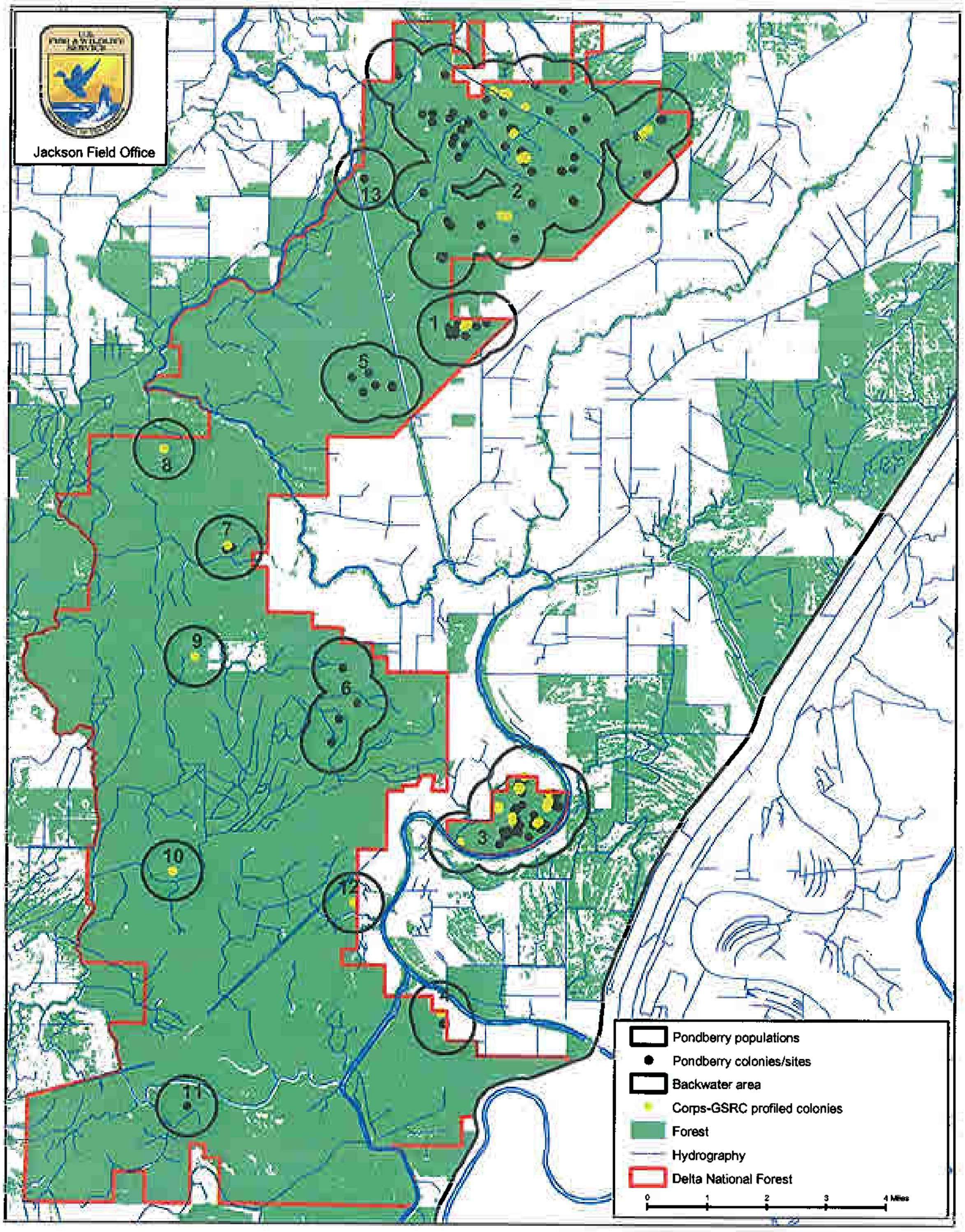


Plate 7. Distribution of 177 pondberry colonies/sites and 13 populations in Delta National Forest. Population 1 is the Colby population, population 2 is the Red Gum population, and population 3 is the Spanish Fort population.

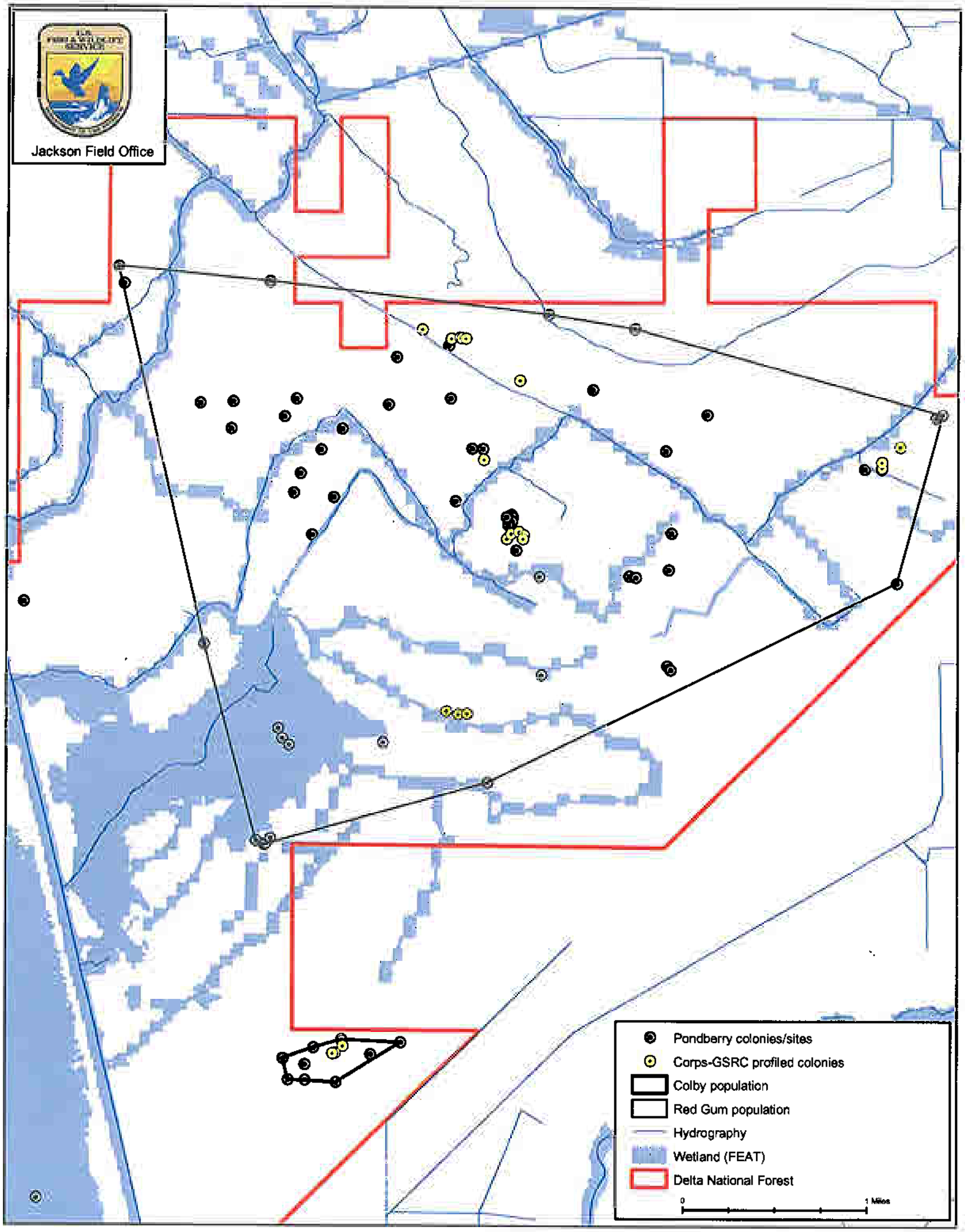


Plate 8. Colby and Red Gum populations, with wetland (FEAT) areas.

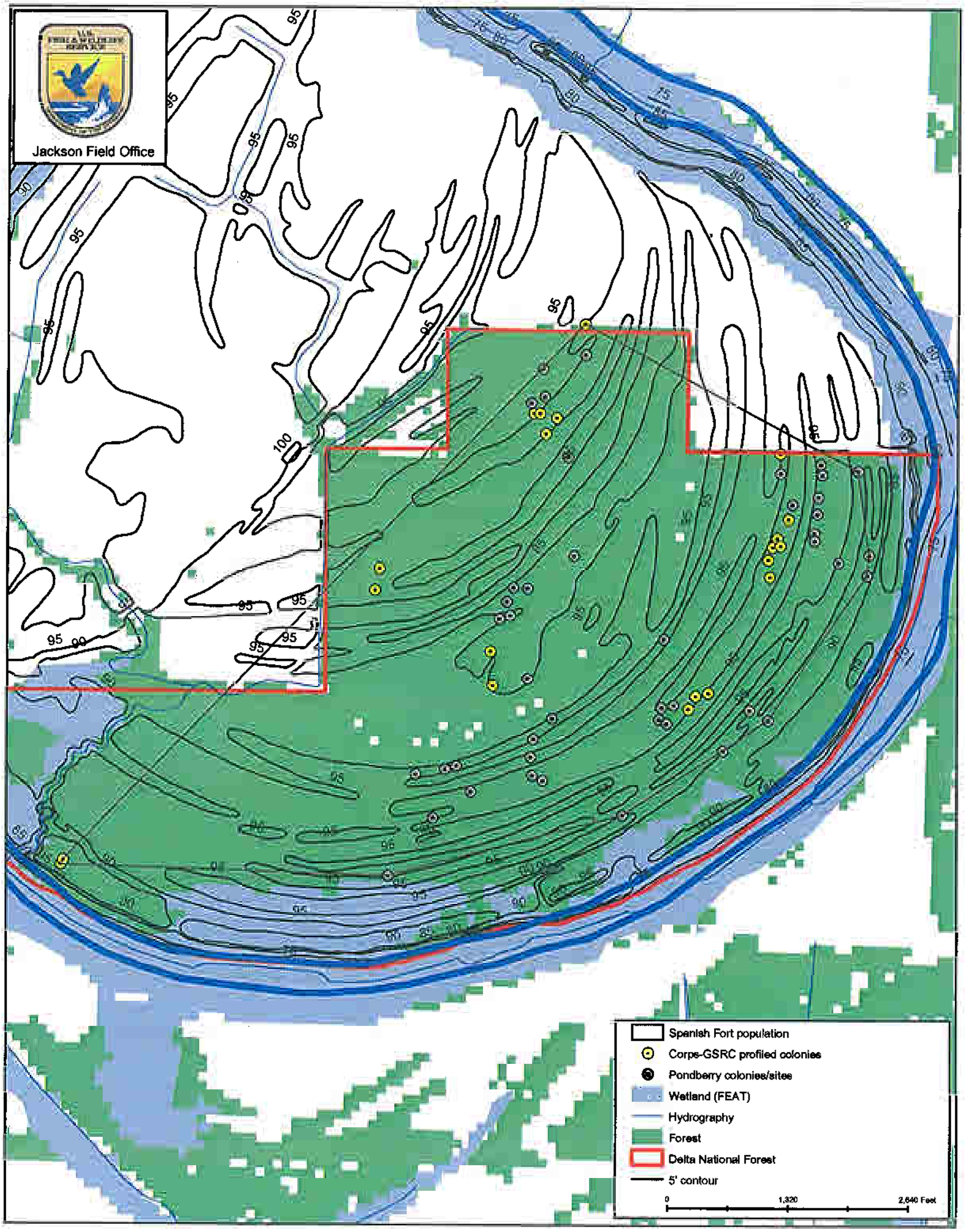


Plate 9. Spanish Fort population.

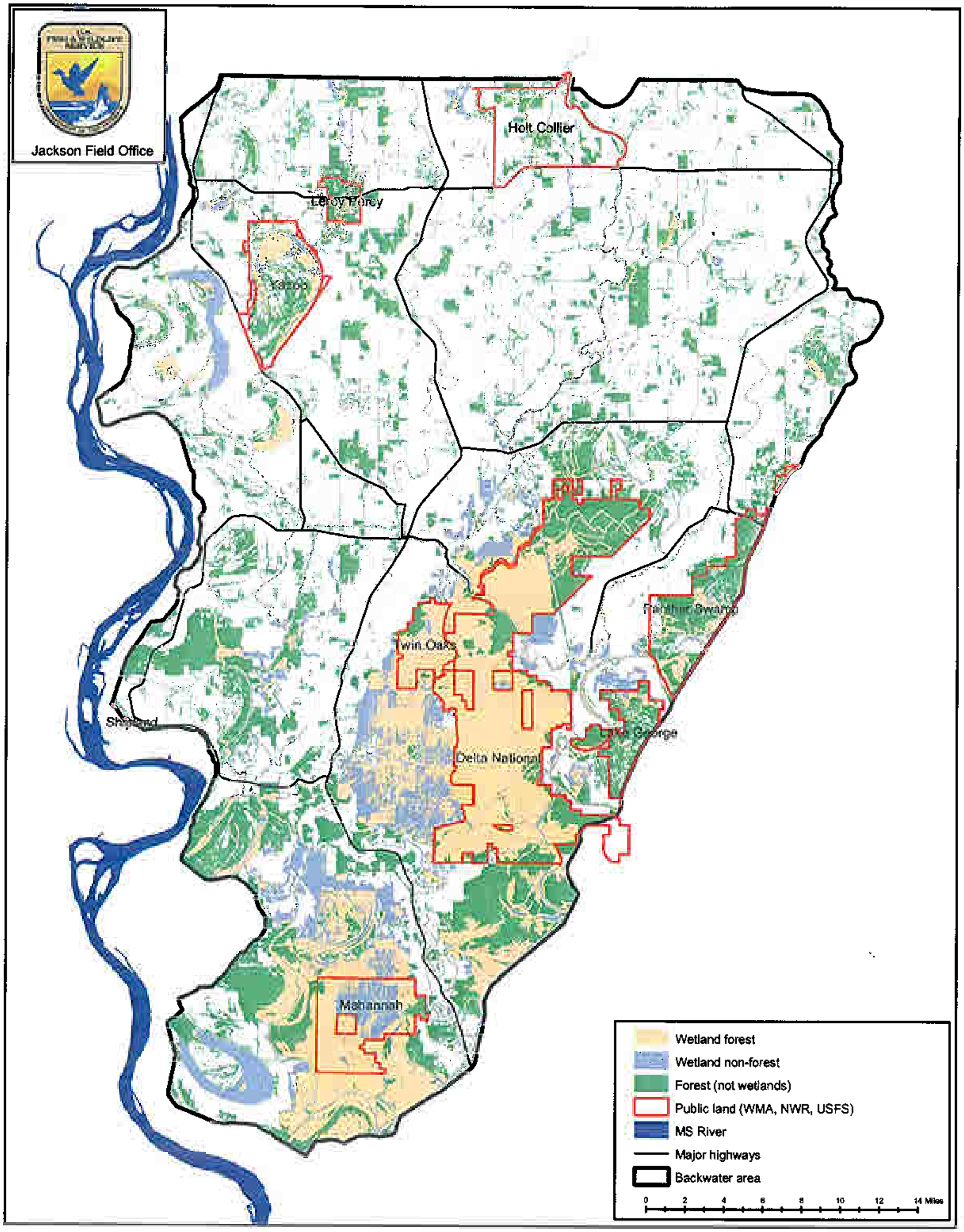


Plate 10. Forest cover and forested wetlands (FESM), 2005, in the backwater area.

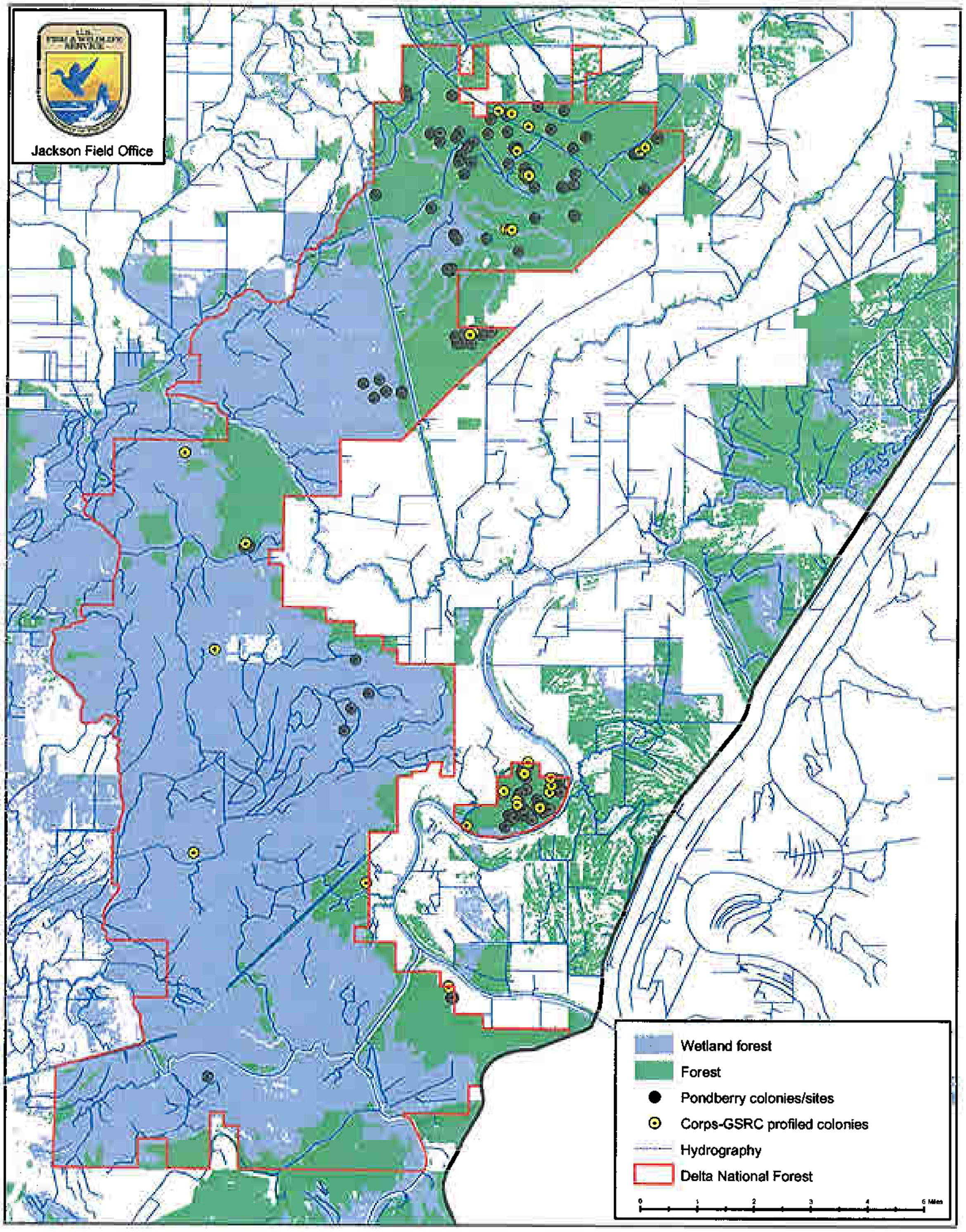


Plate 11. Pondberry colonies/sites in relation to wetlands (FEAT), Delta National Forest.

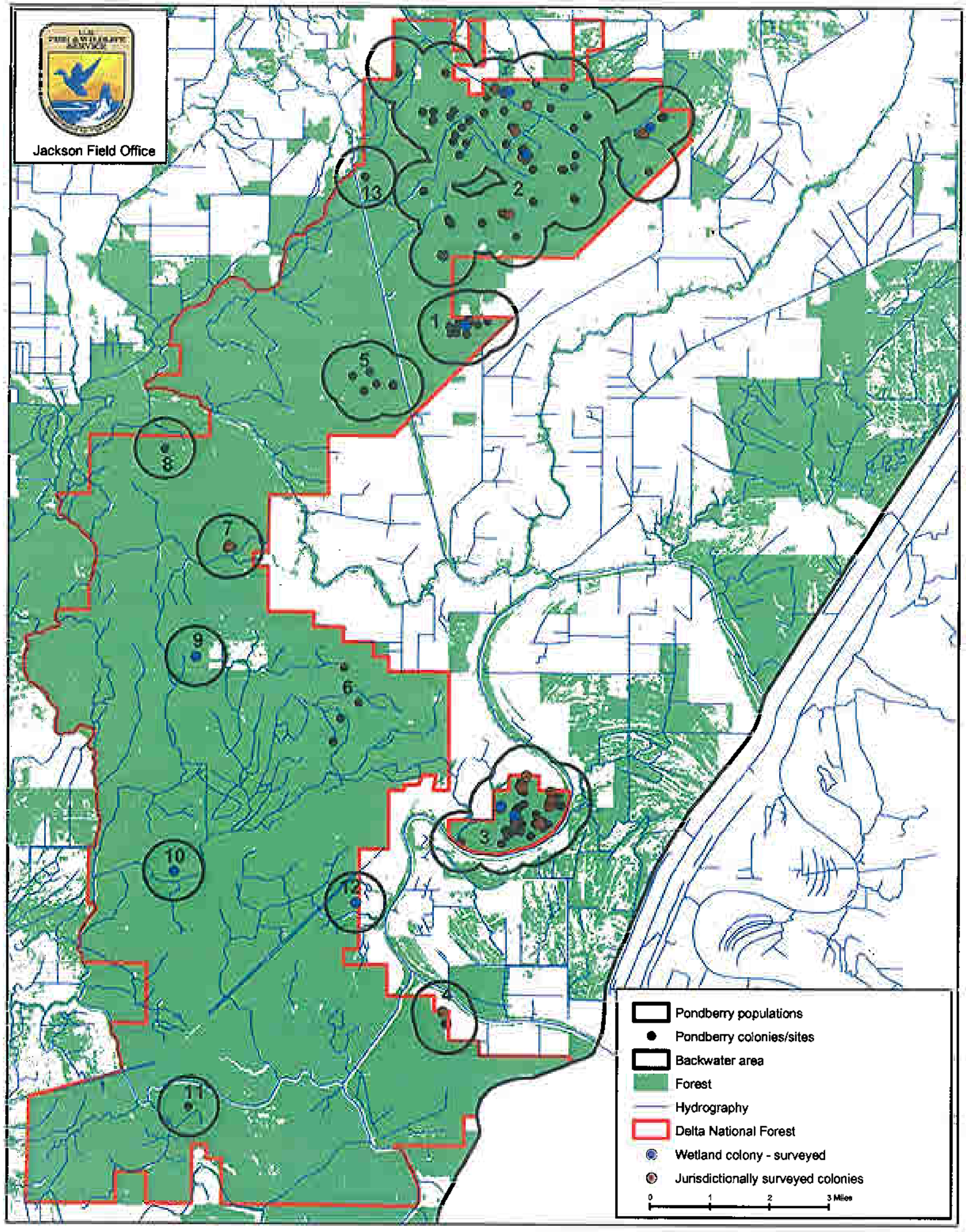


Table 12. Colonies/sites field surveyed (47) for jurisdictional wetlands, and colonies/sites with wetland field determinations (13).

