# Management Assessment of the Water Corridor Units of the Big Thicket National Preserve

## Final Report

**Prepared by**

**Dr. Paul A. Harcombe, Principal Investigator**
**Professor, Department of Ecology and Evolutionary Biology**
**Rice University**

**Glenda Callaway, Co-Principal Investigator**
**Principal, Ekistics Corporation**

**Under Cooperative Agreement with**
**National Park Service**
**Big Thicket National Preserve**
**Mr. Richard (Pete) Peterson, Superintendent**

**September 1997**

# Table of Contents


Page

**Executive Summary** ..... vi

**1.0 Introduction** ..... 1
- 1.1 Description of the Preserve and Mission Statement ..... 1
- 1.2 Role/Function of the Water Corridors in the Preserve ..... 3
- 1.3 Purpose of the Water Corridor Management Assessment ..... 3
- 1.4 The Concept of Critical Resources ..... 4
- 1.5 The Identification of Critical Resources of the Water Corridors ..... 5
  - 1.5.1 Water (quality, quantity and timing). ..... 8
  - 1.5.2 Woody in-stream substrate (snags) ..... 9
  - 1.5.3 Stream banks. ..... 10
  - 1.5.4 Floodplain forest. ..... 10
- 1.6 Management to Protect Critical Resources ..... 12

**2.0 Resource Protection** ..... 13
- Authority ..... 13
- Background ..... 13
- 2.1 Biodiversity ..... 13
  - 2.1.1 Impacts to water corridor resources ..... 14
  - 2.1.2 Recommended management actions ..... 14
  - 2.1.3 Considerations for NPS research ..... 15
- 2.2 Endangered Species ..... 15
  - 2.2.1 Impacts to water corridor resources ..... 16
  - 2.2.2 Recommended management actions ..... 17
  - 2.2.3 Considerations for NPS research ..... 17
- 2.3 Exotic Species ..... 17
  - 2.3.1 Impact to water corridor resources ..... 18
  - 2.3.2 Recommended management actions ..... 18
  - 2.3.3 Considerations for NPS research ..... 18
- 2.4 Water Quality ..... 19
  - 2.4.1 Impact to water corridor resources ..... 22
  - 2.4.2 Recommended management actions ..... 23
  - 2.4.3 Considerations for NPS research ..... 23
- 2.5 Water Flow: Impoundments, Diversions, Releases ..... 23
  - 2.5.1 Impact to water corridor resources ..... 25
  - 2.5.2 Recommended management actions ..... 26
  - 2.5.3 Considerations for NPS research ..... 26
- 2.6 Woody In-stream Substrate (Snags) ..... 26
  - 2.6.1 Impact on water corridor resources ..... 27
  - 2.6.2 Recommended management actions ..... 27
  - 2.6.3 Considerations for NPS research ..... 27

## Table of Contents (continued)


Page

2.7 Stream Banks (Erosion and River Meander) . . . . . 27
2.7.1 Impact to water corridor resources . . . . . 28
2.7.2 Recommended management actions . . . . . 28
2.7.3 Considerations for NPS research . . . . . 29
2.8 Floodplain Forest Habitat . . . . . 29
2.8.1 Impact on water corridor resources . . . . . 29
2.8.2 Recommended management actions . . . . . 30
2.8.3 Considerations for NPS research . . . . . 30
2.9 Aesthetic/Scenic Qualities . . . . . 30
2.9.1 Impacts to water corridor resources . . . . . 31
2.9.2 Recommended management actions . . . . . 31
2.9.3 Considerations for NPS research . . . . . 31
2.10 Archaeological and Cultural Resources . . . . . 31
2.10.1 Impacts to water corridor resources . . . . . 34
2.10.2 Recommended management actions . . . . . 34
2.10.3 Considerations for NPS research . . . . . 34

**3.0 Public Use of the Preserve** . . . . . 35
3.1 Hunting and Trapping . . . . . 39
3.1.1 Background . . . . . 41
3.1.2 Possible general guidelines . . . . . 42
3.1.3 Recommended general guideline . . . . . 43
3.1.4 Recommended management actions . . . . . 43
3.2 Fishing . . . . . 44
3.2.1 Background . . . . . 45
3.2.2 Possible general guidelines . . . . . 46
3.2.3 Recommended general guideline . . . . . 46
3.2.4 Recommended management actions . . . . . 46
3.3 Boating . . . . . 47
3.3.1 Background . . . . . 50
3.3.2 Possible general guidelines . . . . . 54
3.3.3 Recommended general guideline . . . . . 54
3.3.4 Recommended management actions . . . . . 54
3.4 Swimming and Picnicking . . . . . 55
3.4.1 Authority . . . . . 55
3.4.2 Background . . . . . 57
3.4.3 Possible general guidelines . . . . . 60
3.4.4 Recommended general guideline . . . . . 60
3.4.5 Recommended management actions . . . . . 60
3.5 Camping . . . . . 61
3.5.1 Authority . . . . . 61
3.5.2 Background . . . . . 63

**Table of Contents** (continued)


Page

3.5.3 Possible general guidelines . . . . . 64
3.5.4 Recommended general guidelines . . . . . 64
3.5.5 Recommended management actions . . . . . 64
3.6 Houseboats in the BTNP . . . . . 65
3.6.1 Background . . . . . 65
3.6.2 Impacts to water corridor resources . . . . . 65
3.6.3 Considerations for NPS research plan . . . . . 66
3.6.4 Recommended management actions . . . . . 66
3.7 Mineral Extraction and Transport . . . . . 67
3.7.1 Impacts to water corridor resources . . . . . 67
3.7.2 Considerations for NPS research plan . . . . . 68
3.7.3 Recommended management actions . . . . . 68
3.8 Trash and Waste Disposal . . . . . 68
3.8.1 Authority . . . . . 68
3.8.2 Background . . . . . 69
3.8.3 Possible general guidelines . . . . . 70
3.8.4 Recommended general guidelines . . . . . 70
3.8.5 Recommended management actions . . . . . 70
3.9 River Access . . . . . 70
3.9.1 Background . . . . . 70
3.9.2 Possible general guidelines . . . . . 71
3.9.3 Recommended general guideline . . . . . 71
3.9.4 Recommended management actions . . . . . 71
3.10 Littering, Dumping and Vandalism . . . . . 72
3.10.1 Authority . . . . . 71
3.10.2 Background . . . . . 71
3.10.3 Possible general guidelines . . . . . 73
3.10.4 Recommended general guideline . . . . . 75
3.10.5 Recommended management actions . . . . . 75
3.11 Illegal Collection of Plants . . . . . 76
3.11.1 Impact to water corridor resources . . . . . 76
3.11.2 Recommended management actions . . . . . 76
3.11.3 Considerations for NPS research . . . . . 76

**4.0 Partnership Challenges** . . . . . 77
4.1 Air Quality/Fire Management . . . . . 77
4.1.1 Impacts to water corridor resources . . . . . 78
4.1.2 Recommended management actions . . . . . 78
4.1.3 Considerations for NPS research plan . . . . . 78
4.2 Neighboring Land Uses . . . . . 79
4.2.1 Impact to water corridor resources . . . . . 81
4.2.2 Recommended management actions . . . . . 81
4.2.3 Considerations for NPS research . . . . . 81

**Table of Contents** (continued)


Page

4.3 Public Use of Private Lands/Trespassing . . . 82
4.3.1 Impact on water corridor resources . . . 82
4.3.2 Recommended management actions . . . 82
4.3.3 Considerations for NPS research . . . 82
4.4 Salt Water Barriers on the Neches River and Little Pine Island Bayou . . . 82
4.4.1 Impact to water corridor resources . . . 84
4.4.2 Recommended management actions . . . 84
4.4.3 Considerations for NPS research plan . . . 84
4.5 Stream Diversions/Water Rights: Trans-Texas Water Program . . . 84
4.5.1 Impact to water corridor resources . . . 86
4.5.2 Recommended management actions . . . 86
4.5.3 Considerations for NPS research plan . . . 86
4.6 State and Federal Law Enforcement Inconsistencies . . . 86
4.6.1 Impact to water corridor resources . . . 86
4.6.2 Recommended management actions . . . 87
4.6.3 Considerations for NPS research . . . 87
4.7 Unauthorized Commercial Use of Preserve . . . 87
4.7.1 Impact to water corridor resources . . . 87
4.7.2 Recommended management actions . . . 87
4.7.3 Considerations for NPS Research . . . 87
4.8 Economic Development and Tourism . . . 88
4.8.1 Impact to water corridor resources . . . 88
4.8.2 Recommended management actions . . . 88
4.8.3 Considerations for NPS Research . . . 89

**5.0 Summary and Conclusion** . . . 90
5.1 Summary of Actions for Managing Critical Resources of the Water Corridors . . . 90
5.2 Implications for Preserve Management . . . 90
5.2.1 Information needed to protect critical resources . . . 90
Administrative Records . . . 99
Research Needs . . . 99
5.2.2 Staff and funding resources needed. . . . 99
5.2.3 Legislative or administrative action needed. . . . 104
5.3 Conclusion . . . 105

**References** . . . 106

**Bibliography** . . . 112

**Appendices** . . . 148
A Description of Land Cover/Land Use Map
B Methodology for Land Ownership and Land Use Mapping
C Rare Species of Big Thicket National Preserve

## List of Tables

**Table** **Page**

1. Water Quality Concerns in the Lower Neches Basin . . . . . 22
2. Total diversions by LNVA from the Neches River and Pine Island Bayou . . . . . 25
3. BTNP Visitation by Month, 1978-1996 . . . . . 36
4. List of Boat Ramps and Water Access Points . . . . . 51
5. Recreational use areas in the water corridors closed during hours of darkness . . . . . 58
6. Recreational use areas in the water corridors open for public use daily . . . . . 58
7. Summary of Recommended Management Actions for Each Management Topic . . . . . 91
8. Staffing Levels of the Big Thicket National Preserve, 1994-1996 . . . . . 100
9. Funding and Expenses of the Big Thicket National Preserve, 1994-1996 . . . . . 100
10. Summary of Research Needs for Each Management Topic . . . . . 101

## List of Figures

**Figure** **Page**

1. BTNP Location Map . . . . . 2
2. BTNP Land Cover/Land Use Map . . . . . 6
3. Critical Resources Matrix . . . . . 7
4. TNRCC Designated Segment Watersheds. . . . . 20
5. Texas Department of Health Advisory Area, Neches River . . . . . 21
6. BTNP Average Monthly Visitation 1987-1996 . . . . . 37
7. Area Boat Ramps . . . . . 52
8. BTNP Day Use Sites . . . . . 59

# MANAGEMENT ASSESSMENT OF THE WATER CORRIDOR UNITS BIG THICKET NATIONAL PRESERVE

## Executive Summary

Situated in the East Texas Pineywoods region, the Big Thicket National Preserve (BTNP or the Preserve) includes parts of Hardin, Jasper, Jefferson, Liberty, Orange, Polk and Tyler Counties. The Preserve is made up of fifteen units, including three added in 1993, and has a total authorized area of 96,970 acres. Eight of the BTNP units are river, creek and bayou corridors. The water corridor units along the low-gradient coastal plain streams are intended to preserve critical aquatic habitat and to serve as a linkage between surrounding floodplain forests, providing some continuity to the otherwise dispersed units of the Preserve. The value of a corridor unit as a preserve is determined by the degree to which that unit represents and will continue to represent a functioning community such as would originally have been present at that location prior to land use changes associated with European colonization. The water corridor units may serve as wildlife corridors, although this function may be diminished by the narrow land area of most of the corridor units. The streams also are used by the public, primarily for boating and fishing.

The purpose of the Water Corridor Management Assessment is to provide a baseline of information and action options for the NPS to accomplish the objectives it has established for the water corridors of the BTNP:

1. To manage water corridor use consistent with the purposes for which BTNP was established and in accordance with the missions and policies of the NPS.

2. To manage the waterways to preserve the natural setting and restore as much as possible of the presettlement scene, preventing further degradation to critical resources, water quality, and ecological integrity of the water corridors.

3. To implement an economically efficient system of management that will provide fair and equitable opportunity for the public to enjoy the water resources of the Preserve.

4. To maintain and enhance diverse opportunities for experiencing nature, solitude, and recreational pursuits.

5. To enhance the visitor's opportunity to learn about, understand, and participate in the protection of the natural and historic setting of the water resources of the Preserve.

6. To promote the acceptance of safety, health and critical resource protection requirements by all water corridor users and by those outside the Preserve that potentially impact the corridors.

7. To implement a scientific monitoring program on key aspects of the riparian and aquatic ecosystem and human use of, and impacts to, the water corridor. This will allow management to establish and recognize threshold levels of adverse impacts and implement appropriate management actions.

The management assessment is organized around the concept of protecting the "critical resources" of the Preserve. Critical resources are defined as ***those resources that are essential to maintaining ecosystem integrity and that are particularly sensitive to adverse impact by external activities and decisions.*** For the water corridors, resources that are most important for their habitat value include: 1) *water (quality, quantity and timing);* 2) *woody in-stream substrate (snags);* 3) *stream banks*; and 4) *floodplain forest (amount and integrity)*. Intact stream banks are particularly important to the scenic and aesthetic values as well as the ecological values of the Preserve's water corridors.

As an overall management goal, the Preserve should be managed to maintain to the maximum extent possible the integrity of its ecosystem components. This goal is consistent with the mission and authority of the Preserve. An examination of each of the resources that comprise the Preserve and issues that face its managers lead to several general observations:

1. The physical configuration of the BTNP makes it imperative that cooperative efforts with neighbors and communities in the southeast Texas area continue to be emphasized and fostered. Many important influences on the future of the Preserve simply are not within the control of the NPS, but they can be affected by NPS activity.

2. Since current levels of public use are relatively low in most units, the Preserve has a wonderful opportunity to plan now for future public use within the constraints of the natural setting.

3. A timely investment in data collection along several fronts to better describe the ecological resources and visitation to the Preserve now would yield management dividends as public use increases in the future.

4. Data that are collected need to be analyzed regularly to glean management information. Quality controls for data collection need to be in place so that data can be used with confidence.

The organic purpose of the BTNP to preserve numerous representative areas typical of the Big Thicket region shapes any recommended management actions for the water corridors. Preservation of the critical resources of the water corridors -- the water, the snags, the stream banks, and the floodplain forest -- must be a central goal. As a result, visitor use of the Preserve needs to be accommodated within the bounds of protecting the natural resources. This suggests a continuing sensitivity to the notion of a "carrying capacity" of the water corridors so that types of permitted activities and levels of visitation do not negate resource protection efforts.

On a positive note, greater numbers of visitors appreciating the natural setting represent a human resource to the Preserve. The importance of working cooperatively with other agencies, organizations and communities, particularly neighboring landowners, in managing the critical resources of the water corridors of the BTNP cannot be overstated.

Findings of the management assessment are reported in this final document. Technical reports that contributed to the assessment are bound in three additional volumes:

Technical Reports Volume 1: Characterization of Water Quality in the Water Corridor Units of the BTNP, July 1996; A Case Study of Flooding in the Neches Bottom Study Site, July 1996.

Technical Reports Volume 2: Characterization of the Biological Resources of the Water Corridor Units of the BTNP, July 1996

Technical Reports Volume 3: Characterization of Public Use of the Water Corridor Units of the BTNP, July 1997; Characterization of Institutional Issues for the Water Corridor Units of the BTNP, July 1995.

# 1.0 Introduction

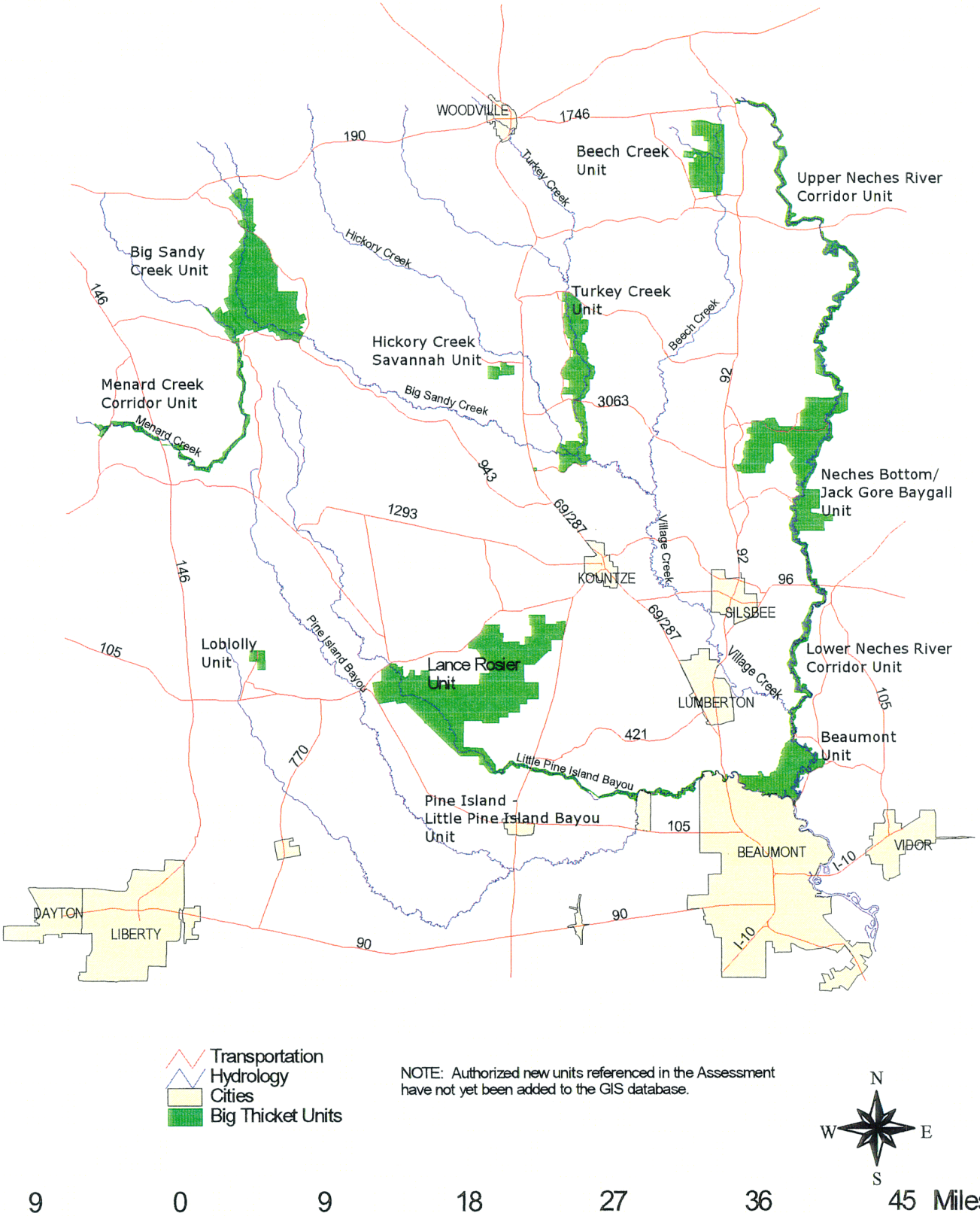
## 1.1 Description of the Preserve and Mission Statement

Situated in the East Texas Pineywoods region, the Big Thicket National Preserve (BTNP or the Preserve) includes parts of Hardin, Jasper, Jefferson, Liberty, Orange, Polk and Tyler Counties. The Preserve is made up of fifteen units, including three added in 1993, and has a total authorized area of 96,970 acres. (See Figure 1, BTNP Location Map.) The widely dispersed land units and the water corridor units were intended "to assure the preservation of numerous representative areas typical of the Big Thicket region and protect and preserve the natural values which make this 'biological crossroads' unique in the United States" (H.R. 93-676, November 29, 1973). Congress has directed the National Park Service (NPS) to manage the units of the Preserve "in a manner which will assure their natural and ecological integrity in perpetuity" and to allow for public use and enjoyment (P.L. 93-439, October 11, 1974; 88 Stat. 1254).

The Preserve is located in an area whose economy has been dominated by the timber and oil and gas industries and agriculture. While the Preserve is close to the major population centers of the Golden Triangle (Beaumont, Port Arthur and Orange) and Houston, it contains some of the most remote "backwoods" remaining in the state. Most of the local population could be characterized as having the very independent rural attitude associated with American pioneers. Some of the local population maintains lifestyles reminiscent of the pioneer era. At the same time, the area is slowly being encroached upon by growth from the nearby urban centers. The tensions created by resistance to urbanization as well as tensions created by a federal presence in an area where many are accustomed to unfettered access to common property resources (whether they are in fact publicly owned), coupled with the pressures of environmentalists to preserve the unique biological heritage embodied in the Preserve in the face of increasing public use and decreasing public funds make a lively mix of challenges faced by the NPS in managing the BTNP. The issues encountered in managing the water corridors of the Preserve are a good example of the types of considerations encountered throughout the BTNP.

**Figure 1.**

# Big Thicket National Preserve



### 1.2 Role/Function of the Water Corridors in the Preserve

Eight of the BTNP units, including the newly authorized Big Sandy Corridor Unit and the Village Creek Corridor Unit, are river, creek and bayou corridors. These eight units, which lie along four waterways, were studied for this management assessment:

Neches River - Upper Neches River Corridor Unit
Neches Bottom and Jack Gore Baygall Unit
Lower Neches River Corridor Unit
Beaumont Unit
Little Pine Island-Pine Island Bayou Corridor Unit
Menard Creek Corridor Unit
Village Creek - Big Sandy Corridor Unit
Village Creek Corridor Unit

The corridor units along these low-gradient coastal plain streams are intended to preserve critical aquatic habitat and to serve as a linkage between surrounding floodplain forests, providing some continuity to the otherwise dispersed units of the Preserve. The value of a corridor unit as a preserve is determined by the degree to which that unit represents and will continue to represent a functioning community such as would originally have been present at that location prior to land use changes associated with European colonization (Harcombe et al 1996). The water corridor units may serve as wildlife corridors, although this function may be diminished by the narrow land area of most of the corridor units. The streams also are used by the public, primarily for boating and fishing.

### 1.3 Purpose of the Water Corridor Management Assessment

The purpose of the Water Corridor Management Assessment is to provide a baseline of information and action options for the NPS to accomplish the seven objectives it has established for the water corridors of the BTNP:

1. To manage water corridor use consistent with the purposes for which BTNP was established and in accordance with the missions and policies of the NPS.

2. To manage the waterways to preserve the natural setting and restore as much as

possible of the presettlement scene, preventing further degradation to critical resources, water quality, and ecological integrity of the water corridors.

3. To implement an economically efficient system of management that will provide fair and equitable opportunity for the public to enjoy the water resources of the Preserve.

4. To maintain and enhance diverse opportunities for experiencing nature, solitude, and recreational pursuits.

5. To enhance the visitor's opportunity to learn about, understand, and participate in the protection of the natural and historic setting of the water resources of the Preserve.

6. To promote the acceptance of safety, health and critical resource protection requirements by all water corridor users and by those outside the Preserve that potentially impact the corridors.

7. To implement a scientific monitoring program on key aspects of the riparian and aquatic ecosystem and human use of, and impacts to, the water corridor. This will allow management to establish and recognize threshold levels of adverse impacts and implement appropriate management actions.

The management assessment is organized around the concept of protecting the "critical resources" of the water corridors of the Preserve.

### 1.4 The Concept of Critical Resources

For purposes of the Water Corridor Management Assessment for Big Thicket National Preserve (BTNP or the Preserve), critical resources are defined as ***those resources that are essential to maintaining ecosystem integrity and that are particularly sensitive to adverse impact by external activities and decisions.*** Ecosystem integrity is defined here as the state of a system in which there exists the natural complement of species, their habitats, and characteristic processes, substantially unaffected by human activity.

Critical resources, then, have two elements: 1) they are important natural components of the BTNP ecosystem and 2) their continued existence may be threatened by human activity. These are the resources that are most critically in need of management. In many cases, the identification of critical resources also points to the form of needed management actions.

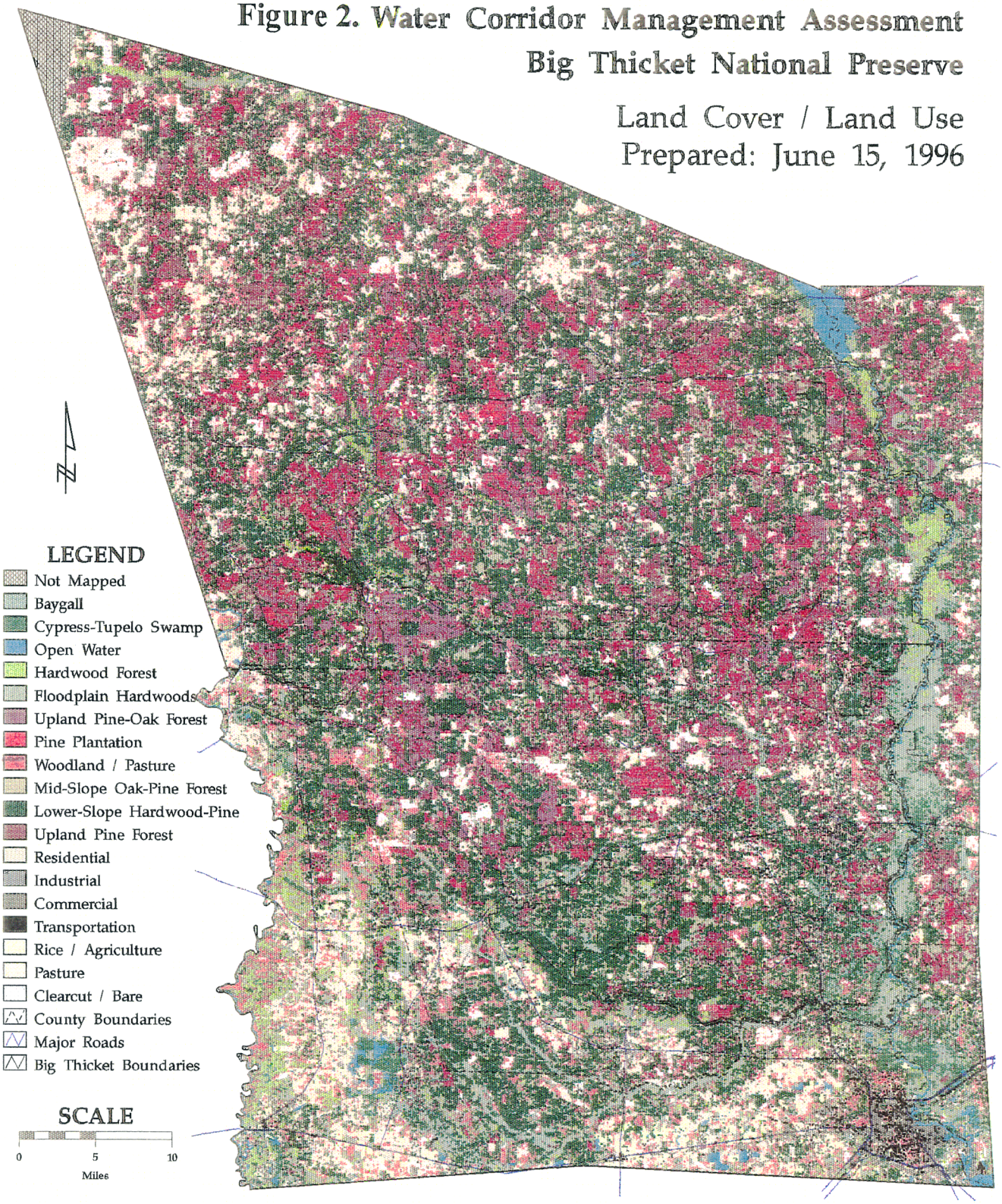
### 1.5 The Identification of Critical Resources of the Water Corridors

The first step in identifying critical resources of the water corridors of the Preserve was to characterize the biota and natural processes of the ecosystem, including: water quality and flow trends; fish and aquatic invertebrates; vegetation; and threatened and endangered species. These elements are described in more detail in *Characterization of the Biological Resources of the Water Corridor Units of the Big Thicket National Preserve* (Harcombe et al, 1996) and *Characterization of Water Quality of the Water Corridor Units of the Big Thicket National Preserve* (Hall and Bruce, 1996). The natural characteristics of the Preserve and surrounding lands were summarized in a *Land Cover/Land Use Map* (Hall et al, 1996) as depicted in Figure 2. The methods used in developing the land cover/land use map are described in Appendix A. Land uses and types of ownership of neighboring lands were mapped as well. A summary of the land ownership land use mapping effort for the Neches River is presented in Appendix B. The next step was to identify and categorize potential threats to the natural elements by impacts associated with: 1) alteration of natural processes; 2) public use of the Preserve; or 3) interagency/inter-institutional relations. Three reports detail these issues: *Characterization of Institutional Issues for Water Corridor Units of the Big Thicket National Preserve* (Callaway, 1995), *A Case Study of Flooding in the Neches Bottom Study Site* (Hall, 1996), and *Characterization of Public Use of the Water Corridor Units of the Big Thicket National Preserve* (Callaway, 1997).

A matrix was then constructed to summarize the relationships between the Preserve's natural resources and those human activities that might impact them. Initially, two matrices were envisioned, one breaking down resource use activities into impacts, and a linked matrix showing the effects of these impacts on Preserve resources. This approach was later simplified and the two matrices were combined into a single Critical Resources Matrix (see Figure 3). The matrix indicates whether an issue affects a resource (>), or a resource influences a given issue (<), or whether influences operate in both directions (X). The single matrix format was selected as being less duplicative and more informative. This matrix is a way of linking activities to impacts on the resources of BTNP in terms of measurable characteristics of those resources. The matrix also suggests areas in which characterization information, particularly quantitative data, is

# Figure 2. Water Corridor Management Assessment
## Big Thicket National Preserve

Land Cover / Land Use
Prepared: June 15, 1996





RICE

R. Hall, P. Harcombe
Department of Ecology and Evolutionary Biology
A. Arenson, H. Rifai, P. Bedient
Department of Environmental Science and Engineering
G. Callaway, Ekistics Corporation


Based on Landsat TM Image taken February 10, 1991

# Figure 3. Critical Resources Matrix

| Resources | Habitat Resources | Minimized fragmentation | Interior habitat (area) | Bottomland hardwood forest, wetlands (area) | Snags-forest | Snags-submerged | Stream banks-vegetation (area) | Submerged aquatic habitat (area) | Air quality-volume of emissions | Air quality-toxics ppm (aerial deposition?) | Water quality-excess nutrients | Water quality-total organic carbon | Water quality-dissolved organic carbon | Water quality-temperature | Water quality-salinity | Water quality-fecal coliform | Water quality-sediment | Water quality-heavy metals | Water quality-toxins | Water quality-dissolved solids | Water quality-suspended solids | Water quality-pH | Water quality-dissolved oxygen | Water flow-amount | Water flow-seasonality | Species Resources* | Birds | Mammals | Reptiles and amphibians | Fish | Invertebrates | Vegetation | Exotic species | Human Use Resources | Scenic and aesthetic qualities | Cultural and archaeological |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Biotic Issues** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Declining biodiversity | | < | < | < | < | | < | | | | | | | < | < | < | < | < | | < | < | < | < | | | x | x | x | x | x | x | < | | > | |
| Threatened and endangered species | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x | | | | | | |
| Introduction of exotic species | | | | > | | | > | > | | | | | | | | | | | | | | | > | | | | | | | > | > | x | | > | |
| **Hydrology Issues** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Erosion | | | | | | | x | | | | | | | | | | > | | | | | | | > | | | | | | | | | | > | > |
| River meander | | > | > | | | | | | | | | | | | | | | | | | | | | | | | | | | > | > | < | | > | > | > |
| Water flow-flood control, inundation frequency | | | | > | | > | > | > | | | > | > | > | | | | > | | | | | | > | > | > | | > | > | > | > | > | > | | > | > | > |
| Water flow-flushing flows | | | | > | | | | > | | | | | | | | | | | | | | | > | > | > | | > | | | > | > | | | > | > | > |
| Water flow-hydroelectric generation | | | | > | | | | > | | | | | | | | | | | | | | | | > | > | | > | | | > | > | | | > | > | > |
| Water flow-withdrawals and diversions | | | | | | | | | | | | | | | | | | | | | | | | > | > | | | | | | | | | > | > | > |
| **Preserve Use Issues** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Boating-safety and navigation | | | | | | | < | | < | | | | | | | | | | | | | | | < | < | | | | | | | | | | | > |
| Boating-use patterns | | | | | | | < | | < | | | | | | | | | | | | | | | < | < | | | | | | | | | | > | |
| Fire management | | | | | | > | | | | > | | | | | | | | | | | | | | | | | > | > | > | | | | | | | |
| Fishing | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | > | | | | | | |
| Houseboats | | | | | | | | > | | | | | | | | > | > | | | > | > | | | | | | | | | | > | | | > | | |
| Human waste disposal | | | | > | | | | | | | | > | > | | | > | | | | > | > | | | | | | | | | | | | | | | |
| Hunting and trapping, poaching | | | | < | | | | | < | | | | | | | | | | | | | | | | | | > | > | | | | | | | | |
| Littering | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | > | |
| Localized visitor impacts | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | > | |
| Mineral extraction and transport (pipelines) | | > | | | | | | | | > | > | | | | | > | | > | | | | | | | | | | | > | > | > | | | > | |
| River access | | > | | | | | | | | | | | | | | | > | | | | | | | | | | | | | | | | | | > | |
| Trash dumping | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | > | |
| Trespassing | | > | > | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Areawide/Neighbor Issues** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Agriculture | | > | | > | | | | | | | > | | | | | | > | | > | | > | | | | | > | > | > | > | > | > | | | > | |
| Burning-industrial and municipal | | | | | | | | | > | | | | | | | | | | | | | | | | | | | > | > | | | | | > | |
| Mineral extraction and transport (pipelines) | | | | | | | | | > | > | | | | | > | | > | | | | | | | | | | | | | > | | | | > | |
| Paper industry | | | | > | | | | | > | > | | | | | | | | > | | | | | | | | > | > | > | > | > | | | | > | |
| Timber industry | | > | | > | | | | | > | | | | | > | | | > | | | | | | | | | > | > | > | > | > | | | | > | |
| Residential | | > | | > | | | | | > | > | > | | | | | > | | | | | | > | > | > | | > | > | > | > | > | > | | | > | |
| Septic tanks | | | | | | | | | | | > | | | | | > | | | | | | | | | | | | | | | | | | > | |
| **Administrative/Regulatory Issues** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Law enforcement | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | > | | | | > |
| State and Federal inconsistencies | | | | | | | | > | | | | | | | | | | | | | | | | | | | | | | > | > | | | | |
| User conflicts | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | > | | |

* Species Resources consider the number and types of species and the number of individuals.

needed, as, for example, when potential impacts are identified to species resources for which trend data are not yet available.