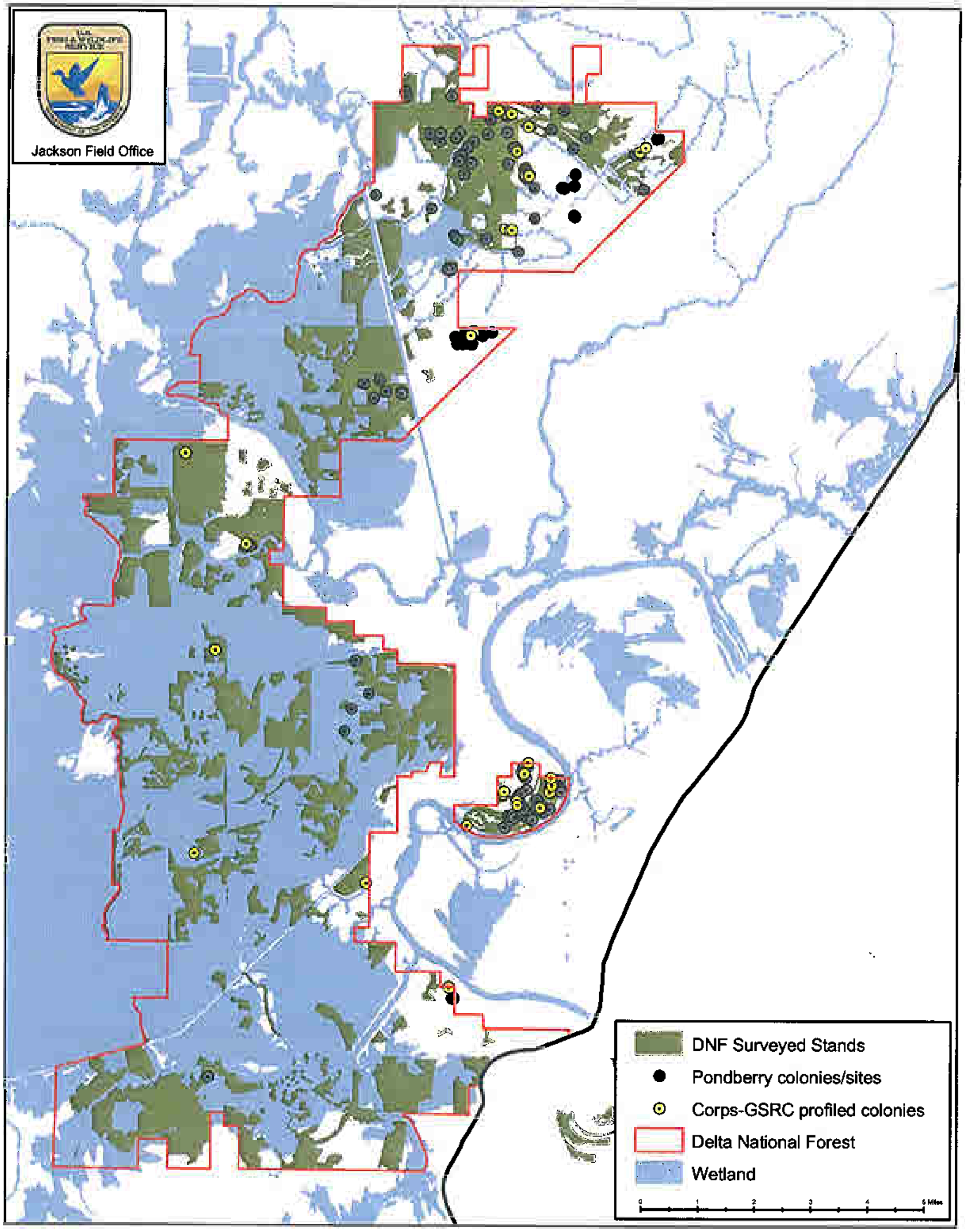


Plate 13. Stands comprehensively surveyed for pondberry by U.S. Forest Service staff in Delta National Forest, with unsurveyed wetlands (FESM).

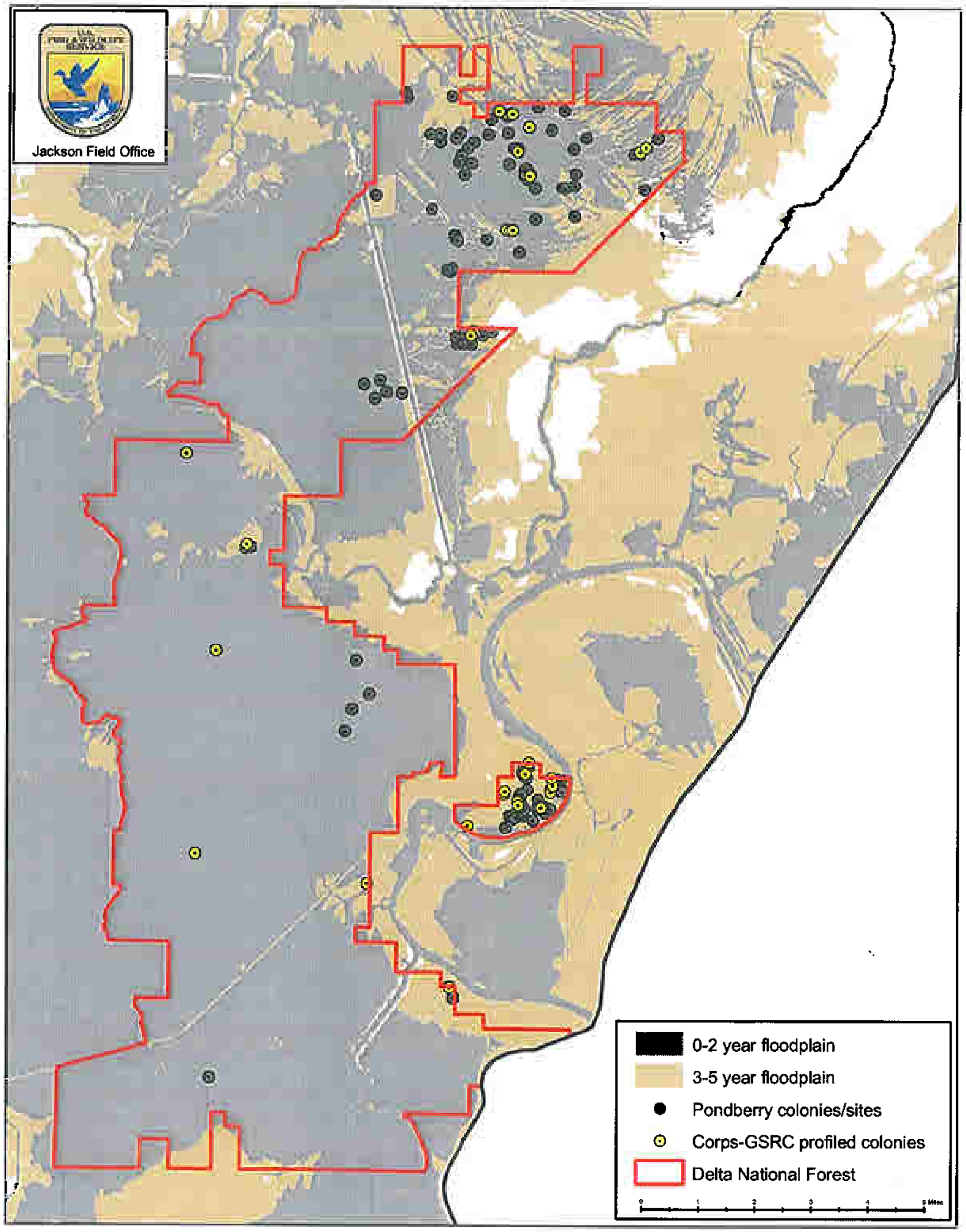


Figure 14. 0-2 and 3-5 year floodplain, from FESM, in Delta National Forest with pondberry colonies/sites.

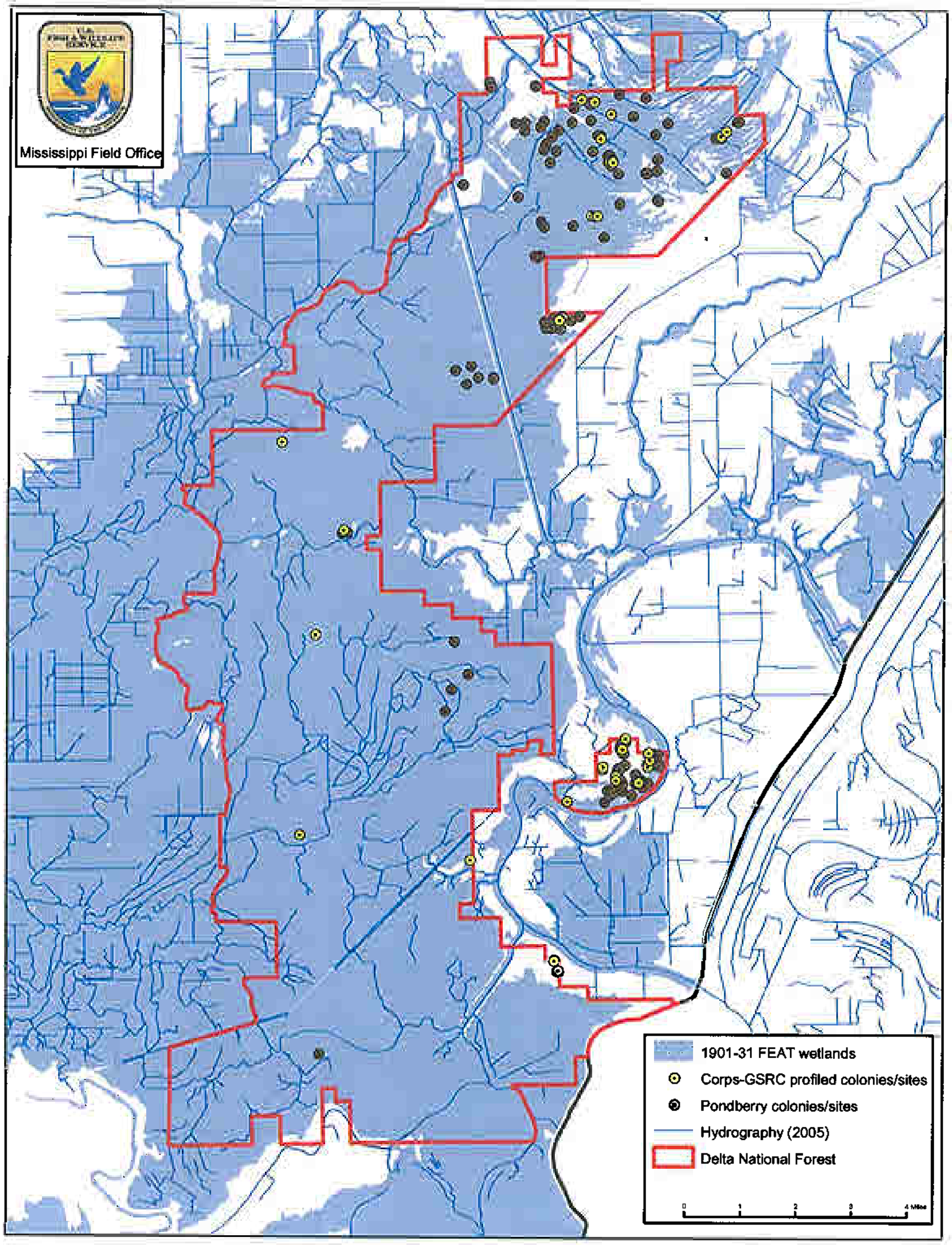


Plate 15. Historical coverage of wetlands (FEAT) during 1901-1931, relative to 177 extant pondberry colonies/sites.

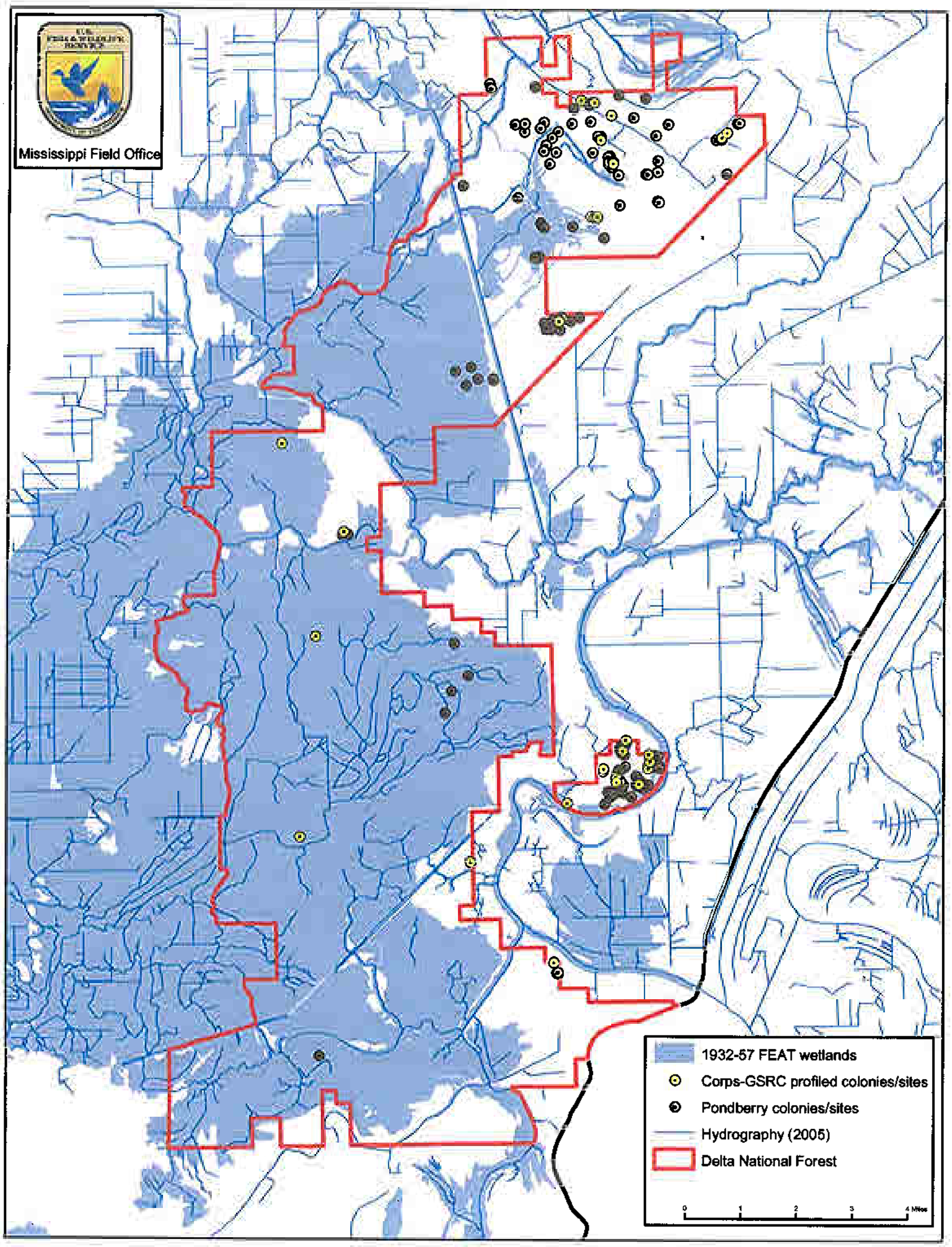


Plate 16. Historical coverage of wetlands (FEAT) during 1932-1957, relative to 177 extant pondberry colonies/sites.

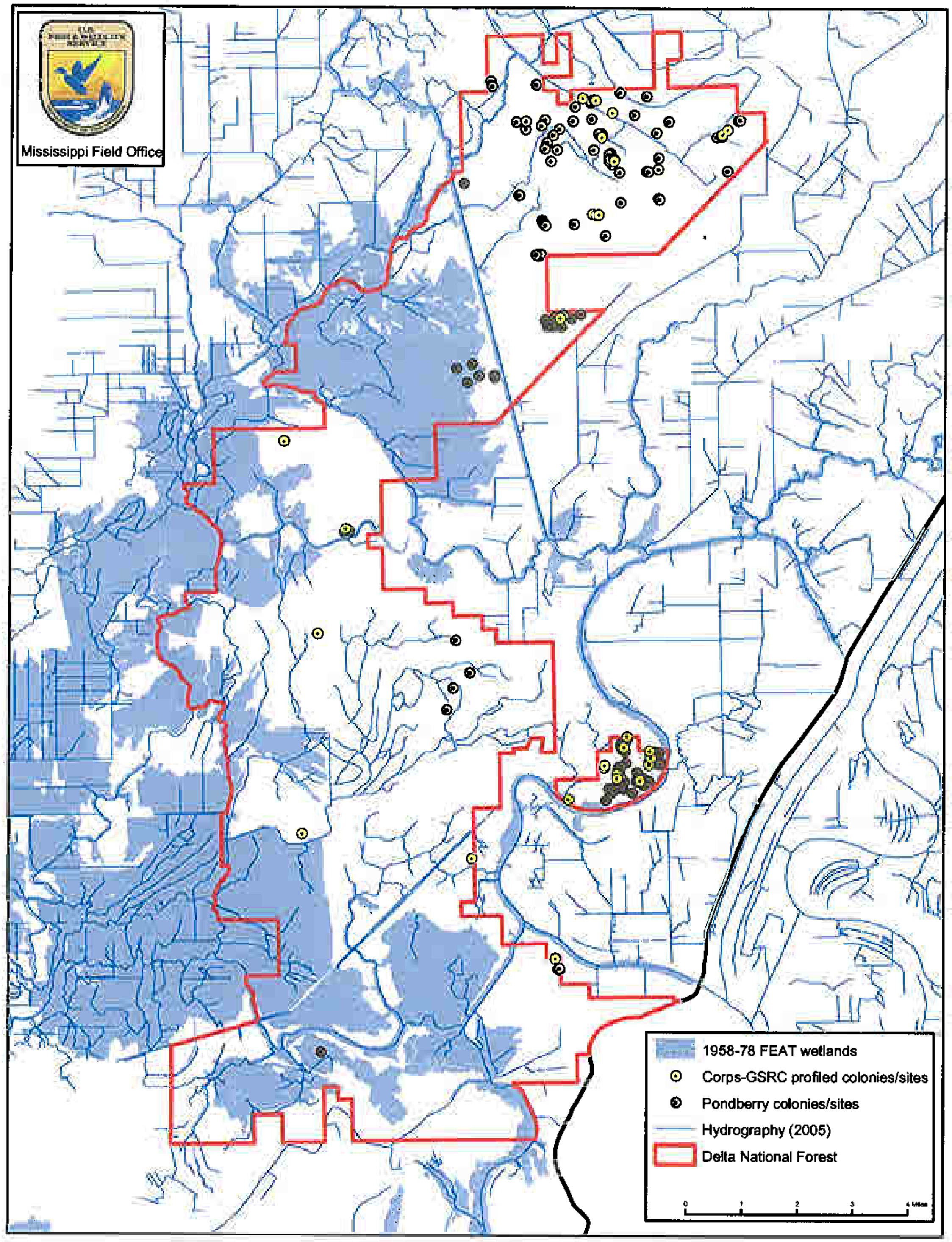


Plate 17. Historical coverage of wetlands (FEAT) during 1958-1978, relative to 177 extant pondberry colonies/sites.