The Critical Resources Matrix presents management "issues" on the vertical axis and "resources", stated in a way that can be monitored, on the horizontal axis. The issues represent widely varying levels and scopes of activities, so quantitative information on the degree of impact or priority of a given issue cannot be drawn from this matrix. Prior assessments based on characterization documents cited above indicate that for the water corridors, resources that are most important for their habitat value include: 1) *water (quality, quantity and timing);* 2) *woody in-stream substrate (snags);* 3) *stream banks*; and 4) *floodplain forest (amount and integrity)*. Intact stream banks are particularly important to the scenic and aesthetic values as well as the ecological values of the Preserve's water corridors. The matrix can be used to identify those natural resource characteristics that are affected by the greatest number of issues relating to ecosystem alteration, public use, or institutional actions. This is one way of indicating which natural elements are threatened.

**1.5.1 Water (quality, quantity and timing).** Water is clearly the most important resource within the water corridors. Both quality and flow are important aspects of the water resource for habitat, species and human use. There is abundant local rainfall, ranging from an average of 36 inches annually in the northwest (well north of the Preserve) to 55 inches annually in the southeast part of the Neches Basin (ANRA 1992, LNVA 1994). The Neches River and its tributaries, including the Angelina River, drain an area of about 10,000 square miles (LNVA 1992). (Menard Creek is a small tributary of the lower Trinity River, which shares many characteristics with the Neches watershed.) Substantial impairment of either quality or quantity of water in the corridors, or major alterations in the timing of flows, will significantly affect the ability of the Preserve to maintain its current ecosystem function and exhibit its current biological diversity.

On the whole, water quality in the Preserve is good, although sampling has indicated some localized impairments (Hall and Bruce, 1996). It appears that where quality is diminished, it

may be related to nearby human activities, such as residential developments or oil and gas production. Flow of the Neches River has been altered by the operation of Sam Rayburn Reservoir on the Angelina River just above the confluence of the Angelina and Neches Rivers and Lake B. A. Steinhagen (also called "Dam B" or Town Bluff Dam) on the Neches River just upstream of the Preserve. Effects of dam operations on the floodplain forest have been noted (Hall, 1996). The traditional attraction of the water resource for the public has continued to the present. Boating and fishing in the water corridors represents one of the most prevalent public uses of the Preserve (Callaway, 1997).

**1.5.2 Woody in-stream substrate (snags).** River bank erosion and natural tree growth cycles result in the fall of dead trees and branches into the watercourses. Snags in the river or stream provide cover for fish and also serve as a stable habitat for invertebrate populations, which provide food for fish (Hall and Lambou 1990 in Harcombe et al 1996). The importance of submerged snags is illustrated by a study conducted for the Satilla River (Benke et al 1979 in Harcombe et al 1996). It was estimated that removal of all the snags in the Satilla River would eliminate approximately 40% of the insect population, with insects accounting for about 80% of the animals that are in drift in the stream. Since many fish depend almost entirely on a food base of drifting invertebrates, the authors conclude that snag removal in the Satilla would be likely to result in a significant reduction in the fish population. They estimate that in some species, the population could drop as much as 50%, and a few species would be eliminated entirely. Comparison of the habitat value for aquatic invertebrates of snags relative to sandy or muddy stream bottoms indicates that snags support greater biomass and a more diverse group of macroinvertebrates than the stream bottom (Benke et al 1984 in Harcombe et al 1996).

From a species or habitat resource perspective, the presence of submerged snags is unequivocally beneficial. However, from a human use perspective, snags may be a hindrance. Residents of areas near BTNP streams point to debris collected in and around snags as a possible cause of increased flooding. Fallen trees are sometimes submerged wholly or partially and present obstacles that boaters interpret as safety hazards. Boaters, including park law enforcement personnel who must patrol the water corridors, have suggested that some snags be removed in the interest of boating safety (personal communication with NPS staff). The need for

user safety and minimization of legal liability must be evaluated within the need to protect the ecological integrity of the BTNP water corridors by preserving submerged snags (Callaway 1997).

**1.5.3 Stream banks.** Intact stream banks are particularly critical to the ability of the BTNP water corridors to function as a showcase of a natural setting. To the extent stream banks have been altered by human activities such as trash dumping, rip-rapping to prevent streambank erosion, ill-placed septic system outfalls, or other man-made structures, they have diminished capacity to provide the scenic or aesthetic experience of a back-country boating or canoe trip.

The destruction of vegetation on the stream banks may also have habitat and species resources effects, possibly for reptiles and amphibians, and it certainly has an effect on future streambank erosion. Streambank erosion, in turn, deposits additional sediment into the stream, affecting water quality.

**1.5.4 Floodplain forest.** The floodplain forest communities in the stream corridors perform three primary roles: 1) habitat/refugium for bottomland hardwood forest species; 2) population dispersal conduits within the landscape; and 3) buffers for the protection of the aquatic community in the streams (Harcombe et al 1996). Characteristics of a functioning bottomland hardwood forest have been identified as:

1) a mature forest canopy of predominantly mast-producing species;
2) abundance of buttrot, bole, and branch cavities;
3) periodic flooding with the deposition of rich alluvium;
4) large-sized tracts so as to maintain viable populations of interior species;
5) natural transition zones between bottomland hardwood forest and adjacent uplands;
6) large enough area so as to sustain the dynamics of natural disturbance processes: windthrow, insect outbreaks, etc.

If the above ecological characteristics are diminished by human activity, the integrity of the bottomland hardwood forest and the associated aquatic communities decline (Harcombe et al 1996).

Fragmentation resulting from different activities such as land clearing or barrier construction associated with agriculture and silviculture, road, pipeline and utility construction and residential development has varying ecological impacts. However, in general, habitat fragmentation has two major interrelated consequences for biological diversity: 1) population isolation and decrease in effective population size, and 2) creation of edge habitat and its effects. Both population isolation and edge effects are related to the size and shape of the fragmented forest area (Harcombe et al 1996). Because the edge-to-interior ratios for the water corridor units of BTNP are extremely high, the effect of edges is of prime concern in limiting the role of the units as functional bottomland hardwood forest preserves (Harcombe et al 1996). Edge-to-interior ratios (computed as the ratio of land/water area within one-quarter mile of a boundary to the land/water area that is one-quarter mile or more from a boundary) within the water corridors of the Preserve can be high. For example, Little Pine Island Bayou Unit is all edge (2,270:0); Lower Neches River Unit is high (600:1), as is the Upper Neches River Unit (40:1). In contrast, the land units of the Preserve range from 13:1 (Hickory Creek Unit) to 0.5:1 (Big Sandy Unit). Although likely consequences of high edge-to-interior ratios have been identified, the effects of fragmentation on the ecology of bottomland hardwood forests have been virtually unstudied (Harris 1988a in Harcombe et al 1996).

Very little is known about the effectiveness of the corridors for the movement of birds and mammals within landscapes on the scale of BTNP, where corridors extend kilometers rather than meters. In general, wider corridors decrease the risk of invasion from feral animals and thereby reduce predation. Narrow corridors have the problem of being one long continuous edge zone. This edge increases the exposure of animals in the corridor to human contact, facilitating poaching and invasion by domestic and exotic species. Little research has been done to establish minimum widths for corridors to facilitate use by animals. Birds use migration corridors in other parts of the world (Saunders and de Rebeira 1991 in Harcombe et al 1996). However, it is not known to what extent the water corridors are used by birds for movement between units of BTNP (Harcombe et al 1996). No studies of BTNP corridor use by reptiles or amphibians have been conducted (Harcombe et al 1996).

## 2.0 Resource Protection

As an overall goal, the Preserve should be managed to maintain to the maximum extent possible the integrity of its ecosystem components. This goal is consistent with the mission and authority of the Preserve.

***Authority.*** The enabling legislation for the Preserve clearly assigns the task of resource protection to the NPS. The Service is directed to manage the units of the Preserve "in a manner which will assure their natural and ecological integrity in perpetuity" (P.L. 93-439, October 11, 1974; 88 Stat. 1254).

***Background.*** BTNP was created to preserve representative remnants of an ecosystem that is threatened with modern development. At the same time, human activities that have existed in the area for many years were specifically mentioned and provided for in the enabling legislation. As a result, the option of totally prohibiting some human activities that may impact the natural resources is not present. Nevertheless, the natural resources of the Preserve should be managed in a manner that, to the maximum extent possible, preserves the integrity of its ecosystem components.

### 2.1 Biodiversity

The Big Thicket was set aside in recognition of its high biodiversity. Further recognition is evidenced by its designation as a "Man and the Biosphere Reserve" by the United Nations in 1981 (US Department of State, 1994). Because of the large number of species, some of which are listed as threatened or endangered (Harcombe et al 1996), protection of this biodiversity is of special concern. Furthermore, species diversity within the Preserve is an important indicator of ecosystem integrity; the presence of threatened or endangered species indicates an important responsibility to maintaining worldwide biodiversity. Assessments of diversity of major species groups (see references in Harcombe et al 1996) suggest regional declines in fish and some stream invertebrate groups, probably owing to regionwide modifications of waterways. For other

groups, less specific information is available. There are broadscale trends in the southeastern United States suggesting that declining biodiversity is a concern.

For example, many amphibian species worldwide are believed to be experiencing population decline, range reduction, and possible extinction (Blaustein and Wake 1990 in Harcombe et al 1996) at least partly because of habitat decline and waterway acidification. Water corridors in general may have a special role in facilitating amphibian recolonization because their life cycles are dependent upon water (Blaustein et al 1992 in Harcombe et al 1996). Although no amphibian population studies have been carried out in the Preserve (Harcombe et al 1996), the potential of the Preserve to contribute to maintaining worldwide biodiversity suggests that studies should be conducted to document habitat requirements and population trends of amphibian species within the Preserve.

Similarly, the numbers of neotropical migrant birds have diminished. It is not known whether this is more the result of habitat destruction and fragmentation of breeding grounds in the U.S. or from deforestation of wintering grounds in the tropics (Terborgh 1989 in Harcombe et al 1996). It is known that the extinction of one neotropical migrant, Bachman's warbler *(Vermivora bachmanii)*, that formerly bred in the Big Thicket region was coincident with the loss of bottomland forest and the increase of open fields in the Southeastern coastal plains (Harris 1988b in Harcombe et al 1996). The degree to which the stream corridors serve as migration routes between BTNP units or between other areas is not known.

**2.1.1 Impacts to water corridor resources.** Biodiversity is affected by both habitat resources and species resources of the BTNP (see Figure 2). The reciprocal is also true: declining biodiversity reduces species resources, and therefore by definition negatively affects ecosystem integrity.

**2.1.2 Recommended management actions.** To address the issue of declining biodiversity, the NPS should:

1) continue to support the mission of maintaining ecological integrity of the Preserve;

2) carry out and support an active research program to assess and manage for biodiversity;

3) work cooperatively with other conservation partners in the region,

4) encourage neighbors to adopt management practices and land uses that help protect BTNP biodiversity.

**2.1.3 Considerations for NPS research.** Studies are needed to address declining biodiversity issues including:

1) understanding species habitat requirements and documenting population trends;

2) understanding community structure within the corridors; and

3) determining if the water corridors effectively function as movement corridors.

**2.2 Endangered Species**

As a federal nature reserve, BTNP has a legal responsibility to manage for threatened and endangered species that may rely on habitat within the Preserve. Harcombe et al (1996) detailed the species listed as endangered, threatened, rare, or of concern in the counties containing units of BTNP. Appendix C lists these species; a brief summary follows. Of 48 species on the list, plants are most numerous (20), followed by birds (12), mammals (5), reptiles (5), fish (3), and invertebrates (3). In terms of habitat use, 23 species can live in bottomland hardwood forest and elsewhere (facultative bottomland hardwood forest species), and 8 are restricted to such habitats (obligate bottomland hardwood forest species).

Twelve species of birds are listed. Of these, three are facultative users of bottomland hardwood forests (wood stork - *Mycteria americana*, bald eagle - *Halioaeetus leucocephalus*, and swallowtail kite - *Elanoides forficatus*). The two obligate bottomland hardwood forest species on the list (ivory-billed woodpecker - *Campephilus principalis*, and Bachman's warbler - *Vermivora bachmanii*) are believed extinct.

The list of five mammal species includes two species of bats, the southeastern bat (*Myotis austroriparius*) and Rafinesque's big-eared bat (*Corynorhinus rafinesquii*), the hog-nosed skunk (*Conapatus mesuleucus telmalestes*), the red wolf (*Canis rufus*), now believed extinct, and the

Louisiana black bear (*Ursus americanus luteolus*), which is being studied for a reintroduction program by the Texas Parks and Wildlife Department and the U.S. Fish and Wildlife Service. A recently released report on the Louisiana black bear reintroduction program ranked the BTNP lowest of four sites studied for habitat suitability, based principally on the potential for human impact (TPWD 1997). The southeastern bat is an obligate bottomland hardwood forest species; the others are facultative users of that habitat.

Of five reptiles on the list, BTNP floodplain forests may serve as habitat for three, the timber/canebreak rattlesnake (*Crotalus horridus,*), the alligator snapping turtle (*Macroclemys temmincki*), and the Texas diamondback terrapin (*Malaclemys terrapin littoralis*).

Three fish species are listed: the paddlefish (*Polyodon spathula*), the creek chubsucker (*Erimyzon oblongus*), and the blue sucker (*Cycleptus elongatus*). The paddlefish is being restocked by the Texas Parks and Wildlife Department (Pittman 1992a); because of this restocking, the use of gill, hoop, and trammel nets by fishermen is no longer permitted on the Neches River.

Listed invertebrates include two insects (American burying beetle - *Nicrophorus americanus*, Big Thicket emerald dragonfly - *Somatochlora margarita*) and the Texas heelsplitter mussel (*Potamilius amphichenus*).

Twenty species of vascular plants are listed as threatened, endangered, rare, or of concern for the Big Thicket region. Of these, ten are facultative residents of bottomland hardwood forests, and two are obligate bottomland hardwood forest species (Texas screwstem - *Bartonia texana* and Texas least trillium -*Trillium pusillum* var. *texanum*).

**2.2.1 Impacts to water corridor resources.** Endangered species issues affect both Habitat Resources and Species Resources of the BTNP (see Figure 2).

**2.2.2 Recommended management actions.**

1) Consider impacts of human uses of the Preserve on resident threatened and endangered, rare, or uncommon species.

2) Continue to support protection of threatened and endangered species by cooperating with the U.S. Fish and Wildlife Service and the Texas Parks and Wildlife Department and by implementing USFWS recovery plan criteria for threatened and endangered species known to occur in the Preserve.

3) Work cooperatively with non-governmental organizations and individual landowners to support the protection of threatened and endangered species.

**2.2.3 Considerations for NPS research.** Specific research needs related to threatened, endangered, rare, or uncommon species include:

1) mapping potential habitats of threatened and endangered and candidate species;

2) conducting field surveys of populations;

3) monitoring species known to inhabit the Preserve.

**2.3 Exotic Species**

The negative effects of non-native species invasion have been documented in a number of cases. Mammal species introduced to BTNP include the nutria, feral cat, feral dog and feral hog (Harcombe et al 1996). These animals directly compete with native species for food and habitat. There is a concern that feral hogs may be damaging plants by wallowing near and foraging on bottomland mast-producing tree species (comments of BTNP Resource Management staff, 1995).

Within the water corridors, exotic species that may become a concern include the grass carp, zebra mussels, non-native aquatic vegetation and the Chinese Tallow tree. In other areas of southeast Texas, grass carp (introduced to control vegetation in ponds and reservoirs) have damaged native aquatic vegetation, diminishing the habitat of aquatic species and encouraging bank erosion (Chilton 1995). The spread of Zebra mussels across waterways in the U.S., with

the Zebra mussels outcompeting native aquatic species, has been a concern for state officials (personal communication with Larry McKinney, TPWD). The water hyacinth has for many years grown prolifically in low-flowing southern U.S. waters, choking out native species and degrading water quality by lowering dissolved oxygen levels (Johnson 1995). The Chinese Tallow is proliferating in many native bottomland hardwood areas (Cameron et al 1995a; Bruce et al in press).

All of the water corridor units have the potential for non-native species invasion. The Neches River and its tributaries within the Preserve may be susceptible to the introduction of exotic aquatic species such as the grass carp and zebra mussel because of their connection to the Gulf Intracoastal Waterway. The fierce competitive nature of these introduced species may result in lowered natural biodiversity in the Preserve.

**2.3.1 Impact to water corridor resources.** The introduction of exotic species to the water corridors of the BTNP affects both Habitat Resources and Species Resources. Specific habitat characteristics affected include: submerged aquatic habitat, streambank (emergent) vegetation, and water quality. Species resources currently affected most strongly include aquatic invertebrates and bottomland hardwood forests.

**2.3.2 Recommended management actions.** Many of the actions needed to control introduction of exotic species to BTNP are not within the purview of the NPS.

1) NPS should support the efforts of the Texas Parks and Wildlife Department, U.S. Fish and Wildlife Service, and the U.S. Natural Resources Conservation Service and the Agricultural Extension Service to prevent introduction of and to control the spread of exotic species.

2) NPS should work with neighboring landowners, industry and interested groups such as garden clubs to educate the general public about the potential impacts of exotic species.

**2.3.3 Considerations for NPS research.** Information needed to address the introduction of exotic species include:

1) studies of distribution, invasiveness, and effects of exotics within BTNP;

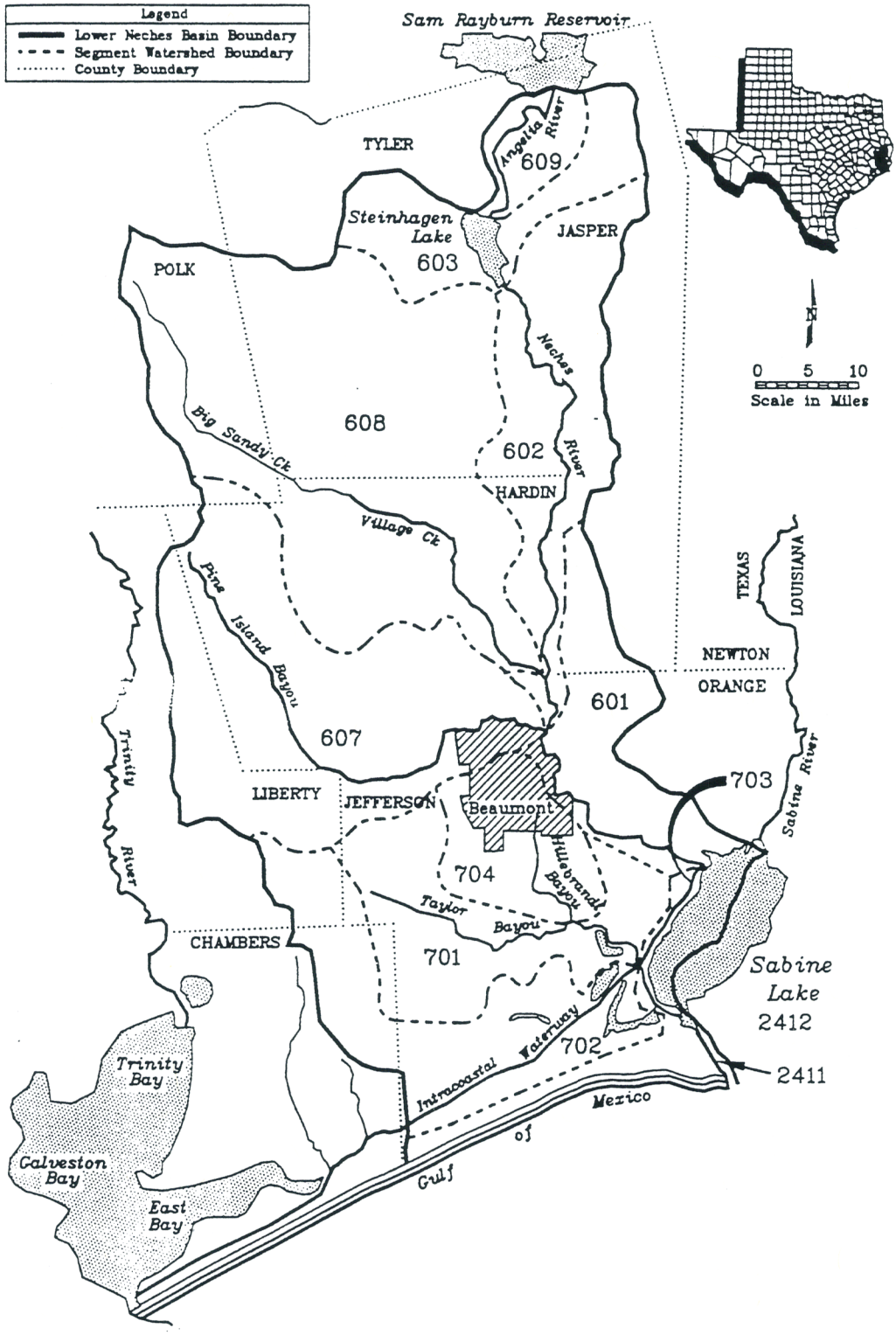
2) research on means of preventing introduction of or controlling exotics in the BTNP.

### 2.4 Water Quality

Figure 4 depicts stream segments designated by the Texas Natural Resource Conservation Commission for watersheds around the BTNP. Water quality monitoring data indicate that declining dissolved oxygen levels may be a regional concern, and certainly are a concern for the Little Pine Island Bayou Corridor (Hall and Bruce 1996). The Pine Island Bayou watershed has the poorest water quality in the region; dissolved oxygen levels do not meet standards more than 10% of the time. Additionally, chlorides and fecal coliform levels, sulfate concentrations and total dissolved solids are high in the bayou (Hall and Bruce 1996; Kaiser et al 1994). Oilfield brines, municipal sewage discharge, and runoff from rice farming and residences are probable contributors to these conditions. Elevated levels of chlorides, apparently from oilfield brines, also are a concern for Menard Creek. Turkey Creek has some problem with fecal coliform, and the upper Neches River sampling sites registered high in total dissolved solids (Hall and Bruce 1996). Several studies have indicated that saltwater intrusion and industrial pollution carried into the Neches River impair the habitat value of the lower reaches of the river for benthic communities (Harcombe et al 1996). An analysis of trends from ten years of data collected by BTNP suggests that there has been a reduction in brine-related pollution (Hall and Bruce 1996).

As part of the National Bioaccumulation Study, the U.S. Environmental Protection Agency (EPA) found concentrations of dioxin exceeding the accepted ($10^{-4}$) risk level in fish tissue samples from the lower Neches River downstream from Evadale (EPA 1990). The sampling site was approximately 1/2 mile downstream from the Temple-Eastex paper mill discharge canal. Based on the EPA findings, the Texas Department of Health issued a fish consumption advisory for the lower Neches River below Highway 96 (see Figure 5). More recent samples show reduced concentrations of this toxin (Harcombe et al 1996). During 1994, 66 fish samples were collected from an area just below, but within swimming range of, the previous sample site and were examined for dioxin and a full suite of priority pollutants. Dioxin levels were below the acceptable risk level, but polychlorinated biphenyls (PCBs) in excess of the federal safety

## Figure 4. TNRCC Designated Segment Watersheds




Source: Lower Neches Valley Authority, 1992.

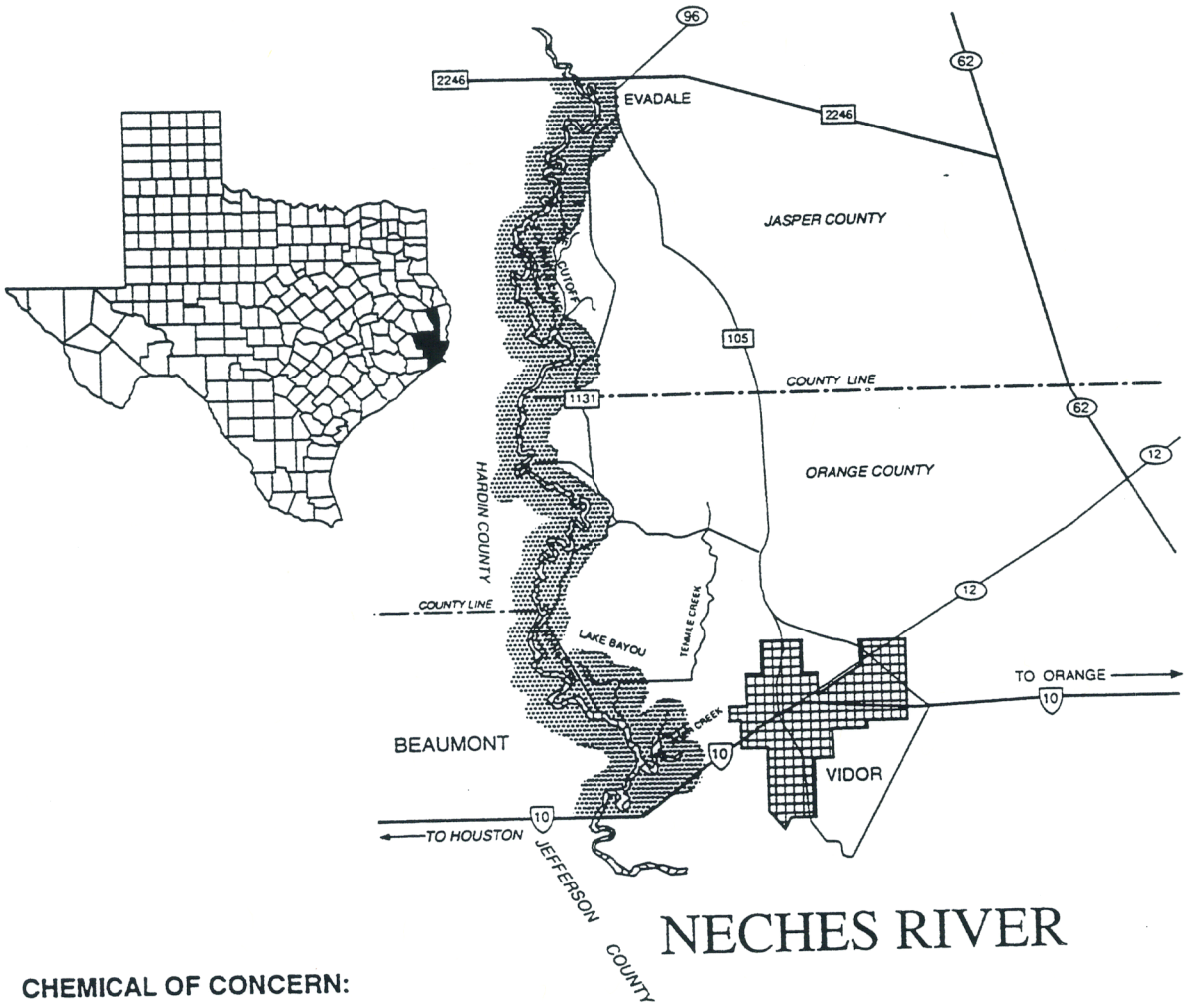
**Figure 5. Texas Department of Health Advisory Area, Neches River**

# NECHES RIVER

## ORANGE, JEFFERSON, JASPER, AND HARDIN COUNTIES

**ADVISORY AREA:**

The Neches River and all contiguous waters south of the U.S. 96 Bridge near Evadale to the Interstate 10 Bridge near Beaumont




**CHEMICAL OF CONCERN:**
Dioxin

**CONSUMPTION ADVICE:**
The advisory includes all species of fish and recommends consumption of no more than one meal, not to exceed eight ounces, each month. Women of childbearing age and children should not consume any fish from this area.

Source: Texas Department of Health, 1995.

standard were found in one sample. Based on that finding, the Department of Health retained the advisory pending analysis of additional samples (Texas Department of Health, 1995). In 1995, six additional fish samples were collected for analysis (Lisa Williams, TDH, 1995). In December 1995, the advisory was removed (LNVA 1996).

In a regional assessment of streams in the lower Neches basin, very few areas of water quality concern were identified (LNVA 1996). Table 1 provides a summary of the water quality concerns (a revision of previous assessments) listed for streams in the BTNP. Similar data are not available for Menard Creek, which is in the lower Trinity River basin (personal communication with Dr. Richard Browning, TRA, 1996).

**Table 1. Water Quality Concerns in the Lower Neches Basin**
Source: LNVA Clean Rivers Program Regional Assessment of Water Quality, 1996

| Stream Segment | Parameter | Classification |
|---|---|---|
| 0601 - Neches River Tidal | Fecal Coliform | Possible Concern |
| 0602 - Neches River | Cadmium | Insufficient Data |
| | Copper | Possible Concern |
| | Lead | Insufficient Data |
| | Mercury | No Concern |
| | Zinc | No Concern |
| 0607 - Pine Island Bayou | Fecal Coliform | Possible Concern |
| | Dissolved Oxygen | Possible Concern |
| | Total Phosphorus | No Concern |
| 0608 - Village Creek | Fecal Coliform | Possible Concern |
| | pH | No Concern |
| | Aluminum | No Concern |

**2.4.1 Impact to water corridor resources.** Impaired water quality has effects on both Species Resources and recreational opportunities in the Preserve.

**2.4.2 Recommended management actions.** The water quality monitoring program should be supported and coordinated with data collection efforts of other state and federal agencies. Cooperative water quality sampling efforts with the Lower Neches Valley Authority (LNVA) should be pursued. Water quality data should be collected under a quality assurance plan that is approved by the Texas Natural Resource Conservation Commission to allow NPS data to be used in state and federal enforcement actions.

**2.4.3 Considerations for NPS research.**

1) The data base established by the NPS should be maintained or expanded.
2) Periodic analysis and reporting of the data should be performed.

**2.5 Water Flow: Impoundments, Diversions, Releases**

Principal alterations to water flow result from 1) impoundments, 2) diversions, and 3) timing of releases (Hall 1996). Unintentional changes to water flow may also be caused by the construction of roads and bridges or by urban development. Roads and bridges can act as large-scale weirs impeding and changing the course of natural runoff.

The construction and operation of Sam Rayburn Dam and Lake B. A. Steinhagen (Dam B) on the Neches and Angelina Rivers have changed the flow characteristics of the Neches River by reducing the frequency and duration of both high and low flows (Gooch, 1996; Hall 1996). Town Bluff Dam (Dam B), 113.7 miles above the mouth of the Neches River, at the upstream end of the BTNP Upper Neches Unit was completed in June 1953 and created a reservoir called B. A. Steinhagen Lake (U.S. Army Corps of Engineers, 1976). The Fort Worth District of the U.S. Army Corps of Engineers operates the dam in conjunction with the much larger Sam Rayburn Reservoir, which was completed in 1965 and is located on the Angelina River about 25 river miles above Steinhagen. The Corps controls the timing and volume of releases from Rayburn/Steinhagen for the principal purposes of electricity generation, water supply and recreation on the lakes. Dam B and Steinhagen Lake function to ameliorate fluctuations in water

flow related to hydropower generation at Sam Rayburn. The Texas Parks and Wildlife Department operates Martin Dies Jr. State Park on the northeastern shore of the Lake Steinhagen.

Changes in the duration and frequency of floods on the Neches River attributable to construction of the Rayburn/Steinhagen dams have resulted in changes in the species composition and distribution of floodplain forest communities (Hall 1996). Hydropower generation affects the timing of releases (Gooch, 1996-Table 6); however, no effects within the water corridors have yet been documented. Operating restrictions on pool elevations and on releases related to power generation as measured by flow rates at Evadale (U.S. Army Corps of Engineers, 1976) minimize the likelihood of short-term fluctuations in the Neches River below Dam B that would be detrimental to aquatic biota of BTNP.

One impact of lake and dam operations on the water corridors is the use of drawdowns and "flushing flows" to control nuisance vegetation (such as hydrilla, water hyacinth, and lotus) in Lake Steinhagen. In 1994, the BTNP registered complaints about the dead vegetation flushed into the Upper Neches Unit as a result of this practice (Callaway 1997).

Diversion measures may alter flooding frequency and duration by reducing (or increasing) the amount of water flowing through stream channels (Pearlstine et al 1985 in Hall 1996). An assessment carried out by the Lower Neches Valley Authority (LNVA) under the State's Clean Rivers Program found that currently permitted withdrawals from the water corridors do not appear to have any significant effect on water quality in the streams (LNVA 1994). Table 2 provides amounts of water diverted by the LNVA system for 1990 - 1993. Water is also diverted by the City of Beaumont for municipal purposes. Most of the diversion is at the south end of the Preserve and therefore does not substantially alter volume of flows within the water corridors. However, because the freshwater diversion points are near the tidal portion of the river (much of which has been channelized), saltwater intrusion is a periodic problem. The issues surrounding the use of temporary saltwater barriers on the Lower Neches River and Pine Island Bayou to combat saltwater intrusion are discussed below in section 4.4.

**Table 2. Total diversions by LNVA from the Neches River and Pine Island Bayou**
Source: Dennis Becker, Lower Neches River Authority, 14 September 1994.

| Year | Diversion (acre feet/year) |
|---|---|
| 1990 | 349,911 |
| 1991 | 339,891 |
| 1992 | 381,264 |
| 1993 | 354,685 |

Proposed future withdrawals or transfers that involve crossing any of the water corridors may have substantial impacts on stream flow. Potential changes that may affect flow and circulation include water withdrawals associated with regional agricultural, industrial and municipal water use and water transfer projects such as the interbasin transfers being studied under the state's Trans-Texas Water Program (Callaway 1997), which is discussed further in section 4.5.

**2.5.1 Impact to water corridor resources.** Changes in the seasonality and peaking of flows on the Neches River have altered the floodplain forest (Hall, 1996). Manipulation of the lake water level to control the growth of aquatic vegetation may result in negative effects to habitat resources downstream from the dam on the Upper Neches River Corridor Unit. The flushing of dead vegetation after the lake is refilled may result in impairment of water quality (lower dissolved oxygen (DO) levels, odor problems) and diminished quality of scenic and aesthetic resources downstream on the Neches River; these probably are short-term impacts on water quality and nuisance to users. There is no known impact to important species resources.

Permanent changes in the overall amounts and timing of stream flows may affect the stream corridors. Direct effects to habitat resources may include changes in channel morphology, rate of meandering, sedimentation and water quality, and the amount and type of submerged habitat. Secondary effects to species resources may include changes in growth, mortality and

regeneration of vegetation along the riparian corridor (Hall 1996). Any of these changes together with associated structures on the stream banks may affect the scenic and aesthetic quality of the water corridors. Specific impacts of possible interbasin water transfers are unknown at this time.

**2.5.2 Recommended management actions.** The NPS should:

1) continue to actively participate on the Technical Advisory Committee of the Trans-Texas Water Program to ensure that avoidance of impacts to BTNP remains a principal criterion for evaluating alternatives. NPS should make certain that location and design of any proposed river crossings have no negative impact on water corridor functions and values.

2) monitor the timing of drawdowns and flushes and work with the COE to influence the operation of the Steinhagen Dam (Dam B) so that any negative impacts on the water corridors are avoided.

**2.5.3 Considerations for NPS research.**

1) Recent developments on the Colorado River above the Grand Canyon in Arizona indicate that it may be possible to affect the operation of dams that impact NPS water resources. Research into these possibilities is highly desirable.

2) To deal with the potential impacts of "flushing flows" from Dam B, the NPS needs the following information: a) water quality data for Upper and Lower Neches River; water quality surveys of Upper Neches during periods of flushing; and b) record of BTNP user reactions during periods of flushing -- either reports to rangers or special surveys.

3) The NPS needs to know the potential impacts of any stream crossings proposed by the Trans-Texas Water Program or other water supply plans.

**2.6 Woody In-stream Substrate (Snags)**

River bank erosion and natural tree growth cycles result in dead trees and branches falling to the watercourses. The fallen trees are sometimes submerged and present obstacles/hazards to boaters who would like to have the trees removed from the riverway. Law enforcement personnel also must contend with these obstacles in patrolling the waterways. Fallen trees are

part of the natural habitat of aquatic species in BTNP. Removal of snags (or "desnagging") destroys that habitat. Removal of snags also allows water to flow more quickly and may contribute to streambank erosion.

The fate of snags is an issue affecting the Neches River, Pine Island Bayou, and Village Creek. Each of these water corridors has significant boat and canoe usage.

**2.6.1 Impact on water corridor resources.** Snag removal has substantial impact on submerged aquatic habitat and fish and invertebrate species resources of the water corridors. The presence of snags in the reaches of the streams that are used for boating can affect human use of the Preserve through a concern for boating safety.

**2.6.2 Recommended management actions.** To address the issue of snags, NPS should:

1) Review incident reports relative to boating safety to determine if there is a significant threat to human use of the water corridors.

2) Increase boater education about the presence of snags and their importance for habitat.

3) Consider identifying some areas as boating zones within which some snags will be removed for safety reasons.

4) Incorporate information on the importance of snags for aquatic habitat into general educational activities with area residents.

**2.6.3 Considerations for NPS research.** The importance of woody in-stream substrate (snags) has been documented in other locales. Similar research on the importance of snags as habitat to species in the water corridors would be helpful in supporting management decisions.

**2.7 Stream Banks (Erosion and River Meander)**

Intact stream banks are important to a high-quality scenic or aesthetic experience on the Preserve's rivers and streams. Rivers are dynamic entities, eroding some areas and accreting others. This characteristic is particularly notable in the Neches River. Eroding banks are subject

to further alteration as property owners neighboring the Preserve attempt to stem the erosion by placing rocks, concrete, or other materials on the banks. In addition to being unsightly, the destruction of vegetation on the stream banks may have a negative effect on habitat and species such as reptiles and amphibians. The loss of vegetation, whether man-caused or natural, results in additional erosion and an increased sediment load within the stream. This natural meander process also produces sand bars and banks in accreting areas which are popular for recreational activities.

Because of the narrowness of the boundaries of the water corridor units and potential impact of river meander, boundaries of the Neches River units are designated in the enabling legislation for the Preserve by stream gradient boundaries for bank-to-bank inclusion (Fed. Reg. vol. 52, Mar. 17, 1975, Part II). Over time the Neches River has meandered from the original course existing at the time properties were acquired for the water corridors. Additionally, there are indications from field reconnaissance and Preserve staff that the river course in specific locations may have been purposely altered by human activity (Pers. comm., D. McHugh, BTNP, NPS).

**2.7.1 Impact to water corridor resources.** Natural river meander is occurring within the Preserve. However, minimal impact to the water corridors has been documented. Field observations have indicated substantial visual impacts in specific locales resulting from modifications to banks by nearby property owners in an attempt to control erosion.

**2.7.2 Recommended management actions.** The NPS should consider the following options:

1) continue legally defining water corridors, or at least the Neches River corridor units, in terms of stream-gradient-boundary for bank-to-bank inclusion in the Preserve;

2) identify areas in which river meander has the potential to create boundary problems and determine if management conflicts with neighbors are likely to arise;

3) acquire additional lands bordering the Neches River corridor units, particularly in areas of active erosion, to bring more streambanks within Preserve management.

**2.7.3 Considerations for NPS research.**

1) The extent to which streambank modification has affected habitat for important species within the Preserve has not been adequately studied.

2) Information on alternative methods of stabilizing streambanks in areas with high rates of erosion, and educational programs that might inform neighbors of these methods, are needed to produce less intrusive bank stabilization practices.

3) Information needs relating to river meander include: a) assessment of rates of stream channel changes with maps of water corridors and stream paths over time; and b) property ownership information in areas in which meander is occurring.

## 2.8 Floodplain Forest Habitat

The water corridor units consist of two distinct biological communities: the bottomland hardwood forest community located on the floodplain terrace adjacent to the waterway and the aquatic community present within the active channels and connected oxbows. While these communities are fairly distinct, an important ecotone exists between these two communities, the streambank (Harcombe et al 1996). The biological integrity of one of these, the aquatic community, is highly dependent upon the extent of bottomland hardwood forests both inside and outside the Preserve. Therefore, the integrity of the corridor units is strongly challenged by the fragmentation associated with land use practices within and adjacent to the corridor unit. Pipelines, roads, agriculture, timber harvests, and residential developments all occur in the vicinity of the Preserve, creating pressures to reduce the total amount of bottomland hardwood forests and contributing to fragmentation of the floodplain forest habitat.

**2.8.1 Impact on water corridor resources.** The principal ecological impacts of habitat fragmentation are 1) population isolation and a decrease in effective population size, resulting in the possible loss of some species, and 2) the creation of edge habitat and "edge" effects such as change in microclimatic conditions, increased predation and roadkills in open areas, and increased human access.

**2.8.2 Recommended management actions.**

1) Make certain that NPS facilities minimize fragmentation within the Preserve.

2) Participate in public planning activities, such as those for road construction, to prevent avoidable fragmentation and negative habitat impacts from neighboring uses.

3) Continue working with the oil and gas and pipeline companies in accordance with the Oil and Gas Management Plan to minimize the impact of their activities within or near the Preserve on habitat.

4) Encourage neighbors to adopt management practices and land uses that minimize additional fragmentation of bottomland hardwood forests.

**2.8.3 Considerations for NPS research.** There are many questions unanswered about habitat quality and the effects of fragmentation on the BTNP. Among them are:

1) How does aquatic diversity respond to increased width of the forest strip in the corridors?

2) What are the specific impacts of neighboring human land uses on water quality, species diversity and corridor integrity?

3) In the corridor units, what is the relative importance of quality of water as it enters the corridors versus characteristics of the forested buffer zone in contributing to in-stream habitat quality?

## 2.9 Aesthetic/Scenic Qualities

There have been no landscape-level studies of the BTNP. Studies of archaeological and cultural resources (see below) have identified specific sites, but no larger communities or cultural landscapes are known to exist in the corridor units. The major public uses of the Preserve (fishing, boating, hunting, hiking, backcountry camping) all reflect an appreciation for undeveloped, backcountry-type experiences. Partly as a result of this, scenic quality is an important condition of streambanks along the water corridors. Village Creek is a popular stream for canoeists because of its pastoral qualities. There are long reaches of the Neches River which are uninterrupted by development and which are extremely scenic. For the areas in which the NPS does not own the streambanks, neighboring uses have a great impact on the quality of recreational experience provided by the water corridors. Based on field observation during

1993, these scenic qualities are most seriously diminished in residential areas where banks have been altered, usually in an effort to prevent erosion.

**2.9.1 Impacts to water corridor resources.** Any diminution of the scenic quality of the water corridors is likely to decrease public use and enjoyment of the Preserve. Furthermore, the condition of the streambanks has ecological importance as well as aesthetic value (see discussion of critical resources above).

**2.9.2 Recommended management actions.**

1) Work with neighbors in residences along river and stream banks to preserve the scenic quality of the corridors and discourage unsightly stream bank alterations.

2) Work with appropriate governmental units to prevent avoidable intrusions and minimize effects of unavoidable facilities such as roads and bridges.

3) Work with pipeline companies to minimize the visual impacts of pipeline crossings.

**2.9.3 Considerations for NPS research.** None at this time. In the long run, landscape scale studies of the corridors might help establish the importance to Preserve users of having undisturbed natural areas visible along the banks.

**2.10 Archaeological and Cultural Resources**

The NPS is required to comply with federal laws and regulations that provide for identifying, evaluating, and protecting archaeological and cultural resources (NPS 1988a, 5:1-15). Principal among these federal laws are the Antiquities Act of 1906 (16 USC 431-433, 1988); the Historic Sites, Buildings and Antiquities Act of 1935 (16 USC 461 et seq., 1988); the National Historic Preservation Act of 1966 (16 USC 470 et seq., 1966); and the Archaeological Resources Protection Act of 1979 (16 USC 470aa, 1988).

General surveys of archaeological and cultural resources of BTNP were undertaken in 1975. Since that time, only small area surveys associated primarily with specific projects such as oil

and gas pipeline construction have been added. In 1991-1992, NPS personnel from the Branch of Cultural Resources Management investigated a reported archaeological find in the Neches River (see Bradford 1992 below).

Shafer et al. found twelve archaeological sites "within or near" the BTNP boundaries, mostly on "elevated landforms such as abandoned stream levees, terrace remnants and upland features located in the proximity of larger streams or rivers." (Shafer et al. 1975). Most sites were placed in the early ceramic period (about 200 B.C.) or later. One site also showed evidence of early European influence, perhaps a small settlement. The Final Environmental Statement for Establishment of the Big Thicket National Preserve, Texas indicates that seven of the sites Shafer et al. identified were within Preserve boundaries, and only one of those was possibly a "significant site" -- the De Gave site in or near the Lance Rosier Unit (NPS 1976).

An interesting aspect of Shafer et al.'s work was an extensive analysis of the factors that might explain the "paucity" of aboriginal sites observed. These are summarized as:

1. Proposed boundaries include mostly bottomland and swamp -- elevated landforms where habitation might be expected occurred outside the boundaries.

2. Cultural material may be buried so deeply under soil and humus that evidence cannot be detected on the surface. This explanation was advanced particularly for the Neches River.

3. Landowner denial of access prevented inspection of some areas.

4. Aboriginal populations may have used the Big Thicket area for hunting or water transportation, but these activities leave little for the archaeological record.

5. The meander pattern of the lower Neches River has resulted in the loss of archaeological sites.

Based on their findings, Shafer et al. recommended a "thorough survey" upon purchase of the BTNP lands. Because of the configuration of individual preserve units, a watershed approach to surveying, including both public and private lands, was recommended (although the authors on several occasions noted the difficulty of gaining land owner access to many of those lands). Also suggested are a description of the Quaternary geology of the area and a pollen analysis of

the peat bogs in and near the BTNP. In summarizing, Shafer et al. point out that the BTNP was established because of its "unique botanical resources" and that while archaeological resources are present, they do not "warrant a priority for interpretative development" (Shafer et al. 1975).

Dethloff and Treat surveyed historical resources of the Preserve in 1975 (Dethloff and Treat, 1975). At that time, no historic sites or structures in Hardin, Jasper, Liberty or Polk counties were listed in the National Register for Historic Places or were suggested by the Texas Historical Commission for inclusion in the Register. Dethloff and Treat included in their survey "buildings, sites and structures in the general vicinity of the Units, although in some instances these locations were 10-20 miles away from the Preserve boundaries" Much of their report emphasizes the general history of southeast Texas to provide a "general historical orientation of the Big Thicket." The General Management Plan for the BTNP lists three structures or sites as "worthy of notation", two of which are in water corridor units:

Richardson house, a pioneer home in the Turkey Creek Unit
Voth mill, remains of a steam-powered lumber mill in the Beaumont Unit
Old Yellow Bluff ferry site in the Neches Bottom/Jack Gore Baygall Unit.

The Dethloff and Treat team concluded that it described "practically all" structures within the Preserve, but suggest that additional unmarked burial plots or former river landings or ferry crossings may yet be found. The implication of their study is that there may be high potential for future historical study and development of interpretive materials within the Preserve in an examination of river landings or ferry crossings within the Neches River corridor units.

An NPS report titled "Discovery of a Neches River Ferryboat, Big Thicket National Preserve, Tyler County, Texas" by James E. Bradford (1992) documents the discovery in the upper portion of the river of remains of a ferryboat dated as early nineteenth century. This report notes that during the 1800's there were at least four ferryboat operations on the Neches within the fifteen miles below Town Bluff Dam. Bradford (1992) recommends additional historical research on those operations, both to add to the Preserve's interpretive program and to provide information on the archaeological site. He also recommends excavation and removal for conservation as a

means of protecting the site from threats of damage from floods or water level fluctuations, from destruction in the interest of boating safety, and from vandalism.

A project-specific survey within the Beaumont Unit in 1994 discovered no additional archaeological or cultural sites (Moore and Aronow, 1994).

**2.10.1 Impacts to water corridor resources.** The two cultural sites that have been identified within the water corridors are not developed to encourage visitation and accordingly have little impact on the natural resources of the corridors. The more recently recorded archaeological site similarly has not been developed.

**2.10.2 Recommended management actions.**

(1) Consideration should be given to improved public presentation (printed materials and displays) of archaeological and cultural information already in the possession of the NPS.

(2) Recommendations made by Bradford (1992) should be implemented.

**2.10.3 Considerations for NPS research.** Other than the historical and archaeological research recommended by Bradford for the Neches River ferryboat, no archaeological/cultural research needs have been identified within the water corridors. When acquired, the recently authorized units along the Big Sandy/Village Creek watersheds should be reviewed to make certain that these areas were adequately included in previous cultural and archaeological research.

## 3.0 Public Use of the Preserve

Public use issues are those that occur within the BTNP boundaries and frequently involve members of the public. The 1916 NPS organic act (16 USC 1) provides the basic mission of national parks and preserves as providing for public use and enjoyment while leaving the resource unimpaired for future generations (NPS Management Policies, 1988 8:1). Although the BTNP was authorized in 1974, it is a relatively young park facility. To date, unlike many older, more well-known national parks, the Preserve is not generally faced with problems of overuse by park visitors. One explanation frequently given for this is the difficulty in identifying the 15 widely dispersed units as a visitor destination. For much of the general public, the Visitor Information Station at the Turkey Creek Unit is the BTNP.

Monthly counts of visitors to BTNP units are made by Park Rangers and compiled by the Division of Interpretation (Callaway, 1997). Relating historical visitor counts to park units is complicated by the reporting units that have been used. For example, the entire length (87 miles) of the Neches River is treated as one facility. Until 1993, Lakeview Beach (sandbar) was treated individually in visitor counts; no counts were made for Menard Creek; and it was uncertain whether Little Pine Island Bayou/Pine Island Bayou Corridor visitation was included within counts for the Lance Rosier Unit. In 1993, reporting units for visitor counts were changed. Table 3 provides available visitor counts by facility since 1982. As shown in Figure 6, Preserve visitation traditionally has peaked in October annually, coinciding with hunting season (Callaway 1997). A secondary peak experienced in July has been associated with use of the Neches River. In the last few years, the July visitation peak has exceeded October counts. For all units, the month of lowest visitation is February.

During 1992, a 2% sampling was made of visitors to the Turkey Creek Visitor Information Station. Data collected indicated that the vast majority (85%) of visitors surveyed were from Texas, were Anglo (96%), and were visiting the Preserve for the first time (76%) (Callaway 1997). It is not probable that these first-time visitors have the same profile as boaters and fishers who use the water corridors, who are generally thought to be residents of the region and repeat

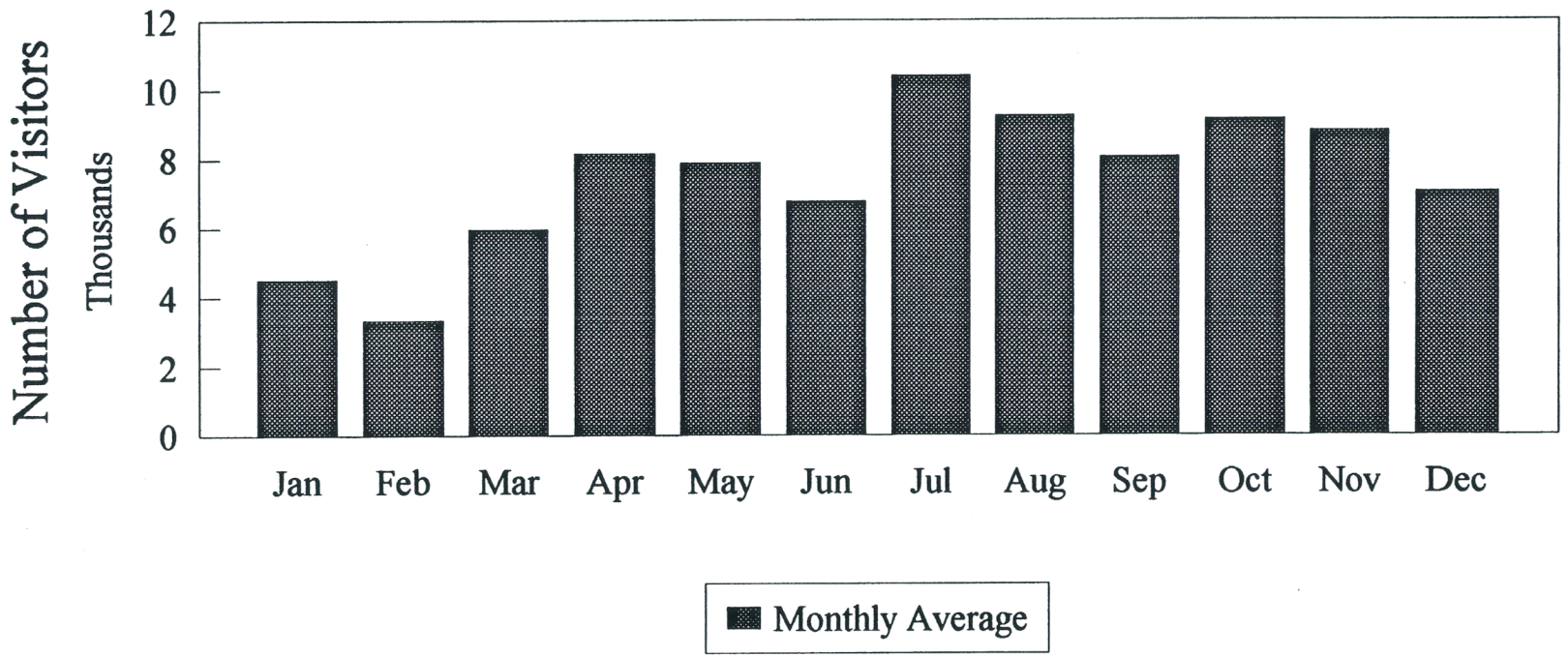
**Table 3. Big Thicket National Preserve Visitation Information**

**Yearly Visitation by Month**

| Year/Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | TOT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1978 | | | | | | | | | | | 44 | 19 | 63 |
| 1979 | 27 | 27 | 74 | 95 | 199 | 258 | 200 | 193 | 341 | 554 | 623 | 341 | 2932 |
| 1980 | 342 | 545 | 1192 | 1698 | 977 | 702 | 622 | 1256 | 1411 | 1209 | 1549 | 654 | 12157 |
| 1981 | 575 | 616 | 1142 | 1306 | 1245 | 939 | 849 | 2590 | 4864 | 4698 | 2268 | 4992 | 26084 |
| 1982 | 3628 | 2246 | 2727 | 3088 | 2844 | 2513 | 3505 | 7485 | 3325 | 7721 | 5864 | 4304 | 49250 |
| 1983 | 2826 | 1754 | 2960 | 3894 | 2567 | 1408 | 1920 | 2948 | 1739 | 5451 | 4911 | 1549 | 33927 |
| 1984 | 2345 | 2474 | 6815 | 5420 | 7281 | 11019 | 8394 | 9708 | 6536 | 8150 | 10099 | 5758 | 83999 |
| 1985 | 4439 | 2597 | 5141 | 7023 | 8297 | 8683 | 7290 | 10326 | 6706 | 8019 | 5691 | 5617 | 79829 |
| 1986 | 5162 | 3636 | 5348 | 4666 | 10324 | 5660 | 3838 | 7438 | 5830 | 5578 | 6411 | 4197 | 68088 |
| 1987 | 4499 | 3093 | 4720 | 5950 | 8199 | 4020 | 5987 | 6225 | 3473 | 6081 | 6082 | 4928 | 63257 |
| 1988 | 3795 | 3055 | 6970 | 6356 | 7410 | 6296 | 9848 | 5549 | 4054 | 5400 | 7988 | 6013 | 72734 |
| 1989 | 4511 | 2431 | 6062 | 24612 | 4395 | 3640 | 4802 | 4020 | 8117 | 15160 | 17301 | 8896 | 103947 |
| 1990 | 5027 | 2580 | 6595 | 7754 | 8673 | 6816 | 6969 | 6827 | 6420 | 7056 | 7228 | 5985 | 77930 |
| 1991 | 4532 | 2209 | 5627 | 4614 | 4542 | 2459 | 7616 | 5308 | 6528 | 10107 | 6764 | 4999 | 65305 |
| 1992 | 6524 | 2088 | 4934 | 4259 | 7841 | 6296 | 7542 | 5648 | 5968 | 8601 | 6961 | 5607 | 72269 |
| 1993 | 4419 | 5335 | 7743 | 9010 | 5643 | 7150 | 6998 | 8391 | 7391 | 5811 | 4263 | 10700 | 82854 |
| 1994 | 4742 | 4559 | 5751 | 6386 | 10238 | 10437 | 10287 | 20354 | 16994 | 18278 | 11265 | 8022 | 127313 |
| 1995 | 3550 | 3934 | 5720 | 4063 | 10019 | 6956 | 30832 | 14883 | 8854 | 6786 | 11313 | 8556 | 115466 |
| 1996 | 3638 | 3999 | 5380 | 8471 | 11889 | 13596 | 13061 | 15294 | 12711 | 8123 | 8834 | 6630 | 111626 |
| Avg. Monthly (1987-1996) | 4524 | 3328 | 5950 | 8148 | 7885 | 6767 | 10394 | 9250 | 8051 | 9140 | 8800 | 7034 | 89270 |
| Avg. Monthly (1980-1996) | 3797 | 2774 | 4990 | 6386 | 6611 | 5799 | 7668 | 7897 | 6525 | 7778 | 7341 | 5730 | 73296 |
| Avg. Monthly (1978-1996) | 3588 | 2621 | 4717 | 6037 | 6255 | 5492 | 7253 | 7469 | 6181 | 7377 | 6603 | 5146 | 65738 |

*Reporting units (facility designations) changed in 1993.
SOURCE: BTNP Monthly Public Use Report, NPS Form 10-157.

## Figure 6. Big Thicket National Preserve Average Monthly Visitation 1987-1996




Source: BTNP Monthly Public Use Report, NPS Form 10-157

visitors to the BTNP. Fishing is reported by the Texas Parks and Wildlife Department to be more important than walking for recreation in the Deep East Texas region that includes much of the BTNP (TPWD 1990 in Callaway 1997).

A recent survey of several conservation and recreation groups who were expected to be more knowledgeable than the general public of the BTNP, found that 95% of respondents had visited one or more units of the Preserve. Seventy-three percent (73%) had visited the Information Center and Turkey Creek Unit, while 85% had visited Village Creek, a water corridor unit that is among the new units authorized by Congress in 1993 (Callaway 1997). This level of use found among an attractive target population indicates that a supportive audience exists within the region for getting out the message of the BTNP.

As part of its mission to provide natural resource education, the Division of Interpretation works actively with area schools and exploits other opportunities to reach beyond the current audience. Approximately 6,000 schoolchildren visit the Preserve annually as part of cooperative programs between BTNP and area school districts and an additional 4,000 are reached through in-school visits (Personal communication with R. Valen and L. Dubey, BTNP, NPS). While these activities are rarely centered on the water corridors, they raise general appreciation of the intrinsic worth of the Preserve's resources and they introduce members of a new audience to existence of the BTNP. New programs have been initiated to reach particular groups, such as boaters, with both resource interpretive and safety information.

The issue of resource carrying capacity has been discussed by Preserve staff, but the current level of public use has not made it an urgent issue. The importance of identifying baseline conditions and building data bases that will support future management decisions has been recognized. Additional information on public use, as well as natural resources, within the water corridors will be needed to manage the water corridors.

On the whole, the current level of public use does not appear to have negatively impacted water corridor resources. The potential for specific activities to affect specific resources or for some

public uses to conflict with other public uses is discussed in several sections of this report. Two actions could be taken to assist management with respect to public use: 1) Place more emphasis on collection of data on visitation (such as visitor counts) and 2) add sites as appropriate to better describe visitation within the water corridors. Additionally, Preserve management might consider developing a survey to be administered periodically at river access points to provide better information about users of the water corridors.

### 3.1 Hunting and Trapping

Hunting and trapping are recognized as legitimate uses of a park under certain circumstances. NPS Management Policies (NPS 1988a, 4:7) state that "hunting and trapping wildlife will be allowed only in parks where such use is specifically authorized." In such cases, the NPS will still seek "to perpetuate native animal life and to protect the integrity of natural ecosystems." Further, management programs "will be conducted through cooperative efforts with individual states under memoranda of understanding." Hunting and trapping (8:4)

> will be conducted in accordance with federal law and applicable laws of the state or states where the park is located. However, the National Park service may establish regulations or closures that are more restrictive than applicable state regulations based upon a finding that such restrictions are necessary for public safety, resource protection, or visitor enjoyment. Before regulations or other restrictions are implemented by the Park Service, representatives of appropriate state and federal agencies will be consulted. Any such regulations or other restrictions will be developed with public involvement.

36 CFR 1.5 gives the superintendent authority to locally issue limits on activity within parks to further a number of objectives (public safety, resource protection etc.). 36 CFR 2.2(c) provides that the superintendent will consult with appropriate State agencies before invoking the authority given in section 1.5 except in cases of emergency or areas of exclusive federal jurisdiction. 36 CFR 2.2 addresses wildlife protection and section 2.2(b) specifically addresses hunting and trapping.

The Big Thicket National Preserve Establishment Act of 1974 [P.L. 93-439, Sec. 4(c)] directs that hunting and trapping be permitted. The intent was to allow (protect) the continuation of

traditional uses of wild lands of the Big Thicket. These activities may be restricted to certain areas or times for reasons of public safety, administration, resource protection, or public use and enjoyment. Except in emergencies, hunting and trapping restrictions "shall be put into effect only after consultation with the appropriate State agency." For BTNP, this is the Texas Parks and Wildlife Department.

The BTNP General Management Plan (NPS 1980, p.47) recognizes the requirements of P.L. 93-439 and directs that the NPS "will establish an action plan for hunting, fishing, and trapping management" to provide for resource protection and visitor safety. The Plan states (p. 49) that the hunting, fishing, and trapping management action plan will determine the intensity and yearly distribution of hunters and fishermen.

The BTNP Final Draft Statement for Management (NPS 1995a, pp. 16-17) recognizes "hunting and the carrying of weapons in the Preserve" as a "major and continuing issue" affecting visitor safety, resource protection, and neighboring uses. The statement notes a shortage of law enforcement rangers for effective monitoring and enforcement and provides that public education efforts will be continued as resources permit.

36 CFR 7.85 sets out Special Regulations for BTNP and addresses regulations for hunting, trapping, and weapons possession and use. Sec. 7.85(c) provides that in addition to State permits, permits will be issued by the Preserve.

BTNP Standard Operating Procedure (Superintendent's Orders) 94-7141-02 (NPS 1994a) establishes Preserve procedures for the hunting and trapping programs. Section 1.5(a)(1) provides that there will be no hunting in any Water Corridor Unit except the Neches Bottom/Jack Gore Baygall Unit and the Beaumont Unit.

Annual Hunting Regulations establish the hunting season and areas of the Preserve in which a BTNP hunting permit is valid. The Regulations establish restrictions on hunting within 500 feet of a road or waterway. Maps incorporated in the hunter education packet accompanying the

permit indicate the boundaries of the hunting areas within each of the Preserve units.

**3.1.1 Background.** Public hunting and trapping was initiated in 1979 by permit only after consultation with the Texas Parks and Wildlife Department (NPS 1988b; NPS 1975). All hunting and trapping is done in accordance with State regulations as directed by Preserve authorization and NPS policies cited above. Adherence to State hunting and trapping regulations within BTNP minimizes confusion and conflict, and it simplifies enforcement. State laws permit hunting of white-tailed deer, rabbits, feral hogs, squirrels, and waterfowl and trapping of raccoons, possums, mink, fox, and nutria. TPWD information suggests that recreational hunting is increasing slowly in East Texas. There is a strong hunting tradition in Texas, but it has been offset by changing patterns of culture/leisure activities, so a dramatic increase in hunter pressure is not expected (Callaway 1997).

Fewer than 20 trapping permits are issued annually. In the 1990-96 period, about 2,300 hunter permits were issued each year; the policy is to set a limit of 3,200 permits. Permits are issued on a first-come, first-served basis at scheduled sites and times. Hunters and trappers are asked to return game harvest cards. Though the initial return rate was low, the number of returns increased when future permits were made conditional on return of harvest cards. The permit process is important in promoting hunter safety and adherence to regulations. However, it makes heavy seasonal demands on personnel (Callaway 1997).

Visitor safety, especially for boaters, is dealt with by the prohibition of hunting within 500 feet of roads and watercourses and the prohibition of loaded guns in boats. During hunting season, the need to patrol hunting areas to promote safety and enforce regulations seriously limits the ability of Rangers to respond to boater emergencies in a timely fashion. While there have not yet been any incidents in which inability of Rangers to respond to an emergency has been an issue, there is a potential conflict between the hunting program and visitor protection in river corridor units.

TPWD wildlife population monitoring programs (Harcombe et al 1996) suggest that game

populations in BTNP and surrounding areas are sustainable at current levels of hunting and trapping pressure with current regulations. However, field observations by enforcement and resource management personnel suggest that illegal taking of game has reduced populations of both game and non-game species to an extent that detracts from public enjoyment. An implication of these observations is that additional information on levels of animal populations may be necessary.

There are no specific wildlife protection issues in the Neches Bottom or Beaumont Units that are known to require additional restrictions to hunting or trapping that are more restrictive than the general hunting and trapping regulations. Instead, the major issue reported by field personnel is related to the illegal (rather than permitted) taking of game without regard to season, bag limit, or mode of taking. These practices appear to be a cultural norm within some communities of the Big Thicket. (Abernathy 1967 provides examples of the colorful culture of the Big Thicket region.)

The Neches Bottom Unit presents specific law enforcement difficulties because of its inaccessibility. First, limited public road access makes it difficult to patrol except by boat. Second, low visibility of boundary markers makes it hard for hunters to know exactly when they are in the unit. An additional issue is that Federal laws regarding the transport of guns in boats are more restrictive than State laws. (36 CFR 2.4(b) prohibits carrying a loaded gun in a motor vehicle or vessel unless the vessel is being used as a shooting platform in accordance with federal law; Texas law does not prohibit carrying loaded guns in boats.) Finally, there is a problem with hunters using the river as an access route for unauthorized hunting on private lands that abut the Neches Corridor units.

**3.1.2 Possible general guidelines.** With respect to hunting and trapping in the Water Corridor Units, the following alternative strategies are identified:

1) Allow hunting in the Neches Bottom and Beaumont Units in accordance with existing hunting regulations.
2) Allow hunting in the Neches Bottom but restrict dates (beyond general restrictions) to

minimize visitor protection problems and enforcement costs.

3) Declare the Neches Bottom closed to hunting for reasons of visitor protection and enforcement difficulties.

**3.1.3 Recommended general guideline.** Hunting and trapping should be allowed in the Neches Bottom and Beaumont Unit in accordance with established Hunting Policy, with any additional restrictions necessary to sustain wildlife populations, visitor safety, and a strong land/water and resource protection ethic.

**3.1.4 Recommended management actions.**

1) Curtail illegal taking of game through field patrols and contact with adjacent landowners, hunting clubs, and timber company hunting lease administrators.

2) Reduce problems caused by inconsistencies between Federal and State firearm laws. This can be accomplished in part by seeking the assistance of TPWD in advising hunters about compliance with Federal laws while hunting on Federal preserves and refuges.