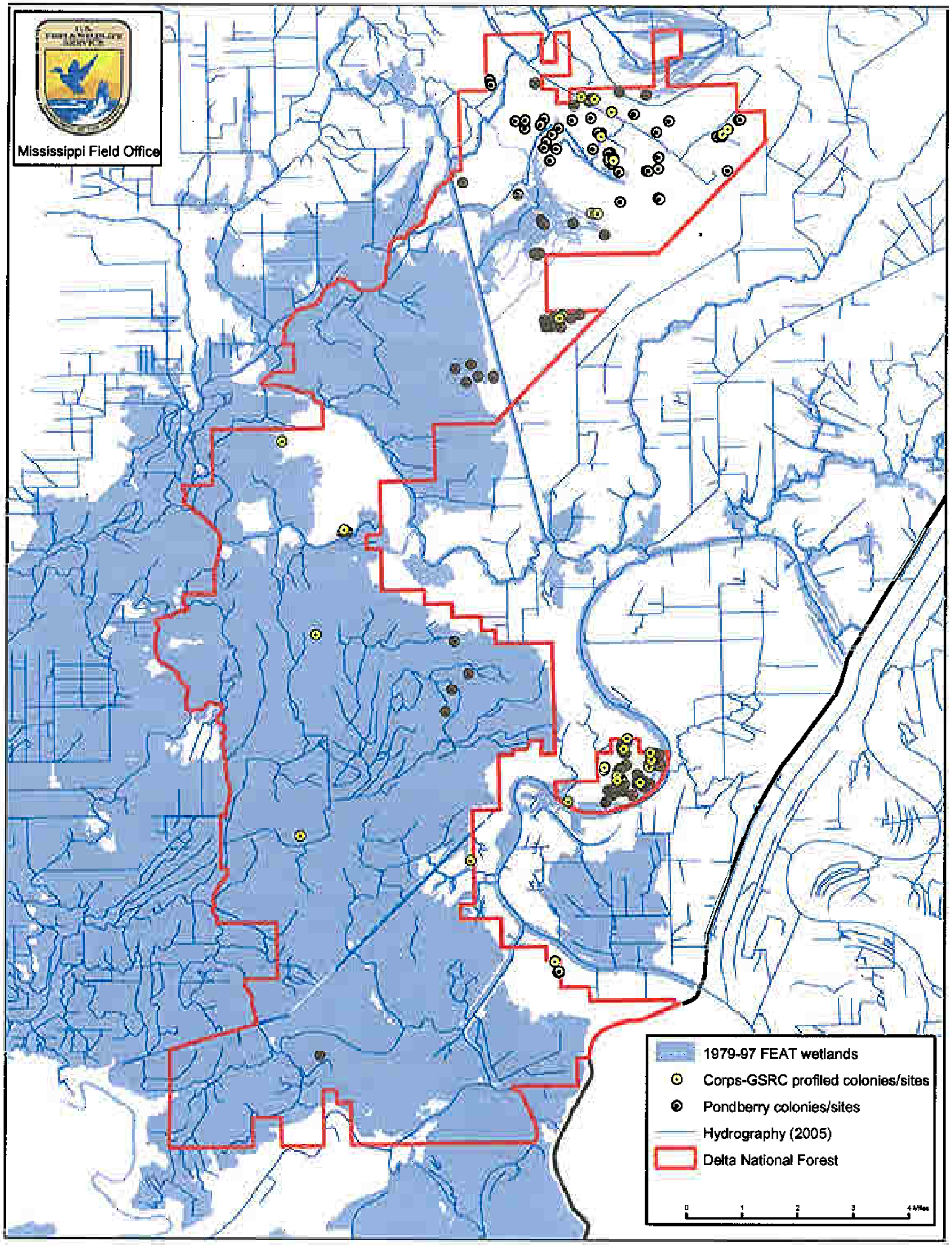


Plate 18. Historical coverage of wetlands (FEAT) during 1979-1997, relative to 177 extant pondberry colonies/sites.

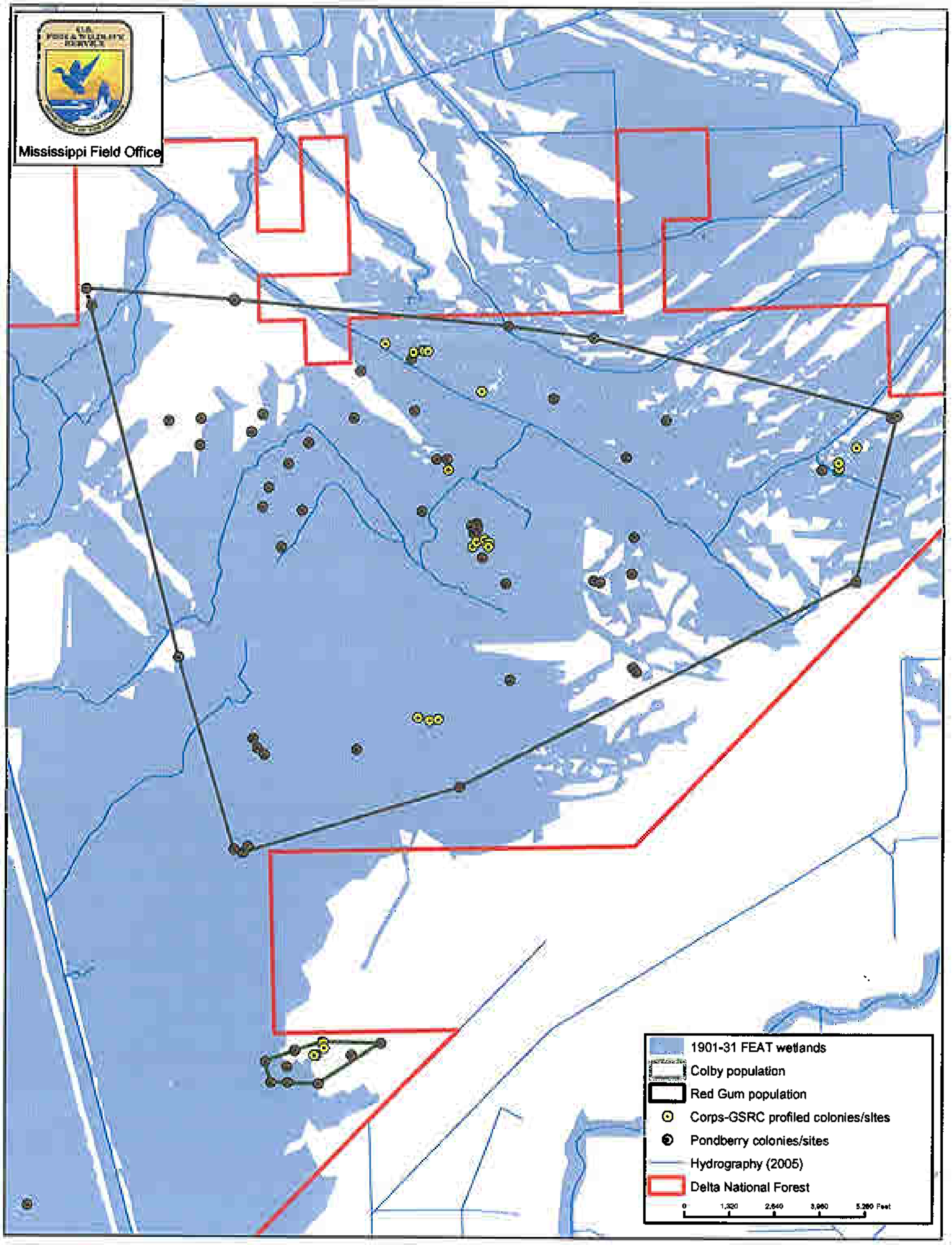


Plate 19. Historical coverage of wetlands (FEAT), during 1901-1931, in the Colby and Red Gum pondberry populations.

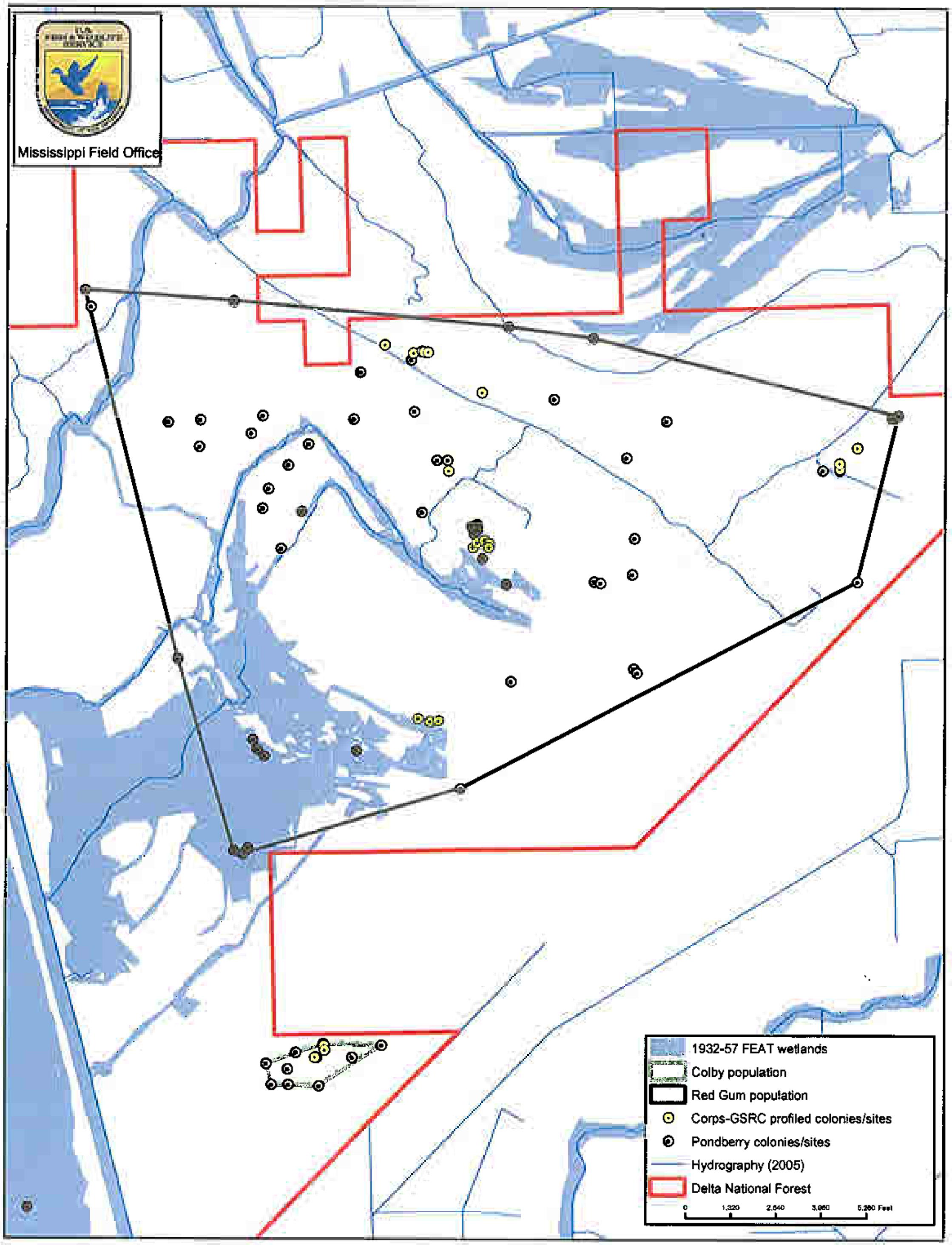


Plate 20. Historical coverage of wetlands (FEAT), during 1932-1957, in the Colby and Red Gum pondberry populations.

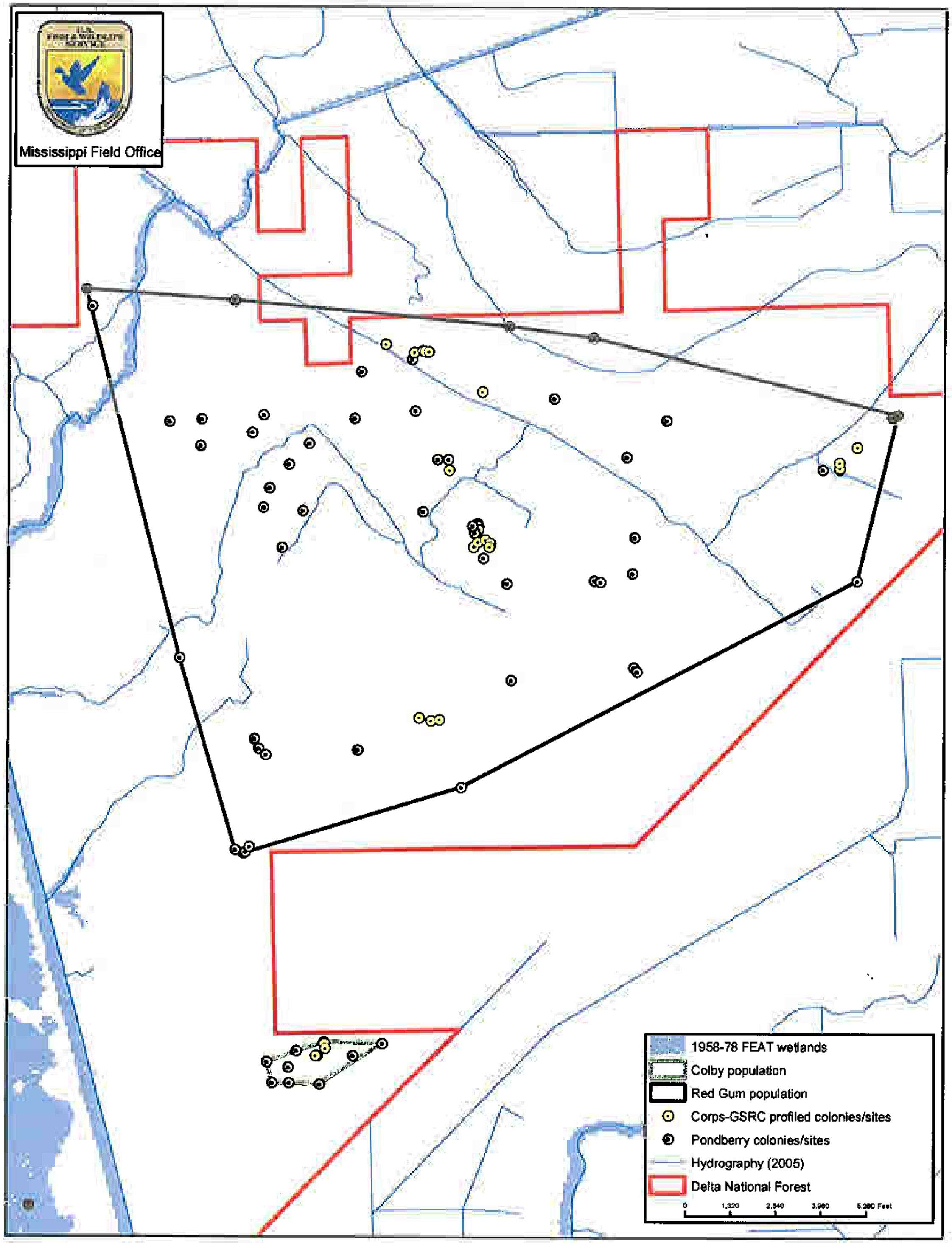


Plate 21. Historical coverage of wetlands (FEAT), during 1958-1978, in the Colby and Red Gum pondberry populations.

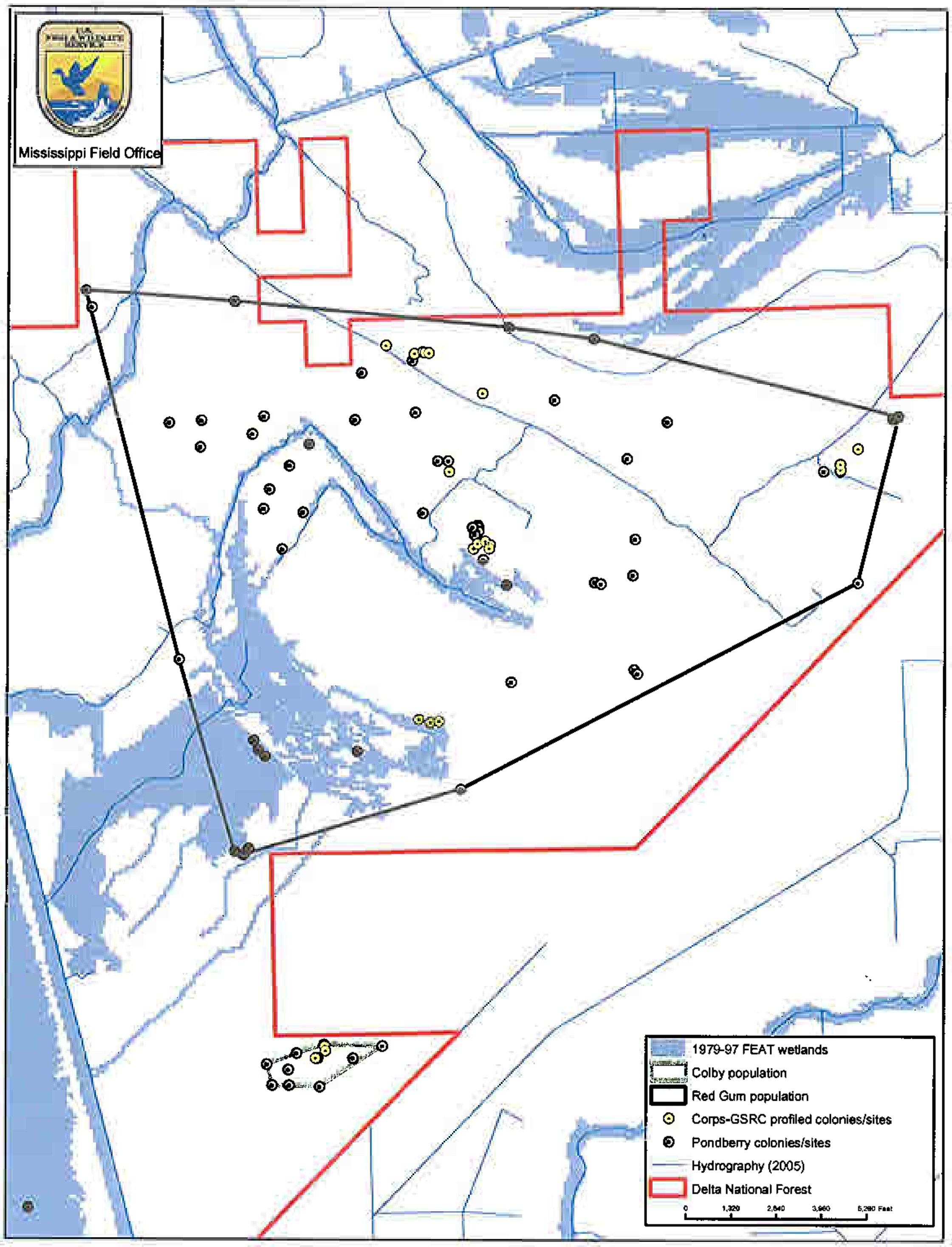


Plate 22. Historical coverage of wetlands (FEAT), during 1979-1997, in the Colby and Red Gum pondberry populations.

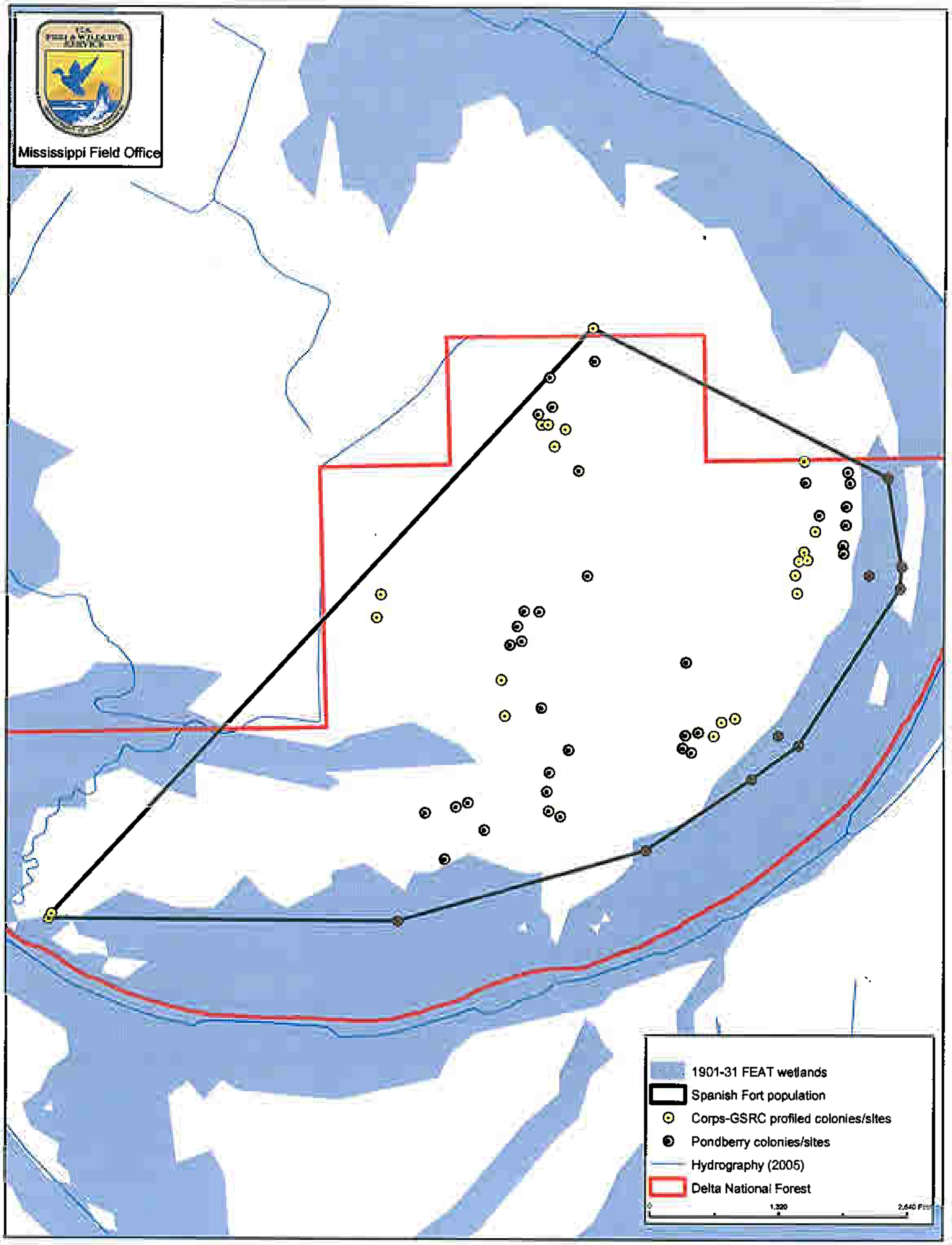


Plate 23. Historical coverage of wetlands (FEAT), 1901-1931, in the Spanish Fort pondberry population.