3) Promote safety of hunters in the Neches Bottom and Beaumont Units and visitors on waterways or neighboring lands by continuing to provide educational materials along with the hunter registration packet that promote safe handling of fire arms, good hunting etiquette, and a strong conservation ethic. Maps that clearly delineate areas open to hunting must be provided to hunters and other visitors, as well. Ensure that adequate boundary and other orientation markings are established and maintained within the Neches Bottom Unit.

4) Establish a program for monitoring populations and harvest levels for game species within the preserve. Redesign of the hunter and trapper harvest reports to include more information on size, weight, and condition of harvested game can contribute valuable ancillary information. In addition to its value for resource protection, it provides a scientifically credible basis for determining the number of permits to issue and areas open to hunting and trapping.

### 3.2 Fishing

Fishing is recognized as a legitimate park use under certain circumstances. NPS Management Policies (NPS 1988a, 8:4) provide that recreational fishing will be allowed in parks when authorized, or not specifically prohibited, by federal law. Fishing is to be conducted in accordance with federal laws, treaties, and applicable laws of the state in which the park is located. The National Park Service may restrict fishing activities to achieve objectives of the park's resource management plan. Commercial fishing is allowed "only where specifically authorized by federal law or treaty right" (8:4).

Fishing may be restricted to meet a number of objectives as part of a fisheries management program (4:8). For example, restrictions may be put in place to protect endangered species; for scientific study, interpretation, or other public benefits; for species population management; to protect the integrity of aquatic areas in natural zones; or to maintain fish as a food source for native wildlife species. In general, stocking programs are limited to native species (4:8).

36 CFR Sec. 1.5 gives the superintendent authority to locally issue limits on activity within parks to further a number of objectives (public safety, resource protection etc.). 36 CFR 2.3(c) provides that the superintendent will consult with appropriate State agencies before invoking the authority given in section 1.5 except in cases of emergency or areas of exclusive federal jurisdiction. 36 CFR 2.3(a) provides that fishing will occur in accordance with state law, and "nonconflicting State laws are adopted as a part of these regulations".

Sec. 2.3.(d) sets out a list of prohibited fishing practices, including fishing in locations that might conflict with other public uses such as swimming and boating (Sec. 2.3.(d)(8)). Section 2.4 proscribes the use of certain weapons, traps and nets, and section 2.5 describes the conditions under which the taking of research specimens is allowed.

Big Thicket National Preserve Establishment Act of 1974 [P.L. 93-439, Sec. 4(c)] directs that fishing be permitted. The intent was to allow (protect) the continuation of traditional uses of wild lands of the Big Thicket. These activities may be restricted to certain areas or times for

reasons of public safety, administration, resource protection, or public use and enjoyment. Except in emergencies, fishing restrictions "shall be put into effect only after consultation with the appropriate State agency." For BTNP, the appropriate state agency is the Texas Parks and Wildlife Department.

The BTNP General Management Plan (NPS 1980, p.47) recognizes the requirements of P.L. 93-439 and directs that the NPS "will establish an action plan for hunting, fishing, and trapping management" to provide for resource protection and visitor safety. The Plan states (p. 49) that the hunting, fishing, and trapping management action plan will determine the intensity and yearly distribution of hunters and fishermen.

The BTNP Final Draft Statement for Management (NPS 1995a, pp. 11-12) states that fishing in the Neches River and Little Pine Island Bayou is under the jurisdiction of the Texas Parks and Wildlife Department, while the NPS has jurisdiction in "the numerous streams, creeks, oxbows, and sloughs in the majority of the Preserve units." (NPS exercises concurrent jurisdiction with TPWD on the navigable streams.) A lack of data to determine the impact of recreational or commercial fishing is noted. It states that a fisheries management plan is being prepared.

BTNP Standard Operating Procedure 94-7141-02 (Superintendent's Orders) (NPS 1994a) does not mention any restrictions pertaining to fishing beyond those set by state law.

**3.2.1 Background.** Public fishing is allowed in accordance with State and federal law, and enforcement is shared with the Texas Parks and Wildlife Department (NPS 1988b; NPS 1975). State regulations governing fishing are published annually by TPWD. There are some differences in practices permitted by TPWD and those allowed under federal law (NPS 1995a, pp. 11-12). These differences have the potential to generate unnecessary confusion. Adherence to a single set of fishing regulations within all areas of BTNP would minimize confusion and conflict, and would simplify enforcement.

Fishing is probably the source of most visitor hours spent in the Preserve (Callaway 1997).

State licenses for recreational fishing are not place-specific; therefore, information on fishing use of the Preserve is not obtainable from administrative records. Survey data are limited.

TPWD monitoring programs provide only limited information about gamefish populations in the Neches River (Harcombe et al 1996). Additional catch data would be desirable, particularly with regard to the impacts of practices permitted by State regulations that are prohibited under federal regulations (e.g., commercial fishing and the use of nets). NPS Ranger monitoring of fishing practice and enforcement of regulations is done infrequently because of limited staff.

TPWD recently reintroduced the endangered Paddlefish into the Upper and Lower Neches River (Pitman 1991, 1992).

There is a potential for user conflict between fishers and hunters in the units near the water corridors. Visitor safety during hunting seasons, especially for boaters, is dealt with by the prohibition of hunting within 500 feet of roads and watercourses and the prohibition of loaded guns in boats.

**3.2.2 Possible general guidelines.** With respect to fishing in the Water Corridor Units, the following alternative strategies are identified:

1) Allow fishing in accordance with existing regulations.
2) Promulgate new regulations through TPWD to prohibit commercial activity and use of nets.

**3.2.3 Recommended general guideline.** Fishing should be allowed in the river corridor units in accordance with established state law, with any additional restrictions necessary to sustain fish populations, visitor safety, and a strong land/water and resource protection ethic.

**3.2.4 Recommended management actions.**

1) Promote adherence to applicable fishing laws through casual field interviews initiated by Rangers on routine patrol.

2) Reduce problems caused by inconsistencies between Federal and State fishing laws. This can be accomplished in part by seeking the assistance of TPWD in advising fishermen about compliance with Federal laws while fishing in Federal preserves and refuges. A complete solution will involve switching to a single set of fishing laws through legislative action at the Federal level.

3) Promote safety of fishers by continuing to provide educational materials and signage.

4) Acquire the fish population data necessary to assure that fish resources are adequately protected. This may be accomplished through transfer from other agencies, contract research, or staff monitoring of populations. Fisher harvest reports based on Ranger interviews, which include information on size, weight, and condition of harvested fish, as well as level of effort and mode of fishing, can provide some information for this purpose.

5) Prepare fishing action plan per the directive of the General Management Plan

### 3.3 Boating

Provision in the NPS organic act for public use and enjoyment of park facilities can be construed as permissive of recreational boating and associated activities. NPS Management Policies (NPS 1988a, 8:2) specifically recognize boating as allowed in parks when authorized, or not specifically prohibited, by federal law. Boating is to be conducted in accordance with federal laws, treaties, and applicable laws of the state in which the park is located. The National Park Service may restrict boating activities to achieve objectives of the park's resource management plan. When boating is allowed, the NPS will provide facilities such as boat ramps and sewage pump-out stations as appropriate for "safe visitor enjoyment of water recreational resources and to protect natural resources" (9:14). Navigation aids are to be planned in collaboration with the U.S. Coast Guard and meet Coast Guard standards, except that NPS and USCG can jointly modify those standards to meet specific park needs (9:11).

NPS Management Policies (8:3) state that a "river management plan will be developed for each park having significant levels of river use, or the potential for such use." River management plans are intended to prevent unacceptable impacts on aquatic resources. Each plan is required to address the disposal of refuse and human waste.

36 CFR Sec. 1.5 gives the superintendent authority to locally issue limits on activity within parks to further a number of objectives (public safety, resource protection etc.). 36 CFR 2.3(c) provides that the superintendent will consult with appropriate State agencies before invoking the authority given in section 1.5, except in cases of emergency or areas of exclusive federal jurisdiction. 36 CFR 3.1 provides that boating and water use activities are governed by Title 14 USC, 33 CFR, 46 CFR and 49 CFR as well as NPS regulations and those of the State; the superintendent is authorized to act as "captain of the port" under federal laws.

36 CFR 3.3 provides that the superintendent may require a permit for use of a boat within a park area. BTNP has not exercised this authority. Authorized park personnel also are allowed to inspect boats within the park for compliance with safety regulations (Sec. 3.5).

36 CFR 3.6 provides a list of prohibited operations, including:

(a) operating a vessel recklessly or negligently so as to endanger persons or property;
(b) operating a vessel under the influence of alcohol or a controlled substance;
(c) failing to observe restrictions established by a regulatory marker;
(d) and (e) operating a vessel in excess of 5 mph or creating a wake in designated areas of within 100 feet of swimmers, or within 500 feet of a swimming beach;
(f) allowing a person to ride on the gunwales, transom, or decking of a motorboat operating in excess of 5 mph except in special circumstances;
(g) attaching a vessel to or interfering with a marker, buoy, or other navigational aid;
(h) using trailers to launch or recover vessels, except at designated launching sites;
(i) launching a motor boat at other than designated sites;
(j) operating a motor boat on waters not directly accessible by road;
(k) launching or operating airboats; or
(l) operating a vessel in excess of designated size, length or width restrictions.

Sec. 3.7 establishes noise limits for boats. Operating a vessel at noise levels greater than 82 decibels measured at a distance of 82 feet (25 meters) from the vessel is prohibited and testing procedures are established.

Big Thicket National Preserve Establishment Act of 1974 [P.L. 93-439] cites the "preservation, conservation, and protection of the natural, scenic, and recreational values of a significant portion of the Big Thicket area in the State of Texas" and "the enhancement and public enjoyment thereof," as the reason for the preserve's creation. Sec. 4(b) provides that "in the interest of maintaining ecological integrity of the preserve" construction of facilities and the use of motorized water vehicles (among other uses) will be limited and controlled.

The BTNP General Management Plan (NPS 1980, pp.16-18) establishes recreation zones within which uses such as boating are appropriate. Continued boating use of the Neches River and Little Pine Island Bayou downstream of the U.S. 69 bridge was anticipated, and upgrading of existing access points and construction of new sites was planned (p. 49). All streams (other than the Neches River and Little Pine Island Bayou downstream of U.S. 69--p. 16), including the Menard Creek Corridor unit and the Little Pine Island Bayou unit upstream of the U.S. 69 bridge are planned to have "small water access points for hand-launched boats, and use of motors will not exceed 5 hp." (p. 49). Table 4 of the Plan (p. 53 et seq.) lists Interpretive Media planned in conjunction with boat launch and other sites. The Management Plan provides that no hiking trails will be developed along water corridors (p. 49).

The General Management Plan reiterates the limits on recreational development and communicates the philosophy that most support facilities will be located outside the preserve. There is an implied preference for private development and ownership of these facilities.

The BTNP Final Draft Statement for Management (NPS 1995a, pp. 9-10) mentions boating in a list of current recreational uses of waters of the Preserve. It also notes that increasing boat use has created a demand for boating related concessions. No boat ramps are discussed in the facilities maintenance section (pp. 24-27). Two sites are noted in the background information on facilities (p. 41, p. 44): a ramp at McQueen's Landing on the east side of the Neches River below Dam B, and a ramp at the confluence of the Neches River and Pine Island Bayou.

BTNP Standard Operating Procedure 94-7141-02 (Superintendent's Orders) (NPS 1994a) does not mention any restrictions pertaining to boating, other than Sec. 3.20(a) which provides that water skiing is allowed on the Neches River and Pine Island Bayou. Boating is managed under general NPS regulations and those of the State of Texas.

State boat registration is enforced by Rangers under a general MOU with the Texas Parks and Wildlife Department covering all NPS areas in Texas and initially signed June 26, 1975, and renewed April 4, 1987 (NPS 1975, 1995, pp. 37-38).

**3.3.1 Background.** River corridor units fall into two distinct types, those associated with the Neches River (Upper Neches River Corridor Unit, Neches Bottom and Jack Gore Baygall Unit, Lower Neches River Corridor Unit, Beaumont Unit, and the Little Pine Island Bayou Corridor Unit below the U.S. 69 bridge) and those associated with its tributaries (Pine Island Bayou/Little Pine Island Bayou above the U.S. 69 bridge and Village Creek) and Menard Creek, a tributary of the Trinity River. Because these two type of streams are so different, they will be considered separately as necessary in this and following boating subsections.

Public use is allowed in the water corridors of the Preserve, and boating is a major use of the Preserve, in spite of a limited number of boat ramps and access points to the waterways. Most of the boat ramps are administered by entities other than the NPS (Texas Parks and Wildlife Department, Hardin County, and private individuals). (See Table 4 and Figure 7.) Partly as a result of this, the level of use of these facilities is uncertain (Callaway 1997).

Maintenance personnel visit the two BTNP ramps every month, and perform close visual inspections about once every three months. If possible, they will observe boat launches and converse with boaters to determine if any maintenance actions are required. According to maintenance observations, the Four Oaks-Confluence boat ramp, which was built by NPS, is heavily used. The McQueen's Landing boat ramp, which is very old and accessed by a long dirt road, is less heavily used and is no longer shown on the "Official Map and Guide" for BTNP. The ramps do not require much actual repair or maintenance.

**Table 4. List of Boat Ramps and Water Access Points**
Source: National Park Service, Official Map and Guide, Big Thicket National Preserve, 1997.

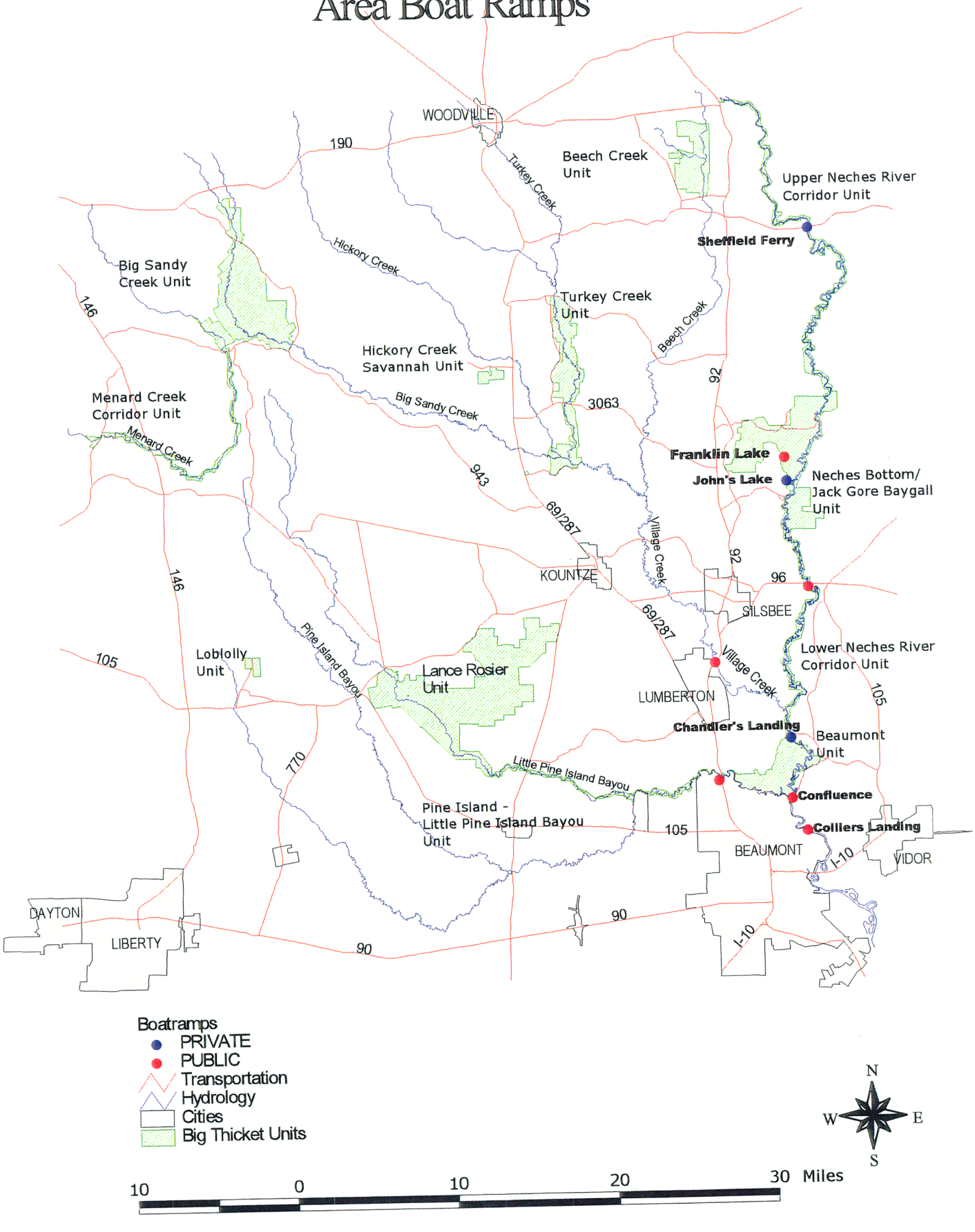
| Facility | Name | Location | Private/Public |
|---|---|---|---|
| Ramp | McQueen's Landing | Neches River below Dam B | Public |
| Ramp | Sheffield Ferry | Neches River @ FM 1013 | Private |
| Access | Unnamed | Neches River @ Jack Gore Baygall | Public |
| Ramp | Franklin Lake | Tributary to Neches River | Public |
| Ramp | Johns Lake | Tributary to Neches River | Private |
| Access | County Park | Neches River off FM 2927 | Public |
| Ramp | TPWD Ramp | Neches River @ SH 96 | Public |
| Ramp | Chandlers Landing | Neches River off FM 1131 (below Lakeview Sandbar) | Private |
| Access | Unnamed | Neches River on confluence road | Public |
| Ramp | Confluence | Neches River @ confluence with Pine Island Bayou | Public |
| Ramp | TPWD Ramp | Pine Island Bayou @ SH 69/96 | Public |
| Ramp | TPWD Ramp | Village Creek @ SH 96 | Public |
| Ramp | TPWD Ramp | Village Creek @ V.C. State Park | Public |

Ranger monitoring is constrained by staff levels. Because of the time required to cover distances between the launch sites, patrol of launch areas is extremely limited.

There is a potential for conflict between motor-boaters (and jet skis) and others (e.g., fishers, swimmers, non-motor-boaters). This can be mitigated by establishment of zones which segregate incompatible activities or minimize incompatibilities through restrictions on boats (horsepower limits), boat operation (such as the no-wake zone at Lakeview), or other activities. Up to 1996, few complaints have been logged in the incident report files, and, except for the Lakeview area, no safety incidents have been reported. Nevertheless, it may be prudent to delineate additional zones before problems arise. It is also desirable to put appropriate mechanisms in place to allow monitoring of public activity and early detection of conflicts that may require delineation of river recreation zones.

Figure 7.

# Area Boat Ramps



Boating also poses potential threats to resources. Wakes can exacerbate bank erosion. Some wake erosion has been noted at Pine Island Bayou, Cook's Lake and along the Neches River (Personal communication with R. Appling, BTNP, NPS, 12 April 1996). Deposition of human feces on sandbars and into the water can potentially create contamination problems. Picnicking on beaches accessible only by boat can result in deposition of trash that is difficult for NPS to collect. Sand bars are visited infrequently by maintenance personnel for cleanup, particularly in the winter season (Personal communication with Ray Martinez, BTNP, NPS). While all these potentially may have resource impacts, they are mostly nuisances or disamenities at current levels of river use. To prevent resource issues from developing, and also to maintain the amenity value of clean waterways and sandbars, regulations need to be posted and widely communicated and sanitary facilities need to be provided at key locations to promote appropriate disposal of trash and human wastes.

There is a potential safety issue related to existence of snags, abandoned oil wells and pipelines. Several structures were noted in field observations (Callaway et al 1993). Lighted warning makers have been suggested as one safety feature. Maps and/or warnings could be included as part of general brochures on boating in BTNP.

Village Creek has the highest concentration of visitor use of the corridor units, and has the potential for problems with vandalism, litter, illegal trespass, and difficulty with public contact. These potential problems also are a concern for The Nature Conservancy of Texas, which owns land along the Creek.

Public use of the water corridors is influenced by canoe liveries operating out of Houston, Beaumont, Kountze, and Silsbee (Callaway 1997). These existing liveries promote public use of the Preserve; at the same time they limit use, since the number of canoes available is limited. (Given the small number of BTNP staff available for monitoring use, a rough estimate of canoe pressure could be gained by having volunteers count cars/boats on Village Creek at Highways 327, 418 or 69.) A foreseeable problem with canoing on Village Creek is parking at put in/take out locations -- some degradation of habitat has been observed around the bridges over Village

Creek in the proposed Village Creek Corridor. Limited parking space also serves as a de facto restriction on the number of boats and canoes in the corridors. This is mitigated in part by use of the Village Creek State Park lot, which requires payment of a $2 state park entry fee (Personal communication with Nelda Overstreet, Timber Ridge Tours). BTNP could limit use by requiring permits for liveries, tour operators, or guides who run fee operations within the preserve. Permitting could also serve as a vehicle to assure that livery operators have appropriate liability coverage and pay attention to regulations that promote visitor safety and resource protection.

**3.3.2 Possible general guidelines.** With respect to boating in the Water Corridor Units, the following alternative strategies are identified:

1) Actively discourage public boating use through promulgation of restrictive policies.

2) Actively encourage public boating use through construction of additional boat ramps and other facilities at access points where appropriate and consistent with use zones of the corridors.

3) Maintain the status quo.

**3.3.3 Recommended general guideline.** The general policy of BTNP with respect to boating use of Water Corridor Units should be to promulgate such policies and regulations that promote safe, enjoyable boating experiences consistent with protection of resources and of quality of the outdoor experience.

**3.3.4 Recommended management actions.**

1) Promote adherence to boat registration and boating safety laws through field interviews initiated by Rangers on a routine/casual basis, as well as routine patrols at strategic places and times.

2) Initiate monitoring programs to track visitor satisfaction and resource quality to provided a basis for identifying the recreational carrying capacity of the corridors.

3) Produce and distribute additional information brochures identifying opportunities for safe

and resource-compatible recreational use. Consider distribution to targeted audiences such as those found at commercial outlets catering to boaters.

4) Acquire the data necessary to assure that biotic resources are not impaired by boating uses. This may be accomplished through transfer from other agencies, contract research, or staff monitoring of populations and bank conditions.

5) Address the use of boats for hunting, trapping and fishing activities in the hunting, trapping and fishing action plan to be prepared as directed by the General Management Plan.

6) Cooperate with other law enforcement agencies to prevent conflicts among users and between users and neighboring land owners from arising.

7) Maintain NPS boat ramps in safe condition with suitable facilities for trash and human waste disposal.

### 3.4 Swimming and Picnicking

**3.4.1 Authority.** The 1916 NPS organic act (16 USC 1) provision for public use and enjoyment can be construed as permissive of swimming and picnicking activities in the water corridors. NPS Management Policies (NPS, 1988, 8:2) specifically recognize swimming and picnicking as recreational activities allowed in parks when authorized, or not specifically prohibited, by federal law. Recreational activities are to be conducted in accordance with federal laws, treaties, and applicable laws of the state in which the park is located and the National Park Service may restrict recreational activities to achieve objectives of the park's resource management plan.

NPS Management Policies (8:3) state that a "river management plan will be developed for each park having significant levels of river use, or the potential for such use." River management plans are intended to prevent unacceptable impacts on aquatic resources. Each plan is required to address the disposal of refuse and human waste.

36 CFR Sec. 1.5 gives the superintendent authority to locally issue limits on activity within parks to further a number of objectives (public safety, resource protection etc.). 36 CFR 3.1 provides that water use activities are governed by Title 14 USC, 33 CFR, 46 CFR and 49 CFR as well as NPS regulations and those of the State; the superintendent is authorized to act as "captain of the port" under federal laws.

36 CFR 3.6 provides a list of prohibited boating operations that includes: (d) and (e) operating a vessel in excess of 5 mph or creating a wake in designated areas of within 100 feet of swimmers, or within 500 feet of a swimming beach.

Sec. 2.11 provides that picnicking is allowed, except in designated areas closed under Sec. 1.5. The superintendent may establish conditions for picnicking and the violation of those conditions in prohibited.

Sec. 3.21 details prohibited activities associated with swimming. The superintendent may restrict activities at designated swimming beaches (Sec. 3.21 (b)).

Big Thicket National Preserve Establishment Act of 1974 [P.L. 93-439] cites the "preservation, conservation, and protection of the natural, scenic, and recreational values of a significant portion of the Big Thicket area in the State of Texas" and "the enhancement and public enjoyment thereof," as the reason for the preserve's creation. Sec. 4(b) provides that "in the interest of maintaining ecological integrity of the preserve" construction of facilities and the use of motorized water vehicles (among other uses) will be limited and controlled.

The BTNP General Management Plan (NPS 1980, pp.16-18) establishes recreation zones within which uses such as swimming are appropriate. Lakeview Sandbar (also called Lakeview Beach) in the Beaumont Unit is the only major swimming site in the Preserve. Two smaller sites on Menard Creek (Holly Grove and Whoop-N-Holler) have traditionally been used for swimming and baptisms. Picnicking/day use sites have been identified at several locations. The Plan provides that no linear hiking trails will be developed along water corridors (p. 49).

The General Management Plan reiterates the limits on recreational development and communicates the philosophy that as many support facilities will be located outside the preserve. There is an implied preference for private development and ownership of these facilities.

The BTNP Final Draft Statement for Management (NPS 1995a, pp. 9-10) mentions swimming in a list of current recreational uses of waters of the Preserve. It also notes that while visitor use is increasing, visitor protection efforts are hampered by underfunding of law enforcement ranger activity (p. 22).

BTNP Standard Operating Procedure 94-7141-02 (Superintendent's Orders) (NPS 1994a) establishes visiting hours for Lakeview Sandbar Day Use Area in the Beaumont Unit (p. 5) and Edgewater Day Use Area on Pine Island Bayou (p. 6) . These areas are closed to public use during "the hours of darkness", defined as 1/2 hour after sunset until 1/2 hour before sunrise and signs are posted with that information (see Table 5). Additional day use areas in the water corridors (see Table 6) are designated for closing from 11 p.m. until 6:00 a.m. daily (p. 7). Alcoholic beverages are prohibited from all of the designated recreational areas (p. 16).

**3.4.2 Background.** Public use is allowed in the water corridors of the Preserve, and swimming and picnicking are traditional uses of the area. Information on the current level of use of the recreational areas is inadequate to determine carrying capacity of the river corridors (Callaway 1997).

Ranger monitoring is constrained by staff levels. Because of the time required to cover distances between the recreational sites, patrol of recreational areas is extremely limited.

There is a potential for conflict between recreational users of the Preserve and neighbors near the recreational areas. For this reason, most of the areas are designated for day use. (See Tables 5 and 6 and Figure 8.) There is also a potential for conflict among users of the Preserve's water resources: motor-boaters (and jet skis) and others (e.g., fishers, swimmers, non-motor-boaters).

**Table 5. Recreational use areas in the water corridors closed during hours of darkness: 1/2 hour after sunset until 1/2 hour before sunrise**

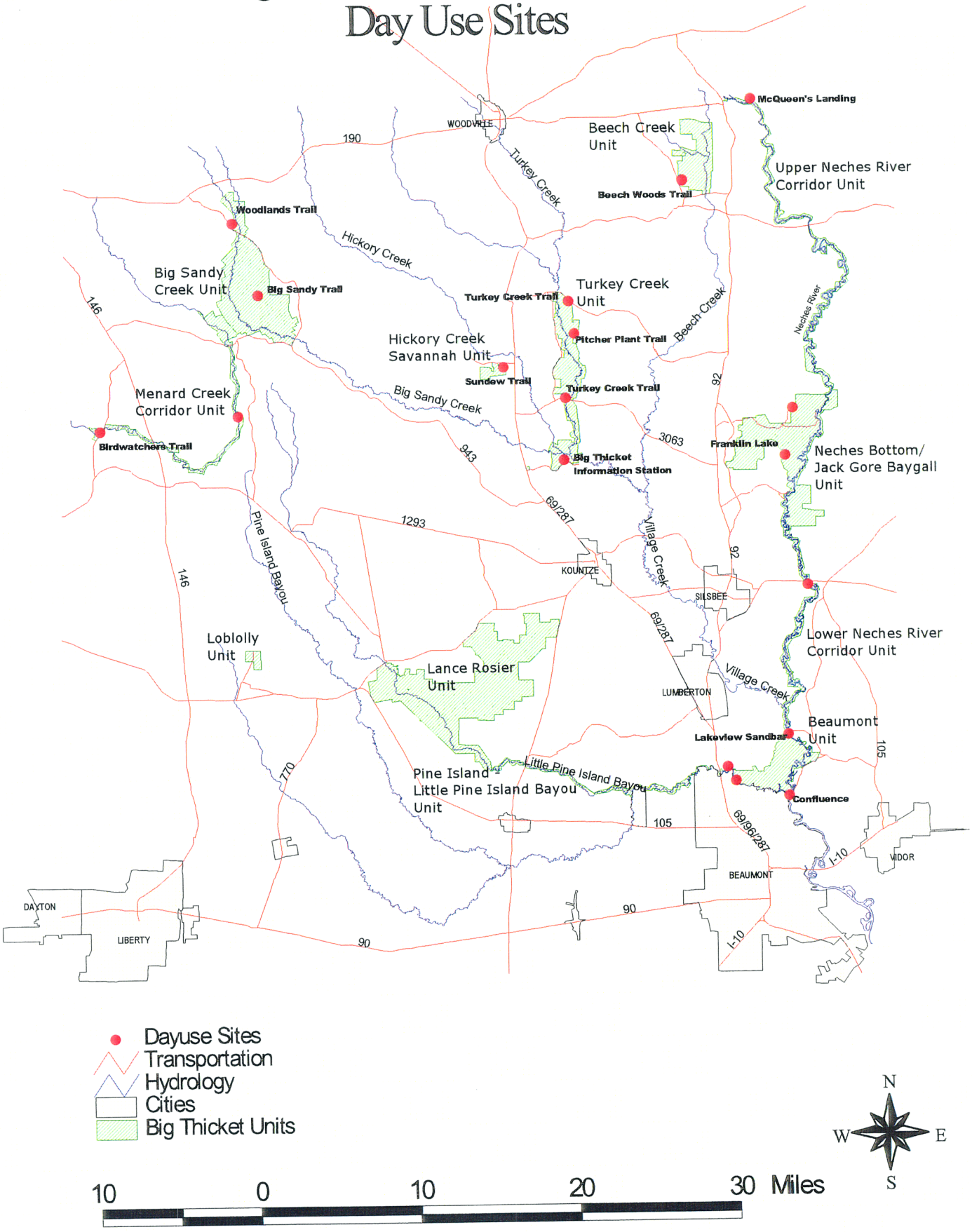
| Unit | Recreational Use Area |
|---|---|
| Beaumont Unit | Lakeview Sandbar (Lakeview Beach) swimming area, west of Booth's Bayou (part of Tract 194-01) |
| Pine Island Bayou/ Little Pine Island Bayou Corridor Unit | Edgewater Day Use Area (part of Tract 189-19) |

**Table 6. Recreational use areas in the water corridors open for public use daily: 6:00 a.m. to 11:00 p.m.; closed 11:00 p.m. to 6:00 a.m.**

| Unit | Recreational Use Area |
|---|---|
| Neches Bottom/ Jack Gore Baygall Unit | Franklin Lake recreational use area<br>Timber Slough Road recreational use area, at Neches River |
| Lower Neches River Corridor Unit | Highway 96 recreational use area, Evadale Bridge |
| Beaumont Unit | Confluence recreational use and boat ramp parking area, Four Oaks Ranch Road<br>Four Oaks Ranch Road recreational use and parking area, Four Oaks Ranch Road |
| Pine Island Bayou/ Little Pine Island Bayou Corridor Unit | Cook's Lake Road recreational use and parking area |
| Menard Creek Corridor Unit | Holly Grove recreational use and parking area<br>Whoop-N-Holler recreational use area |

Figure 8.

# Big Thicket National Preserve Day Use Sites



This can be mitigated by establishment of zones which segregate incompatible uses or minimize incompatibilities through restrictions on boats (horsepower limits) or boat operation (such as the no-wake zone at Lakeview). To 1996, few complaints or safety incidents have been logged in the incident report files, and those which have been filed occur mostly at Lakeview. It may be prudent to put appropriate mechanisms in place to allow monitoring of public activities and early detection of conflicts that may require delineation of river recreation zones.

Swimming and picnicking can be a threat to resources. Human and other waste must be disposed of properly. Picnicking on beaches accessible only by boat can result in trash deposition. While all these potentially may have resource impacts, they are mostly nuisances or disamenities at current levels of river use. So as to prevent resource issues from developing, and also to maintain the amenity value of clean waterways and sandbars, regulations need to be posted and sanitary facilities need to be provided to promote appropriate disposal of trash and human wastes.

**3.4.3 Possible general guidelines.** With respect to swimming and picnicking in the Water Corridor Units, the following alternative strategies are identified:

1) Actively discourage public use through promulgation of restrictive policies.

2) Actively encourage public use through construction of additional facilities as currently designated day use sites and designate additional sites.

3) Maintain the status quo.

**3.4.4 Recommended general guideline.** The general policy of BTNP with respect to swimming and picnicking use of the Water Corridor Units should be to promulgate such policies and regulations that promote safe, enjoyable recreational experiences consistent with protection of resources and of quality of the outdoor experience.

**3.4.5 Recommended management actions.**

1) Promote adherence to Preserve visitor use and safety regulations through casual field

interviews initiated by Rangers on routine patrol, as well as by regular patrols at strategic places and times.

2) Initiate monitoring programs to track visitor satisfaction and resource quality, so as to identify the recreational carrying capacity of the corridors.

3) Produce additional information brochures identifying opportunities for safe and resource-compatible recreational use.