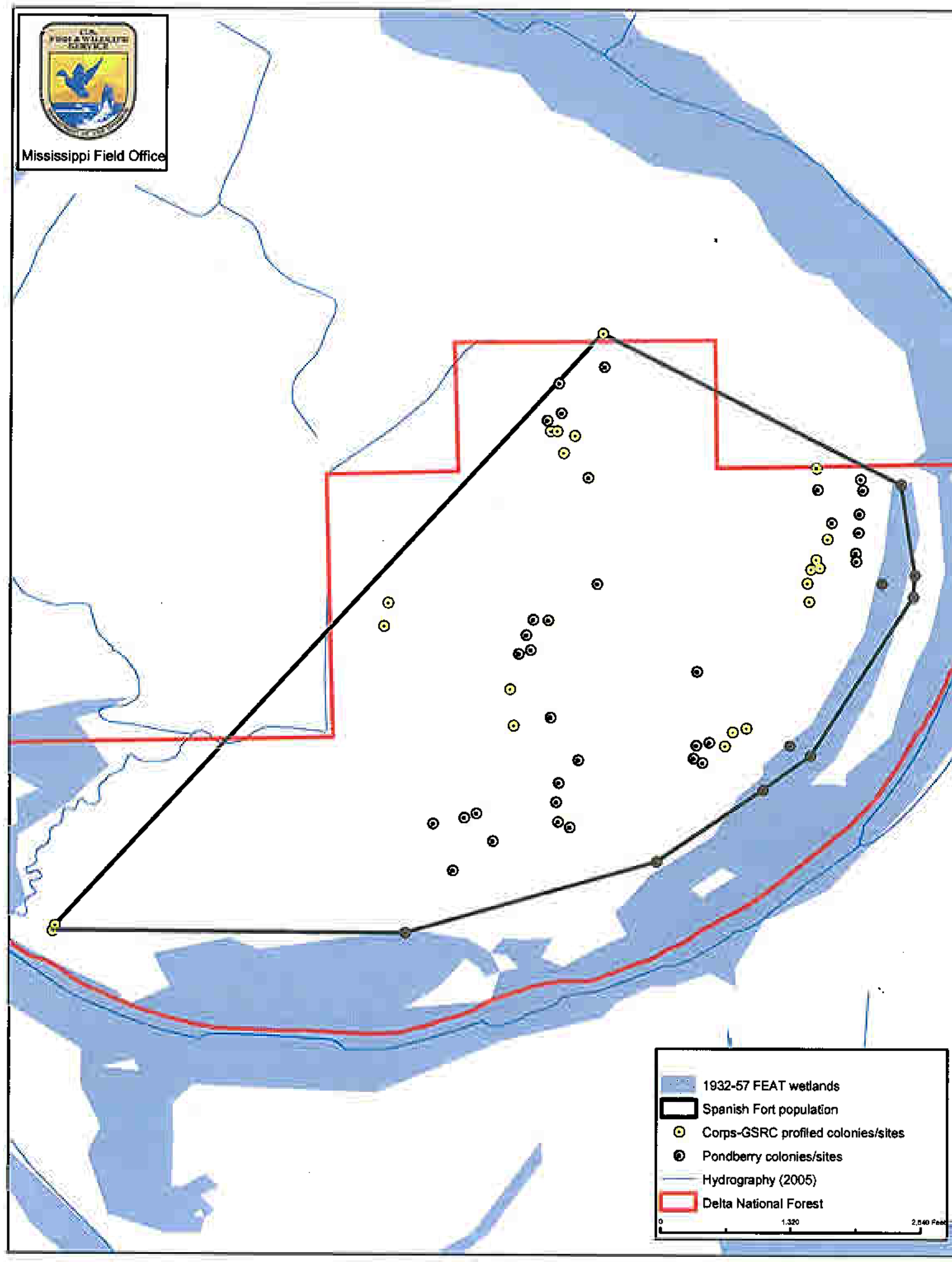


Plate 24. Historical coverage of wetlands (FEAT), 1932-1957, in the Spanish Fort pondberry population.

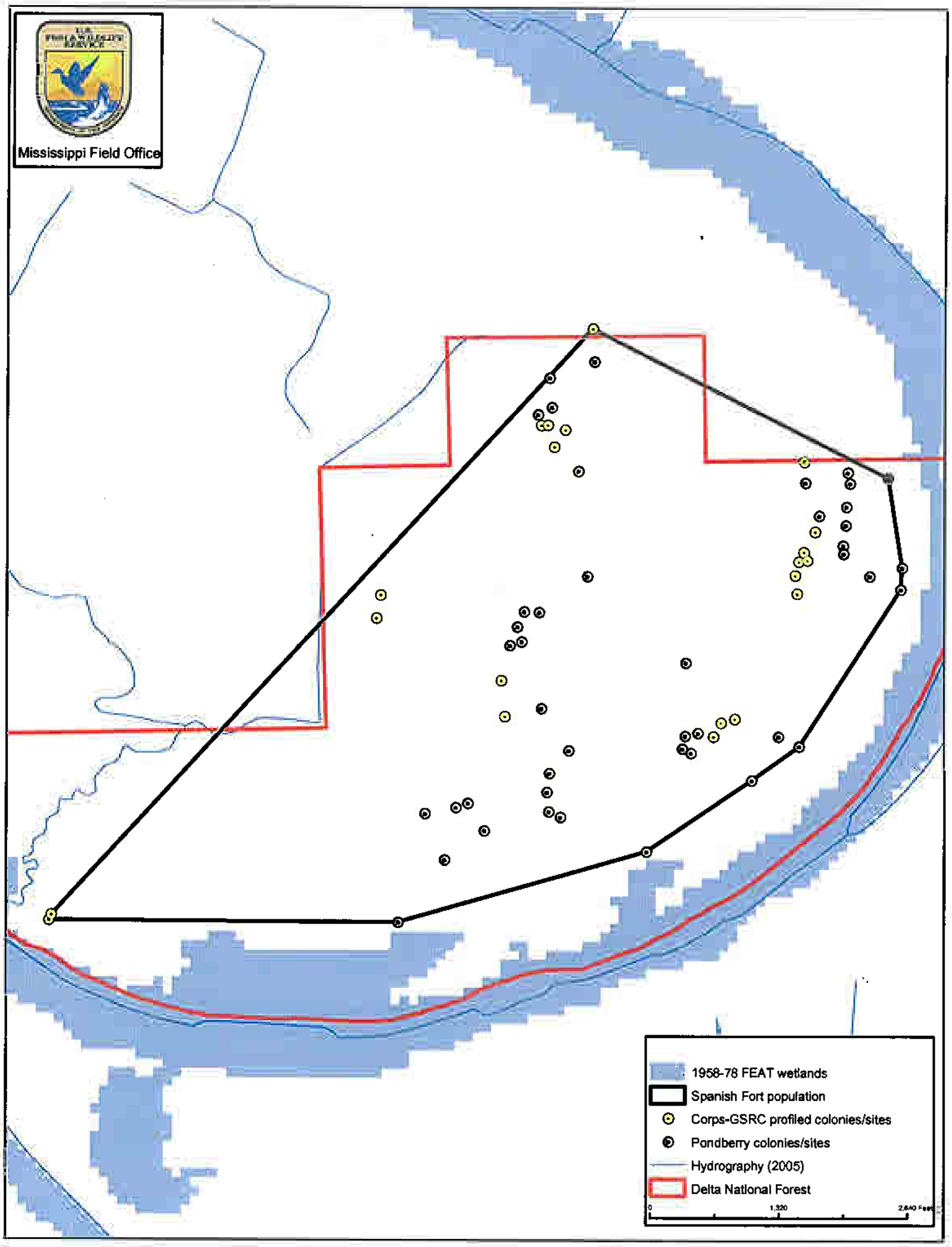


Plate 25. Historical coverage of wetlands (FEAT), 1958-1978, in the Spanish Fort pondberry population.

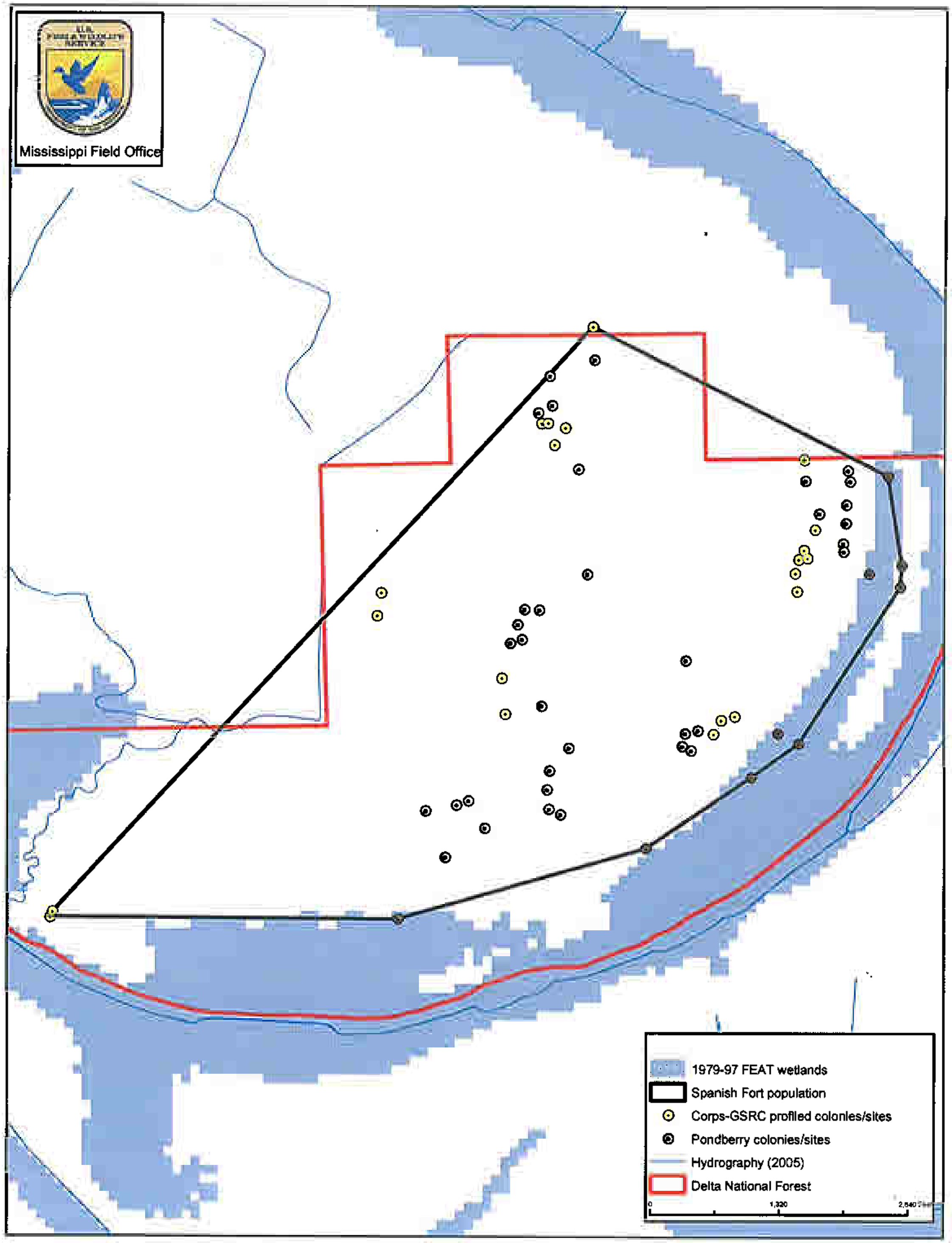


Plate 26. Historical coverage of wetlands (FEAT), 1979-1997, in the Spanish Fort pondberry population.

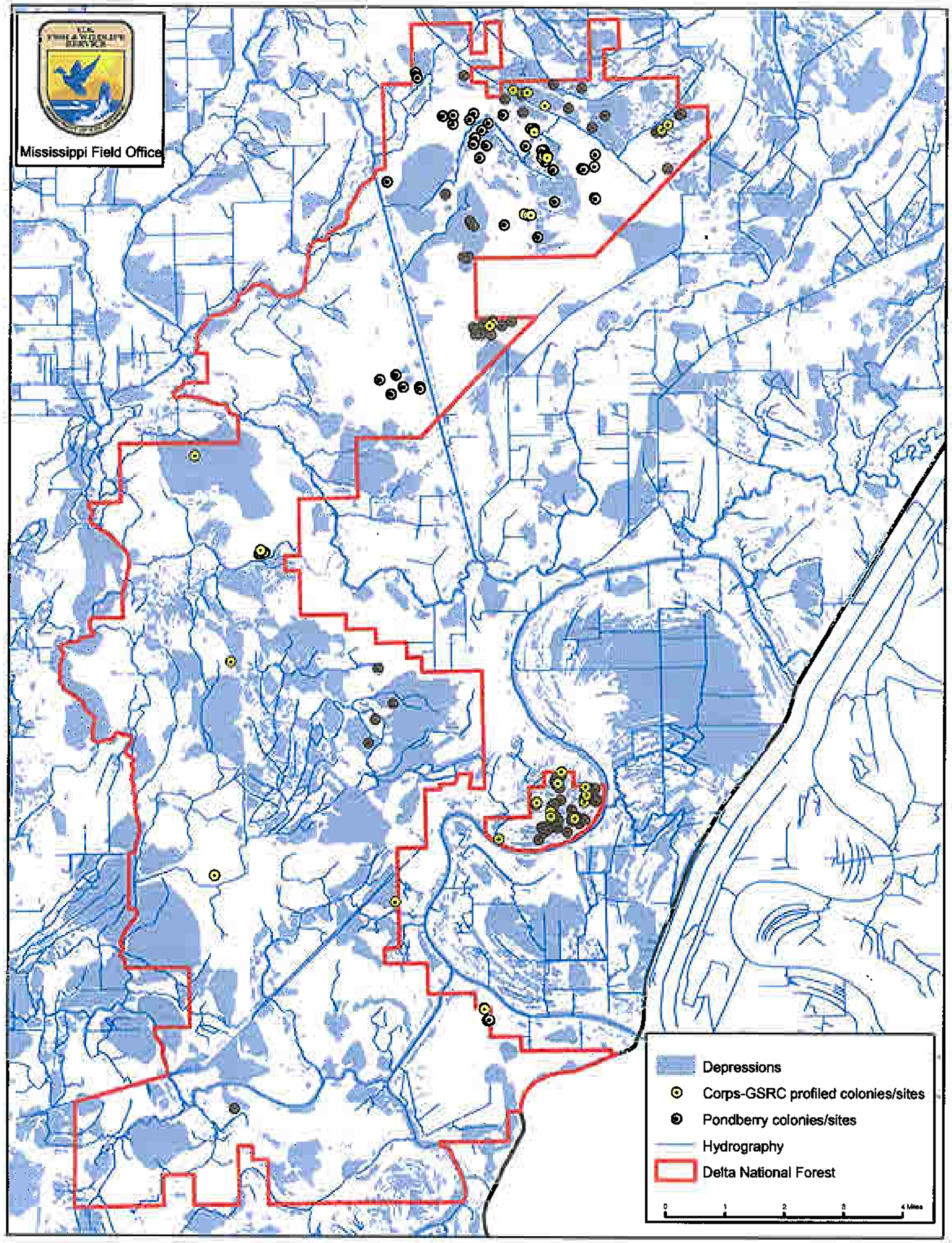


Plate 27. Association of 177 pondberry colonies/sites with depressions delineated from a USGS 10-m DEM.

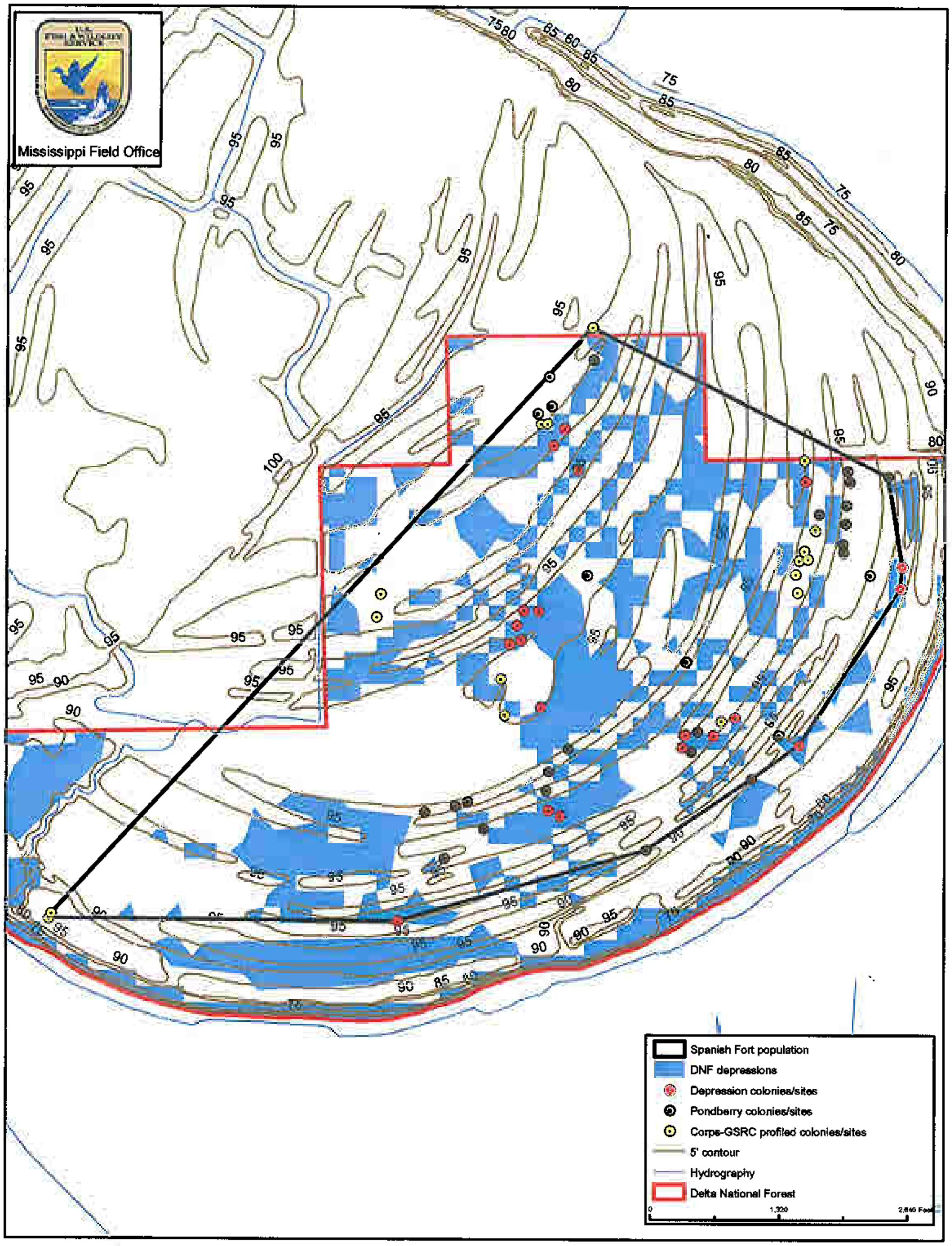


Plate 28. Association of depressions delineated from a USGS 10-m DEM with pondberry colonies/sites in the Spanish Fort population.

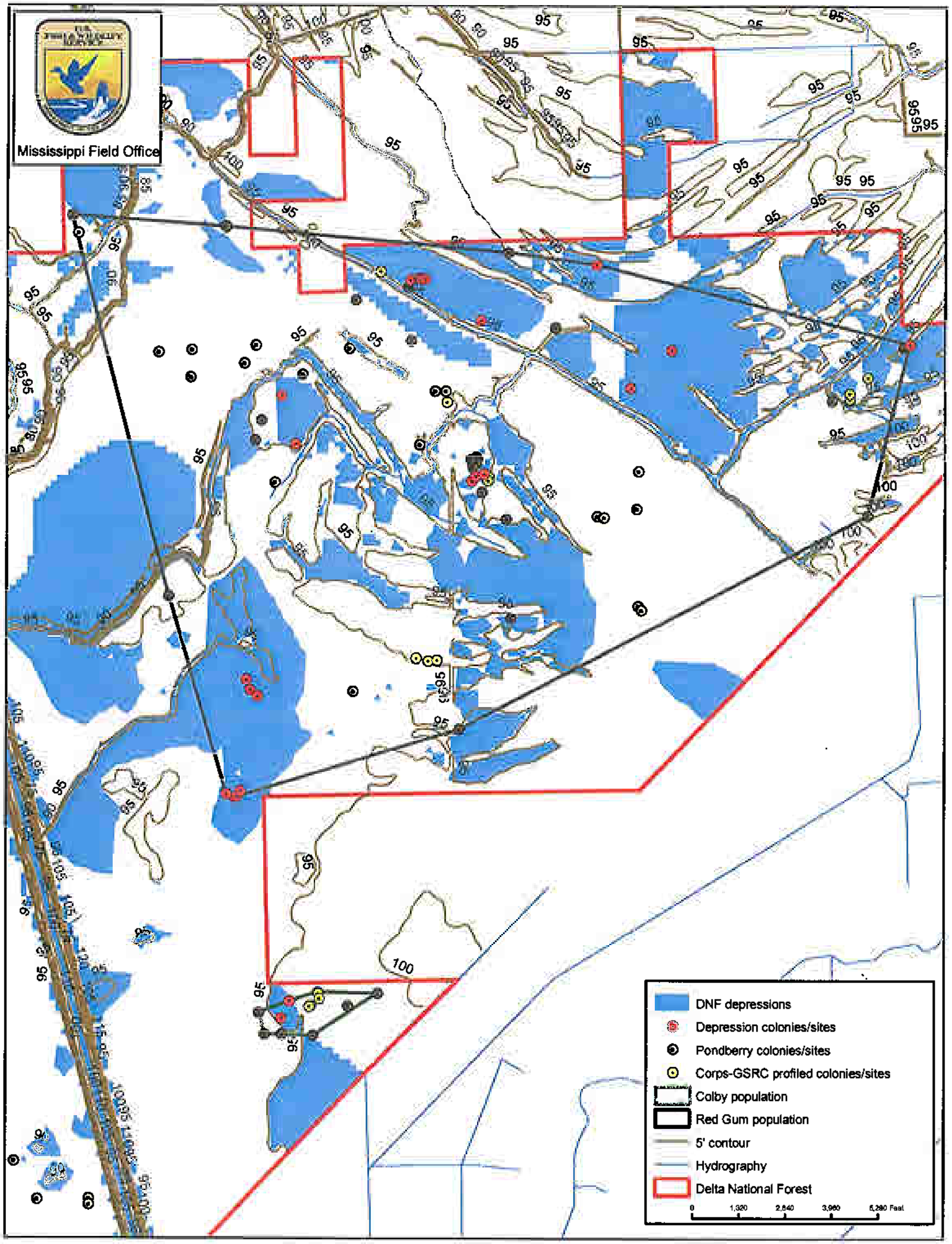


Plate 29. Association of depressions delineated from a USGS 10-m DEM with pondberry colonies/sites in the Colby and Red Gum populations.

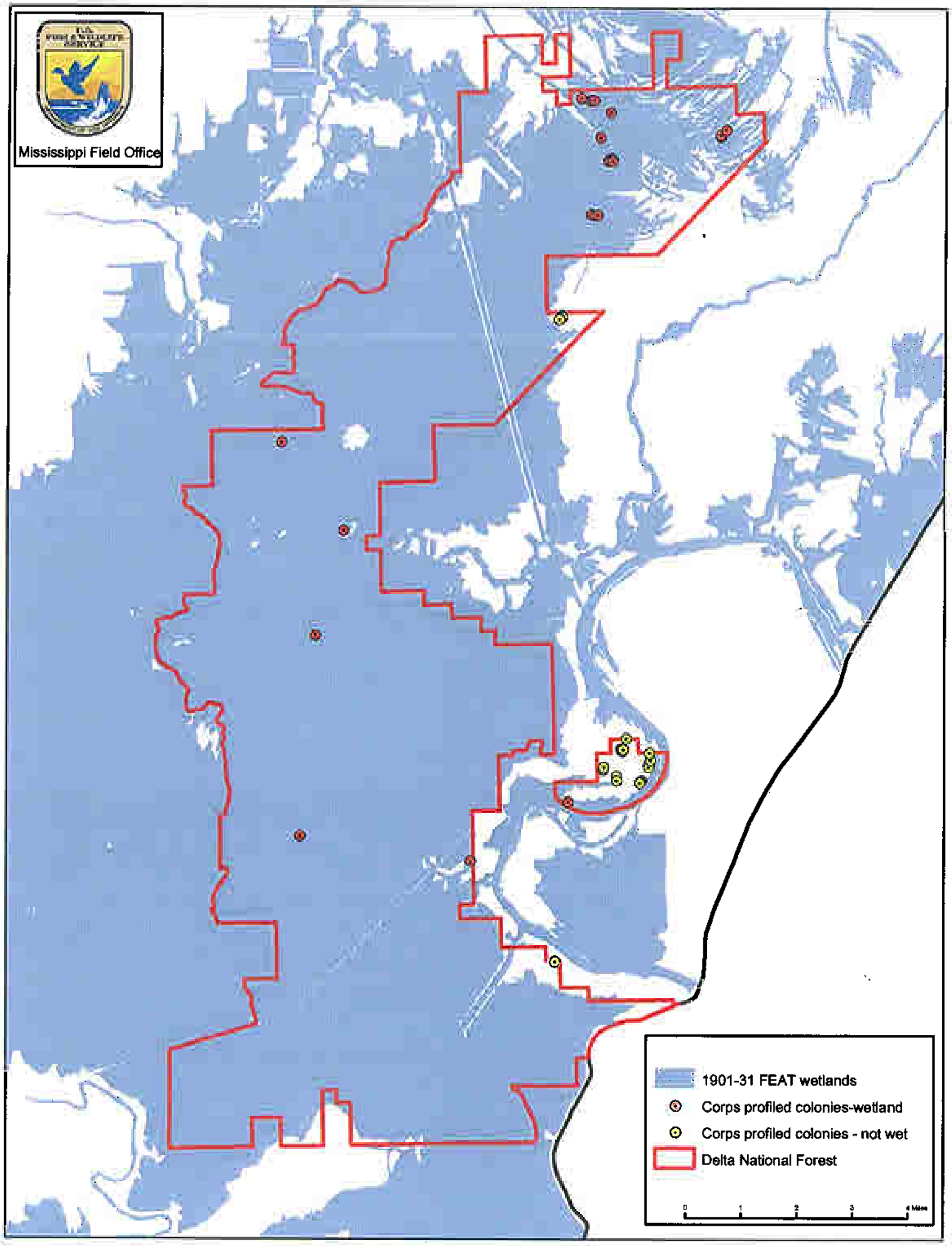


Plate 30. Historical coverage of wetlands, 1901-1921, in relation to Corps profiled colonies/sites.

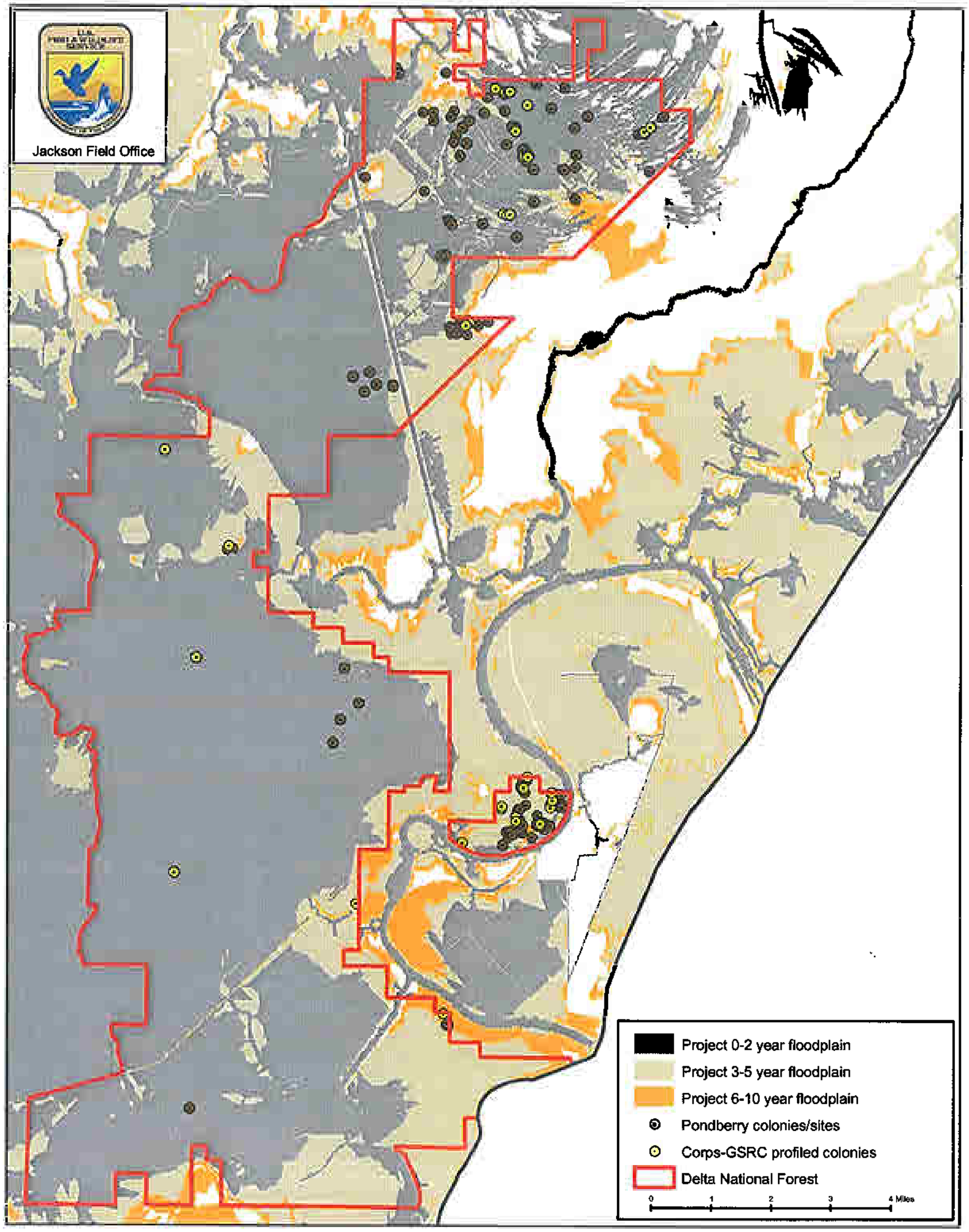


Plate 31. 0-2, 3-5, 6-10 year floodplains with the proposed project, Delta National Forest and pondlberry colonies/sites.

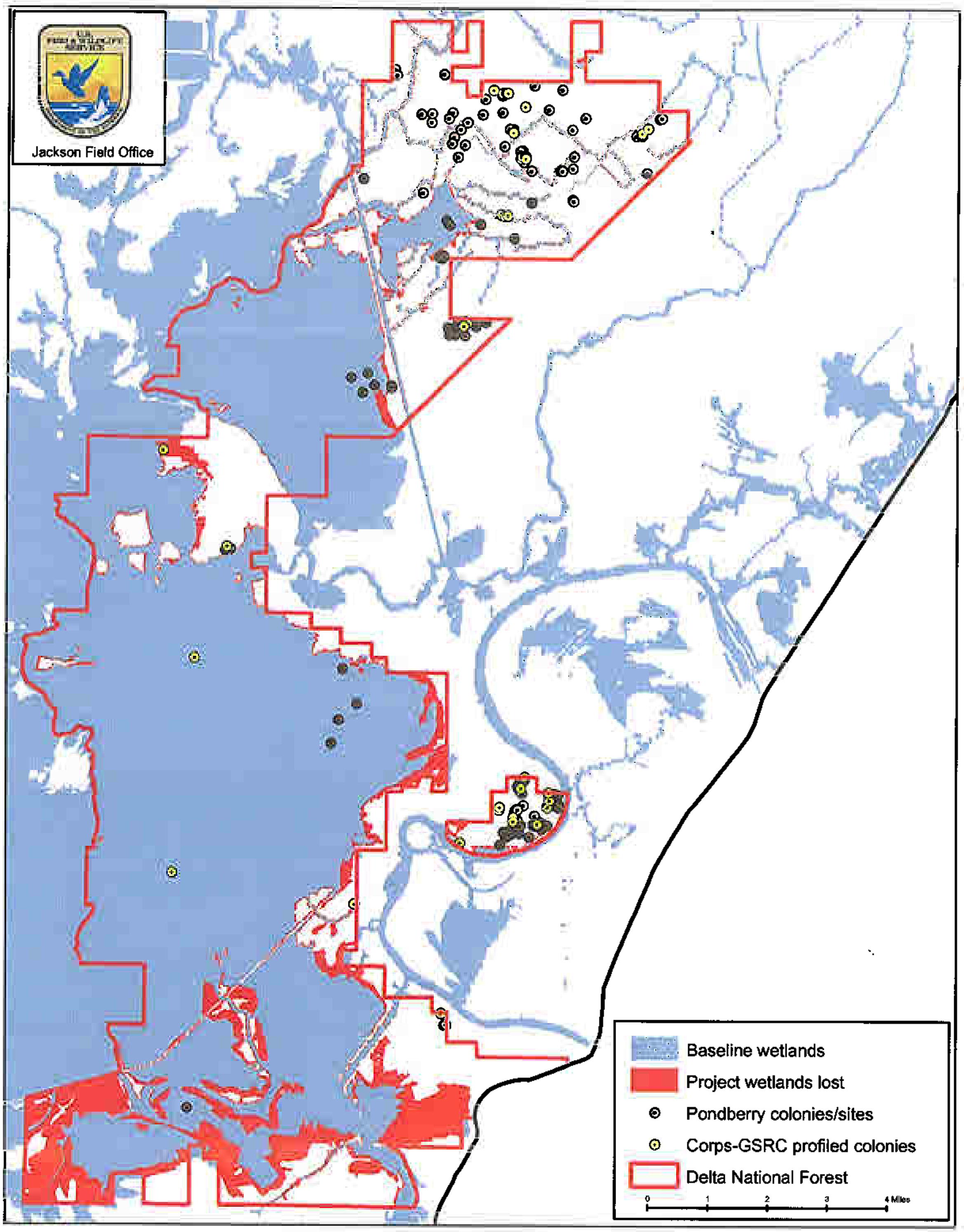


Plate 32. Baseline wetlands (FEAT) and wetlands lost with the proposed project, Delta National Forest and pondberry colonies/sites.

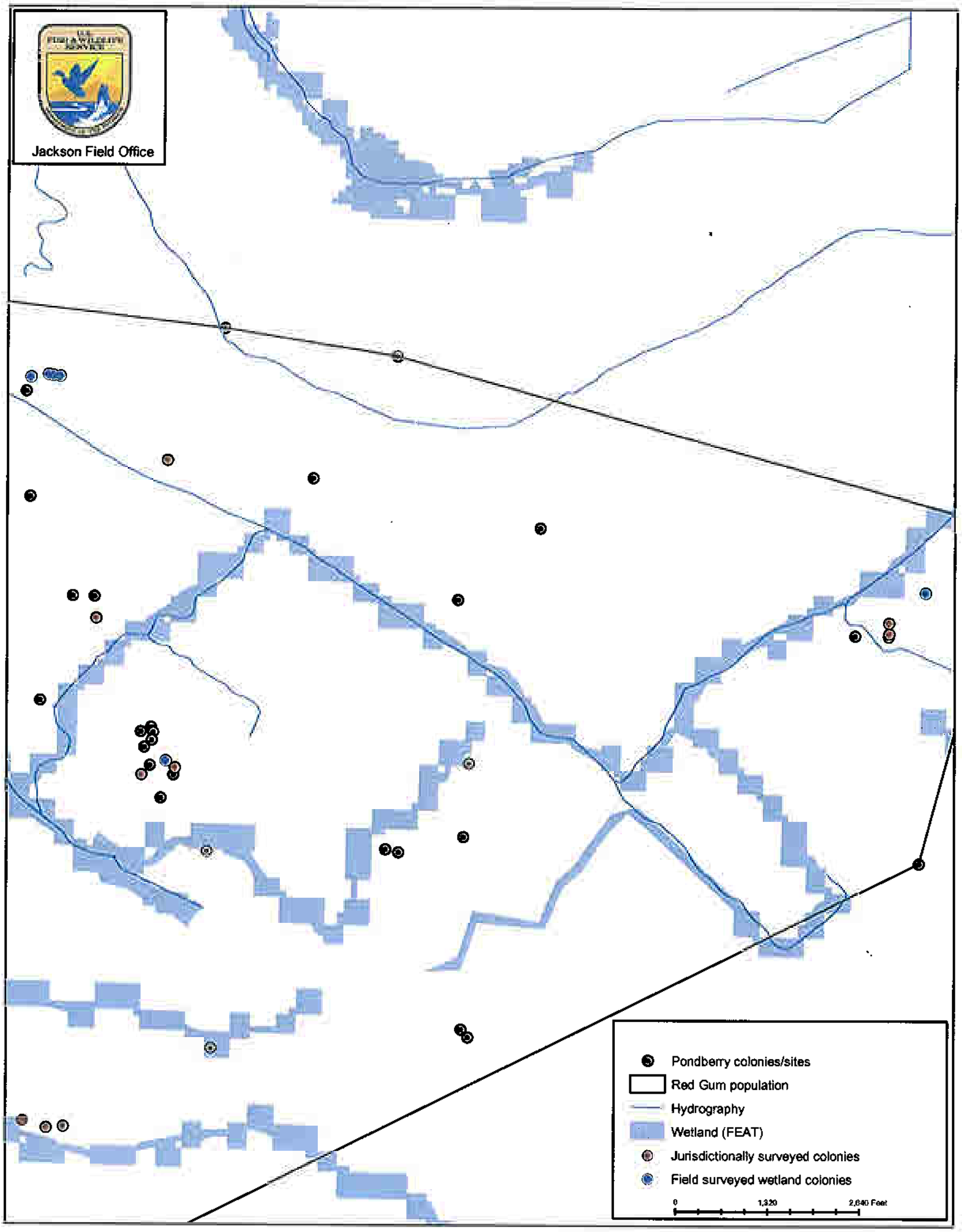


Plate 33. Jurisdictionally field surveyed colonies, Red Gum population, with 6 colonies/sites with a local wetland hydrology independent of overbank flooding, located at three sites.

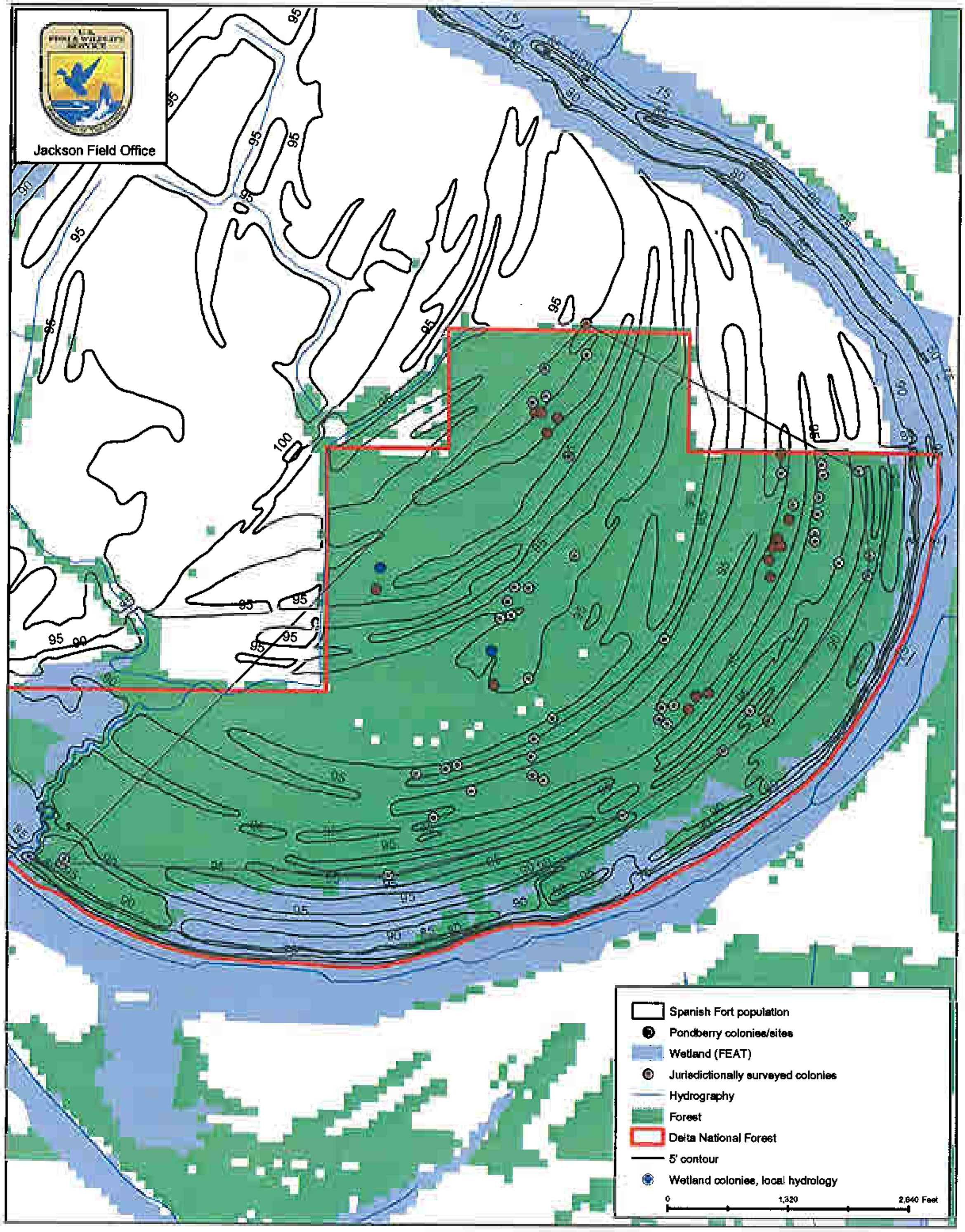


Plate 34. Jurisdictionally field surveyed colonies (17) in the Spanish Fort population, with two colonies/sites with a local wetland hydrology.