### 3.5 Camping

**3.5.1 Authority.** Camping is recognized as a legitimate park use under certain circumstances. NPS Management Policies (NPS 1988a, 8:2) provide that recreational camping will be allowed in parks when authorized, or not specifically prohibited, by federal law. Camping may be restricted by the National Park Service to "protect park resources, provide for public enjoyment, promote public safety, and minimize conflicts with other visitor activities and park uses" (8:2).

NPS Management Policies (8:3) define "backcountry" as primitive, undeveloped portions of parks. Within these areas the number and types of facilities, including sanitation facilities, to support visitor use are to be very limited (8:3,4). A backcountry management plan must incorporate management strategies to prevent unacceptable impacts of visitor use (8:3). The Policies provide that NPS will: (1) identify acceptable limits of impacts; (2) monitor backcountry use levels and resource conditions; and (3) take prompt corrective action when unacceptable impacts occur (8:3). Backcountry campsites may be permitted within acceptable limits of use (9:13).

In some circumstances, NPS Management Policies provide for "boaters' campgrounds in parks with waters used for recreational boating" (9:13). These campgrounds are to be considered only after considering: the type of water body; the availability and resiliency of potential campsites; the feasibility of providing and maintaining docking, beaching, mooring, camping, and sanitary facilities; and potential impacts on park natural and cultural resources (9:13).

36 CFR Sec. 1.5 gives the superintendent authority to locally issue limits on activity within parks to further a number of objectives (public safety, resource protection etc.). Sec. 2.10(a) specifically provides that the superintendent may require permits, designate sites or areas, and establish conditions for camping.

Prohibited activities include:

(1) digging or leveling the ground at a campsite;
(2) leaving camping equipment, site alterations, or refuse after departing from the campsite;
(3) camping within 25 feet of a water hydrant or main road, or within 100 feet of a flowing stream, river or body of water, except as designated;
(4) creating or sustaining unreasonable noise between the 10:00 p.m. and 6:00 a.m.
(5) installing permanent camping facilities;
(6) displaying wildlife carcasses or other remains, except as provided in Sec. 2.2, wildlife protection;
(7) connecting to a utility system, except as designated;
(8) failing to obtain a permit, where required;
(9) violating conditions established by the superintendent;
(10) camping outside of designated sites or areas.

Big Thicket National Preserve Establishment Act of 1974 [P.L. 93-439, Sec. 1(a)] states that one of the purposes of the Preserve is to protect natural, scenic, and recreational values of the area and to provide for enhancement and public enjoyment of the Big Thicket. Public use may be restricted to certain areas or times for reasons of human safety, administration, resource protection, or public use and enjoyment.

The BTNP General Management Plan (NPS 1980, p.50) states that "general development for camping is not planned". Backcountry primitive camping is allowed in designated units of the Preserve -- within the water corridors, only the Neches Bottom/Jack Gore Baygall Unit was named as a backcountry camping area. A primitive camping area is identified within that area; a self-contained toilet is the only facility envisioned (p. 80).

The BTNP Final Draft Statement for Management (NPS 1995a) does not mention camping in its discussion of public use of the Preserve.

BTNP Standard Operating Procedure 94-7141-02 (Superintendent's Orders) (NPS 1994a) Sec. 2.1 pertains to camping. Areas open to backcountry camping include, among others, the Beaumont Unit, Neches Bottom/Jack Gore Baygall Unit; sandbars along the Neches River within the Preserve boundary; and islands within the Neches River (p. 12). Camping is prohibited on three sandbars which are designated for more intensive day use: Lakeview sandbar, the sandbar in Orange County directly across from Lakeview, and the sandbar located at the eastern end of Timber Slough Road in Hardin County (p. 13). During hunting season (October 1 through January 15) all of the Neches Bottom/Jack Gore Baygall Unit is closed to camping; portions of the Beaumont Unit and all of the Neches River units are open to camping year-round (p. 12).

Permits are required in advance for backcountry camping (p. 13). Permits, with accompanying conditions for use, are issued in person only to a member of the party, or to the holder of a Commercial Use License expressly authorizing this activity (p. 13).

**3.5.2 Background.** Only backcountry camping is allowed within the BTNP. This is consistent with the purposes of establishing the park as a natural preserve. The General Plan calls for minimal development within the park (p.50). Through participation with state and local groups dealing with tourism and recreation, such as the Southeast Texas Partnership for Tourism, Recreation and the Environment, the NPS has encouraged the development of supporting services outside the boundaries of the Preserve (Callaway 1995, 1997).

Within the water corridors, backcountry camping on the banks and islands of the Neches River has been permitted as a continuance of local custom. No developed facilities are provided at these locations. The current density of campers does not appear to pose a problem, although litter can create eyesores.

There is a potential for user conflict between campers and hunters in the units near the water corridors. Visitor safety during hunting seasons, especially for campers, is dealt with by the prohibition of hunting within 500 feet of roads and watercourses, the prohibition of loaded guns in boats, and the prohibition of backcountry camping in the Neches Bottom/Jack Gore Baygall Unit during hunting season.

Although there is a body of literature indicating that visitor density affects the quality of backcountry visits (see for example, NPS 1989), no quantitative data exist to establish a density of camping use of the banks and islands of the Neches River, nor have staff resources allowed for surveys of visitor satisfaction. Field observation by rangers and research personnel indicates that densities are low at present and are not likely in the near future to exceed a level which would impact the quality of visitor experience or resource protection.

**3.5.3 Possible general guidelines.** With respect to backcountry camping in the Water Corridor Units, the following alternative strategies are identified:

1) Allow backcountry camping in accordance with existing regulations.

2) Further restrict numbers of backcountry camping permits issued.

3) Encourage backcountry camping by increasing parking and other facilities that give access to the backcountry.

**3.5.4 Recommended general guidelines.** Backcountry camping should be allowed in the river corridor units in accordance with established policy, with any additional restrictions as necessary to protect water quality and bank stability, visitor safety, and a strong land/water and resource protection ethic.

**3.5.5 Recommended management actions.**

1) Promote adherence to applicable backcountry camping regulations through casual field interviews initiated by Rangers on routine patrols.

2) Promote safety of campers by continuing to provide educational materials and signage, particularly at river access points.

3) Acquire the data necessary to assure that resources in visitor use areas are adequately protected. The necessary information can be acquired through (1) annual review of records and

incident reports; (2) annual visual assessment of trash loads and camper impact on sandbar vegetation and bank conditions; and (3) water quality monitoring at sites near camping areas.

4) Adopt formal name for the two unnamed sandbars on which backcountry camping is prohibited to better communicate with the public.

5) Review and update the Backcountry Camping Management Plan periodically -- at least once every five years.

### 3.6 Houseboats in the BTNP

**3.6.1 Background.** Houseboats are a special case of boating use of the Preserve. Houseboats (Fed. Reg. Vol. 61, P. 28530, June 5, 1996) have been permanently moored on the Neches River and its tributaries within Preserve boundaries, relatively unregulated, since before creation of the Preserve. The majority of houseboat owners have been identified by BTNP staff as local residents. Reportedly, the number of houseboats has increased in recent years; however, systematically collected data to document that trend are not available.

Until recently, specific regulations or policies to limit or control houseboat activities in the Preserve did not exist. However, boating regulations such as those pertaining to sanitation and refuse, fire extinguishers, and personal flotation devices on board also apply to houseboats. It has been proposed that all houseboats within the Preserve be required to obtain a permit and post a decal visible to Preserve personnel from the water (NPS 1994a). In 1995, regulations for houseboats in the Preserve were proposed in order to strengthen the Preserve staff's ability to manage impacts of houseboats. NEPA procedures for analysis, review and comment were initiated and proposed regulations were published in the June 5, 1996 issue of the Federal Register (Vol. 61, p. 28530).

**3.6.2 Impacts to water corridor resources.** The presence of houseboats threatens habitat resources in several ways. Mooring and access practices result in damage to surrounding vegetation and in bank erosion. Water pollution (discharge of sewage, animal and fish remains,

etc.), and poaching of fish and game have been reported. Houseboats are a source of noise pollution in backcountry areas and many are aesthetically displeasing to other Preserve visitors. By permanent or semi-permanent mooring, the houseboats prevent other visitors access to some parts of the Preserve. Houseboats can be a safety hazard to other boaters, and many are unsafe to their occupants. Law enforcement personnel have voiced concerns about the suspected use of houseboats as a platform or vehicle for activities which may include poaching, illegal fishing, illegal drug use and other unlawful activity.

**3.6.3 Considerations for NPS research plan.** To deal with the problem of houseboats, NPS needs:

1) a field survey to confirm houseboat presence in tributaries to as well as the main channel of the Neches River; and

2) documentation of negative impacts of houseboats (water quality samples; photos of damaged shoreline vegetation; law enforcement incidents reports) to support enforcement activities.

**3.6.4 Recommended management actions.** Several actions may help the NPS address the houseboat issue:

1) Work with TNRCC and LNVA on water quality sampling to determine impacts of houseboats.

2) Increase Ranger presence to document impacts of houseboats and discourage unlawful activities.

3) Work with State and Federal law enforcement agencies re possible drug activities.

4) Rigorously enforce regulations to control impacts within the Preserve.

5) Issue no permits for houseboats not currently located within the Preserve and do not allow replacement of existing houseboats.

### 3.7 Mineral Extraction and Transport

The Big Thicket area historically has been the scene of oil and gas extraction and transport activities. These historical uses were recognized in the legislation authorizing creation of the Preserve. A number of active or abandoned wells and oil and gas pipelines are present within the Preserve. A total of 32 pipelines have been identified within the Preserve, with an additional seven within one mile of the boundaries of the BTNP (NPS 1996). Some of these facilities are in or near the water corridors.

Meander of the Neches River has resulted in some abandoned wells originally located on the shore now lying within the bounds of the river. The structures for these wells are now a hazard to boaters. Similarly, pipelines crossing the river may be a boating hazard when they lie near the surface or above water at the river banks. The records floods of October 1994 and the related pipeline spills and fire in the Houston area underscore the danger of pipeline operations in a flood hazard area. Petroleum or petrochemical spills in the waterways could do considerable harm to the area's water quality, aquatic habitat, and aquatic life, as well as negatively impacting public use of the Preserve. Although any of the water corridors could be affected, the Neches River, because of its size, may represent the greatest flood hazard to oil and gas facilities and be most at risk of pipeline spill or fire catastrophe.

Pipeline facilities may also have an impact because of clearing activities or fragmentation of habitat, although this is possibly a greater problem in upland areas than in the water corridors. The effects of fragmentation on floodplain forest habitat were discussed above in section 2.8.

**3.7.1 Impacts to water corridor resources.** The most likely impact of oil and gas activities to BTNP habitat resources is the fragmentation of habitat resulting from the construction of structures or land clearing related to operations. Oil and gas activities may impact the habitat resources of the water corridors through impairment of water quality from spills. The risk of fire associated with a spill also represents a threat to species resources.

In addition to potential impacts on habitat and species resources, the presence of pipeline crossings and abandoned wells in the streams is an administrative issue because of human use of the Neches River and a concern for boater safety.

**3.7.2 Considerations for NPS research plan.** There are no specific additional information needs identified at this time.

**3.7.3 Recommended management actions.** Several actions could aid the NPS in addressing the potential impacts of oil and gas activities in the Preserve:

1) Review BTNP Oil and Gas Management Plan for responsiveness to resource and administrative concerns.

2) Work with oil and gas and pipeline companies to develop appropriate operating plans for their activities in the BTNP.

3) Work with other agencies and oil and gas industry to develop appropriate standards for pipelines in sensitive or hazardous locales.

### 3.8 Trash and Waste Disposal

**3.8.1 Authority.** Provision in the NPS organic act (16 USC 1) for public use and enjoyment can be construed as permitting activities that are necessary for public use in the water corridors. NPS Management Policies (NPS 1988a, 8:3) state that a "river management plan will be developed for each park having significant levels of river use, or the potential for such use." River management plans are intended to prevent unacceptable impacts on aquatic resources. Each plan is required to address the disposal of refuse and human waste.

36 CFR Sec. 1.5 gives the superintendent authority to locally issue limits on activity within parks to further a number of objectives (public safety, resource protection etc.). Sec. 2.11 provides that picnicking is allowed, except in designated areas closed under Sec. 1.5. The

superintendent may establish conditions for picnicking and the violation of those conditions is prohibited.

Big Thicket National Preserve Establishment Act of 1974 [P.L. 93-439] cites the "preservation, conservation, and protection of the natural, scenic, and recreational values of a significant portion of the Big Thicket area in the State of Texas" and "the enhancement and public enjoyment thereof," as the reason for the preserve's creation. Sec. 4(b) provides that "in the interest of maintaining ecological integrity of the preserve" construction of facilities and the use of motorized water vehicles (among other uses) will be limited and controlled.

The BTNP General Management Plan (NPS 1980, pp.16-18) establishes recreation zones. The General Management Plan reiterates the limits on recreational development and communicates the philosophy that as many support facilities will be located outside the preserve. There is an implied preference for private development and ownership of these facilities.

**3.8.2 Background.** Public use is allowed in the water corridors of the Preserve. Human and other waste must be disposed of properly. Picnicking on beaches accessible only by boat can result in trash deposition. While all these potentially may have resource impacts, field reconnaissance (Callaway et al 1993) indicates that they are mostly nuisances or disamenities at current levels of river use. (BTNP maintenance personnel report that collections from the entire Preserve amount to two four-cubic-yard dumpsters filled up each week; Personal communication with Ray Martinez, BTNP, NPS.) To prevent resource issues from developing, and also to maintain the amenity value of clean waterways and sandbars, regulations need to be posted and sanitary facilities need to be provided to promote appropriate disposal of trash and human wastes.

BTNP Maintenance Division staff routinely provide for trash and waste collection. The dispersed nature of the Preserve units would make it difficult to contract privately for these services. Disposal services are contracted when possible.

**3.8.3 Possible general guidelines.** Alternative strategies for trash and waste disposal are limited to the level of service and whether providers will be NPS employees or contractors. Trash and waste disposal services of some type must be provided when visitors and employees have access to the Preserve.

**3.8.4 Recommended general guidelines.** The general policy of BTNP with respect to trash and human waste disposal should be to provide only those facilities which are required to support levels of use that will not pose a threat to natural resources. Planning for these services also should take into account the related issues of littering, dumping and vandalism (see section 3.10). Waste disposal should be carried out in a manner that meets all state and federal environmental regulations. To the extent practicable, facilities for waste disposal should be sought outside the limits of the Preserve.

**3.8.5 Recommended management actions.**

1) Post information promoting appropriate disposal of trash and human wastes.

2) Provide trash and human waste disposal facilities at day use sites.

3) Continue to provide regular cleaning and maintenance of waste disposal facilities.

4) Contract for off-Preserve disposal of wastes whenever possible.

5) Work with other jurisdictions to develop alternative disposal sites.

**3.9 River Access**

**3.9.1 Background.** A provision of the General Management Plan dictates that no linear trails will be developed in the water corridors. This, coupled with the small number of streamside sites suitable for development as day use areas included within the Preserve, confines public enjoyment of the water corridors principally to on-the-water activities. Current access to the water corridors is mainly at road and bridge crossings. A very few boat ramps, most privately

owned, provide launching facilities (see Table 4 and Figure 7). A few day use areas provide viewing, and in some instances, swimming opportunities (see Tables 5 and 6 and Figure 8).

This limitation of facilities for access has both positive and negative aspects. On the positive side, limiting the number and size of facilities serves as a constraint on the number of visitors to the water corridors and decreases the pressure of human use on the natural resources. It also minimizes the amount of habitat fragmentation caused by development of such facilities. On the negative side, current limitations on access may restrict use of the Preserve unnecessarily. It is possible that public use, and thus public recognition of the Preserve, could be increased beyond current levels without seriously impairing the quality of the natural resource if facilities were carefully developed.

**3.9.2 Possible general guidelines.**

1) Increase river access by developing sites within the Preserve for canoe and boat launch or day use and/or cooperatively advertising private launch areas.

2) Control river access by restricting development of new sites for public access.

3) No change in current river access.

**3.9.3 Recommended general guideline.** Provide a limited number of high-quality day use and canoe and boat launch facilities to provide public access to the water corridor units while minimizing disturbance to the natural area.

**3.9.4 Recommended management actions.**

1) Maintain or improve current facilities in condition for safe public use.

2) Review General Management Plan and current circumstances to determine if any additional facilities can be developed consistent with protection of the natural resources.

**3.10 Littering, Dumping and Vandalism**

**3.10.1 Authority.** Provision in the 1916 NPS organic act (16 USC 1) for public use and

enjoyment can be construed as a mandate to maintain the Preserve in a natural condition, free of human trash and litter that detract aesthetically or functionally from public use and enjoyment of the resource.

NPS Management Policies (NPS 1988a) specifically addresses trash and litter management in a number of areas.

- Trash disposal and other operational activities are to be operated out of public view of cultural landscapes to the maximum extent feasible (5:6).
- Refuse may not be disposed of in backcountry areas; it is to be carried out. No refuse containers are to be provided by the NPS in backcountry areas. A limited amount of burning of refuse in backcountry areas is allowed if appropriate. (8:4)
- "Solid waste disposal on NPS lands is incompatible with the purpose for which the land was acquired or is being managed; therefore, every effort will be made to dispose of solid waste outside of NPS managed lands using approved regional landfills." (9:6)
- Utilitarian facilities such as solid waste disposal sites, if necessary within a park, are to be sited in remote locations low in resource value (9:16).
- NPS Management Policies (8:3) state that a "river management plan will be developed for each park having significant levels of river use, or the potential for such use." River management plans are intended to prevent unacceptable impacts on aquatic resources. Each plan is required to address the disposal of refuse and human waste.

36 CFR Sec. 1.5 gives the superintendent authority to locally issue limits on activity within parks to further a number of objectives (public safety, resource protection etc.). Sec. 1.5 provides that the superintendent may issue permits to impose a public use limit or establish conditions for activities that are restricted.

36 CFR 2.14(a) prohibits:

(1) disposing of refuse in other than refuse receptacles.
(2) Using government refuse receptacles or other refuse facilities for dumping household, commercial, or industrial refuse, brought as such from private or municipal property, except in accordance with conditions established by the superintendent.
(3) Depositing refuse in the plumbing fixtures or vaults of a toilet facility.
(6) Polluting or contaminating park area waters or water courses.

(7) Disposing of fish remains on land, or in waters within 200 feet of boat docks or designated swimming beaches, or within developed areas, except as otherwise designated.

Big Thicket National Preserve Establishment Act of 1974 [P.L. 93-439] cites the "preservation, conservation, and protection of the natural, scenic, and recreational values of a significant portion of the Big Thicket area in the State of Texas" and "the enhancement and public enjoyment thereof," as the reason for the preserve's creation. Sec. 4(b) provides that "in the interest of maintaining ecological integrity of the preserve" construction of facilities (among other uses) will be limited and controlled.

The BTNP General Management Plan (NPS 1980) deals with refuse and sanitation facilities as part of its general discussion of public use areas -- interpretive or recreational subzones. The General Management Plan reiterates the limits on recreational development and communicates the philosophy that as many as possible support facilities will be located outside the preserve. There is an implied preference for private development and ownership of these facilities.

The BTNP Final Draft Statement for Management ( NPS 1995a, pp. 9-10) cites the dumping of appliances, rubbish and other undesirable items by private landowners on both private and Preserve land in attempts to stabilize banks as a detriment to aesthetic and scenic values and possibly a health and safety hazard to users of the waterways. The Statement for Management discusses flooding and its contribution of litter and nonpoint source pollution to the water corridors (p.10).

BTNP Standard Operating Procedure 94-7141-02 (Superintendent's Orders) (NPS 1994a) append backcountry use regulations to the backcountry camping permit. These regulations dictate that all trash and garbage must be packed out.

**3.10.2 Background.** The dumping of solid waste in rural areas has a long history--dating from county "dumps" that accepted household solid waste. One result of regulations designed to clean up county dumps in Texas was that many counties closed these facilities and householders

turned to undesignated sites for disposal of their trash. The dumping of household refuse such as furniture, appliances, etc. on remote land persists in the Big Thicket area. This presents obvious problems of aesthetics, water quality degradation, and habitat destruction. Since trash accumulations attract additional trash, rapid removal of litter and trash helps keep a littering problem from worsening. One problem area has been identified in the BTNP -- an area near Cook's Lake Road near the park boundary where a culvert at Canal Road discharges from a residential area, trash floats down or is dumped. This affects the Little Pine Island Bayou Corridor, with accumulated trash visible when vegetation is down (Personal communication with Ray Martinez, BTNP, NPS). Another particular concern within the Water Corridors is the disposal of waste from houseboats moored in the Preserve, as discussed above in section 3.6.

A related problem involves unauthorized dumping of building materials and other items to serve as rip-rap in an attempt to stabilize eroding banks. This is particularly prevalent along the Neches River in areas where there are homes along the bank (Callaway et al 1993). The impact of this practice on stream banks has been discussed in section 2.7.

Littering is associated with public activities in the Preserve, particularly swimming and picnicking. A particular issue with respect to the Water Corridors is litter left on sandbars and islands in the Neches River. This type of littering presents a special kind of problem because these areas are not developed and are operated under backcountry rules -- pack it in, pack it out. At current levels of visitor activity, volunteer clean-ups such as that of the state Clean Rivers Program sponsored locally by the Lower Neches Valley Authority or other volunteer efforts can provide substantial assistance.

In some instances, efforts by the NPS to provide appropriate disposal facilities have been thwarted by persistent vandalism. For example, the designated primitive camping area near Timber Slough Road once included a self-contained toilet and trash receptacles. These were removed because of repeated incidents of vandalism (Personal communication with R. Appling, BTNP, NPS, 12 April 1996).

**3.10.3 Possible general guidelines.** With respect to littering, dumping and vandalism in the Water Corridor Units, the following alternatives are identified:

1) Actively discourage littering and dumping by prosecuting violators.

2) Actively encourage appropriate disposal by increasing the number of trash receptacles at day use sites and working with local jurisdictions to improve opportunities for appropriate disposal sites outside the Preserve.

3) Maintain the status quo.

**3.10.4 Recommended general guideline.** The general policy of BTNP should be to eliminate littering, dumping and vandalism problems which threaten resources and diminish the quality of the outdoor experience through providing facilities in appropriate areas, and through education and enforcement of regulations.

**3.10.5 Recommended management actions.**

1) Remediate existing trash dump sites by removing trash and restoring habitat whenever possible.

2) Promote compliance with Preserve regulations by intensifying Ranger patrols at strategic places and times.

3) Encourage volunteer trash cleanup programs in the water corridors such as those under the state Clean Rivers Program administered in the Big Thicket area by the Lower Neches Valley Authority.

4) Expand cooperative efforts with local anti-litter and beautification organizations.

5) Include anti-litter information in visitor information brochures.

6) Provide trash receptacles in appropriate areas.

### 3.11 Illegal Collection of Plants

In 1990, 99 species of native plants were known to have been illegally collected in 37 NPS units nationwide; in 1991, 88 species were taken from 41 NPS units. Although the presence of rare plants indicates that illegal collection could be a potential problem for the Preserve, there are no known incidents of illegal collection in the water corridors. This is not thought to be a serious problem in the Big Thicket water corridors at this time.

**3.11.1 Impact to water corridor resources.** Illegal collection of plants is a potential threat to species resources. No location in the BTNP has been identified as particularly vulnerable at present. Impact on the water corridors is thought to be minimal.

**3.11.2 Recommended management actions.**

This is a potential future problem, so the NPS can prepare for future management needs by 1) reviewing preventive measures taken at other similar NPS facilities or other preserves; and 2) monitoring plant resources and documenting evidence of any plant removal to signal a need for further management actions.

**3.11.3 Considerations for NPS research.** The NPS needs baseline inventory information on its plant resources.

## 4.0 Partnership Challenges

Partnership challenges deal with topics that involve the areawide setting of BTNP, its borders, neighbors and other institutions. All NPS facilities have neighbors with whom they must coexist; partly because of its physical configuration, BTNP has a large number of external contacts that are necessary to accomplish Preserve objectives.

### 4.1 Air Quality/Fire Management

Studies by Egan and Gordy (1981) and Gordy (1986) of lichens in the BTNP found no negative effects on populations or distributions directly attributable to air quality. An air quality monitoring station was established by the NPS in the Turkey Creek Unit in 1985 to monitor sulfur dioxide and ozone concentrations and related climatological data, and has found that significant ozone events occur during the summer months.

Prescribed burning is reported to be an effective resource management tool that may be less available under currently developing air pollution control regulations. A large part of the Big Thicket is located within an Air Quality Maintenance Area (an area in which some air quality standards are not met) subject to regulation under the federal Clean Air Act and its amendments. As a result, fire management techniques that traditionally have been available for forest and range resource management have been curtailed by restrictions on outdoor burning promulgated by the Texas Natural Resource Conservation Commission (TNRCC) and the U.S. Environmental Protection Agency. Current air pollution control regulations incorporate a concept of limiting total emissions within an airshed. Restricting outdoor burning could be used to offset additional emissions from other sources. Petrochemical industries and forest products industries in southeast Texas are major sources of emissions that influence air quality in the BTNP area.

The restrictions on outdoor burning may have considerable impact on forest and rangelands bordering the corridor waterways. Prescribed burning is not considered to be extensive within the water corridors, thus the impact of changes in regulations affecting fire management is expected to be minimal within the corridors.

**4.1.1 Impacts to water corridor resources.** Restricted burning for management purposes may affect both habitat (air quality and forest snags) and species (birds, mammals and reptiles) resources. Fire management is not thought to be particularly important within the water corridors.

**4.1.2 Recommended management actions.** Several possible management actions could improve response to the issue of fire management under current air quality regulations:

1) BTNP staff should participate in regional and state air quality planning efforts so that NPS views are known to regulators. Sound scientific data should be used to show that prescribed burns are beneficial and that the impacts of prescribed burns are acceptable.

2) Cooperative efforts with the timbering and agricultural communities, such as seminars, to provide scientific information to the public and regulators should be pursued.

3) Continued/expanded air quality monitoring would contribute to scientific data base available to resolve this issue. Given NPS budgetary constraints, funding from the Texas Natural Resource Conservation Commission or from the U.S. Environmental Protection Agency should be explored to assist in supporting this activity.

**4.1.3 Considerations for NPS research plan.**

1) Proponents of prescribed burning question the accuracy of models used by regulators to characterize the impacts of those burns and suggest the models lead to needlessly restrictive policies. Additional information may be needed to improve the characterization capabilities of those models. BTNP can collect sound scientific data on the air quality impacts of prescribed burns in the Preserve.

2) To the extent its resources allow, BTNP should continue or expand air quality monitoring to contribute to the scientific data base available to resolve issues of fire management and air quality.

3) In other geographic areas, aerial deposition of toxics to waters is a growing concern. If water quality analyses at BTNP indicate the presence of toxics, the relationship between air and water quality may become a topic of needed research.

### 4.2 Neighboring Land Uses

The BTNP, and particularly the water corridor units, have very long "edges" where privately-owned lands abut the Preserve. A number of land uses with potential negative effects exist or are expected in neighboring area:

residential development (primary and secondary);
timbering operation (commercial and private);
industrial development (oil and gas; forest products);
agriculture;
publicly-owned facilities (e.g. water diversion, sewage treatment facilities).

Negative effects such as rip-rap, trash dumping, and sewage runoff from streambank development have been observed in field reconnaissance (Callaway et al 1993). Air and water pollution and the introduction of domestic pets and exotic species to the natural environment also are possible consequences of neighboring uses. As the southeast Texas area grows and becomes more urban, it is likely that challenges to avoid conflicts over external uses affecting the Preserve also will grow.

Residential development in the area of the BTNP would generally be called rural; however, there are several higher density subdivisions more typical of suburban areas (e.g. Wildwood). Particularly when these developments are situated along the banks of the rivers and streams of BTNP, conflicting values can come into play.

An extremely unusual meteorological event in October 1994 resulted in massive flooding in the area, including about 300 homes in the Bevil Oaks subdivision near the Pine Island/Little Pine Island Bayou Water Corridor. This flood was the second to occur within a few years and the last in a long sequence of less severe flooding. Many of the homes are in the 100-year flood plain. At least two U.S. Army Corps of Engineers' studies have been issued on the subject of how to

alleviate flooding in the area, neither finding a benefit/cost ratio sufficient to warrant a project on the bayou (U.S. Army COE 1975, 1985). A number of Bevil Oaks homeowners believe that alterations to the bayou can prevent future floods from occurring. They are particularly interested in the removal of snags, which they contend jam flows and contribute to flooding (NPS 1994b). Because snags as important habitat for aquatic species (see discussion in sections 1.5 and 2.6) and stream modifications to increase flood carrying capacity might conflict with the NPS mandate to maintain the resource in pre-European settlement condition, NPS has been unable to meet their requests. A group of homeowners continues to discuss with NPS the possibility of altering the bayou as a way to alleviate flooding. Nevertheless, in November 1996, a few of the residents filed a class-action lawsuit against the NPS and other agencies who operate in the area requesting compensation for flood damages. The potential for this type of conflict increases as more tracts bordering the Preserve are subdivided for suburban development.

The timber industry is a major factor in the economy of East Texas. In terms of potential impact on Preserve resources, timbering is probably the most important land use in areas surrounding the BTNP. Of neighboring land uses, timbering accounts for about 95% of the land area. The effects of timber cultivation and harvesting have been examined in a number of southeastern U.S. settings (Shaw, 1995, in Hall and Bruce, 1996; Carraway and Norris, 1996). Among the potential impacts of this land use are: 1) land clearing, resulting in invasion of exotic species of vegetation, decreased food and cover for native animals, increased erosion, decreased shade for streams, and increased runoff pollution, including chemicals, sediment and debris; and 2) road and bridge construction and use, resulting in erosion at stream crossings, increased runoff pollution to streams, changes to drainage patterns and stream circulation, and increased fragmentation of habitat. Directly relevant to the water corridors, a study of forestry "best management practice" compliance and effectiveness in East Texas found that 1) erosion associated with stream crossings of logging roads was the most significant water quality problem encountered (Lord et al. 1992, cited in Shaw, 1995, in Hall and Bruce, 1996) and 2) of the 162 sample sites, 88% received ratings of fair or better on best management practices.

Additional issues related to timbering include unauthorized use of public land (encroachment

onto BTNP lands), safety concerns relative to hunting clubs on neighboring timber industry land, and use by the public of private timber company roads to access BTNP facilities. All BTNP corridor units appear to have a substantial amount of neighboring timbering activities.

The industrial base of southeast Texas is mostly concentrated to the south and east of the BTNP. There are industrial developments, mostly related to the timber industry, at sites that are near or border the Preserve. The paper mill located at Evadale has raised concerns about pollution of the Neches River (see discussion of water quality in sections 1.5 and 2.4). Continued development of privately-owned lands abutting the water corridors of the BTNP holds the potential to adversely affect BTNP resources. GIS capability is currently being developed by the NPS to monitor uses and ownership of lands neighboring the Preserve.

**4.2.1 Impact to water corridor resources.** Neighboring land uses have a significant local effect on habitat resources (water quality, streambank condition, aesthetics). Potential future development may result in more widespread impacts.

**4.2.2 Recommended management actions.** Because neighboring land uses are beyond the direct control of the NPS, cooperative efforts are needed.

1) Education and partnership programs with area residents and organizations should continue.

2) Special efforts to work cooperatively with timber companies in the area should be continued to avoid potential adverse impacts of this prevailing neighboring use.

3) Law enforcement activities may need to be expanded.

**4.2.3 Considerations for NPS research.** To address impacts of neighboring land uses, two types of information are needed.

1) Information on changes in current land use and periodic documentation of any negative effects of those uses is needed. The baseline inventory of neighboring uses for the Neches River corridor should be maintained and expanded to other corridors.

2) Research on specific effects of neighboring land uses on natural resources is needed.

### 4.3 Public Use of Private Lands/Trespassing

The BTNP has very long borders relative to the size of Preserve acreage. This configuration plus the backcountry nature of the Preserve makes it possible for visitors to BTNP to trespass on private lands neighboring the NPS lands. The water corridors, where in many cases lands abutting the waters are privately held, are particularly subject to this occurrence. This problem, which applies to all border areas of the Preserve, has the potential to create conflicts with BTNP neighbors.

At current levels of park use, the number of complaints of trespass are few. This problem may increase in severity as park use increases.

**4.3.1 Impact on water corridor resources.** There appears to be no current impact on water corridors.

**4.3.2 Recommended management actions.** Although this is not currently a serious problem within the water corridors, several preventive actions can be taken:

1) Increase and improve boundary markings in a way that does not detract from the backcountry experience for Preserve visitors. Uniform boundary markings might be more recognizable and would lend identity to BTNP lands.

2) Educate visitors about BTNP area and boundaries.

3) Work cooperatively with The Nature Conservancy of Texas and state and local law enforcement agencies to monitor trespass problems along Village Creek.

4) Increase Ranger presence.

**4.3.3 Considerations for NPS research.** Monitor incident reports for any increasing occurrences of trespass incidents so that appropriate actions can be taken when needed.

### 4.4 Salt Water Barriers on the Neches River and Little Pine Island Bayou

"The Lower Neches Valley Authority has submitted an application for a Department of the Army

permit to install temporary steel sheet piling salt water barriers, when needed throughout a three year period, in the Neches River at an area located between stream mile 33.5 and stream mile 35.0 and in Pine Island Bayou at or near stream mile 3.0, near Beaumont in Jefferson County, Texas" (U.S. Army COE, 1992). These sites are within the BTNP.

The saltwater barriers are needed to protect fresh water diversion points of the LNVA when water levels are low in Sam Rayburn Reservoir preventing releases of fresh water to combat upstream movement of saltwater. The temporary barriers are intended to be removed when lake elevations increase.

The need to prevent saltwater encroachment upstream is a recurring situation and "temporary" barriers have been used for many years (reportedly 36 times since 1944 in Pine Island Bayou, staying up for 3 days to 11 months) generating a considerable amount of negative public sentiment and subsequent debate. A long-term solution to the saltwater intrusion problem that has been proposed is a permanent saltwater barrier lower on the Neches River, below the confluence with Pine Island Bayou, and outside the boundaries of the BTNP. LNVA estimates that the permanent barrier would cost 20 times the average annual cost of using temporary barriers.

At public hearing in January 1993, LNVA summarized six issue areas that had been raised during public discussion:

1) Trapping fresh water fish downstream.
2) Steel cables anchored to trees on shore damaging trees.
3) Failed dams become eyesores when not removed.
4) Residences are being flooded by a backwater effect when dams are left in place.
5) Dams block boat traffic.
6) Warning signs and hazard lighting are needed.

Additionally, the NPS has raised the issue of National Environmental Policy Act (NEPA) procedures.

LNVA has negotiated an agreement with NPS. BTNP has agreed that LNVA will be permitted two structures with mitigating modifications, principally the installation of boat ramps. To assist in its planning, the COE has requested studies of boat use of the river to justify building boat ramps as a mitigation element. The permit to LNVA will be issued for a five-year period while the permanent saltwater barrier is being studied.

During a flood episode in 1996, the temporary structures were "blown out" by flood waters, but not according to design specifications. The dams were designed to fail in the center, so that stream banks would not be damaged. In fact, they held in the center and washed out on the ends so that a considerable amount of scour resulted in loss of land and vegetation on the banks of Little Pine Island Bayou. The LNVA is currently trying to find a way to remedy the design failure (Personal communication with T. Hebert, 1996).

**4.4.1 Impact to water corridor resources.** Saltwater barriers prevent saltwater intrusion to fresh water habitat, and as a result will have beneficial impacts on species resources (fish and invertebrates, possible reptiles and birds) as well as on water quality. The temporary saltwater barriers have negative impacts on shoreline vegetation and on the scenic and aesthetic quality of the Preserve. Without mitigating facilities, saltwater barriers also impede boating use of the water corridors, including use by law enforcement personnel.

**4.4.2 Recommended management actions.** The NPS should continue participating in the study and decision to build a permanent saltwater barrier lower on the Neches River to prevent saltwater intrusion without interfering with boating and other uses of the water corridors.

**4.4.3 Considerations for NPS research plan.** The COE has requested a study of boating usage of the Lower Neches River and Pine Island Bayou. This information also would be valuable to the interpretive division of BTNP.

### 4.5 Stream Diversions/Water Rights: Trans-Texas Water Program

Studies are currently underway for a "Trans-Texas Water Program" that is considering among

other options, the transfer of water between river basins. The state of Texas, represented by the Texas Water Development Board as lead agency, and several river authorities and cities looking for future surface water supplies, are exploring the possibility of meeting central and south Texas water needs by transporting water from basins with excess water (more water than the amount needed to meet in-basin needs projected for fifty years). Neither the Neches River nor the Trinity River is being considered as a source of additional water for transfer, but all proposed transfer routes from the Sabine River must cross both of these basins. Routes across the Neches will possibly pass through the BTNP.

A draft Phase I report for the Trans-Texas Water Program (TTWP) was issued in March 1994. Sixteen possible routes are proposed for the transfer of water from Toledo Bend Reservoir on the Sabine River to the Houston area in the San Jacinto River basin. These routes will be more closely examined in later planning phases, which will take 5 - 10 years to complete. Of these routes, transfers from the Sabine to the Neches are contemplated in the very northern reach into Lake B. A. Steinhagen, and at the southern end of the Neches to make use of existing LNVA canals. The Neches to Trinity transfer options include taking water out of Steinhagen and moving it into the Trinity below Menard Creek (a BTNP water corridor unit) and, in the south, crossing the Lower Neches Corridor Unit at the LNVA canals and through Devers and other canals to the Trinity below Liberty.

Although avoiding impacts to BTNP has been one criterion for reviewing early routing alternatives, the possibility exists for disruptions to the water corridors from construction, fragmentation of habitat and/or alterations in water circulation or quantity. As part of the TTWP, a permanent saltwater barrier on the lower Neches River is being evaluated by the U.S. Army Corps of Engineers, Galveston District, to augment in-basin water availability by preventing salt water intrusion to the lower Neches River and Little Pine Island Bayou.

The Southeast Study Area Policy Management Committee of the TTWP has established a Technical Advisory Committee (TAC) of about 50 members to review and comment on work plans and products. Members include state and federal agencies, local and regional agencies,

environmental and public interest groups, and private sector interests. The National Park Service is represented by BTNP Resource Management Division on the TAC.

**4.5.1 Impact to water corridor resources.** Specific impacts of possible interbasin water transfers are unknown at this time. The impacts of future full use of current water rights (currently permitted diversions) also are unknown.

**4.5.2 Recommended management actions.** NPS should continue to actively participate on the Technical Advisory Committee of the Trans-Texas Water Program to ensure that avoidance of impacts to BTNP continues as a principal criterion for evaluating alternatives.

**4.5.3 Considerations for NPS research plan.**

1) The NPS needs to know the potential impacts of any proposed stream crossings.

2) The NPS should cooperate with state agencies such as the Texas Parks and Wildlife Department and the Texas Natural Resource Conservation Commission to examine the implications of full use of currently permitted water rights on instream flows within the Preserve.

**4.6 State and Federal Law Enforcement Inconsistencies**

Inconsistencies between state and federal hunting, fishing and boating laws and regulations present difficulties to BTNP Rangers. Specific examples are: (1)The Texas Parks and Wildlife Department allows commercial fishing in the Neches River; BTNP allows only recreational and consumptive fishing; (2) state law allows loaded guns in boats; federal law prohibits loaded guns in boats. Inconsistencies create confusion and resentment of federal law among Preserve users. Rangers prefer the more restrictive federal laws about guns for personal safety reasons.

**4.6.1 Impact to water corridor resources.** There is a potential impact on submerged aquatic habitat resources and species resources (fish and invertebrates) from commercial fishing. No impact from commercial fishing activities has been documented at this time. Gun regulations affect the safety of law enforcement officers and users of the water corridors.

**4.6.2 Recommended management actions.** The NPS ability to respond unilaterally to this issue is limited. The following actions may aid in resolving this problem.

1) Work with other federal facilities in Texas to negotiate changes in gun regulations with TPWD.

2) Seek legislative remedies when conflicts in state and federal law impinge on BTNP ability to carry out its mission.

**4.6.3 Considerations for NPS research.** NPS should obtain information from TPWD on any commercial fishing operations in the water corridors.

**4.7 Unauthorized Commercial Use of Preserve**

BTNP has extensive borders and is configured in fifteen separate units, eight of which are water corridors. The rural nature of the area, together with its grazing and timbering land uses, also contributes to the potential for encroachment on Preserve property. Unauthorized use of BTNP property may result in degradation of the natural habitat and the conversion of public resources to private gain.

**4.7.1 Impact to water corridor resources.** Unauthorized use of Preserve resources has potential impacts to bottomland hardwood forest and may fragment habitat. Clearing or grazing would impact vegetation and may introduce exotic species. Encroachments from timbering and grazing activities may occur within the BTNP but have not been documented as a current problem for the water corridors.

**4.7.2 Recommended management actions.** If incidents of encroachment appear imminent based on neighboring land use activities, the NPS should increase and improve boundary markers and the presence of law enforcement personnel in the area.

**4.7.3 Considerations for NPS Research.** To address potential encroachment on BTNP area, the analysis of two types of information would be helpful:

1) information on type and location of neighboring land uses;

2) incident reports on unauthorized use of Preserve resources.

**4.8 Economic Development and Tourism**

The oil bust recession that hit Texas in the 1980's was particularly hard on the Beaumont-Port Arthur area. As a result, the South East Texas and Deep East Texas regions, within which BTNP is located, are actively seeking economic development. (South East Texas and Deep East Texas are the names of designated multi-county state planning regions.) The maximization of recreational and tourism amenities such as the BTNP is an important component of this effort. The objective from the economic development point of view is to attract visitors in large numbers and to create jobs.

Government ownership of land and habitat preservation measures are sometimes viewed negatively as obstacles to economic development. Offsetting that view is a growing realization that substantial benefits can be gained from the tourism industry and that natural areas are important tourist attractions. Former BTNP Superintendent Ron Switzer was instrumental in forming the Southeast Texas Partnership for Tourism, Recreation and Environmental Education (SETPTREE), which has become an important regional group for both discussion and cooperative action. SETPTREE works closely with the Texas Department of Commerce Tourism Division and includes a membership of cities, counties, convention bureaus, chambers of commerce, private businesses, schools, parks and agency personnel.

**4.8.1 Impact to water corridor resources**. The potential impact of economic development activities is extremely variable. The extent of impact depends principally on the level and type of recreational and tourist use of water corridors promoted and the management techniques instituted to prevent negative impacts on natural resources. BTNP participation in economic development efforts benefits the Preserve generally through greater community support and awareness of its mission.

**4.8.2 Recommended management actions.**

1) Continue active support of and participation with SETPTREE.

2) Continue and expand use of press releases and speaking opportunities to provide community education on economic importance of BTNP to region.

**4.8.3 Considerations for NPS Research.** Data on the regional, statewide and national economic importance of passive and nature-related recreation as well as more traditional activities would help BTNP garner support for preservation efforts.

# 5.0 Summary and Conclusion

## 5.1 Summary of Actions for Managing Critical Resources of the Water Corridors

Table 7 summarizes the management actions recommended for each of the topics presented in preceding sections. The actions are recommended in light of the seven management objectives established by the BTNP (see pp. 3-4 above) for the water corridors. These recommendations were developed in awareness of the funding and staffing constraints of the BTNP. Although these are not pie-in-the-sky recommendations, resource requirements to fully implement them exceed the current funding and staff resources currently available to managers of the Preserve (see Tables 8 and 9).

## 5.2 Implications for Preserve Management

Several general observations have been drawn from the study and the recommendations. 1) The physical configuration of the BTNP makes it imperative that cooperative efforts with neighbors and communities in the southeast Texas area continue to be emphasized and fostered. Many important influences on the future of the Preserve simply are not within the control of the NPS, but they can be affected by NPS activity. 2) Since current levels of public use are relatively low in most units, the Preserve has a wonderful opportunity to plan now for future public use within the constraints of the natural setting. 3) A timely investment in data collection along several fronts to better describe the ecological resources and visitation to the Preserve now would yield management dividends as future public use increases. 4) Data that are collected need to be analyzed regularly to glean management information. Quality controls for data collection need to be in place so that data can be used with confidence.

**5.2.1 Information needed to protect critical resources.** Resource management information can be gained on a project-by-project basis or as part of the day-to-day activities of Preserve staff. With staff resources fully utilized, the use of project consultants either from NPS personnel or other sources is an attractive way to meet information needs. For some topics, data collection over time by BTNP staff will probably be the most cost effective approach to compiling basic data. This is particularly true in the area of human uses of the Preserve.

**Table 7. Summary of Recommended Management Actions for Each Management Topic**

| Topic | Recommended Management Actions |
|---|---|
| **2.1 Biodiversity** | 1) Continue to support the mission of maintaining ecological integrity of the Preserve;<br>2) Carry out and support an active research program to assess and manage for biodiversity;<br>3) Work cooperatively with other conservation partners in the region;<br>4) Encourage neighbors to adopt management practices and land uses that help protect BTNP biodiversity. |
| **2.2 Endangered Species** | 1) Consider impacts of human uses of the Preserve on resident threatened and endangered species.<br>2) Continue to support protection of threatened and endangered, rare or uncommon species by cooperating with the U.S. Fish and Wildlife Service and the Texas Parks and Wildlife Department and by implementing USFWS recovery plan criteria for threatened and endangered species known to occur in the Preserve.<br>3) Work cooperatively with non-governmental organizations and individual landowners to support the protection of threatened and endangered species. |
| **2.3 Exotic Species** | 1) Support efforts of the Texas Parks and Wildlife Department, U.S. Fish and Wildlife Service, and the U.S. Natural Resources Conservation Service to prevent introduction of and to control the spread of exotic species.<br>2) Work with neighboring landowners, industry and interested groups, such as garden clubs, to educate the general public about the potential impacts of exotic species. |
| **2.4 Water Quality** | 1) The water quality monitoring program should be supported and coordinated with data collection efforts of other state and federal agencies.<br>2) Cooperative water quality sampling efforts with the Lower Neches Valley Authority (LNVA) should be pursued.<br>3) Water quality data should be collected under a quality assurance plan that is approved by the Texas Natural Resource Conservation Commission to allow NPS data to be used in state and federal enforcement actions. |

**Table 7. Summary of Recommended Management Actions for Each Management Topic (continued)**

| Topic | Recommended Management Actions |
|---|---|
| **2.5 Water Flow: Impoundments, Diversions, Releases** | 1) Continue to actively participate on the Technical Advisory Committee of the Trans-Texas Water Program to ensure that avoidance of impacts to BTNP remains a principal criterion for evaluating alternatives. NPS should make certain that location and design of any proposed river crossings have no negative impact on water corridor functions and values.<br>2) Monitor the timing of drawdowns and flushes and work with the COE to influence the operation of the Steinhagen Dam (Dam B) so that any negative impacts on the water corridors are avoided. |
| **2.6 Woody In-stream Substrate (Snags)** | 1) Monitor incident reports relative to boating safety to determine if there is a significant threat to human use of the water corridors.<br>2) Increase boater education about the presence of snags and their importance for habitat.<br>3) Consider identifying some areas as boating zones within which some snags will be removed for safety reasons.<br>4) Incorporate information on the importance of snags for aquatic habitat into general educational activities with area residents. |
| **2.7 Stream Banks (Erosion and River Meander)** | 1) Continue legally defining water corridors, or at least the Neches River corridor units, in terms of stream-gradient-boundary for bank-to-bank inclusion in the Preserve;<br>2) Identify areas in which river meander has the potential to create boundary problems and seek management solutions with neighbors to any potential conflicts that are likely to arise;<br>3) Acquire additional lands bordering the Neches River corridor units, particularly in areas of active erosion, to bring more streambanks within Preserve management. |
| **2.8 Floodplain Forest Habitat** | 1) Make certain that NPS facilities minimize fragmentation within the Preserve.<br>2) Participate in public planning activities, such as those for road construction, to prevent avoidable fragmentation and negative habitat impacts from neighboring uses.<br>3) Continue working with the oil and gas and pipeline companies in accordance with the Minerals Management Plan to |

**Table 7. Summary of Recommended Management Actions for Each Management Topic (continued)**

| Topic | Recommended Management Actions |
|---|---|
| | minimize the impact on habitat of their activities within or near the Preserve.<br>4) Encourage neighbors to adopt management practices and land uses that minimize additional fragmentation of bottomland hardwood forests. |
| **2.9 Aesthetic/Scenic Qualities** | 1) Work with neighbors in residences along river and stream banks to preserve the scenic quality of the corridors and discourage unsightly stream bank alterations.<br>2) Work with appropriate governmental units to prevent avoidable intrusions and minimize effects of unavoidable facilities such as roads and bridges.<br>3) Work with pipeline companies to minimize the visual impacts of pipeline crossings. |
| **2.10 Archaeological and Cultural Resources** | 1) Consider improved public presentation (printed materials and displays) of archaeological and cultural information already in the possession of the NPS.<br>2) Conduct historical research and protect site of Neches River ferryboat as recommended by Bradford (1992). |
| **3.0 Public Use of the Preserve** | 1) Place more emphasis on collection of data on visitation (such as visitor counts) and add sites as appropriate to better describe visitation within the water corridors. |
| **3.1 Hunting and Trapping** | 1) Curtail illegal taking of game through field patrols and contact with adjacent landowners, hunting clubs, and timber company hunting lease administrators.<br>2) Seek to eliminate problems caused by inconsistencies between Federal and State firearm laws. This can be accomplished in part by securing the assistance of TPWD in advising hunters about compliance with Federal laws while hunting on Federal preserves and refuges.<br>3) Promote safety of hunters in the Neches Bottom and Beaumont Units and visitors on waterways or neighboring lands by continuing to provide educational materials along with the hunter registration packet that promote safe handling of fire arms, good hunting etiquette, and a strong conservation ethic.<br>a) Promote safety by providing maps that clearly delineate |

**Table 7. Summary of Recommended Management Actions for Each Management Topic (continued)**

| Topic | Recommended Management Actions |
|---|---|
| | areas open to hunting to hunters and to other visitors, as well.<br>b) To promote safety, ensure that adequate boundary and other orientation markings are established and maintained within the Neches Bottom Unit.<br>4) Establish a program for monitoring populations and harvest levels for game species within the preserve.<br>5) Consider redesigning the hunter and trapper harvest reports to include more information on size, weight, and condition of harvested game to contribute valuable ancillary information for resource protection and to provide a scientifically credible basis for determining the number of hunting and trapping permits to issue. |
| **3.2 Fishing** | 1) Promote adherence to applicable fishing laws through casual field interviews initiated by Rangers on routine patrol.<br>2) Seek to eliminate problems caused by inconsistencies between Federal and State fishing laws. This can be accomplished in part by seeking the assistance of TPWD in advising fishermen about compliance with Federal laws while fishing in Federal preserves and refuges. A complete solution may involve switching to a single set of fishing laws through legislative action at the Federal level.<br>3) Promote safety of fishers by continuing to provide educational materials and signage.<br>4) Acquire the fish population data necessary to assure that fish resources are adequately protected. This may be accomplished through transfer from other agencies, contract research, or staff monitoring of populations. Fisher harvest reports based on Ranger interviews, which include information on size, weight, and condition of harvested fish, as well as level of effort and mode of fishing., can provide some information for this purpose.<br>5) Prepare fishing action plan per the directive of the General Management Plan |
| **3.3 Boating** | 1) Promote adherence to boat registration and boating safety laws through field interviews initiated by Rangers on a routine/casual basis, as well as routine patrols at strategic places and times. |

**Table 7. Summary of Recommended Management Actions for Each Management Topic (continued)**

| Topic | Recommended Management Actions |
|---|---|
| | use areas are adequately protected. The necessary information can be acquired through (1) annual review of records and incident reports; (2) annual visual assessment of trash loads and camper impact on sandbar vegetation and bank conditions; and (3) water quality monitoring at sites near camping areas.<br>4) Adopt formal name for the two unnamed sandbars on which backcountry camping is prohibited to better communicate with the public.<br>5) Review and update the Backcountry Camping Management Plan periodically -- at least once every five years. |
| **3.6 Houseboats in the BTNP** | 1) Work with TNRCC and LNVA on water quality sampling to determine impacts of houseboats.<br>2) Increase Ranger presence to document impacts of houseboats and discourage unlawful activities.<br>3) Work with State and Federal law enforcement agencies with regard to possible drug activities.<br>4) Rigorously enforce regulations to control impacts within the Preserve.<br>5) Issue no permits for houseboats not currently located within the Preserve and do not allow replacement of existing houseboats. |
| **3.7 Mineral Extraction and Transport** | 1) Review BTNP Oil and Gas Management Plan for responsiveness to resource and administrative concerns.<br>2) Work with oil and gas and pipeline companies to develop operating plans for their activities in the BTNP that provide maximum biodiversity protection and minimum visual/aesthetic impact.<br>3) Work with other agencies and oil and gas industry to develop standards for pipelines that are appropriate to sensitive or hazardous locales such as waterways. |
| **3.8 Trash and Waste Disposal** | 1) Post information promoting appropriate disposal of trash and human wastes.<br>2) Provide trash and human waste disposal facilities at all day use sites.<br>3) Continue to provide regular cleaning and maintenance of waste disposal facilities. |

**Table 7. Summary of Recommended Management Actions for Each Management Topic (continued)**

| Topic | Recommended Management Actions |
|---|---|
| | 4) Contract for off-Preserve disposal of wastes whenever possible.<br>5) Work with other jurisdictions to develop alternative disposal sites. |
| **3.9 River Access** | 1) Maintain or improve current facilities in condition for safe public use.<br>2) Review General Management Plan and current circumstances to determine if any additional facilities can be developed consistent with protection of the natural resources. |
| **3.10 Littering, Dumping and Vandalism** | 1) Remediate existing trash dump sites by removing trash and restoring habitat whenever possible.<br>2) Promote compliance with Preserve regulations by intensifying Ranger patrols at strategic places and times.<br>3) Encourage volunteer trash cleanup programs in the water corridors such as those under the state Clean Rivers Program administered in the Big Thicket area by the Lower Neches Valley Authority.<br>4) Expand cooperative efforts with local anti-litter and beautification organizations.<br>5) Include anti-litter information in visitor information brochures.<br>6) Provide trash receptacles in appropriate areas. |
| **3.11 Illegal Collection of Plants** | This is a potential future problem. Steps to prepare for future management can be taken now.<br>1) Review preventive measures taken at other similar NPS facilities or other preserves.<br>2) Monitor plant resources and document evidence of any plant removal to signal a need for further management actions. |
| **4.1 Air Quality/ Fire Management** | 1) Participate in regional and state air quality planning efforts so that NPS views are known to regulators and sound scientific data are presented to show that prescribed burns are beneficial and the impacts of prescribed burns are acceptable.<br>2) Pursue cooperative efforts with the timbering and agricultural communities, such as seminars, to provide scientific information to the public and regulators. |

**Table 7. Summary of Recommended Management Actions for Each Management Topic (continued)**

| Topic | Recommended Management Actions |
|---|---|
| | 2) Initiate monitoring programs to track visitor satisfaction and resource quality to provided a basis for identifying the recreational carrying capacity of the corridors.<br>3) Produce and distribute additional information brochures identifying opportunities for safe and resource-compatible recreational use. Consider distribution to targeted audiences such as those found at commercial outlets catering to boaters.<br>4) Acquire the data necessary to assure that biotic resources are not impaired by boating uses. This may be accomplished through transfer from other agencies, contract research, or staff monitoring of populations and bank conditions.<br>5) Address the use of boats for hunting, trapping and fishing activities in the hunting, trapping and fishing action plan to be prepared as directed by the General Management Plan.<br>6) Cooperate with other law enforcement agencies to prevent conflicts among users and between users and neighboring land owners from arising.<br>7) Maintain NPS boat ramps in safe condition with suitable facilities for trash and human waste disposal. |
| **3.4 Swimming and Picnicking** | 1) Promote adherence to Preserve visitor use and safety regulations through casual field interviews initiated by Rangers on routine patrol, as well as by regular patrols at strategic places and times.<br>2) Initiate monitoring programs to track visitor satisfaction and resource quality, so as to identify the recreational carrying capacity of the corridors.<br>3) Produce additional information brochures identifying opportunities for safe and resource-compatible recreational use. |
| **3.5 Camping** | 1) Promote adherence to applicable backcountry camping regulations through casual field interviews initiated by Rangers on routine patrols.<br>2) Promote safety of campers by continuing to provide educational materials and signage, particularly at river access points.<br>3) Acquire the data necessary to assure that resources in visitor |

**Table 7. Summary of Recommended Management Actions for Each Management Topic (continued)**

| Topic | Recommended Management Actions |
|---|---|
| | 3) Explore cooperative funding arrangements with TNRCC or USEPA to continue or expand air quality monitoring to contribute to the scientific data base available to resolve issues of fire management and air quality. |
| **4.2 Neighboring Land Uses** | 1) Because neighboring land uses are beyond the direct control of the NPS, continue cooperative efforts such as education and partnership programs with area residents and organizations.<br>2) Special efforts to work cooperatively with timber companies in the area should be continued to avoid potential adverse impacts of this prevailing neighboring use.<br>3) Law enforcement activities may need to be expanded. |
| **4.3 Public Use of Private Lands/Trespassing** | Although this is not currently known to be a serious problem within the water corridors, preventive actions can be taken.<br>1) Increase and improve boundary markings in a way that does not detract from the backcountry experience for Preserve visitors; consider uniform boundary markings that might be more recognizable and lend identity to BTNP lands.<br>2) Educate visitors about BTNP area and boundaries.<br>3) Work cooperatively with The Nature Conservancy of Texas and state and local law enforcement agencies to monitor trespass problems along Village Creek.<br>4) Increase Ranger presence. |
| **4.4 Salt Water Barriers on the Neches River and Little Pine Island Bayou** | 1) Continue participating in the study and decision to build a permanent saltwater barrier lower on the Neches River to prevent saltwater intrusion without interfering with boating and other uses of the water corridors. |
| **4.5 Stream Diversions/Water Rights: Trans-Texas Water Program** | 1) Continue to actively participate on the Technical Advisory Committee of the Trans-Texas Water Program to ensure that avoidance of impacts to BTNP remains a principal criterion for evaluating alternatives. |
| **4.6 State and Federal Law Enforcement Inconsistencies** | 1) Work with other federal facilities in Texas to negotiate changes in gun regulations with TPWD.<br>2) Seek legislative remedies when conflicts in state and federal law impinge on BTNP ability to carry out its mission. |

**Table 8. Authorized Staffing Levels of the Big Thicket National Preserve, 1994-1996***
**(Full-time and part-time employees)**

| Category | 1994 | 1995 | 1996 |
|---|---|---|---|
| Office/Superintendent | 3 | 3 | 7 |
| Administration | 7 | 6 | 6 |
| Ranger Activities | 16 | 15 | 13 |
| Interpretation | 6 | 6 | 5 |
| Resource Management | 9 | 7 | 6 |
| Facility Management | 8 | 12 | 7 |
| Total | 43 | 43 | 43 |

*Some authorized positions were unfilled.

**Table 9. Funding and Expenses of the Big Thicket National Preserve, 1994-1996***

| Category | 1994 | 1995 | 1996 |
|---|---|---|---|
| **Funding** | | | |
| Base | 1,504,700 | 1,720,100 | 1,599,900 |
| Other Program | 399,905 | 474,040 | 246,965 |
| Carry Over | | 50,658 | |
| **Total Funding** | **1,904,605** | **2,244,798** | **1,846,865** |
| **Expenses** | | | |
| Personnel | 1,518,746 | 1,548,158 | 1,349,177 |
| Vehicles | 90,839 | 68,805 | 80,854 |
| Travel & Transportation | 61,551 | 68,805 | 50,005 |
| Printing & Supplies | 105,501 | 242,602 | 76,330 |
| Utilities | 29,674 | 35,396 | 26,730 |
| Services | 301,071 | 226,749 | 91,457 |
| Property | - | - | 74,122 |
| Equipment & Misc. | - | 114,571 | - |
| **Total Expenses** | **2,138,956** | **2,236,281** | **1,748,675** |

*In 1994, $1,867,914 was appropriated to complete construction of the maintenance facility. Expenses include construction costs.

**Table 10. Summary of Research Considerations for Each Management Topic**

| Topic | Research Considerations |
|---|---|
| **2.1 Biodiversity** | 1) Understanding species habitat requirements and documenting population trends;<br>2) Understanding community structure within the corridors;<br>3) Determining if the water corridors effectively function as movement corridors. |
| **2.2 Endangered Species** | 1) Mapping potential habitats of threatened and endangered and candidate species;<br>2) Conducting field surveys of populations;<br>3) Monitoring species known to inhabit the Preserve. |
| **2.3 Exotic Species** | 1) Studies of distribution, invasiveness and effects of exotics within BTNP.<br>2) Research on means of preventing introduction of or controlling exotics in the BTNP. |
| **2.4 Water Quality** | 1) Continue or expand collection of water quality data.<br>2) Periodically analyze and report on data collected. |
| **2.5 Water Flow: Impoundments, Diversions, Releases** | 1) Research the possibility of affecting the operation of dams that affect NPS water resources (as with recent developments on the Colorado River above the Grand Canyon).<br>2) Collect information to determine the impacts of "flushing flows" from Dam B: water quality data from the Upper and Lower Neches River and water quality surveys of Upper Neches during periods of flushing; and records of BTNP user reactions during periods of flushing--either reports to rangers or special surveys.<br>3) Research the potential impacts of any stream crossing proposed by the Trans-Texas or other water supply plans. |
| **2.6 Woody In-stream Substrate (Snags)** | 1) Research on the importance of snags as habitat to species in the water corridors. |
| **2.7 Stream Banks (Erosion and River Meander)** | 1) Study the extent to which stream bank modification has affected habitat for important species within the Preserve.<br>2) Research alternative methods of stabilizing stream banks in areas with high rates of erosion, and educational programs to inform neighbors of less intrusive stabilization methods.<br>3) Study rates of stream channel changes over time with maps of water corridors and stream paths; include property ownership information in areas of meander. |

**Table 10. Summary of Research Considerations for Each Management Topic (continued)**

| Topic | Research Considerations |
|---|---|
| **2.8 Floodplain Forest Habitat** | 1) Research on the manner and extent to which aquatic diversity responds to increased width of the bordering forest strip.<br>2) Research on the specific impacts of neighboring human land uses on water quality, species diversity and corridor integrity.<br>3) Research to determine the relative importance of quality of water as it enters the corridors versus characteristics of the forested buffer zone in contributing to in-stream habitat quality. |
| **2.9 Aesthetic/Scenic Qualities** | 1) Research on the aesthetic value of intact streambanks may be warranted in the future. |
| **2.10 Archaeological and Cultural Resources** | 1) Historical and archaeological research has been recommended for the Neches River ferryboat site within the older water corridors.<br>2) Archaeological/cultural investigations may be needed on the newly acquired Big Sandy Creek and Village Creek Corridors. |
| **3.0 Public Use of the Preserve** | 1) Develop a survey to be administered periodically at river access points to develop better information about users of the water corridors. |
| **3.1 Hunting and Trapping** | 1) Establish program for monitoring populations and harvest levels for game species. |
| **3.2 Fishing** | 1) Consider establishing program of contract research or staff monitoring to acquire fish population data. |
| **3.3 Boating** | 1) Develop program of surveys on visitor satisfaction and resource quality.<br>2) Consider contract research or staff monitoring of populations and bank conditions to assure that biotic resources are not impaired by boating uses. |
| **3.4 Swimming and Picnicking** | 1) Develop program of surveys on visitor satisfaction and resource quality. |
| **3.5 Camping** | 1) Acquire the data necessary to assure that resources in visitor use areas are adequately protected, including:<br>(a) annual review of records and incident reports; |

**Table 10. Summary of Research Considerations for Each Management Topic (continued)**

| Topic | Research Considerations |
|---|---|
| | (b) annual visual assessment of trash loads and camper impact on sandbar vegetation and bank conditions; and<br>(c) water quality monitoring at sites near camping areas. |
| **3.6 Houseboats in the BTNP** | 1) Field survey to document houseboat presence in tributaries as well as the main channel of the Neches River.<br>2) Research on the impacts of houseboats (water quality, shoreline vegetation, law enforcement incidents). |
| **3.7 Mineral Extraction** | 1) Research on impacts of closed/abandoned oil and gas facilities. |
| **3.8 Trash and Waste Disposal** | 1) No specific research activities identified at this time. |
| **3.9 River Access** | 1) No specific research activities identified at this time. |
| **3.10 Littering, Dumping and Vandalism** | 1) No specific research activities identified at this time. |
| **3.11 Illegal Collection of Plants** | 1) Collect baseline inventory information on plant resources. |
| **4.1 Air Quality/ Fire Management** | 1) Collect sound scientific data on the air quality impacts of controlled burns in the BTNP.<br>2) Continue or expand air quality monitoring to contribute to the scientific data base available to resolve issues of fire management and air quality.<br>3) The relationship between air and water quality may be a topic for research in the future. |
| **4.2 Neighboring Land Uses** | 1) Expand baseline inventory of neighboring uses for the Neches River corridor to other corridors and monitor changes in uses.<br>2) Research on specific effects of neighboring land uses is needed. |
| **4.3 Public Use of Private Lands/Trespassing** | 1) Monitor incident reports for occurrences of trespass incidents. |
| **4.4 Salt Water Barriers on the Neches River and Little Pine Island Bayou** | 1) Study boating usage of the Lower Neches River and Pine Island Bayou. |

**Table 10. Summary of Research Considerations for Each Management Topic (continued)**

| Topic | Research Considerations |
|---|---|
| **4.5 Stream Diversions/ Water Rights: Trans-Texas Water Program** | 1) Study the impacts of any proposed stream crossings.<br>2) Participate in studies of instream flows for environmental purposes. |
| **4.6 State and Federal Law Enforcement Inconsistencies** | 1) Obtain information on commercial fishing in water corridors from TPWD. |
| **4.7 Unauthorized Commercial Use of Preserve** | 1) Monitor information on type and location of neighboring land uses.<br>2) Monitor incident reports on unauthorized use of Preserve resources. |
| **4.8 Economic Development and Tourism** | 1) Research on the regional, statewide and national economic importance of passive and nature-related recreation as well as more traditional activities. |

dollars per year. (Preserve staff report that actual full-time-equivalency has averaged about 36 per year over this period. R. Strahan, personal communication, 1997.) Considering this information along with the dispersed geography of the Preserve and growth in public visitation (see section 3.0), efforts to expand activities devoted to managing the Preserve's critical natural resources realistically face considerable financial constraints.

**5.2.3 Legislative or administrative action needed.** Legislative action is not required for implementation of the recommended management actions, with the possible exception of clearing up ambiguities between state and federal law relating to fire arms. Administrative action may be needed on several fronts if permitting or regulatory activities are pursued, as for instance with the permitting and regulation of houseboats. A full public review of any management plan based on the recommendations contained in this report will also be needed, not only because of NEPA or other administrative requirements, but because so many of the management actions require the cooperation of neighbors and other organizations.

## 5.3 Conclusion

The organic purpose of the BTNP to preserve numerous representative areas typical of the Big Thicket region shapes any recommended management actions for the water corridors. Preservation of the critical resources of the water corridors -- the water, the snags, the stream banks, and the floodplain forest -- must be a central goal. As a result, visitor use of the Preserve needs to be accommodated within the bounds of protecting the natural resources. This suggests a continuing sensitivity to the notion of a "carrying capacity" of the water corridors so that types of permitted activities and levels of visitation do not negate resource protection efforts.

On a positive note, greater numbers of visitors appreciating the natural setting represent a human resource to the Preserve. The importance of working cooperatively with other agencies, organizations and communities, particularly neighboring landowners, in managing the critical resources of the water corridors of the BTNP cannot be overstated.