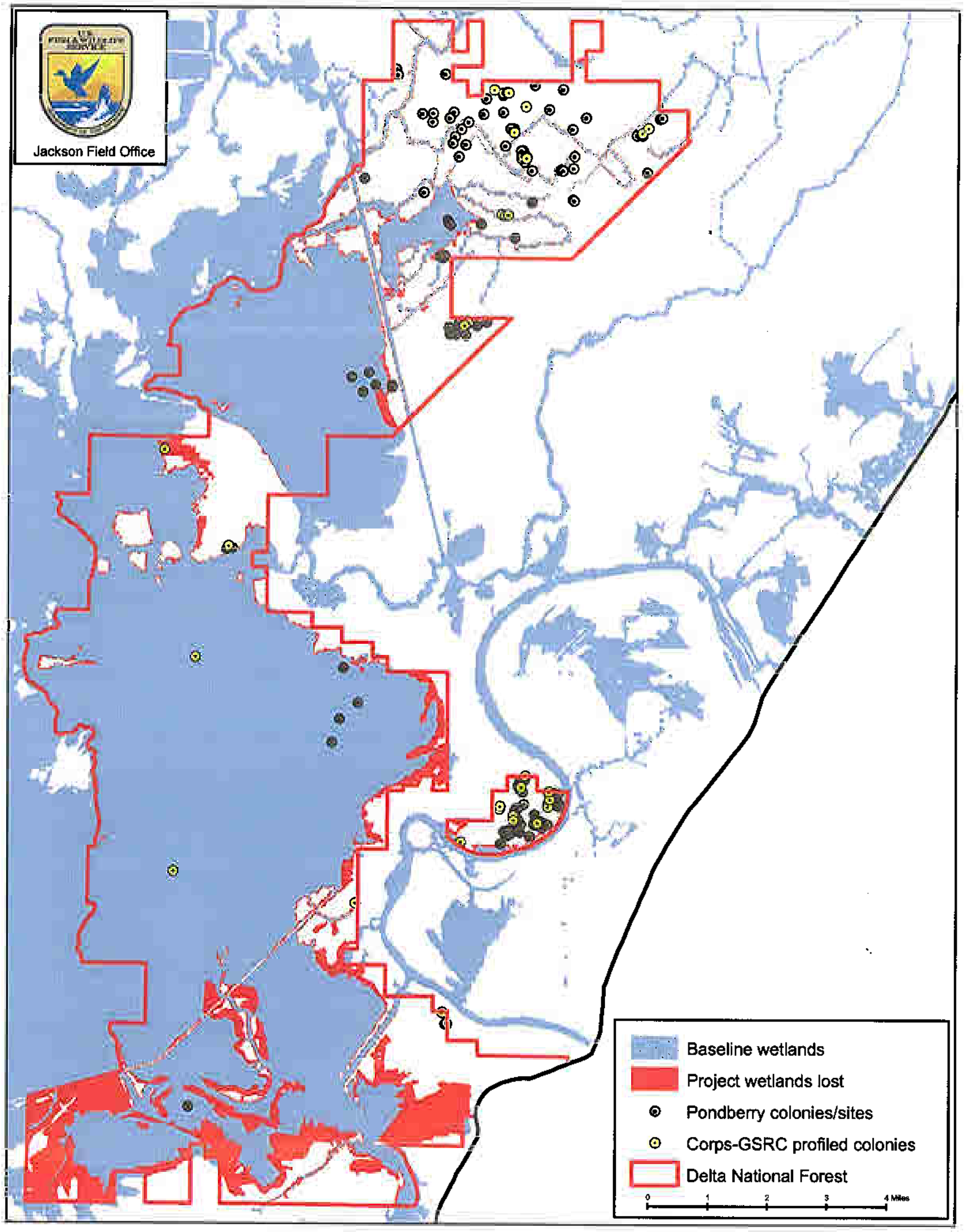


Plate 35. Baseline wetlands (FESM) and wetlands lost with the proposed project, Delta National Forest and pondberry colonies/sites.

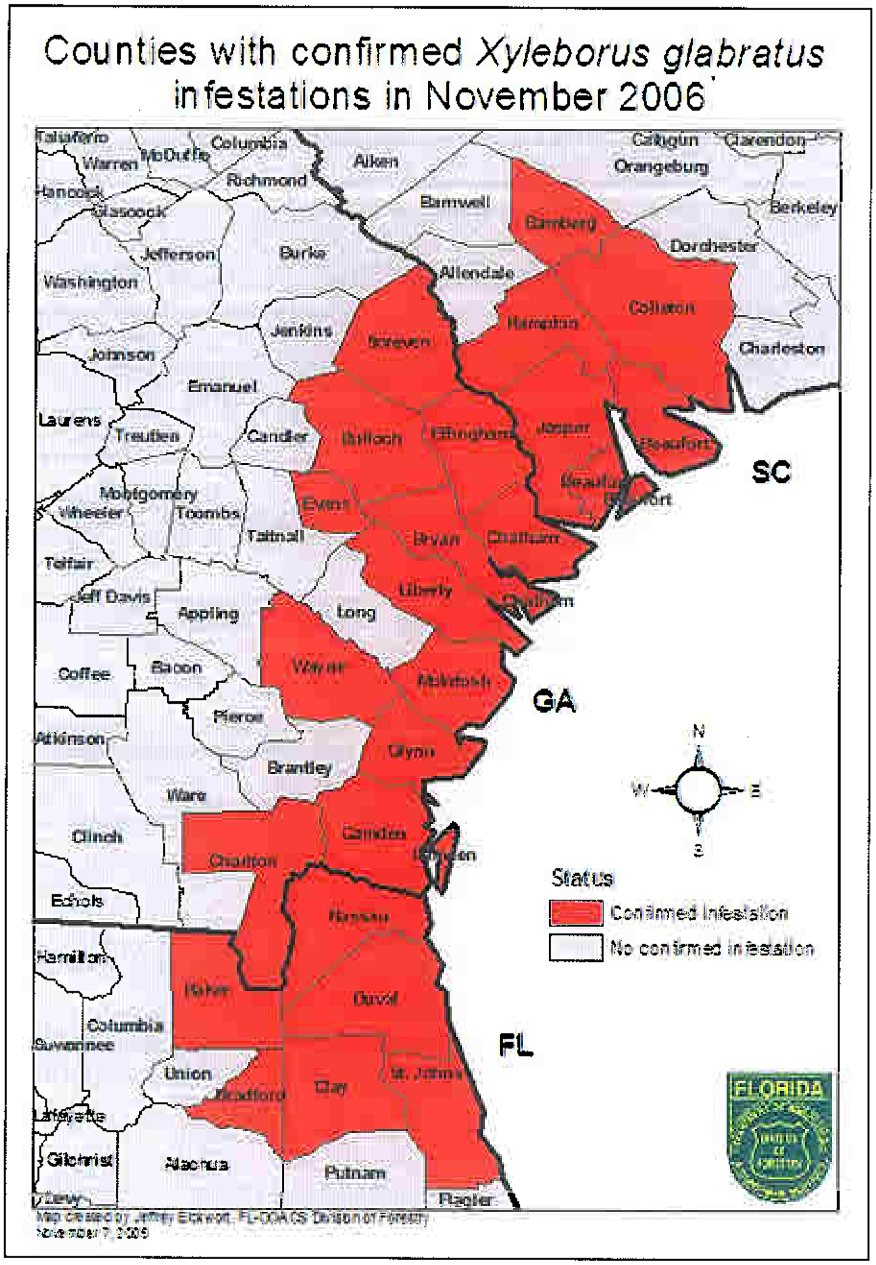


Plate 36. Distribution of laurel wilt disease, affecting red bay (*Persea borbonia*).

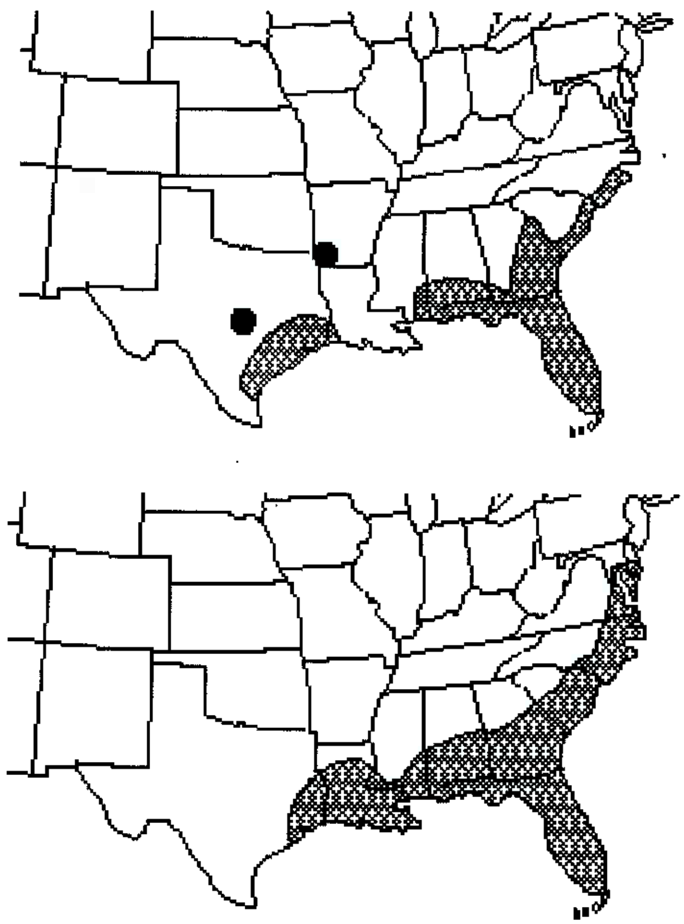


Plate 37. Distribution of red bay (*Persea borbonia*), top, and swamp red bay (*Persea palustris*), from the Flora of North America.

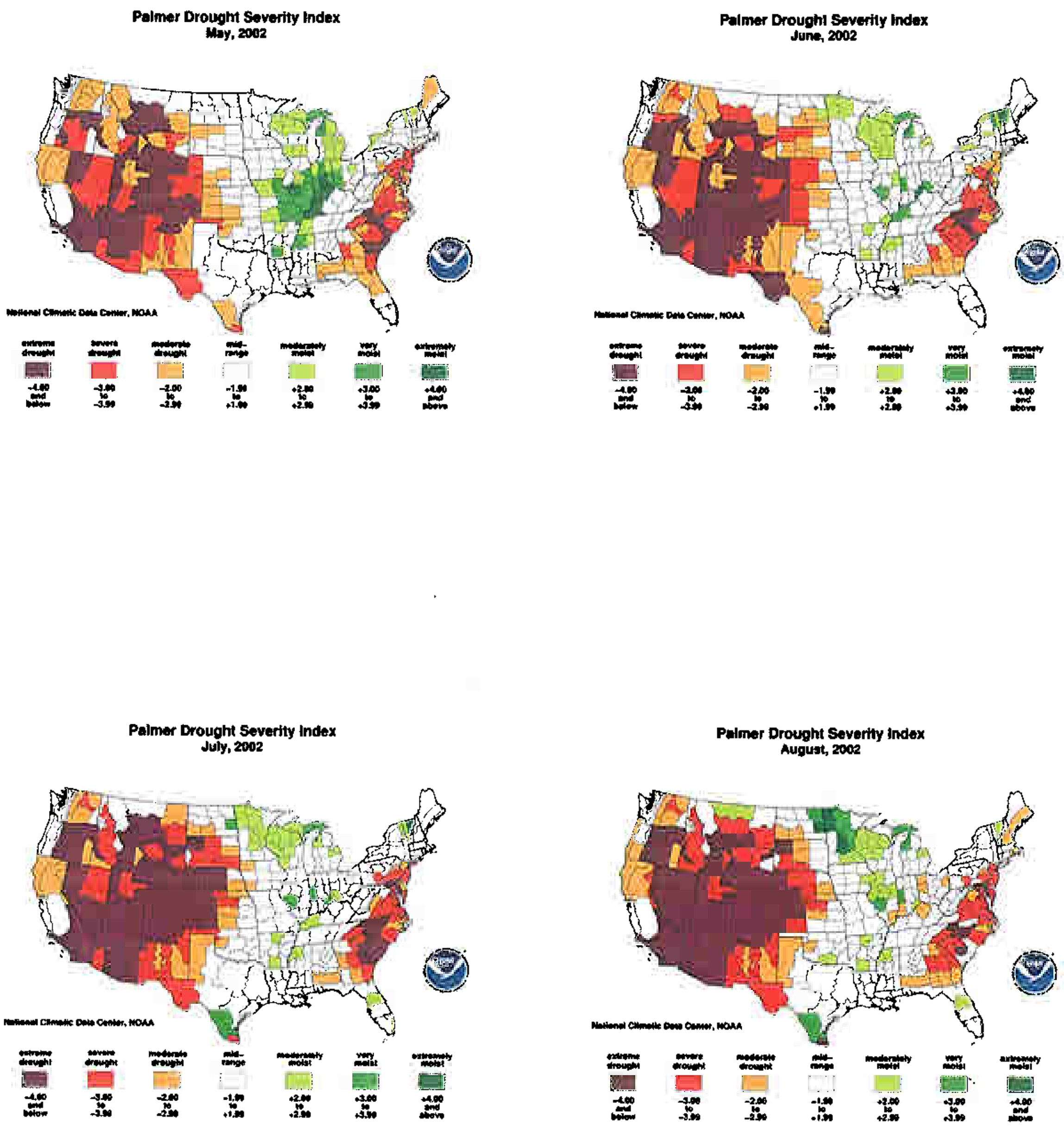


Plate 38. Palmer drought severity index, May – August 2002, with severe to extreme drought in pondberry regions in the Atlantic Coastal Plain, normal conditions in pondberry areas in Mississippi, Arkansas, and Missouri.

U.S. Fish and Wildlife Service Biological Opinion: U.S. Army Corps of Engineers Yazoo Backwater Reformulation Project

APPENDIX 1: Memorandum of Agreement, U.S. Army Corps of Engineers and U.S. Fish and Wildlife Service, Implementing a Pondberry Conservation and Recovery Program with the Yazoo Backwater Area Reformulation Project

MEMORANDUM OF AGREEMENT
BETWEEN THE
U.S. ARMY CORPS OF ENGINEERS, VICKSBURG DISTRICT,
AND THE
U.S. FISH AND WILDLIFE SERVICE

1. **Purpose.**

This Memorandum of Agreement (MOA) is entered into by and between the U.S. Department of the Army, U.S. Army Corps of Engineers (Corps), Vicksburg District, and the U.S. Fish and Wildlife Service (Service), Region 4, (collectively "parties"). The purpose of this MOA is to establish a framework for, and to implement a conservation and recovery program for the federally listed endangered plant, pondberry, in association with the Yazoo Backwater Area Reformulation Project, Mississippi (the "Project"). Specifically, this program consists of a pondberry propagation and stocking program as described herein. The Corps will also undertake a research project designed to evaluate the effects of flood frequency, sunlight, competition, and pathogens on pondberry.

2. **Authority.**

This MOA is entered into pursuant to Section 1536(a)(1) [generally known as Section 7(a)(1)] of the Endangered Species Act (ESA), 16 U.S.C. 1531, et seq.

3. **Scope.**

The scope of conservation and recovery activities is contained in Attachment A to this MOA.

4. **Responsibilities of the Parties.**

a. Responsibilities of the Corps.

(1) The Corps will be responsible for administering and funding the development, implementation, and monitoring of the conservation and recovery activities detailed in Attachment A.

(2) The Corps may, at its sole discretion, use other agencies, contractors, or other third parties to accomplish the development, implementation, and/or monitoring contained in Attachment A.

(3) By 31 January of each year after execution of this MOA, the Corps will provide an annual report on the status of its ongoing activities to conserve and recover pondberry as provided in Attachment A. The reporting period will be for activities from January through December of the previous year.

(4) The Corps will make available required planting sites on Mahannah Wildlife Management Area in accordance with Attachment A.

b. Responsibilities of the Service.

(1) The Service will provide technical assistance in the development, implementation, and monitoring of the conservation and recovery activities contained in attachment A at no cost to the Corps.

(2) The Service will assist the Corps in obtaining permits issued by the Service and its refuges, including those required by the ESA and its regulations.

(3) The Service may contribute additional funding, at its sole discretion.

(4) The Service will make available required planting sites on Panther Swamp National Wildlife Refuge in accordance with Attachment A and in accordance with a refuge Special Use Permit.

c. Responsibilities of both Parties.

(1) The Parties will work cooperatively to implement this MOA.

(2) In the event a dispute over a material term of this MOA or terms and conditions of a pondberry propagation and stocking plan and implementation of a research project as generally provided in Attachment A, or other issues which may arise, the parties will notify each other in writing the nature of the issue or purported dispute and will seek in good faith to resolve the dispute at the lowest organization level before seeking elevation.

(3) If a successful outcome cannot be reached by negotiation, the parties will elevate an unresolved dispute first to the Service's Assistant Regional Director – Ecological Services and the Commander, Vicksburg District, and if necessary, to the Service's Regional Director and the Commander, Mississippi Valley Division, for resolution.

(4) With respect to other agencies, the parties shall work cooperatively to address any concerns of other agencies.

5. **Funding.**

a. Corps funding to implement and monitor the pondberry propagation and stocking plan and to implement the research project, more specifically described in Attachment A, will be allocated from funding received to construct the Project. Implementation of activities described in Attachment A is subject to project approval and funding.

b. The parties may enter into interagency agreements under the Economy Act (31 U.S.C. §1535) for goods or services for the implementation of these conservation and recovery activities to include additional funding or in-kind work from other Federal agencies.

6. **Interagency Communications.**

Points of contact for the parties are:

a. Corps:

Kent Parrish
Senior Project Manager
Vicksburg District, U.S. Army Corps of Engineers
4155 Clay Street
Vicksburg, MS 39183-3435
(601) 631-5006

b. Service:

Ray Aycock
U.S. Fish and Wildlife Service
6578 Dogwood View Parkway, Suite A
Jackson, MS 39213
(601) 321-1124

7. **Amendment, Modification, and Termination.**

This MOA may be modified, amended, or terminated only by written mutual agreement of the parties prior to the completion and analysis of 10 years of monitoring data from the stocked populations and pondberry research sites.

8. **Miscellaneous.**

a. The Corps shall reference this MOA in the Record of Decision for the Project.

b. The Service shall describe in the Biological Opinion (BO) these conservation and recovery activities which were developed by the Corps in response to the Service's conservation recommendations made during the consultation.

c. This MOA shall not affect the independent obligations of the Corps or the Service, including any preexisting or independent relationships between the Corps and Service.

d. If any provision of this MOA is determined to be invalid or unenforceable, the remaining provisions shall remain in force and unaffected to the fullest extent permitted by law and regulation.

9. **Effective Date.**

a. This MOA is effective on the date of the last signature of approval.

b. This MOA is effective until 10 years from the first planting of pondberry in accordance with Attachment A.

IN WITNESS WHEREOF, the parties have caused this MOA to be executed. Each signatory represents that the signatory has been appropriately authorized to execute this MOA on its behalf.