## References (Citations)


Abernethy, Francis E., ed. 1967. Tales of the Big Thicket. UT Press, Austin, TX.

Acts of the U.S. Congress. 1916. National Park Service organic act (16 USC 1).

Angelina & Neches River Authority. 1992. Regional Assessment of Water Quality, Neches River Basin, Upper Neches River Basin Study Area, Vol. 1. Prepared in cooperation with the Texas Water Commission under authorization of the Clean Rivers Act; October 1, 1992.

Becker, Dennis. 1994. Letter to author dated September 14, 1994 providing information on water diversions of the Lower Neches Valley Authority systems.

Benke, A. C., D. M. Gillespie, F. K. Parrish, T. C. Van Arsdall, R. J. Hunter, & R. L. Henry. 1979. Biological basis for assessing impacts of channel modification: invertebrate production, drift, and fish feeding in a southeastern blackwater stream. Georgia Institute of Technology, Atlanta, GA.

Benke, A. C. T. C. Van Arsdall, Jr., D. M. Gillespie & F. K. Parrish. 1984. Invertebrate productivity in a subtropical blackwater river: the importance of habitat and life history. Ecological Monographs 54(1):25-63.

Blaustein, A. R., D. B. Wake. 1992. Declining Amphibian Populations: A Global Phenomenon? In: Trends in Ecology and Evolution 5:203-204.

Blaustein A. R., D. B. Wake, W. P. Sousa. 1994. Amphibian Declines: Judging stability, persistence and susceptibility of populations to local and global extinctions. Conservation Biology 8:60-71.

Bounds, R. L., E. P. Seidensticker, C. D. Travis. 1981. Performance Report as required by Federal Aid in Fisheries Act, Federal Aid Project F-30-R-6, Statewide Fishery Management Recommendations, Neches River, Job A: Existing Reservoir and Stream Management Recommendations, Neches River. Texas Parks and Wildlife Department, Austin, TX.

Bradford, James. E. 1992. Discovery of a Neches River Ferryboat, Big Thicket National Preserve, Tyler County, Texas. National Park Service, Division of Anthropology, Branch of Cultural Resources Management, Park Papers BITH-02. Santa Fe, NM.

Bruce, Katherine A., G. N. Cameron, P. A. Harcombe. In press. Introduction, impact upon native habitats, and management of a woody invader, the Chinese Tallow tree, *sapium sebiferum* (L.) Roxb. Natural Areas Journal.

Cain, Brian (U.S.Fish and Wildlife Service), Samra Jones-Bufkins (Galveston Bay Foundation). 1996. Chemical control of water hyacinth, in Galveston Bay Foundation, Soundings, Vol. 7, No. 4, Winter 1995-1996.

Callaway, Glenda L. 1995. Characterization of Institutional Issues for Water Corridor Units of the Big Thicket National Preserve. Prepared for the National Park Service, Big Thicket National Preserve.

Callaway, Glenda L. 1997. Characterization of Public Use of the Water Corridor Units of the Big Thicket National Preserve. Prepared for the National Park Service, Big Thicket National Preserve.

Callaway, Glenda L., Rosine W. Hall, David McHugh. 1993. Field Notes, Annotated U.S.G.S. Quad Maps, Photographs.

Cameron, Guy N. (U. Houston), Katherine A. Bruce, Paul A. Harcombe (Rice U.). 1995a. Invasion of the Chinese Tallow, in Galveston Bay Foundation, Soundings, Vol. 7, No. 2, Summer 1995.

Cameron, Guy N. (U. Houston), Katherine A. Bruce, Paul A. Harcombe (Rice U.). 1995b. Management of Chinese Tallow, in Galveston Bay Foundation, Soundings, Vol. 7, No. 3, Fall 1995.

Carraway, Burl and John Norris. 1996. Voluntary Compliance with Forestry Best Management Practices in East Texas, Results from Round 2 of BMP Compliance Monitoring. Texas Forest Service, March 1996.

Chilton, Earl (Texas Parks and Wildlife Department). 1995. Grass carp in the Galveston Bay System, in Galveston Bay Foundation, Soundings, Vol. 7, No. 1, Spring 1995.

Commander, Darrell. 1979. A Study of the Nuisance Flooding along Little Pine Island and Pine Island Bayous. Aquatic Services, Port Neches, TX, 20 August 1979.

Dethloff, Henry C. and Victor H. Treat. 1975. A Preliminary Report on The Historical Survey of The Big Thicket National Preserve. Texas A&M University, February 1975.

Egan, R. S and V. R. Gordy. 1981. Baseline study of microlichen distribution in the Big Thicket National Preserve, Texas, in relation to present and future air pollution levels. University of Nebraska at Omaha, Omaha, NE. PX7029-0-0425.

Federal Register, Vol. 40, No. 52, Monday, March 17, 1975. Part II: Department of the Interior, National Park Service, Big Thicket National Preserve Boundaries Description.

Federal Register. 1995. Proposed regulations for houseboats, Big Thicket National Preserve.

Gooch, Tom, P.E., Freese and Nichols, Inc. 1996. Rainfall patterns and historical inflow from the Sabine and Neches Rivers into Sabine Lake. Paper presented at Sabine Lake Conference, Beaumont, Tx., 13 September 1996.

Gordy, V. R. 1986. Revisit of the Big Thicket National Preserve, Texas, for the assessment of microlichen distribution. Report to National Park Service, Air Division, Denver, CO.

Hall, D. H. and V. W. Lambou. 1990. The ecological significance to fisheries of bottomland hardwood systems: values, detrimental impacts, and assessment: the report of the fisheries workgroup. In Ecological Processes and Cumulative Impacts. Edited by J. G. Gosselink, L. C. Lee, and T. A. Muir. Lewis Publishing, Chelsea, MI, USA. pp. 481-531.

Hall, Rosine W. 1996. A Case Study of Flooding the Neches Bottom Study Site. Prepared for the National Park Service, Big Thicket National Preserve.

Hall, Rosine W. and Kathy A. Bruce. 1996. Characterization of Water Quality of the Water Corridor Units of the Big Thicket National Preserve. Prepared for the National Park Service, Big Thicket National Preserve.

Hall, Rosine W., Paul A. Harcombe, Hanadi Rifia, Phil Bedient, Glenda Callaway. 1996. Land Cover/Land Use Map. Prepared for the National Park Service, Big Thicket National Preserve.

Harcombe, Paul A., Elizabeth N. Hane, Jonathan P. Evans, Rosine W. Hall, Kathy A. Bruce, Keith C. Hoffman, Patrick D. Conant. 1996. Characterization of the Biological Resources of the Water Corridor Units of the Big Thicket National Preserve. Prepared for the National Park Service, Big Thicket National Preserve.

Harris, L. D. 1988a. The faunal significance of fragmentation of southeastern bottomland forests. In Proceedings of the symposium. The Forested Wetlands of the Southern United States. Edited by D. D. Hook and R. Lea. Forest Service, Ashville, S.C. pp. 126-134.

Harris, L. D. 1988b. Edge effects and conservation of biotic diversity. Conservation Biology 2:330-332.

House Resolution 93-676, November 29, 1973.

Johnson, Joyce (Texas Parks and Wildlife Department). 1995. Water hyacinth, an exotic aquatic plant pest, in Galveston Bay Foundation, Soundings, Vol. 7, No. 4, Winter 1995-1996.

Kaiser, Ronald A., Steven E. Alexander and J. Porter Hammitt. 1994. Protecting the National Parks in Texas through enforcement of water quality standards: an exploratory analysis. For National Park Service, U.S. Department of Interior, Technical Report NPS/NRWRD/NRTR-94/18, November 1994.

Lower Neches Valley Authority. 1992. Regional Assessment of Water Quality, Lower Neches River Basin and Neches-Trinity Coastal Basin. Prepared with assistance of Alan A. Plummer and Associates, Inc. and in cooperation with the Texas Water Commission under authorization of the Clean Rivers Act; October 1992.

Lower Neches Valley Authority. 1994. Regional Assessment of Water Quality, Lower Neches River Basin and Neches-Trinity Coastal Basin. Prepared with assistance of Alan A. Plummer and Associates, Inc. and in cooperation with the Texas National Resource Conservation Commission under authorization of the Clean Rivers Act; October 3, 1994.

Lower Neches Valley Authority. 1996. Regional Assessment of Water Quality, Lower Neches River Basin and Neches-Trinity Coastal Basin. Prepared with assistance of Alan A. Plummer and Associates, Inc. and in cooperation with the Texas National Resource Conservation Commission under authorization of the Clean Rivers Act; July 1996 (draft).

Moore, Roger G. and Saul Aronow. 1994. Archeological and Geomorphological Investigations of a Proposed Weems Geophysical, Inc. Seismic Line within the Beaumont Unit of the Big Thicket National Preserve, Hardin County, Texas. Moore Archeological Consulting, Houston, Texas.

Nailon, Robert W. (Entrix). 1995. Grass carp management and control, in Galveston Bay Foundation, Soundings, Vol. 7, No. 1, Spring 1995.

Nailon, Robert W. (Entrix) and Leslie Sanderson (National Association of Conservation Districts). 1994. Exotic species management and control (overview and focus on nutria), in Galveston Bay Foundation, Soundings, Vol. 6, No. 4, Winter 1994-1995 (originally published in GulfWatch, August 1994).

National Park Service, U.S. Department of Interior. 1975. Big Thicket National Preserve Memorandum of Understanding with Texas Parks and Wildlife Department, June 26, 1975.

National Park Service, U.S. Department of Interior. 1976. Final Environmental Statement for Establishment of the Big Thicket National Preserve Texas.

National Park Service, U.S. Department of Interior. 1980. General Management Plan, Big Thicket National Preserve, September 1980.

National Park Service, U.S. Department of Interior. 1988a. Management Policies, U.S. Department of the Interior, National Park Service.

National Park Service, U.S. Department of Interior. 1988b. Big Thicket National Preserve Draft Statement for Management.

National Park Service, U.S. Department of Interior. 1989. River Use Management Plan, Ozark National Scenic Riverways. May 1989.

National Park Service, U.S. Department of Interior. 1994a. Superintendent's Orders: Big Thicket National Preserve Standard Operating Procedures.

National Park Service, U.S. Department of Interior. 1994b. Minutes of meeting with Bevil Oaks homeowners in files of Big Thicket National Preserve.

National Park Service, U.S. Department of Interior. 1995a. Big Thicket National Preserve Final Draft Statement for Management.

National Park Service, U.S. Department of Interior. 1995b. An Introduction to Selected Laws Important for Resources Management in the National Park Service. By Napier Shelton and Lissa Fox, Natural Resources Report NPS/NRPO/NRR-94/15.

National Park Service, U.S. Department of Interior. 1996. Petroleum/Pipeline Information for Big Thicket National Preserve. Denver Service Center, National Park Service.

Pearstine, L., H. McKellar, and W. Kitchens. 1985. Modelling the impacts of a river diversion on bottomland forest communities in the Santee River floodplain, South Carolina. Ecol. Modelling 29:281-302.

Personal communications (cited) of the authors with:
Members of the staff of the Big Thicket National Preserve, 1993 - 1996.
Robert Appling, NPS-BTNP, 1996.
Tommy Hebert, Lower Neches Valley Authority, 1996.
David McHugh, NPS-BTNP, 1993.
Larry McKinney, Texas Parks and Wildlife Department, 1995.
Lisa Williams, Texas Department of Health, 1995.
Richard Browning, Trinity River Authority, 1996.

Pitman, Virginia M. 1991. Synopsis of Paddlefish Biology and Their Utilization and Management in Texas, Special Report. Texas Parks and Wildlife Department, Fisheries and Wildlife Division, Inland Fisheries Branch, Austin TX. 70 pp.

Pitman, Viginia M. 1992. Texas Paddlefish Recovery Plan, Special Report. Texas Parks and Wildlife Department, Fisheries and Wildlife Division, Inland Fisheries Branch, Austin TX. 30 pp.

Public Law 93-439, October 11, 1974, 88 Stat. 1254 et seq. (16 USC 698). Establishment legislation for Big Thicket National Preserve.

Saunders, D. A. and C. P. de Rebeira. 1991. Values of corridors to avaian populations in a fragmented landscape. In Nature Conservation 2: The Rose of Corridors. Edited by D. A. Saunders & R. J. Hobbs. Surrey Beatty & Sons Pty Limited. Norton, New South Wales, Australia. pp. 221-240.

Seidensticker, P. 1994. Performance Report as required by Federal Aid in Fisheries Restoration Act, Federal Aid Project F-30-R-20, Job A: Existing reservoir and stream management recommendations, Neches River, (in preparation). Texas Parks and Wildlife Department, Austin, TX.

Shafer, Harry. J., Edward P. Baxter, Thomas B. Stearns, James Phill Dering. 1975. An Archeological assessment of the Big Thicket National Preserve. Report by the Anthropology

Laboratory, Texas A&M University to the Office of Archeological Resources, Southwestern Region, National Park Service, Santa Fe, N.M., October 1975.

Shaw, Chad. 1995. Timber Effects on Water Quality. Appendix D in Hall and Bruce, 1996.

Terborgh, J. 1989. Where Have All the Birds Gone? Essays on the Biology and Conservation of Birds that Migrate to the American Tropics. Princeton: Princeton, NJ. USA.

Texas Department of Health, Seafood Safety Division. 1995. Fish Advisories and Bans.

Texas Parks and Wildlife Department. 1990. 1990 Texas Outdoor Recreation Plan: Assessment and Policy Plan. Report prepared by James A. DeLoney (dir.), Maria I. Araujo, Andrew Goldbloom, Kathryn Nichols, Joel S. Seffel, Consumer Planning Section, Comprehensive Planning Branch, Parks Division, Texas Parks and Wildlife Department, Austin, TX..

Texas Parks and Wildlife Department. 1997. Wildlife Research Highlights, 1997: Vol. 2. Wildlife Division, Texas Parks and Wildlife Department, Austin, TX.

Trans-Texas Water Program. 1994. Phase I Report for the Southeast Area of the Trans-Texas Water Program. Prepared by Brown & Root Inc. and Freese & Nichols, March 1994.

U.S. Army Corps of Engineers, Fort Worth District. 1976. Final Environmental Impact Statement on the Operation and Mainteanance Programs for the Town Bluff Dam-B. A. Steinhagen Lake, Sam Rayburn Dam and Reservoir, Neches-Angelina Rivers Basin, Texas.

U.S. Army Corps of Engineers, Galveston District. 1976. Neches River and Tributaries, Texas: Reconnaissance Report on Flood Problem at Pinewood Estates Subdivision, Hardin County, Texas. October 1976.

U.S. Army Corps of Engineers, Galveston District. 1985. Pine Island Bayou Watershed, Texas: Flood Damage Prevention. June 1985.

U.S. Army Corps of Engineers, Galveston District. 1992. Notice of Public Hearing, CESWG-CO-RN, Permit Application 19611.

U.S. Department of Interior, National Park Service. 1993. National Park Service Regulations, 36 CFR Ch. 1.

U.S. Department of State, Biosphere Reserve Directorate, US. Man and the Biosphere Program. 1994. Strategic Plan for the U.S. Biosphere Reserve Program. Department of State Publication 10186, December 1994.

Wilson, Paul C., Jr. 1981. History of the saltwater barrier on the Neches River. The Texas Gulf Historical and Biographical Record 17:29-37.

## Bibliography


Abernethy, Francis E., ed. 1967. Tales of the Big Thicket. UT Press, Austin, TX.

Abernethy, Y. & R.E. Turner. 1987. US forested wetlands: 1940-1980: field-data surveys document changes and can guide national resource management. BioScience 37: 721-727.

Acts of the U.S. Congress. 1916. National Park Service organic act (16 USC 1).

Adams, C.E. & J.K. Thomas. 1989. Public Uses of Texas Wildlife and Natural Areas. Texas Agricultural Experiment Station. Texas A&M University. College Station, TX.

Agee, J.K. & D.R. Johnson. 1988. Ecosystem Management for Parks and Wilderness. University of Washington Press. Seattle, WA.

Alan Plummer and Associates. 1992. Regional Assessment of Water Quality, Lower Neches River Basin and portion of Neches-Trinity Coastal Basin. Lower Neches River Valley Authority and Texas Water Commission. Beaumont, Texas.

Alcala, A.C. & M.T. Dy-Liacco. 1989. Habitats. In Crocodiles and Alligators. Edited by C.A. Ross. Weldon Owen Pty. Lmt. pp. 136-145.

Allen, A.W. 1987. Habitat Suitability Index Models: Barred Owl. National Ecology Center, Fish and Wildlife Service, U.S. Department of the Interior. Washington D.C. 17 pp.

American Ornithologists' Union. 1983. Check-list of North American Birds, 6th Edition. Allen Press, Lawrence, KS.

Anderson, S. & R. Masters. 1991. Riparian Forest Buffers. O.S.U. Extension Facts No. 5034. Cooperative Extension Service. Division of Agricultural Sciences and Natural Resources, Oklahoma State University, Stillwater, OK.

Andrén, H. 1994. Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: a review. OIKOS 71:355-366.

Angelina & Neches River Authority. 1992. Regional Assessment of Water Quality, Neches River Basin, Upper Neches River Basin Study Area, Vol. 1. Prepared in cooperation with the Texas Water Commission under authorization of the Clean Rivers Act; October 1, 1992.

Aronow, S.A. 1974. A review of the origins of undrained depressions and some related microrelief features of the Big Thicket region of east Texas. Manuscript. Lamar University, Beaumont, TX.

Ashcraft, J. A. 1973. Physicochemical conditions and macrobenthic community structure in the lower Neches River. M.S. Thesis. Lamar University, Beaumont, TX. 50 pp.

Baker, B.B., R.C. Peckham, J.W. Dillard, & V.L. Sounders. 1963. Reconnaissance investigation of the groundwater resources of the Neches River basin, Texas. Texas Water Commission. Bulletin 6308. 67pp.

Baker, L.A. 1992. Introduction to nonpoint source pollution in the United States and prospects for wetland use. Ecological Engineering 1:1-26.

Baker, R.H. 1956. Former distribution of animals in eastern Texas, Texas J. Sci. 8:356-359.

Barclay, C. M. & R. C. Harrel. 1985. Effects of Pollution Effluents on Two Successive Tributaries and Village Creek in Southeastern Texas. The Texas Journal of Science 37: 175-188.

Bass, D.G. 1979. Physicochemical conditions, fecal bacteria, and benthic macroinvertebrates of Menard Creek in the Big Thicket National Preserve. M.S. Thesis. Lamar University, Beaumont, TX. 66pp.

Batema, D.L., G.S. Henderson, & L.H. Fredrickson. Wetland invertebrate distribution in bottomland hardwoods as influenced by forest type and flooding regime. In Proceedings of the Central Hardwoods Conference. Department of Forestry, University of Illinois, Urbana-Champaign, Illinois. pp.196-202.

Baxter, E.P., H.J. Shafer, & P. Dering. 1975. A preliminary archaeological assessment of the Big Thicket National Preserve. Texas A&M University, College Station, TX.

Beck, K.C. & J.H. Reuter. 1974. Organic and inorganic geochemistry of some coastal plain rivers of the southeastern United States. Geochimica et Cosmochimica Acta 38:341-364.

Becker, C.D. 1973. Development of Simulinium (Psilozia) vittattum Zett. (Diptera : Simulidae) from larvae to adults at thermal increments from 17.0°C to 27.0°C. American Midland Naturalist 89 : 246-251.

Becker, C.D. & D.A. Neitzel. 1992. Water Quality in North American River Systems. Battelle Press. Columbus, OH.

Becker, Dennis. 1994. Letter to author dated September 14, 1994 providing information on water diversions of the Lower Neches Valley Authority systems.

Bellrose, F.C. & N.M. Trudeau. 1988. Wetlands and their relationship to migrating and winter populations of waterfowl. In The Ecology and Management of Wetlands Vol. 1. Edited by D.D. Hook, W.H. McKee, Jr., H.K. Smith, J. Gregory, V.G. Burrell, Jr., M.R. DeVoe, R.E. Sojka, S. Gilbert, R. Banks, L.H. Stolzy, C. Brooks, T.D. Matthews, & T.H. Shears. Croom Helm, London, England. pp. 183-194.

Belt, G.H., J. O'Laughlin, & T. Merrill. 1992. Design of forest riparian buffer strips for the protection of water quality : analysis of scientific literature. Idaho Forest, Wildlife and Range Policy Analysis Group, Report No. 8. University of Idaho, Moscow, ID.

Benke, A.C., D.M. Gillespie, F.K. Parrish, T.C Van Arsdall, R.J. Hunter, & R.L. Henry. 1979. Biological basis for assessing impacts of channel modification: invertebrate production, drift, and fish feeding in a southeastern blackwater stream. Georgia Institute of Technology, Atlanta, GA.

Benke, A.C., R.L. Henry, III, D.M. Gillespie, & R.J. Hunter. 1985. Importance of snag habitat for animal production in southeastern streams. Fisheries 10:8-13.

Benke, A. C., T. C. Van Arsdall, Jr., D. M. Gillespie, & F. K. Parrish. 1984. Invertebrate productivity in a subtropical blackwater river: the importance of habitat and life history. Ecological Monographs 54(1):25-63.

Bennett, A. 1991. What types of organism will use corridors? In Nature Conservation 2: The Role of Corridors. Edited by D.A.Saunders & R.J. Hobbs. Surrey Beatty & Sons Pty Limited. Norton, New South Wales, Australia. pp. 407-408.

Bennett, A.F. 1990. Habitat corridors and the conservation of small mammals in a fragmented forest environment. Landscape Ecology 4:109-122.

Bernstein, R. 1990. Texas Department of Health, Fish and Shellfish Consumption Advisory. Texas Department of Health. Internal document. Austin, TX.

Biercevicz, M. 1977. An avifauna list of the Big Thicket National Preserve and Vicinity. Manuscript. NPS, Beaumont, TX.

Big Thicket National Preserve. 1993a. Big Thicket National Preserve, 1992-93 Hunter Harvest. U.S. Department of the Interior, National Park Service, Big Thicket National Preserve. Beaumont, TX.

Big Thicket National Preserve. 1993b. Trapping Records (internal document). U.S. Department of the Interior, National Park Service, Big Thicket National Preserve. Beaumont, TX.

Big Thicket Reporter. 1993. Clinton signs addition bill. Big Thicket Reporter. Batson, TX. No. 4, July-Aug.

Bigler, J. & A. Greene. 1993. EPA Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Vol. 1. Office of Science and Technology, Office of Water, U.S. Environmental Protection Agency. Washington, D.C.

Birstein, V.J. 1993. Sturgeons and paddlefishes: threatened fishes in need of conservation. Conservation Biology 7(4): 773-787.

Blaustein A.R. and D.B. Wake. 1992. Declining Amphibian Populations: A global Phenomenon? In: Trends in Ecology and Evolution 5:203-204.

Blaustein, A.R., D.B. Wake, W.P Sousa. 1994. Amphibian Declines: Judging stability, persistence and susceptibility of populations to local and global extinctions. Conservation Biology 8:60-71.

Borradaile, L. A. , F. A. Potts, L. E. S. Eastham, & J. T. Saunders, Revised by G. A. Kerkut. 1963. The Invertebrata, 4th ed. Cambridge University Press, Cambridge, UK.

Boschung, Jr., H. T., J. D. Williams, D. W. Gotshall, D. K. Caldwell & M. C. Caldwell. 1983. The Audubon Society Guide to North American Fishes, Whales, and Dolphins. Alfred A. Knopf, Inc. Random House, Inc., New York, NY.

Bounds, R.L., E.P. Seidensticker & C.D. Travis. 1981. Performance Report as required by Federal Aid in Fisheries Act, Federal Aid Project F-30-R-6, Statewide Fishery Management Recommendations, Neches River, Job A : Existing Reservoir and Stream Management Recommendations. Texas Parks & Wildlife Department. Austin, TX.

Bounds, R.L., E.P. Seidensticker & C.D. Travis. 1982. Performance Report as required by Federal Aid in Fisheries Restoration Act, Federal Aid Project F-30-R-7, Statewide Fishery Management Recommendations, Job A : Existing Reservoir and Stream Management Recommendations, Neches River. Texas Parks & Wildlife Department. Austin, TX.

Boydston, G. 1993. Big Game Research and Surveys, Job No. 4 : White-tailed Deer Harvest Surveys. Interim Report as required by Federal Aid in Wildlife Restoration Act. Federal Aid Project No. W-127-R-2. Texas Parks & Wildlife Department. Austin, TX.

Bradford, James. E. 1992. Discovery of a Neches River Ferryboat, Big Thicket National Preserve, Tyler County, Texas. National Park Service, Division of Anthropology, Branch of Cultural Resources Management, Park Papers BITH-02. Santa Fe, NM.

Briceland, Richard H., Assistant to the Director, Science and Technology, United States Department of the Interior. 1994. Managers guide to Visitors Survey.

Brinson, M.M. 1990. Riverine forests. In Ecosystems of the World : Forested Wetlands. Edited by A.E. Lugo, M.M. Brinson, & S. Brown. Elsevier Scientific, Amsterdam, The Netherlands.

Brinson, M.M., A.E. Lugo, & S. Brown. 1981. Primary productivity, decomposition and consumer activity in freshwater wetlands. Annual Review of Ecology and Systematics 12:123-161.

Brittingham, M.C. & S.A. Temple. 1983. Have cowbirds caused forest songbird decline? BioScience 33:31-35.

Brode, J. M. & R.B. Bury. 1984. The importance of riparian systems to amphibians and reptiles. In California riparian systems: ecology, conservation, and productive management. Edited by R.E. Warner & K.M. Hendrin. University of California Press, Berkeley, CA. pp. 30-36.

Brooks, R.P., M.J. Croonquist, E.T. D'Silva, J.E. Gallagher, & D.E. Arnold. 1991. Selection of biological indicators for integrating assessments of wetland, stream, and riparian habitats. In Proceedings of a Symposium: Biological Criteria: Research and Regulation. U.S. Environmental Protection Agency. Washington, D.C.

Brown, K. & R. Frye. 1981. An eye on east Texas, space-age inventory shows loss of wildlife habitat. Texas Parks & Wildlife Magazine. Texas Parks & Wildlife Department. Austin, TX. Jan: 28-30.

Brown, T.C., D. Brown, & D. Binkley. 1993. Laws and programs for controlling nonpoint source pollution in forest areas. Water Resources Bulletin 29(1):1-13.

Bruce, Katherine A., G. N. Cameron, P. A. Harcombe. In press. Introduction, impact upon native habitats, and management of a woody invader, the Chinese Tallow tree, *sapium sebiferum* (L.) Roxb. Natural Areas Journal.

Bryan, K.B., C.D. Fisher, D.E. Manry, & L.S. Risley. 1976. Community structure and distribution of the breeding avifauna of the Big Thicket National Preserve. Report to Office of Natural Sciences, Southwest Region, National Park Service, Santa Fe, N.M.

Bull, E. L. & J. M. Skovlin. 1982. Relationships between avifauna and streamside vegetation. In Transactions of the Forty-Seventh North American Wildlife and Natural Resources Conference. Edited by K. Sabol. Wildlife Management Institute, Washington, D. C.

Burdick, D.M., D. Cushman, R. Hamilton, & J.G. Gosselink. 1989. Faunal changes and bottomland hardwood forest loss in Tensas Watershed, Louisiana. Conservation Biology 3: 282-291.

Burt, W. H. 1964. A Field Guide to the Mammals. Hourton Mifflin Co., Boston, MA.

Burton, T. M. & G. E. Likens. 1975. Energy flow and nutrient cycling in salamander populations in the Hubbard Brook Experimental Forest, NH. Ecology 56: 1068-1080.

Bury, R.B. 1968. The distribution of *Ascaphus truei* in California. Herpetologia 24:39-46.

Cagle, F. R. 1950. The life history of the slider turtle, *Pseudemys scripta troosti*. Ecological Monographs. 20:32-54.

Cain, Brian (U.S.Fish and Wildlife Service), Samra Jones-Bufkins (Galveston Bay Foundation). 1996. Chemical control of water hyacinth, in Galveston Bay Foundation, Soundings, Vol. 7, No. 4, Winter 1995-1996.

Callaway, Glenda L. 1995. Characterization of Institutional Issues for Water Corridor Units of the Big Thicket National Preserve. Prepared for the National Park Service, Big Thicket National Preserve.

Callaway, Glenda L. 1997. Characterization of Public Use of the Water Corridor Units of the Big Thicket National Preserve. Prepared for the National Park Service, Big Thicket National Preserve.

Callaway, Glenda L., Rosine W. Hall, David McHugh. 1993. Field Notes, Annotated U.S.G.S. Quad Maps, Photographs.

Cameron, G.N. 1972. Analysis of insect trophic diversity in two salt marsh communities. Ecology 53:58-73.

Cameron, Guy N. (U. Houston), Katherine A. Bruce, Paul A. Harcombe (Rice U.). 1995a. Invasion of the Chinese Tallow, in Galveston Bay Foundation, Soundings, Vol. 7, No. 2, Summer 1995.

Cameron, Guy N. (U. Houston), Katherine A. Bruce, Paul A. Harcombe (Rice U.). 1995b. Management of Chinese Tallow, in Galveston Bay Foundation, Soundings, Vol. 7, No. 3, Fall 1995.

Campo, J.J. & J.G. Dickson. 1990. The Eastern Wild Turkey In Texas (pamphlet). Texas Parks & Wildlife Department. Austin, TX.

Carley, C.J. 1975. The red wolf program. Manuscript. U.S. Fish & Wildlife Service. Beaumont, TX.

Carlough and Meyer. 1989.

Carlough and Meyer. 1990.

Carraway, Burl and John Norris. 1996. Voluntary Compliance with Forestry Best Management Practices in East Texas, Results from Round 2 of BMP Compliance Monitoring. Texas Forest Service, March 1996.

Catterall, C. P., R. J. Green & D. N. Jones. 1991. Habitat use by birds across a forest-suburb interface in Brisbane: implications for corridors. In Nature Conservation 2: The Role of Corridors. Edited by D.A. Saunders & R.J. Hobbs. Surrey Beatty & Sons Pty Limited. Norton, New South Wales, Australia. pp. 247-258.

Chabreck, R.H, Love, J.R, Linscombe, G. 1981. Foods and Feeding Habits of Nutria in Brackish March in Louisiana. Worldwide Furbearer Conference proceedings, 1(1):531-543.

Chapman, R.J., T.M. Hinckley, L.C. Lee, R.O. Teskey, & B. Swift. 1978. Impact of water level changes on woody riparian and wetland communities, Vol. X, Index and Addendum to Volumes I-VIII. U.S. Dept. of the Interior, U.S. Fish & Wildlife Service. Washington, D.C.

Childers, D.L. & J.G. Gosselink. 1990. Assessment of cumulative impacts to water quality in a forested wetland landscape. Journal of Environmental Quality 19:455-464.

Chilton, Earl (Texas Parks and Wildlife Department). 1995. Grass carp in the Galveston Bay System, in Galveston Bay Foundation, Soundings, Vol. 7, No. 1, Spring 1995.

Cibula,W. 1978. Survey of the mycoflora of the Turkey Creek Unit, Big Thicket National Preserve. Picayune, MS.

Cibula, W. 1979. Myco-ecological study of the Jack Gore Baygall Unit and the Turkey Creek Unit, Big Thicket National Preserve. Picayune, MS.

Clark, J.R. 1980. River corridor approach to bottomland management. Transactions of the North American Wildlife and Natural Resources Conference 45: 387-391.

Clark, T. 1978. A better view of wildlife management. Texas Parks & Wildlife Magazine. Texas Parks & Wildlife Department. Austin, TX. Mar: 13-15

Cloud, T., W. Roach & T. Czapla. 1992. Planning Aid on the Fish and Wildlife Resources of the Lower Trinity River, Texas. U. S. Fish & Wildlife Service, Arlington, TX.

Commander, D. 1978. An evaluation of the fecal coliform loads instream densities of coliform organisms in Pine Island Bayou. Lower Neches Valley Authority Technical Report No. 78-3. 77pp.

Commander, Darrell. 1979. A Study of the Nuisance Flooding along Little Pine Island and Pine Island Bayous. Aquatic Services, Port Neches, TX, 20 August 1979.

Comstock, J. H. 1975. The Spider Book. Revised and edited by W. J. Gertsch. Comstock Publishing Associates, a division of Cornell University Press, Ithaca, NY.

Conant, R. & J. T. Collins. 1991. A Field Guide to Reptiles and Amphibians, third edition. Houghton Mifflin Company, Boston, MA.

Conner, J.V. 1977. Zoogeography of freshwater fishes in western Gulf slope between the Mississippi and the Rio Grande. Ph.D. dissertation. Tulane University, New Orleans, LA. 268pp.

Conner, J.V. & R.D. Suttkus. 1986. Zoogeography of freshwater fishes of the Western Gulf Slope of North America. In The Zoogeography of North American Freshwater Fishes. Edited by Hocutt, C.H. & E.O. Wiley. Wiley & Sons, NY, NY. pp.413-456.

Conner, R.N., D.C. Rudolph, D. L. Kulhavy, & A.E. Snow. 1991. Causes of mortality of red-cockaded woodpecker cavity trees. Journal of Wildlife Management 55: 531-537.

Copeyon, C. K., J. R. Walters, & J. H. Carter III. 1991. Induction of Red-Cockaded Woodpecker Group Formation by Artificial Cavity Construction. Journal of Wildlife Management 55(4):549-556.

Correll, D.L., T.E. Jordan, and D.E. Weller. 1992. Cross media inputs to Eastern United States watersheds and their significance to estuarine water-quality. Water Science and Technology 26(12): 2675-2683.

Cozine, J., Jr. 1976. Assault on a Wilderness : the Big Thicket of East Texas. Ph.D. dissertation. Texas A&M University, College Station, TX.

Crist, E.P., and R.J. Kauth. 1986. The Tasseled Cap de-mystified. Photogrammetric Engineering & Remote Sensing 52(1): 81-86.