U.S. DEPARTMENT OF THE ARMY	U.S. FISH AND WILDLIFE SERVICE
BY: [signature]	BY: [signature]
Anthony C. Vesay Colonel, Corps of Engineers District Engineer	Sam Hamilton Regional Director Southeast Region
DATE: 16 Mar 07	DATE: 2/28/07

ATTACHMENT A

1. **Background.**

a. Pondberry (*Lindera melissifolia*) was listed federally as an endangered species on 31 July 1986 (Federal Register 51 (47):27495-27500). It is a low-growing, deciduous shrub ranging in height from 1.5 to 6.5 feet. The plants commonly grow in clumps of numerous scattered stems. The older portions of the stems are dark green to almost black with numerous irregularly spaced, but prominent lenticels, which appear very similar to saplings of young stems of sassafras.

b. There are an estimated 196 pondberry colonies/sites in the Delta region of Mississippi. An estimated 177 of these colonies/sites occur in the Yazoo Backwater Area Reformulation Project Area. In 2001, the U.S. Army Corps of Engineers, Vicksburg District, entered into a 7-year, $5 million interagency agreement with the U.S. Department of Agriculture (USDA), Forest Service, to investigate pondberry biological and ecological requirements. The Agreement was entered into pursuant to Section 7(a)(1) of the Endangered Species Act (ESA), which allows Federal agencies to utilize their authorities to carry out programs for the conservation and recovery of listed species. These ongoing research activities were specifically designed to address recovery tasks described in the 1993 U. S. Fish and Wildlife Service Pondberry Recovery Plan. The additional activities contained in this Attachment also address tasks in the Recovery Plan and are also being conducted in accordance with Section 7(a)(1) of the ESA.

2. **Conservation and Recovery Activities.**

Two additional conservation and recovery activities will be conducted:

(1) Propagation and stocking of pondberry at or below the 1-year Backwater flood frequency.

(2) Establishment of field experiments to evaluate the effects of flood frequency, sunlight, competition, and pathogens on pondberry.

3. **Propagation and Restocking.**

a. Location:

(1) Stocking of pondberry will be conducted on Mahannah Wildlife Management Area, Issaquena County, MS, and Panther Swamp National Wildlife Refuge, Yazoo County, MS, or other areas, any and all of which must be agreed upon by the parties. Specific planting sites within each property will be jointly selected by the parties.

(2) The selected properties will have adequate conservation and management provisions to maintain suitable forest habitat for pondberry conservation for the duration of the MOA.

b. Restocking Specifications:

(1) Initial restocking will be 40,000 plants: 20,000 plants on Mahannah Wildlife Management Area and 20,000 plants on Panther Swamp National Wildlife Refuge. These stock plants will be derived and propagated by tissue culture from existing selected parental stock maintained by the USDA, Forest Service.

(2) A propagation/stocking plan will be jointly developed by the Corps and the Service within 12 months of the effective date of the MOA. The propagation/stocking plan will establish the following: (a) number of sites to be planted (no less than 4 nor more than 10), (b) planting schedule for each site, and (c) planting spacing and quantities of plants for each site.

(3) Site conditions will meet the following flood frequency and duration guidelines:

(a) At or below 1-year backwater flood frequency.

(b) Below the 5 percent backwater flood duration determined by the Flood Event Simulation Model.

(c) Determined a jurisdictional wetland using the 1987 "Corps of Engineers Wetland Delineation Manual," Technical Report Y-87-1, U.S. Army Engineer Research and Development Center.

(4) Forest stand characteristics will be similar to known colonies in the Yazoo Backwater Area's 1-year flood frequency.

(5) Pondberry planting will consist of plants with genetic attributes based on known genetics as established by the USDA, Forest Service, or other mutually agreed upon genetic population parameters.

(6) Within 12 months of the effective date of the MOA, the Corps and Service jointly will develop a plan for monitoring and managing the propagation program. The plan will include the following elements: (a) establishment of measurable performance standards for evaluating the propagation sites; (b) establishment of criteria for reporting on attainment of performance

standards at the propagation sites for a period of 10 years following initial planting, which reports will be included in annual report described in MOA paragraph 4.a.3; and
(c) establishment of criteria for evaluating possible corrective measures if performance standards are not met. Implementation of corrective measures will be treated as an amendment of the MOA.

(7) The parties will work cooperatively to implement these restocking specifications.

4. **Field Experiments.**

a. The Corps will conduct field experiments for the purpose of investigating the relationship of pondberry to flood frequency, sunlight, competition, and pathogens under forest conditions.

b. Location: Experimental plots will be established in Delta National Forest, Sharkey County, MS, as approved by the USDA, Forest Service. The plots with artificially propagated pondberry stock will be geographically separated from existing pondberry colonies/sites and clearly identified as research plots.

c. Experimental Design:

(1) The experimental design will contain the following treatments, depending on site availability.

(a) Flood frequencies investigated at 1, 2, 5, 10, and 15 year.

(b) Stand sunlight investigated with light thinning, heavy thinning and control.

(c) Competition investigated with herbicide treatment and control.

(2) The Corps will provide a detailed research plan to the Service within 12 months of the effective date of the MOA.

(3) Data collection and analysis will be conducted annually for 10 years. The Corps will provide annual reports to the Service.

(4) The parties will work cooperatively to develop and implement the field experiment.

5. **Schedule.**

The parties agree to the following general schedule:

Item	Propagation and Restocking		Field Experiment	
	Initiation	Duration	Initiation	Duration
1. Determine Genetics	MOA Execution	3 months	MOA Execution	3 months
2. Determine Required Stand Characteristics	MOA Execution	4 months	MOA Execution	4 months
3. Site Selection (hydrology/stand parameters)	After Item 2	6 months	After Item 2	6 months
4. Determine Planting Specifications	After Item 3	1 month	After Item 3	1 month
5. Pondberry Propagation a/	ROD Execution	12 months/yr	ROD Execution	12 months
6. Pondberry Outplanting	After Item 5	3 months/yr	After Item 5	3 months
7. Monitoring/Data Collection	After Item 6	Annual/10 yrs	After Item 6	Annual/10 yrs
8. Reporting	After Item 7	Annual/10 yrs	After Item 7	Annual/10 yrs

a/ Propagation and outplanting for restocking will be phased in over 4 years.

APPENDIX 2: Factors Considered for the Spatial Definition of a Pondberry Population

For the purposes of pondberry research and analysis at the U.S. Forest Service Center for Bottomland Hardwoods Research (CBHR), Devall et al. (2002) currently consider a pondberry population as a colony or colonies separated by at least 1 mile from other colonies, as an interim working definition, based on long-distance flights of ground dwelling bees that pollinate the species. We have adopted this definition, in conjunction with the definition in the recovery plan and other information, to circumscribe and assess pondberry populations. According to the recovery plan, a pondberry population is "one or more colonies that are in close enough proximity to regularly interbreed and be separated from other populations by a sufficient distance to preclude interbreeding on a regular basis" (U.S. Fish and Wildlife Service 1993). The recovery definition recognizes a population as a demographic and genetic unit. With a distance of up to 1 mile, pollination between male and female plants would be required regularly and sufficiently as one demographic component of reproduction to produce fruits and seeds. Genetically, by this definition, plants would not be isolated or significantly different from one another at these distances because they would be, for the most part, offspring of parents from within this spatial population.

Populations identified at this distance actually may be subdivided into more than one population due to other biological factors, particularly the patterns of gene flow and the distances between certain colonies/sites within a population. One measure of interbreeding is the spatial pattern of gene flow by the dispersal of pollen and seeds. The 1-mile provisional population definition of Devall et. al. (2002) for pondberry, based on long distance pollinator flights, includes the element of pollen dispersal, although neither pollen or seed dispersal distances have been measured to actually estimate a pondberry population by methods of genetic neighborhood analysis. The ecology of pondberry pollination is poorly known, including the foraging behavior of pollinators and actual patterns of pollen dispersal. Relative to pollen dispersal, most seed dispersal in pondberry probably occurs over much shorter distances, on average, although very infrequent dispersal over much greater distances than pollen is likely. Seed dispersal is related to the distance fruits fall when dropping from plants at maturity, and the distances transported if they are eaten from plants, and later either disgorged or defecated by animals. Hermit thrushes have been identified eating, dispersing, and regurgitating viable pondberry seeds, although the estimated dispersal distances are relatively short, about 160 feet on average, because of the animals small winter home range (Smith et al. 2004). In the absence of specific studies or data on pollen and seed dispersal for pondberry, the only other available data to consider consists of the scientific information derived from studies of other species.

Overall, there are more studies and data on the distances and patterns of pollen dispersal than seed dispersal in plants. Also, pondberry reproduction is predominately asexual by sprouting at the base of stems, root collars, or from underground rhizomes. Since sexual reproductive success as measured by the establishment of seedlings is rarely observed for pondberry, the working definition of a population emphasizes the pollination component as a first step toward successful fertilization and seed production. This doesn't mean that animal-dispersed seeds are unimportant. Seed dispersal distances from animals may be much greater than pollination distances in pondberry. Periodic long distance seed dispersal also is vital for the establishment of new colonies and populations, and to maintain genetic variation. The limited seed dispersal data from studies of other species in the scientific literature, however, is a greater impediment than pollen dispersal data for understanding pondberry gene flow and population structure.

The provisional population definition is based on long distance pollinator flights. However, long distance flights do not necessarily correspond to an effective pollination distance. The distance pollen is transported by a pollinator between plants is related to flight distance, but the frequency distribution of flight distances typically is positively skewed and leptokurtic, with most flights occurring over shorter distances and fewer flights at longer distances (Levin and Kerster 1974; Levin 1981; Hamrick 1987; Price and Waser 1979; Schaal 1980). A predominance of shorter flight distances between plants reflects a foraging strategy where pollinators will tend to visit the closest plants available to increase the rate of food intake from floral rewards (nectar and/or pollen) relative to energy expended for flight (Heinrich 1975; Pyke 1978, 1980). Yet, the distance pollen is transported normally is greater than the distance of pollinator flight from a male to female flower because of pollen carryover. Carryover occurs because only a part of the pollen deposited on a pollinator from a male flower is deposited on the next female flower visited. A portion of the pollinator's pollen load remains, and is transported to subsequent flowers and plants. The pattern of pollen carryover from studies of other plants, generally, also conforms to a leptokurtic distribution (Morris et al. 1994, 1995).

The genetically effective distance of pollen dispersal is a function of the mean distance and the variation (statistical variance) about the mean (e.g. Levin and Kerster 1974). Genetically effective pollination distances and the area of a plant population , even with carryover, are more influenced by the frequent flights of shorter distance than less frequent longer flights for skewed and leptokurtic patterns of pollen dispersal. From the various species in which pollen dispersal, pollinator foraging behavior, and pollinator carryover have been directly studied, there is no data for pollinator-mediated dispersal up to 1 mile, at least as it would define plant population genetic structure at such a scale (e.g. Thomson and Plowright 1980; Schaal 1980; Price and Waser 1982; Waser and Price 1982, 1983, 1984; Galen and Plowright 1984; Campbell 1985; Geber 1985; Svensson 1985; Thomson 1986; Thomson et al. 1986; Waser 1988; Roberson 1992). However, the vast majority of these species and studies have involved annual and perennial herbaceous plants, occurring at relatively high population densities, with numerous plants and inflorescences where pollen dispersal was studied at geographic scales of less than 300 feet (100 meters). Thus, patterns of relatively restricted pollen flow and plant population structure at small scales identified by these studies is of limited value to estimating pondberry population structure if pollen dispersal occurs regularly at greater distances.

Studies of pollen dispersal and gene flow at larger geographic scales have been restricted mostly to wind-pollinated trees in temperate North American. To our knowledge, Schnabel and Hamrick (1995) conducted the only study of pollinator-mediated gene flow in a widely spaced temperate tree. They investigated pollen dispersal from known outside trees into two reference stands of honey locust (*Gleditsia triacanthos*) by genetically analyzing the paternity (pollen source) of seeds produced by trees within each reference stand. From 17 – 30% of the pollen flow into reference stands came by pollinators from trees in other stands located 304 – 790 feet (85 – 240 meters) away. As a direct genetic analysis, Schnabel and Hamrick (1995) did not measure pollinator flight distances. Clearly, however, pollinator flights from trees in outside stands at distances up to 790 feet were sufficiently frequent to account for about one-quarter of all pollinations producing seed. These were not exceptionally rare, long-distance events.

The spatial distribution of known pondberry colonies/sites within DNF populations, for example, mostly is patchy, separated by areas without colonies/sites. Pollination and potential interbreeding within a population would have to occur within patches of colonies/sites and between colonies/sites, assuming male and female plants inhabit each colony/site. Long distance pollination distances from honey locust data are less than the provisional pondberry definition of 1 mile. If effective pollen flow between pondberry colonies is greater than 790 feet, then it also will exceed the longest pollinator-transported distance measured and reported in the scientific literature for any plant in temperate North America.

The provisional pondberry population definition is conservative in that, in the absence of other more reliable data, the number of populations is probably a minimum estimate based on pollen dispersal. Given the available data on the distribution of pondberry colonies and sites, more than 54 range wide populations may exist because effective gene flow via pollinator foraging behavior and flight distances between pondberry colonies/patches may be less than 1 mile. If there actually are fewer populations, then the subdivided populations most likely would be in the sand ponds of Arkansas, Delta National Forest in Mississippi (Red Gum and Spanish Fort populations), and Francis Marion National Forest in South Carolina. Subdivided populations would increase the total number of populations, but reduce the estimated size of each population, potentially increasing the likelihood of extirpation by stochastic demographic, genetic, and environmental effects.

Current and ongoing pondberry genetic studies with DNA microsatellites are congruent with this spatial population definition (Echt et al. 2007; Echt, pers. comm., 2007). For example, the Colby, Red Gum, and Spanish Fort pondberry populations in DNF as delineated by the 1-mile function are genetically very similar, but sufficiently distinctive to be separable as populations.

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APPENDIX 3: A Statistical Evaluation of Certain Tests Assessing Effects of Flooding to Pondberry, and Corps-Service Disagreements

To more specifically assess the relationship between the performance of the profiled pondberry colonies/sites, we used a repeated measures analysis of variance (ANOVA) to evaluate the effects of flood frequency regimes over two time periods, in 2000 and 2005, on the average number of pondberry at profiled colonies sites. Our analysis was in response to the single factor ANOVA by Applied Research and Analysis, Inc. (APR) on the effects of flood frequency class to the average number of pondberry per colony/site, which the Corps included as Attachment 5 in their 2005 biological assessment (U.S. Army Corps of Engineers 2005e). The flood frequency class intervals were 0-2, 3-5, 6-10, and 10+ years. The flood frequency at each colony/site is the frequency determined by the Corps and reported in their data, based on ground surveys to determine the elevation at each colony/site. Also, the number of pondberry in each colony is the data measured and reported by the Corps in 2000 and 2005. This is a repeated measures ANOVA because the same colonies/sites measured in 2000 were measured again by the Corps in 2005. ANOVA with repeated measures is the appropriate test, instead of a two-way ANOVA, because the number of plants in a colony during 2000 and 2005 are correlated. The variation between the paired observations or counts of pondberry at each colony is incorporated in the repeated measures ANOVA as a more accurate test. Statistically, this is an additional source of variation which can increase the F statistic value, and increases the chance of rejecting a null hypothesis that there is no effect of flood frequency and time when the hypothesis is actually false. In this case, the null hypothesis is that the mean number of pondberry plants per colony does not significantly differ among sites with different flood frequencies or at different times.

Since the mean number of plants per colony were not normally distributed, the data were log transformed ($X = \log(X + 1)$ (e.g. Zarr 1999), which satisfied the Shapiro-Wilk statistic for normality ($W = 0.989$, $p<W = 0.3836$) and Levene's test for homogeneity of variances. The procedure was run on the Statistical Analysis System (SAS), where the correlation and corvariance structure between the repeated measures was found to best fit an auto-regressive model.

Results revealed that the average colony size (number of pondberry) was affected by both flood frequency ($p= 0.0847$) and year ($p=0.0130$) (Tables 27 and 28). The mean number of plants per colony declined between 2000 and 2005 ($p=0.0130$). Colonies also were significantly different depending on flood frequency. Colonies on the 0-2 year floodplain were larger than colonies on the 11+ year floodplain ($p=0.095$), but not significantly different from those on the 3-5 and 6-10 year floodplain.
The average number of pondberry per colony/site on the 3-5 year floodplain were greater than those on the less frequently flooded 6-10 ($p=0.083$) and 11+ year floodplain ($p= 0.029$). In 2005, the mean colony size differed significantly by flood frequency ($P=0.044$). Between years, colonies on the 11+ year floodplain in 2005 were significantly less than colonies in 2000.

The ANOVA evaluates the mean colony size in relation to flood frequency class and time (2000 and 2005). There was a statistically significant decrease in colony size between years, and flooding regime also affected average colony size. Average colony size was smaller, with fewer plants per colony on the 6-10 and 11+ year floodplains, and average colony size declined at all flood frequencies. While the change in the number of plants per colony between years and at some frequencies were not significantly at some colonies/sites, this mostly reflected a large degree of variation among the number of plants per colony, as well as a small portion that actually increased.

The Corps reviewed this analysis during this consultation by conducting their analysis with the same procedure and data. The Corps agreed that the average number of pondberry per colony/site declined significantly from 2000 to 2005, but the Corps reached the opposite conclusion that flood frequency does not affect the number of pondberry. Our differences are due to the use and acceptance of a different level of alpha (α), which is the probability of a Type I statistical error, beta (β), the probability of a Type II error, and the statistical power of the test, which is $1 - \beta$. We accepted a Type I error of $\alpha = 0.10$, while the Corps chose to use $\alpha = 0.05$. The null hypothesis subject to the statistical test by the repeated measures ANOVA is that the average number of pondberry is not affected by flood frequency and/or year. The alternative hypothesis is that there is an effect.

The Type I error rate is the probability of rejecting a true null hypothesis of no effect, and accepting the alternative hypothesis that an effect exists when it in fact did not actually occur. A Type II error is the probability of failing to reject (or accepting) a null hypothesis of no effect when it is false. Statistical power is the probability of detecting an effect when it in fact occurs, and is the probability of correctly rejecting a false null hypothesis. These error rates are mathematically related, involving a tradeoff in the risks and consequences of decision making considered acceptable and unacceptable.

Investigators typically set Type I errors at either 0.10, 0.05, or 0.01, according to their objectives. When the Type I error is 0.05 and the test statistic (F-value for ANOVA) is less than 0.05, there is a 0.05 probability or less of computing the test statistic for effects simply by chance if there really is no effect. On average, 5 percent of the samples or data would lead to erroneously rejecting the true null hypothesis of no effect, and falsely concluding that flood frequency affected the average number of pondberry. Increasing the Type I error rate from 0.01 or 0.05 to 0.10, as we have done in this test, increases the chances (10 percent) of rejecting the true null hypothesis when there was no effect of flood frequency, but it simultaneously reduces the chances of making a Type II error of concluding there is no effect when in fact a flood effect exists. Also, increasing the Type I error from 0.05 to 0.10 increases the statistical power of actually detecting a flood frequency effect when it occurs, and correctly rejecting a false null hypothesis of no effect.

In the repeated measures ANOVA at the 0.10 Type I error probability level, the F-statistic for the effects of flood frequency was 2.35, with a 0.0847 probability of computing a larger test statistic by chance when there is no effect of flooding (Table 36). Because the probability was less than 0.10, we rejected the null hypothesis of no flood frequency effect, concluding that the flood frequency class intervals affected the average number of pondberry. The Corps, setting a 0.05 Type I error rate, did not reject the null hypothesis (e.g. $0.0847 > 0.05$), and concluded there was no effect of flood frequency.

In assessing the role or effect of flooding to the average number of pondberry, the Service is more sensitive than the Corps to the consequences of a Type II error, by failing to detect an adverse effect of flooding. This is because, as further assessed in later sections, the proposed Backwater Reformulation will reduce the frequency of flooding, and the Service is more averse to the risk of failing to identify an adverse effect when it occurs. In this instance, the average number of pondberry per colony/site in the less frequently flooded classes is smaller than the average number per colony in more frequently flooded classes. In contrast, the Corps is more sensitive to a Type I error, and wants to reduce the likelihood of committing this error in which a true null hypothesis of no flood effect would be erroneously rejected, with an incorrect conclusion that flooding affected pondberry. A Type II error typically should be the error of concern during null hypothesis tests in risk assessments for endangered species (National Research Council 1995), as well as environmental monitoring and assessment (e.g. Anderson et al. 2000; Dayton 2001; Sanderson and Solomon 2003).

There is a very large scientific literature with at least 400 publications[1] on the limitations, use, and misuse of the classic statistics of null hypothesis testing in the practice of scientific decision-making. One of these issues is the limitations of the conventional values of α-levels 0.01, 0.05, and 0.10 for Type I errors, and the acceptance of *P*- values for these tests and decisions without adequately considering whether the size of the measured effects are – as in this case – biologically meaningful. If the computed *P*-value in one instance is 0.049, then a decision to reject the null hypothsesis and conclude that an effect existed at the 0.05 level (Type I error rate) is not necessarily any more true than if the *P*-value had been 0.051 and the null hypothesis was accepted that there is no effect. It is especially important to consider the size of the effects and their biological meaning when the computed *P*-value is significant at one level and not for the other, as in this case for the effect of flood frequency. Our disagreement with the Corps about the effects of flood frequency by the repeated measures ANOVA ultimately is about whether the differences in the average number of pondberry at different flood frequencies are biologically important indicators of pondberry performance and fitness.

Effect size is a measure of the differences among the average values of the variables measured. The detectable effect size is the biological effect that a given experimental design can detect due to the number of samples and the variability in the acquired data. The biological effect size is the size of an effect that is considered to be of interest and meaning. It is widely recognized that the most effective studies are first designed and then implemented with a sufficient number of samples relative to the expected variation in the data to statistically detect what is decided to be a meaningful level for the biological effect of interest, with a sufficient statistical power to detect an effect when it actually exists (e.g. Lipsey 1990; Fairweather 1991; Hoenig and Heisey 2001). This was not the process by which the pondberry profile survey by the Corps was developed and implemented. These are truly survey data, derived from the original Corps survey protocol, and acquired without an explicit environmental hypothesis or biological effect to statistically measure. This doesn't mean the data can't be used for the repeated measures ANOVA or any other statistical test. In fact, the Corps profile and census data at colonies/sites during 2000 – 2005 is the best available data, which also probably is among the most extensive of any set of trend data for pondberry. This simply means that the data may be of different value with a different ability to now test questions and hypotheses of interest.

Given the outcome of the repeated measures ANOVA, it is our opinion that the differences in the average number of pondberry plants per colony/site at the statistically detected levels of difference are biologically meaningful. The most intuitive comparison of these differences and their magnitudes is to use the raw effect sizes. When comparing the differences between the average number of pondberry per colony/site during 2000 and 2005 at their different flood frequency classes (Table 72), the greatest difference is between the number of pondberry at colonies on the 3 – 5 year floodplain and the less frequently flooded 11+ - year floodplain. The average colony/site on the 3-5 year floodplain had 48 more plants, and was 4.3 times as large as the average colony/site on the 11+ -year floodplain. In other words, at least four colonies/sites would be required, on average, in the 11+year floodplain to produce the same number of plants in a single average colony/site in the 3-5 year floodplain. The difference between this pair, with a *P*-value of 0.0287, was statistically significant.

For another comparison, there are on average 39.8 more plants per colony/site, with colonies 3.7 times as large on average on the 0-2 year floodplain than the 11+ year floodplain (Table 77). The *P*-value computed for this comparative pair is 0.0953, statistically significant at the 0.10 level, but not the 0.05 level of a Type I error. It is not significant at the 0.05 level not because the differences aren't large enough. It is because the variation in the number of plants at colony/sites is greater, and the confidence

[1] References at *http://www.cnr.colostate.edu/~anderson/thompson1.html*, recently updated by W.L. Thompson, U.S. Forest Service, Rocky Mountain Research Station, Boise, Idaho.

intervals for the two computed means overlap to a greater extent. Still, a difference of this magnitude is important for the same rationale concerning colony size and the number of plants.

The larger colonies/sites in the 0-2 and 3-5 year floodplains, relative to those in the 6-10 and 11+ year floodplain, are associated with more frequent flooding that somehow affects, whether directly or indirectly, the growth, reproduction, and survival of pondberry. On the basis of a colony/site unit, the more frequently flooded areas are on average more productive. The number of plants is important for several reasons, including the fact that when all other factors affecting population stability or persistence are equal, larger populations will on average have a greater probability of persisting into the future. Thje rates of extirpation will be greater in smaller populations. A population with the same number of colonies/sites on the more frequently flooded sites will be larger and more potentially viable than a population with colonies on less frequently flooded sites.

Other measures

APR report

During September 2000 prior to the current 2005 biological assessment and formal consultation, the Corps prepared a draft biological assessment which was provided to the Service and released to the public as Appendix 14: Endangered and Threatened Species Biological Assessment of the Draft Yazoo Backwater Area, Mississippi Reformulation Report. In partial response to our review of that document (U.S. Fish and Wildlife Service 2000, in litt.), the Corps consulted with Applied Research and Analysis, Inc. (APR) to evaluate the 2000 pondberry profile data and our conclusions. The Corps included the APR report as Attachment 5 to the current biological assessment. Also, the Corps summarized the APR report in the biological assessment as evidence that the Service's conclusions about the relationships and effects of flood frequency are unsubstantiated. The APR data analysis in Attachment 5 of the BA involves a single-factor ANOVA for the effects of flood frequency to average colony/site size, a multivariate canonical correlations analysis of pondberry attributes in relation to flood frequency, and a response about the nature of the pondberry profile survey data.

Later, during the course of this consultation, APR modified and supplemented their analysis of the single factor ANOVA, and provided an additional discriminate function analysis of pondberry group attributes in relation to flooding (U.S. Army Corps of Engineers 2006). The Corps concluded that all of these analyses are evidence of no relationship between overbank flooding and pondberry. We disagree, as described in the next sections.

In summary, we agree that no significant statistical effect was detected by the single factor ANOVA of 2000 data for the number of pondberry in relation to flood frequency. We disagree, however, with the methods of statistical power analysis and size effects to conclude that the data, sample sizes, and ANOVA test for the 200 data were adequate to detect biologically meaningful differences. Likewise, we disagree that the subsequent computations demonstrate adequate statistical power for a single factor ANOVA for 2005 data, which used the 2000 data for prospective analysis. Most importantly, the single factor ANOVAs have been replaced by a more valuable repeated measures ANOVA for the 2000 and 2005 pondberry data. Second, we concur that the canonical correlations analysis failed to demonstrate any significant set of multivariate relationships between environmental attributes and pondberry characteristics. We don't agree, however, that the absence of any multivariate relationship is strong evidence for the absence of a flood effect, and we also disagree on the interpretations of the canonical functions. Finally, we concur that their discriminate functions analysis failed to group the profiled colonies according to their characters and a classification based on flood frequency class. We find, however, that this absence is not strong evidence.

Study design and data limitations

Most the pondberry data evaluated in the Corps' biological assessment and this biological opinion was generated from their survey of selected and profiled colonies/sites by methods and procedures developed in 1990 and 1991 from the Corps pondberry profile workshop with pondberry experts (U.S. Army Corps of Engineers 1990). The profile was designed as a survey to generate data to begin to characterize the distribution of pondberry and assess the effects of Corps flood control projects. Since that time, however, the profile and survey has not changed substantially in relation to the questions now presented by this proposed project.

We have previously described the general limitations of the use of this survey data for making strong inferences. Scientific practice in the realm of ecology largely is based on inductive reasoning, with the strongest inferences from hypothetico-deductive processes (Platt 1964; Romesburg 1981). An inference is the process of deriving a logical conclusion from a set of premises, whether true or false, by deductive and/or inductive reasoning. The hypothetico-deductive approach derives, classically, from the experimental manipulation of the variable of interest relative to an unmanipulated control in a regulated laboratory environment, to statistically test a null (control-no effect) hypothesis relative to the measured response by an alternative (treatment-effect) hypothesis. Ecological studies in the field have involved experimental manipulations, but these are not common in complex environmental systems where factors that may affect the pattern or process of interest cannot be adequately controlled or manipulated, or where multiple factors are involved (e.g. Mentis 1988, Murphy and Noon 1991).

In the absence of environmental manipulation, the strongest inferences in ecological studies generally are limited to carefully designed field studies where the parameter of interest varies due to natural or other circumstances. Investigations usually involve surveys and sampling to statistically characterize or compare the states of the parameters of interest, often in relation to other parameters to identify patterns, associations, and putative effects (e.g. Eberhardt and Thomas 1991). Inferences become soft when the null or alternative hypotheses are not exclusionary or falsifiable to other plausible explanations or hypotheses, and the acquired data lack the necessary sample sizes for the precision to test and detect the effect of biological interest.

As previously described and in the following sections, the pondberry survey data were not acquired with consideration to random sampling, which is an essential requirement for strong statistical inferences, or the variation in the data, and the sample sizes from a prospective power analysis as required to test the parameter of interest with adequate precision and statistical power. We don't claim that these data are unsuitable for any study or statistical assessments. Their analysis and subsequent inferences must be made cautiously in relation to the nature and limitations of the data.

Single-factor ANOVA

APR used a single-factor ANOVA to evaluate the relationships between flood frequency and the number of pondberry clumps, plants (stems), dead plants (stems), females, mature fruit, plant (stem) height, and average plant stem diameter from profile data in 2000. Implicitly, the null hypothesis was that there was no "effect" of flood frequency, and the average number for each trait would not differ among the flood frequency classes. From this analysis, ARP and the Corps concluded that the number of pondberry in each colony, as well as other traits, was not affected by flooding (Table 78). APR also reported a very high power for the statistical test, claiming that the sample sizes (number of colonies/sites) were adequate to have detected a biologically meaningful effect of flooding, if it had existed (U.S. Army Corps of Engineers 2005e, 2006).

From our analysis of the same data (Tables 79 and 80), we do not disagree with their basic conclusion, that the average number of pondberry at a colony/site was not affected by flood frequency class interval in 2000. However, we disagree with their conclusions about the power of the test, its precision, and biological significance. More importantly the issues concerning the ANOVA for 2000 data have been surpassed by the more updated analysis of the 2005 data, as described in the biological opinion by the repeated measures ANOVA for the 2000 – 2005 period.

As reported in the Corps biological assessment, APR concluded that the statistical power of the ANOVA test was adequate. Power, once again, is the statistical probability of detecting an actual effect, and correctly rejecting a false null hypothesis of no effect. The greater the statistical power, the more likely it is that the desired level of effect will be detected by a study. Statistical power generally increases as sample size, effect size, and α (Type I error rate) increases, and the variability of the data decreases (Cohen 1988). Sample size is the number of colonies/sites measured in this instance. With a statistical power of 0.8, which generally is considered acceptable, then the null hypothesis of no effect will be correctly rejected 80 percent of the time when it is false (when an effect actually exists), and incorrectly accepted 20 percent of the time when it is true.

The proper use of power computations are prospective, when the experimental or survey design is being developed, to increase the likelihood that a biological effect of interest, if it exists, will be detected. Prospective power analysis is an important element in statistical and research design to avoid ambiguous statistical results (e.g. Fairweather 1991; Thomas and Juanes 1996). Studies that are designed with inherently low power, for example 0.50, would erroneously accept a false null hypothesis of no "effect on average 50 percent of the time, when there actually was an effect. The pondberry profile procedures and the resulting data are not the result, however, of any statistically designed plan to assess "effects" of flood frequency or any other relationship with a desired level of precision.

Initially, APR computed statistical power retrospectively for the ANOVA, at a value of 0.80 or greater (U.S. Army Corps of Engineers 2005e). The Corps claimed that the test had more than adequate power to avoid concluding there was no effect of flood frequency on pondberry abundance when an effect may likely exist. Retrospective power computations, in contrast to prospective power, are based on the actual data and effects measured and are often generated after an analysis or study when no statistical effect was observed. The ostensible purpose is to provide evidence that the failure to reject a null hypothesis of no effect was supported by sufficient statistical power.

The use of retrospective power analyses, in contrast to prospective analysis, is a sharply controversial subject among statisticians and scientists. Restrospective power analysis has been criticized in the statistical literature as an inappropriate statistical application for many reasons (Thomas 1997; Steidl et al. 1997; Hoenig and Heisey 2001), despite the fact the procedure is readily available on many statistical software packages, and that it is still not uncommon for the editors of a number of scientific journals to require investigators to perform inappropriate post-experiment power computations (Hoenig and Heisey 2001). The problems with computing statistical power after a study or experiment, particularly when using the P-value of the experiment, is that the computations do not and can not in most instances represent actual power (Goodman and Berlin 1994; Steidl et al. 1997; Hayes and Steidl 1997; Reed and Blaustein 1997; Hoenig and Heisey 2001).

After the Corps prepared the biological assessment, APR modified their power computations by using the 2000 profile data as if it were pilot data to assess the power of detecting an effect with the 2005 data (U.S. Army Corps of Engineers 2006). The use of pilot or preliminary data is a standard practice in planning experimental designs with prospective power calculations, even though the 2000 data in this instance have actually been used by the Corps to make conclusions and inferences. This time, APR used the 2000 pondberry raw data as if it were pilot study data to compute the prospective power of a future study, even though the 2005 data already existed. In other words, the 2000 data were used to assess the power and sample size of 49 colonies/sites actually used in 2005. This is a quasi-retrospective power analysis.

To evaluate the statistical power, APR computed for a given effect size the associated power for the least significant number (LSN). The LSN is the smallest number of observations (sample size or the number of colonies/sites) that reduces the variance just enough so that a significant result (*P*-value, null hypothesis of no effect rejected) is computed for the given values of the Type I error, which was set at α=0.05 (Table 73). APR compared four different standardized effect sizes, from 0.21 to 0.71, which generally corresponds from a small to a large effect. For the three effect sizes from 0.50505 to 0.71424, the LSN ranged from 15 to 50, with a corresponding power from 0.63650 to 0.67133 (Table 73). Since these LSN were either equal to or less than 49, which is the sample size for the 2000 profile data, APR concluded that the study with 49 profiled colonies/sites was sufficient "for reasonable conclusions about the hypotheses of interest."

We don't generally disagree that the data with 49 observations could likely detect medium and large effects of flood frequency to the average number of pondberry per colony/site among different flood frequency classes. This isn't the crucial issue. The issue is the extent that the available 2000 profile data, as well as the 2005 data, with 49 observations could detect the existing and *smaller* effects with sufficient power.

We computed statistical power using prospective and retrospective (post-hoc) procedures with G*Power (Erdfelder et al. 1996). The retrospective power for our ANOVA on these 2000 data was 0.3370, similar to the 0.35712 by APR (Table 81). For the prospective computations with the 2000 data, G*Power uses Cohen's (1988) *f* for ANOVA models as the measure of effect size. The actual effect size (Cohen's *f*) from the observed 2000 data was 0.2918, which is generally considered to be a medium effect. The sample size would have to be increased from 49 to 128 profiled colonies/sites to statistically detect this effect size, and correctly reject a null hypothesis of no flood frequency class effect with the standard statistical power of 0.80. In other words, if the effect differences by flood frequency to the average pondberry abundance at a colony/site in the existing data are real, then more data from about 128 colonies/sites are required to statistically conclude that flood frequency affects pondberry abundance, at a Type I error rate of 0.05, and power of 0.80.

As previously described, the ANOVA for the 2000 data from selected colonies/sites in the profile can't statistically detect any significant differences between the mean number of plants per colony on the four different floodplains because of sample size and sample variation. Increasing the sample size and precision of the test, however, would generate a statistically significant result for a biologically meaningful difference if these exist. For any single-factor ANOVA in which differences exist between the means, there is a sample size at which these differences can be determined as statistically significant. We don't advocate increasing the sample size until such statistics are generated. The proper use of experimental design and statistical tests is not narrowly based on the presence or absence of significant test statistic (e.g. Yocoz 1991; Johnson 1995; Anderson et al. 2000). It includes a judgment on what is a biologically meaningful difference for which a study is designed to statistically detect, if it exists, when the population of interest must be sampled. These are not the conditions under which the pondberry profile survey were designed and intended to measure.

Multivariate studies

APR used canonical correlation analysis (CCA) as a multivariate evaluation of the relationships between two sets of variables. One set characterized seven pondberry attributes and the second set consisted of five variables for environmental site characteristics at each of the profiled colonies/sites in DNF during 2000. APR and the Corps concluded from these results that some of the characteristics of pondberry appear related to site factors, but pondberry is not affected by flooding. In our review of this analysis, there were no statistically significant relationships between the pairs of canonical variates, and the CCA was unreliable and uninterpretable. The CCA provided no evidence or information about these relationships.

Pondberry, as any other plant species, occupies a niche which is an environmental space with suitable abiotic and biotic characteristics for growth, reproduction, and survival. Extensive studies of the distribution and abundance of plant and animal species in the environment, the theory of the plant community continuum (e.g. Austin 1985) and the realized niche (sensu Hutchinson 1957; e.g. Wiens 1989; Austin 1990) would predict that the relative abundance of pondberry should vary along a complex environmental gradient. The effects of the abiotic environment (light, water, nutrient, and other resources) and competition with other plants varies on the gradient, where pondberry will experience and respond to optimal as well as suboptimal, marginal, and unsuitable conditions. Thus, hydrology and flood frequency is one environmental factor that may interact with others to affect the abundance and distribution of pondberry.

Plant ecologists often use multivariate methods of ordination analysis in an attempt to resolve the patterns of distribution and abundance of plant species in response to complex environmental factors and gradients (e.g. Gauch 1982; Pielou 1984; Minchin 1987; Peet et al. 1988). The multiple variables involved in these analyses include the multiple factors that may be associated with species' distribution and abundance. The gradient, as depicted by an ordination, is the multivariate x-axis of the two-dimensional graph. For most species, the shape of the response to the gradient, which is the y-axis, is in the form of a Gaussian curve or bell-shaped normal (Figure ?). The species response curve also can be skewed, bimodal, and non-linear (Mueller-Dombois and Ellenberg 1974; Austin 1976, 1990; Collins et al. 1993).

The multivariate numerical methods for analyzing species and community responses include principal component analysis, reciprocal averaging ordination, detrended correspondence analysis (Hill and Gauch 1980) canonical community ordination, and canonical correspondence analysis (ter Braak 1987-1992). These data consist of biotic and abiotic variables. The biotic parameters normally include qualitative or quantitative measures of the occurrence and abundance of various species. Abiotic variables are measures of the environmental parameters of interest, which may include attributes of soils, hydrology, and other factors considered as factors affecting species distribution and abundance. The data are acquired by an experimental sampling design suitable for statistical inference and testing, including appropriate randomization (Cochran 1977). By ordination, the multivariate data sets are ordered or scaled to identify structure. Ordination typically is considered as a form of indirect gradient analysis. For a more direct analysis, the ordinated axis values of species or abundance frequently are analysed relative to the scores or values of associated environmental parameters using correlation, regression, or multiple regression methods. These and related methods are intended to identify the relationships between the abundance and distribution of species and environmental factors.

Direct and indirect gradient analysis by ordination and related methods in floodplain forests has further clarified the distribution and response of species to hydroperiod, flood frequency, growing season flooding, elevation, soils, and topography (Smith 1996; Bledsoe and Shear 2000; Burke et al. 2003). In our review of the Corps 2000 biological assessment, one of our concerns with their extensive use of correlation coefficients and bivariate plots of pondberry attributes relative to flood frequency was that such data did not fully represent the response of the species to a resource and environmental gradient. We briefly described ordination and related analyses, and noted that using these methods "may potentially assess patterns of pondberry distribution and abundance across resource and environmental gradients that include flooding." We suggested that "such methods should be considered for pondberry, though the available [pondberry profile] data and sampling methods by which it was acquired may likely be inadequate."

In response, the Corps obtained a canonical correlation analysis (CCA) from APR on the relationships between pondberry attributes to the percent herbaceous cover, percent canopy cover, average elevation, and iron rod elevation that was measured at each selected pondberry colony/site during the pondberry profile. The pondberry attributes were number of clumps, plants, dead stems, females, mature fruit, and stem height and average stem diameter at each colony/site.

Based on the CCA, APR made several general conclusions. One was that "changes in elevation and changes in other ground cover species tend to affect different Pondberry bush characteristics, but not the occurrence of Pondberry bush colonies." This conclusion is not justified, however, because the CCA did not provide any significant variates to interpret. And if there had been significance, this still would not have been appropriate. The pondberry profile study and data in the CCA represent various attributes of pondberry and the habitat at selected sites where the species occurred. The study and data did not assess such features at sites where pondberry did not occur, which would be required to make any conclusions about the occurrence of pondberry, its presence, or absence.

APR also found that "elevation and overstory characteristics joint[ly] affect Pondberry colonies, and that these effects are not detrimental, but are changes in characteristics of the colonies." The Corps also referred in the biological assessment (pg. 14-14) to another APR conclusion as evidence that pondberry is not affected by flooding:

> "To further investigate the USFW claim that the analysis of correlations between the density of Pondberry plants in colonies at various sites to the current frequency of flooding at such sites is insufficient to discount any effect of flooding, an in depth multivariate exploration did not support their claim." (pg. 6, Attachment 5, Appendix 14, U.S. Army Corps of Engineers 2005)

By the Corps and APR analysis, the CCA did not demonstrate any relationships to flooding.

In reviewing the results from the CCA, our most important finding is that these data are not reliable and the canonical correlations, coefficients, loadings, and variates should not have been interpreted by standard statistical and ecological practice. This is because the canonical variates are not statistically significant. In using canonical correlation, conventional statistical procedures require as a first step an evaluation of the significance for the number of reliable canonical variate pairs, and if these are not significant, then canonical relationships should not be interpreted (Tabachnick and Fidell 1989; Johnson 1998; McGarigal et al. 2000). None of the five canonical variates were significant. This means there were no correlations different from zero or overall relationships between or among the linear combinations of the two sets of variables.

Canonical correlation analysis computes and reduces the correlations between two sets of variables as linear combinations of variables within and between each set. It is a method to reduce the complexity among many variables to explore their associations, but not their causality (Dieleman et al 2000). In this case, one set represented seven variables of pondberry attributes (P), and the other set consisted of five variables of site attributes (S). The absence of a significant CCA also does not mean there is no relationship between pondberry and overbank flooding. It only means that the given sets of variables could not be combined into significant linear combinations. The usefulness of canonical correlation in vegetation and plant ecology frequently is limited because it depends on linear correlations of parametric data, when the ecological relationships or responses may not be linear (Gauch and Wentworth 1976; Gittins 1979; James and McCulloch 1990).