Crocker, P.A. & C. Young. 1990. Tetrachlorodibenzo-p-dioxins & -dibenzofurans in edible fish tissue at selected sites in Arkansas, Louisiana, and Texas. Internal document. U.S. Environmental Protection Agency, Region 6. Dallas, TX.

Croonquist, M.J. & R.P. Brooks. 1991. Use of avian and mammalian guilds as indicators of cumulative impacts in riparian-wetland areas. Environmental Management 15(5):701-714.

Croonquist, M.J. & R.P. Brooks. 1993. Effects of habitat disturbance on bird communities in riparian corridors. Journal of Soil & Water Conservation 48(1):65-70.

Cummins, K.W. 1974. Structure and function of stream ecosystems. BioScience 24:631-41.

Darville, R.G. 1978. Water Quality in Little Pine Island Bayou in the Big Thicket National Preserve. M.S. Thesis. Lamar University, Beaumont, TX 74pp.

Davis, W.B. 1974. The mammals of Texas. Bulletin No.41. Texas Parks & Wildlife Department. Austin, TX.

Dawson, C.P., D.J. Decker, & T.L. Brown. 1981. River recreation carrying capacity considerations for the upper Delaware scenic and recreational river (unpublished ). Cornell University, Dept. of Natural Resources. Ithaca, NY.

Décamps, H. 1993. River margins and environmental change. Ecological Applications 3(3):441-445.

Delany, M.F. & C.L. Abercrombie. 1986. American alligator food habits in north central Florida. Journal of Wildlife Management 50:348-353.

Deshotels, J.D. 1978. Soil survey for the Big Thicket National Preserve, Texas. U.S. Dept. of Interior, National Park Service, U.S. Dept. of Agriculture, Soil Conservation Service, Texas Agricultural Experiment Station.

Dethloff, H.C. & V.H. Treat. 1975. A historical survey of the Big Thicket National Preserve. Report to the Office of Cultural Resources, Southwest Region. National Park Service. Santa Fe, NM.

Dethloff, Henry C. and Victor H. Treat. 1975. A Preliminary Report on The Historical Survey of The Big Thicket National Preserve. Texas A&M University, February 1975.

Dethloff, H.C. & V.H. Treat. 1979. Historic resources study. Texas A&M University, College Station, TX.

Deuel, D.E. & C.D Fisher. 1977. Community structure of the forest avifauna of the Big Thicket National Preserve during the spring of 1976. Manuscript. U.S. Dept. of Interior. National Park Service, Office of Natural Science, Southwest Region 70 pp.

Devereux, J.C. & J.A. Moser. 1984. Breeding ecology of barred owls in the central Appalachians. Raptor Research 18:49-58.

Diamond, J. 1993. Cougars and corridors. Nature 365:16-17.

Dickson, J.G. 1978. Forest bird communities of the bottomland hardwoods. In Proceedings of the workshop: management of southern forests for nongame birds. Tech. Coord., R.M. DeGraaf. U.S. Forest Service General Technical Report SE-14, Ashville, NC. pp. 66-73.

Dickson, J.G. 1988. Bird communities in oak-gum forests. In Bird Conservation 3. Edited by J.A. Jackson. International Council for Bird Preservation, University of Wisconsin Press, Madison, WI. pp. 51-62.

Dickson, J.G. 1991. Birds and mammals of pre-colonial southern old-growth forests. Natural Areas Journal 11(1):26-33.

Dirzo, R. 1984. Herbivory: a phytocentric view. p. 141-165. In: Dirzo, R. and J. Sarokhan, Eds., Perspectives on Plant Population Ecology. Sinauer Associated Inc. Publishers, Sunderland, MA.

Edwards, E. A. 1983. Habitat suitability index models: bigmouth buffalo. FWS/OBS - 82/10.34. U.S. Dept. of the Interior, Fish & Wildlife Service . 23 pp.

Egan, R.S and V.R. Gordy. 1981. Baseline study of microlichen distribution in the Big Thicket National Preserve, Texas, in relation to present and future air pollution levels. University of Nebraska at Omaha, Omaha, NE. PX7029-0-0425.

Eng, L. L. 1984. Rare, threatened and endangered invertebrates in California riparian systems. In California Riparian Systems: Ecology, Conservation, and Productive Management. Edited by R.E. Warner & K. M. Hendrix. University of California Press, Berkeley, CA.

Ernst, C. H. & R. W. Barbour. 1972. Turtles of the United States. University of Kentucky Press, Lexington, KY.

Ernst, C.H. & R.W. Barbour. 1989. Snakes of Eastern North America. George Mason University Press, Fairfax, Virginia.

Ernst, J.P. & V. Brown. 1989. Conserving endangered species on southern forested wetlands. In Proceedings of the symposium: The Forested Wetlands of the Southern United States. Edited by D.D. Hook & R. Lea. Forest Service, Ashville, SC, USA. pp.135-145.

Eschelle, A.A. 1974. The status of fishes in the Big Thicket National Preserve (Museum study). Stephen F. Austin State University, Nacogdoches, TX.

Ethridge, B.J. & R.K. Olson. 1992. Research and information needs related to nonpoint source pollution and wetlands in the watershed: an EPA perspective. Ecological Engineering 1:149-156.

Evans, J. 1977. A longitudinal distribution of fishes in an east Texas stream. M.S. thesis. Texas A&M University, College Station, TX.

Everett, R. A., and G. M. Ruiz. 1993. Coarse woody debris as a refuge from predation in aquatic communities. Oecologia 93: 475-486.

Ezzel, C. 1992. Wilderness corridors may not benefit all. Science News Aug 29:135.

Federal Register, Vol. 40, No. 52, Monday, March 17, 1975. Part II: Department of the Interior, National Park Service, Big Thicket National Preserve Boundaries Description.

Federal Register. 1995. Proposed regulations for houseboats, Big Thicket National Preserve.

Fields, S. 1992. Regulations and policies relating to the use of wetlands for nonpoint source pollution control. Ecological Engineering 1:135-141.

Fischer, R. A. & N. R. Holler. 1990. Habitat and relative abundance of gray squirrels in Southern Alabama. Journal of Wildlife Management 55(1):52-59.

Fisher, C.D. 1974. A preliminary survey of the avian fauna of Big Thicket National Preserve. Stephen F. Austin State University, Nacogdoches, TX.

Fisher, C.D. & F.L. Rainwater. 1978. Distribution and relative abundance of amphibians and reptiles in forest communities of Big Thicket National Preserve. Manuscript. Stephen F. Austin State University, Nacogdoches, TX. 61 pp.

Flora, M.D. 1984. Developing of a water quality monitoring program for the Big Thicket National Preserve, Texas. WRSFL Project Report No. 84-BITH-1. National Park Service, Water Resources Field Support Laboratory, Colorado State University, Ft. Collins, CO.

Flora, M.D., S. Lawrence, & M. Cavendish. 1985. A summary of water quality for the Big Sandy Creek Unit, Beech Creek Unit, and Turkey Creek Unit of Big Thicket National Preserve, Texas (1975-81). WRSFL Project Technical Report No. 85-BITH-1. National Park Service, Water Resources Division, Applied Resource Branch, Colorado State University, Ft. Collins, CO.

Florida Game & Freshwater Fish Commission. 1978. Conceptual fish and wildlife management plan for lower Apalachicola environmentally endangered lands (EEL) (unpublished). Office of Environmental Services, State of Florida. Tallahassee, FL.

Florida Game & Freshwater Fish Commission. 1982. Lower Apalachicola River EEL (environmentally endangered lands) Management Plan. (unpublished). Office of Environmental Services, State of Florida. Tallahassee, FL.

Foley, R.E., R.J. Sloan, M,K, Brown. 1988. Organochlorine and mercury residues in wild mink and otter: comparison with fish. Environmental toxicology and chemistry 7:363-374.

Forsythe, S.W. & J.E. Roelle. 1990. The relationship of human activities to the wildlife function of bottomland hardwood forests: the report of the wildlife workgroup. In Ecological Processes and Cumulative Impacts: Illustrated by Bottomland Hardwood Wetland Ecosystems. Edited by J.G. Gosselink, L.C. Lee, & T.A. Muir. Lewis Publishing, Chelsea, MI, USA. pp. 533-546.

Fountain, M.S. 1986. Impact of oil/gas exploration and extraction on the vegetation and soils of the Big Thicket National Preserve. Report to National Park Service, Division of Natural Resources Management, Southwest Region, Santa Fe, NM.

Frederick, P. C. & M. W. Collopy. 1989. The role of predation in determining reproductive success of colonially nesting wading birds in the Florida Everglades. The Condor 91:860-867.

Freese, S.W., M.C. Nichols, & S.G. Endress. 1967. Water quality study. Report prepared for Lower Neches Pollution Control Advisory Committee. Beaumont, TX. 73pp.

Frentress, C.D. 1986. Wildlife of bottomlands: species and status. In Bottomland Hardwoods in Texas. Proceedings of an Interagency Workshop on Status and Ecology. Edited by C.A. McMahan & R.G. Frye. Texas Parks & Wildlife, Austin, TX. pp. 37-57.

Fritzell, E.K. 1988. Mammals and wetlands. In The Ecology and Management of Wetlands Vol. 1. Edited by D.D. Hook, W.H. McKee, Jr., H.K. Smith, J. Gregory, V.G. Burrell, Jr.,

M.R. DeVoe, R.E. Sojka, S. Gilbert, R. Banks, L.H. Stolzy, C. Brooks, T.D. Matthews, & T.H. Shears. Croom Helm, London, England. pp. 213-226.

Frye, R. & C. Frentress. 1975. A New Look at Texas. Texas Parks & Wildlife Magazine. Texas Parks & Wildlife Department. Austin, TX. Sept: 7-8.

Frye, R. G. &D. A. Curtis. 1990. Texas Water and Wildlife: An Assessment of Direct Impacts to Wildlife Habitat from Future Water Development Projects. Texas Parks and Wildlife Department and U.S. Fish and Wildlife Service. 59pp.

Garber, S. D. & J. Burger. 1995. A 20-yr study documenting the relationship between turtle decline and human recreation. Ecological Applications 5(4):1151-1162.

Gates, J.E. & L.W. Gysel. 1978. Avian nest dispersion and fledging success in field-forest ecotones. Ecology 59:871-883.

Gates, J. E. & N. R. Giffen. 1991. Neotropical migrant birds and edge effects at a forest-stream ecotone. The Wilson Bulletin 103(2):204-217.

Gibbons, J. W., J. L. Greene, & J. D. Congdon. 1990. Temporal and spatial movement patterns of sliders and other turtles. In Life History and Ecology of the Slider Turtle. Edited by J. W. Gibbons. Smithsonian Institution Press, Washington, D.C. pp. 201-215

Gibbs, J.P. & J. Faaborg. 1990. Estimating the viability of Ovenbird and Kentucky Warbler populations in forest fragments. Conservation Biology 4:193-196.

Gillespie, B.M. 1992. The Nature of Channel Platform Change: Brazos River, Texas. Unpublished Ph.D. dissertation, Texas A&M University, College Station, TX.

Glitzenstein, J.S. & P.A. Harcombe. 1986. Effects of the December 1983 tornado on the vegetation of the Big Thicket. Report to Big Thicket National Preserve, Beaumont, Texas and Southwestern Parks and Monuments Association, Santa Fe, NM.

Gooch, Tom, P.E., Freese and Nichols, Inc. 1996. Rainfall patterns and historical inflow from the Sabine and Neches Rivers into Sabine Lake. Paper presented at Sabine Lake Conference, Beaumont, Tx., 13 September 1996.

Good, R. E., D. F. Whigham, & R. L. Simpson. 1978. Freshwater Wetlands: Ecological Processes and Management Potential. Academic Press, New York, NY.

Gordy,V.R. 1986. Revisit of the Big Thicket National Preserve, Texas, for the assessment of microlichen distribution. Report to National Park Service, Air Division, Denver, CO.

Gosselink, J.G., L.C. Lee, & T.A. Muir. 1990. Ecological Processes and Cumulative Impacts, Illustrated by Bottomland Hardwood Wetland Ecosystems. Lewis Publishing, Chelsea, MI.

Gosselink, J.G., G.P. Shaffer, C.L. Lyndon, D.M. Burdick, D.L. Childers, N.C. Leibowitz, S.C. Hamilton, R. Boumans, D. Cushman, S. Fields, M. Koch, & J.M. Visser. 1990. Landscape conservation in a forested wetland watershed. Can we manage cumulative impacts? BioScience 40:588-600.

Gregory, P.T., J.M. Macartney, & K. W. Larsen. 1987. Spatial patterns and movements. In Snakes: Ecology and Evolutionary Biology. Edited by R. A. Seigel, J.T. Collins, & S. S. Novak. Macmillan Publishing, New York, NY. pp.366-395.

Hairston, N. G. 1987. Community ecology and salamander guilds. Cambridge University Press, Cambridge, UK.

Hall, D. H. & V.W. Lambou. 1990. The ecological significance to fisheries of bottomland hardwood systems: values, detrimental impacts, and assessment: the report of the fisheries workgroup. In Ecological Processes and Cumulative Impacts. Edited by J.G. Gosselink, L.C. Lee, & T.A. Muir. Lewis Publishing, Chelsea, MI, USA. pp. 481-531.

Hall, R. J. 1994. Herpetofaunal Diversity of the Four Holes Swamp, South Carolina. United States Department of the Interior, National Biological Survey. 43 pp.

Hall, Rosine W. 1996. A Case Study of Flooding the Neches Bottom Study Site. Prepared for the National Park Service, Big Thicket National Preserve.

Hall, Rosine W. and Kathy A. Bruce. 1996. Characterization of Water Quality of the Water Corridor Units of the Big Thicket National Preserve. Prepared for the National Park Service, Big Thicket National Preserve.

Hall, Rosine W., Paul A. Harcombe, Hanadi Rifia, Phil Bedient, Glenda Callaway. 1996. Land Cover/Land Use Map. Prepared for the National Park Service, Big Thicket National Preserve.

Halstead, B. G. 1981. Pine Island Bayou Watershed, Texas: A planning-aid report submitted to U. S. Army Corps of Engineers. United States Fish and Wildlife Services, Division of Ecological Sciences, Galveston, Texas, Field Office.

Hamel, P.B. 1989. Breeding bird populations on the Congaree Swamp National Monument, South Carolina. In Freshwater Wetlands and Wildlife. Edited by R.R. Sharitz & J.W. Gibbon. U.S. Department of Energy, Office of Scientific and Technical Information, Oak Ridge, TN. pp. 617-628.

Hamel, P.B. 1992. Land Manager's Guide to the Birds of the South. The Nature Conservancy. Chapel Hill, NC. 367 pp.

Hamel, P.B., H.E. LeGrand, Jr., M.R. Lennartz, & S.A. Gauthreaux, Jr. 1982. Bird-habitat relations on southern forest lands. U.S. Forest Service General Technical Report SE-22. Southeast Forest Experiment Station, Ashville, SC. 417pp.

Hammer, D.A. 1992. Designing constructed wetlands systems to treat agricultural nonpoint source pollution. Ecological Engineering 1:49-82.

Hammond, K.G. 1980. Design for computerized data storage and retrieval for the Big Thicket National Preserve. Houston, TX.

Hansen, A.J., T.A. Spies, F.J. Swanson & J.L. Ohmann. 1991. Conserving biodiversity in managed forests. BioScience 41: 382-392.

Harcombe, P.A. & C.R. Hughes. 1982. Final Report: Big Thicket Insect Inventory. Report to Office of Natural Sciences, U.S. Dept. of Interior, National Park Service, Southwest Region, Santa Fe, NM.

Harcombe, P.A. & P.L. Marks. 1975. A forest type map of the Big Thicket National Preserve. Rice University, Houston, TX.

Harcombe, P.A. & P.L. Marks. 1978. Vegetation of the Big Thicket National Preserve, preliminary description of plant communities and comments on management for Beech Creek and Big Sandy Units. Rice University, Houston, TX.

Harcombe, P.A. & P.L. Marks. 1979. Forest vegetation of the Big Thicket National Preserve. Report to the Office of Natural Sciences, Southwest Region, National Park Service, Santa Fe, NM.

Harcombe, Paul A., Elizabeth N. Hane, Jonathan P. Evans, Rosine W. Hall, Kathy A. Bruce, Keith C. Hoffman, Patrick D. Conant. 1996. Characterization of the Biological Resources of the Water Corridor Units of the Big Thicket National Preserve. Prepared for the National Park Service, Big Thicket National Preserve.

Harrel, R.C. 1975. Water quality and salt water intrusion in the Lower Neches River. Texas Journal of Science 26:107-117.

Harrel, R.C. 1976. Preliminary limnological survey of streams in the Big Thicket National Preserve. Work Order PX7000-5-0770. Report to National Park Service, Santa Fe, NM,. 46pp.+map.

Harrel, R.C. 1977. Water quality monitoring in the Big Thicket National Preserve. Research Project Report #PX7029-6-0846. U.S. Department of the Interior, National Park Service, Southwestern Region, Beaumont, Texas. 38pp.

Harrel, R. C. 1985. Effects of a crude oil spill on water quality and macrobenthos of a southeast Texas stream. Hydrobiologia 124: 223-228.

Harrel, R. C. 1993. Origin and decline of the estuarine clam Rangia cuneata in the Neches River, Texas. American Malacological Bulletin 10:153-159.

Harrel, R.C. & D. Bass. 1979. Water quality monitoring in the Big Thicket National Preserve. U.S. Department of the Interior, National Park Service, Southwestern Region. Research Project Report #PX7029-8-0789.

Harrel, R. C., D. L. Bechler, & R. E. Ogren. 1994. First Texas record of Geoplana arkalabamensis (Turbellaria:Tricladida: Terricola) with a review of other land planarians reported in the state. The Texas Journal of Science 46: 45-49.

Harrel, R.C. & G. Watson. 1975. Limnological and hydrological research in the Big Thicket National Preserve area, problems posed, and recommendations for additional research. Work Order PX7000-5-0475. Report to National Parks Service, Santa Fe, NM. 19pp.

Harrel, R. C., J. Ashcraft, R. Howard, & L. Patterson. 1976. Stress and Community Structure of Macrobenthos in a Gulf Coast Riverine Estuary. Contributions in Marine Science 20: 69-81.

Harrel, R.C. & J.L. Duplechin. 1976. Stream bottom organisms as indicators of ecological change. OWRR Project B-189-TEX. Research Project Completion Report to Texas Water Resources Institute, Texas A&M University 49pp.

Harrel, R. C. & M. A. Hall. 1991. Macrobenthic community structure before and after pollution abatement in the Neches River estuary (Texas). Hydrobiologia 211: 241-252.

Harrel, R.C. & R.G. Darville. 1978. Water quality monitoring in the Big Thicket National Preserve. U.S. Department of the Interior, National Park Service, Southwestern Region. Research Project Report #PX7029-7-00636. 100pp.

Harrel, R.C. & S.D. Commander. 1980. Water quality monitoring in the Big Thicket National Preserve, Turkey Creek Unit. Research Project Report #PX7140-9-0199. U.S. Department of the Interior, National Park Service, Southwestern Region, Beaumont, Texas.

Harrel, R.C. & W. Newberry. 1981. Water quality monitoring in the Big Thicket National Preserve, Big Sandy Creek Unit. Research Project Report #PX7029-1-0114. U.S. Department of the Interior, National Park Service, Southwestern Region. 68pp.

Harris, L. D. 1984. The Fragmented Forest: Island Biogeography Theory and the Preservation of Biotic Diversity. The University of Chicago Press, Chicago, IL.

Harris, L.D. 1988a. The faunal significance of fragmentation of southeastern bottomland forests. In Proceedings of the symposium: The Forested Wetlands of the Southern United States. Edited by D.D. Hook & R. Lea. Forest Service, Ashville, SC. pp. 126-134.

Harris, L. D. 1988b. Edge effects and conservation of biotic diversity. Conservation Biology 2:330-332.

Harris, L. D. & P. B. Gallagher. 1989. New initiatives for wildlife conservation: the need for movement corridors. In Preserving Communities and Corridors. Edited by G. Mackintosh. Defenders of Wildlife, Washington, D. C.

Harrison, R.L. 1992. Toward a theory of inter-refuge corridor design. Conservation biology 6:293-295.

Hawks, L.J., F.W. Cubbage, H.L. Haney, Jr., R.M. Shaffer, & D.H. Newman. 1993. Forest water quality protection, A comparison of regulatory and voluntary programs. Journal of Forestry 91(5):48-54.

Healy, T. J. 1984. Identification of wood duck roosts in the South District of Big Thicket National Preserve. Manuscript. NPS, Beaumont, TX.

Heimlich, R.E. & O.E. Kula. 1991. Economics of livestock and crop production on post-CRP lands. In The Conservation Reserve - Yesterday, Today and Tomorrow. Edited by L.A. Joyce, J.E. Mitchell, & M.D. Skold. Technical Report RM-203. U.S. Dept. of Agriculture, Forest Service. pp. 11-23.

Heitmeyer, M. & L. Fredrickson. 1981. Do wetland conditions in the Mississippi delta hardwoods influence mallard recruitment? Transactions of The North American Wildlife and Natural Resources Conferences 46:44-57.

Henein, K. & G. Merriam. 1990. The elements of connectivity where corridor quality is variable. Landscape Ecology 4(2-3):157-170.

Hepp, G. R. & R. A. Kennamer. 1992. Characteristics and consequences of nest-site fidelity in wood ducks. The Auk 109(4):812-818.

Herlong, D.D. & M.A. Mallin. 1985. The benthos-plankton relationship upstream and downstream of a blackwater impoundment. Journal of Freshwater Ecology 3:47-59.

Hickman, C.A. 1990. Forested-wetland trends in the United States: an economic perspective. Forest Ecology and Management 33/34: 227-238.

Hill, E.F. & M. B. Camardese. 1986. Lethal dietary toxicities of environmental contaminants and pesticides to Coturnix. U.S. Fish and Wildlife Service Technical Report 2. Department of the Interior, U.S. Fish and Wildlife Service. 148 pp.

Hocutt, C.H. & E.O. Wiley. 1986. The Zoogeography of North American Freshwater Fishes. Wiley & Sons, NY, NY.

Holman, J.A. & W.H. Hill. 1961. A mass unidirectional movement of *Natrix sipedon pictiventris*. Copeia 1961:498-499.

Hook, D.D. & R. Lea, editors. 1989. Proceedings of the Symposium, The Forested Wetlands of the Southern United States. Southeastern Forest Experiment Station. Asheville, NC.

Howard, R. 1973. Physicochemical conditions and communities of macrobenthos in the lower Neches River. M.S. Thesis. Lamar University, Beaumont, TX. 43 pp.

Howard, R. J. & J. A. Allen. 1989. Streamside habitats in southern forested wetlands: their role and implications for management. In Proceedings of the symposium: The Forested Wetlands of the Southern United States. Edited by D.D. Hook & R. Lea. Forest Service, Ashville, SC. pp.97-106.

Howells, Robert G. 1996. Freshwater mussels of B.A. Steinhagen Reservoir and the adjacent Neches River drainage. Prepared for Texas Parks and Wildlife Department, Ingram, TX.

Hubert, W.A., S.H. Anderson, P.D. Southall, & J.H. Chance. 1984. Habitat suitability index models and instream flow suitability curves: paddlefish. U.S. Fish and Wildlife Service FWS/OBS - 82/10.80. 32pp.

Hudson, W. E., editor. 1991. Landscape Linkages and Biodiversity. Island Press, Washington, D. C.

Huffman, R.T. & S.W. Forsythe. 1981. Bottomland hardwood forest communities and their relation to anaerobic soil conditions. In Wetlands of Bottomland Hardwood Forests. Edited by J.R. Clark & J. Benforado. Elsevier Scientific: Amsterdam, The Netherlands. pp.187-196.

Hughes, J.C., M.D. Flora, & J.C. Woods. 1987. Big Thicket National Preserve : Water Quality Report 1984-1986, Water Resources Report 87-2. U.S. Dept. of the Interior, National Park Service, Water Resources Division, Ft. Collins, CO.

Hughes, J.C., M.G. Cavendish, and M.D. Flora. 1986. A summary of water quality for the Menard Creek Corridor Unit, Lance Rosier Unit, and Little Pine Island Bayou Corridor Unit of Big Thicket National preserve, Texas (1975-83). Water Resource Report Np. 86-8. National Park Service, Water Resources Division, Colorado State University, Ft. Collins, CO.

Hughes, L.S. & D.K. Leifeste. 1965. Reconnaissance of chemical quality of surface waters of the Neches River Basin, Texas. Report No. 5. Texas Water Development Board. 64pp.

Hunt, W.G., J.M. Jenkins, R.E. Jackman, C.G. Thelander, and A.T. Gerstell. 1992. Foraging ecology of bald eagles on a regulated river. Journal of Raptor Research 26(4): 892-1016.

Ims, R.A., J. Rolstad, & P. Wegge. 1993. Predicting space use responses to habitat fragmentation - can voles (*Microtus oeconomus* ) serve as an experimental-model system EMS for Capercaillie grouse (*Tetrao urogallus* ) in boreal forest. Biological Conservation 63(3): 261-268.

Irland, L.C. Things wild and free: any room for economics in the wilderness? In Ecosystem Management for Parks and Wilderness. Edited by J.K. Agee & D.L. Johnson. University of Washington Press. Seattle, WA. 237pp.

Johnson, Joyce (Texas Parks and Wildlife Department). 1995. Water hyacinth, an exotic aquatic plant pest, in Galveston Bay Foundation, Soundings, Vol. 7, No. 4, Winter 1995-1996.

Joyce, L.A., J.E. Mitchell, & M.D. Skold, eds. 1991. The Conservation Review - Yesterday, Today and Tomorrow. Washington, DC: U.S. Dept. of Agriculture, Forest Service, 65 pp.

Kaiser, Ronald A., Steven E. Alexander and J. Porter Hammitt. 1994. Protecting the National Parks in Texas through enforcement of water quality standards: an exploratory analysis. For National Park Service, U.S. Department of Interior, Technical Report NPS/NRWRD/NRTR-94/18, November 1994.

Karns, P.D. 1993. White-tailed deer population trends. Interim report as required by Federal Aid in Wildlife Act, Federal Aid Project No. W-127-R-2. Big Game Research and Surveys, Job No. 1. Texas Parks & Wildlife Department. Austin, TX. 60pp.

Karr, J.R. and I.J. Schlosser. 1978. Water resources and the land-water interface. Science 201: 229-234.

Keiter, R.B. 1988. Natural ecosystem management in park and wilderness areas: looking into the law. In Ecosystem Management for Parks and Wilderness. Edited by J.K. Agee & D.R. Johnson. University of Washington Press, Seattle, Washington, USA. pp. 15-40.

Keiter, R.B. 1989. Taking account of the ecosystem on the public domain: law and ecology in the Greater Yellowstone region. University of Colorado Law Review 60: 923-1007.

Keller, C.M.E., C.S. Robbins & J.S. Hatfield. 1993. Avian communities in riparian forests of different widths in Maryland and Delaware. Wetlands 13(2): 137-144.

Kennedy, R. S. 1977. Ecological Analysis and population estimates of the birds of the Atchafalaya River Basin in Louisiana. Ph.D. Dissertation. La. State Univ., Baton Rouge. 200 pp.

Kim, Carolyn. 1994.Field investigation focuses on impacts of climate on bottomland hardwood (BLH) seedlings. In: The Wetlands Research Program Bulletin 4(3):5-6. United States Army Corps of Engineers.

Knight, R.L. 1992. Ancillary benefits and potential problems with the use of wetlands for nonpoint source pollution control. Ecological Engineering 1:97-113.

Korte, P.A. & L.H. Fredrickson. 1977. Swamp rabbit distribution in Missouri. Transactions of the Missouri Academy of Science 72-7:10-11.

Kost, D. 1977. Physicochemical conditions and macrobenthos of streams in the Beech Creek Unit of the Big Thicket National Preserve. Masters Thesis. Lamar University. Beaumont, TX. 62pp.

Krohn, W.B. 1992. Sequence of habitat occupancy and abandonment - potential standards for testing habitat models. Wildlife Society Bulletin 20(4): 441-444.

La Polla, V.N. & G.W. Barrett. 1993. Effects of corridor width and presence on the population dynamics of the meadow vole (*Microtus pennsylvanicus* ). Landscape Ecology 8(1): 25-37.

Landres, P.B, J.D. Verner, J.W. Thomas. 1988 Ecological Uses of Vertebrate Indicator Species: A Critique. Conservation Biology 2:316-328.

Laubhan, M. K. & F. A. Reid. 1991. Characteristics of yellow-crowned night-heron nests in lowland hardwood forests of Missouri. 1991. The Wilson Bulletin 103(3):486-491.

Laubhan, M. K., W. D. Rundel, B. I. Swartz, & F. A. Reid. 1991. Diurnal activity patterns and foraging success of yellow-crowned night-herons in seasonally flooded Wetlands. The Wilson Bulletin 103(3):272-277.

Lea, R. 1988. Management of eastern United States bottomland hardwood forest. In The Ecology and Management of Wetlands Vol 2. Edited by D.D. Hook, W.H. McKee, Jr., H.K. Smith, J. Gregory, V.G. Burrell, Jr., M.R. DeVoe, R.E. Sojka, S. Gilbert, R. Banks, L.H. Stolzy, C. Brooks, T.D. Matthews, & T.H. Shears. Croom Helm, London, England. pp.185-194.

Lewis, D.P. 1978. Agaricales of southeast Texas. PX7140-7-0036. M.S. Thesis, Lamar University, Beaumont, TX.

Lewis, S.P. 1974. Physicochemical conditions and macrobenthos of Village Creek, Texas. M.S. Thesis, Lamar University. Beaumont, TX. 43pp.

Lewis, S.P. & R.C. Harrel. 1978. Physicochemical conditions and diversity of macrobenthos of Village Creek, Texas. Southwestern Naturalist 23(2):263-272.

Lord, R., J. Norris, & J. Tullos. 1992. Voluntary Compliance with Forestry Best Management Practices in East Texas, Results from the BMP Compliance Monitoring Project. Texas Forest Service. Texas A&M University System. College Station, TX.

Lovejoy, T. E., R.O. Bierregaard, Jr., A.B. Rylands, J.R. Malcolm, C.E. Quintela, L.H. Harper, K.S. Brown, Jr., A.H. Powell, G.V.N. Powell, H.O.R. Schubart, & M.B.Hays. 1986. Edge and other effects of isolation on Amazon forest fragments. In Conservation Biology: The Science of Scarcity and Diversity. Edited by M.E. Soulé. Sinauer Associates, Inc., Sunderland, MA.

Lower Apalachicola River EEL Management Plan (Environmentally Endangered Lands). 1992. Office of Environmental Services of the Florida Game and Fresh Water Fish Commission, December 1992.

Lower Neches Valley Authority. 1965. Salt water barrier on Neches River below mouth of Pine Island Bayou. Manuscript. Lower Neches Valley Authority. 40pp.

Lower Neches Valley Authority and Alan Plummer & Associates, Inc. 1984. Pine Island Bayou Water Quality Management Study, Task 0607.335, Management Practice Recommendations. Texas Department of Water Resources. Austin, TX.

Lower Neches Valley Authority. 1992. Regional Assessment of Water Quality, Lower Neches River Basin and Neches-Trinity Coastal Basin. Prepared with assistance of Alan A. Plummer and Associates, Inc. and in cooperation with the Texas Water Commission under authorization of the Clean Rivers Act; October 1992.

Lower Neches Valley Authority. 1994. Regional Assessment of Water Quality, Lower Neches River Basin and Neches-Trinity Coastal Basin. Prepared with assistance of Alan A. Plummer and Associates, Inc. and in cooperation with the Texas National Resource Conservation Commission under authorization of the Clean Rivers Act; October 3, 1994.

Lower Neches Valley Authority. 1996. Regional Assessment of Water Quality, Lower Neches River Basin and Neches-Trinity Coastal Basin. Prepared with assistance of Alan A. Plummer and Associates, Inc. and in cooperation with the Texas National Resource Conservation Commission under authorization of the Clean Rivers Act; July 1996 (draft).

Lowrance, R., R. Todd, J. Fail, Jr., O. Hendrickson, Jr., R. Leonard, & L. Asmussen. 1984. Riparian forests as nutrient filters in agricultural watersheds. BioScience 34(6): 374-377.

MacArthur, R. H. & E. O. Wilson. 1967. The Theory of Island Biogeography. Princeton University Press, Princeton New Jersey.

Mackintosh, G., editor. 1989. Preserving Communities and Corridors. Defenders of Wildlife, Washington, D. C.

Marks, P.L. & P.A. Harcombe. 1981. Forest vegetation of the Big Thicket, southeast Texas. Ecological Monographs 51:287-305.

Margulis, L. 1992. Diversity of Life : The Five Kingdoms. Enslow. Hillside, NJ.

Martin, T. E. 1989. Breeding productivity considerations: what are the appropriate habitat features for management? In Ecology and Conservation of Neotropical Migrant Landbirds. Edited by J.M. Hagan III & D.W. Johnston. Smithsonian Institution Press, Washington, D.C. pp. 455-473.

Martin, W.H., S.G. Boyce, & A.C. Echternacht, editors. 1993a. Biodiversity of the Southeastern United States/Lowland Terrestrial Communities, Volume I : Lowland Terrestrial Communities. John Wiley & Sons, Inc. New York, NY.

Martin, W.H., S.G. Boyce, & A.C. Echternacht, editors. 1993b. Biodiversity of the Southeastern United States/Lowland Terrestrial Communities, Volume II : Upland Terrestrial Communities. John Wiley & Sons, Inc. New York, NY.

Maurer B.B, S.G. Heywood. 1993. Geographic Range Fragmentation and Abundance in Neotropical Migratory Birds. Conservation Biology. 7:501-509.

McCauley, G.N. 1993. Rice irrigation water quality demonstration project, Colorado, Matagorda, and Wharton Counties, Final Report. Texas State Soil and Water Conservation Board. Temple, Texas.

McCollough, J.D. 1974. A preliminary survey of the invertebrate fauna of Big Thicket National Preserve. Report to the Office of Natural Sciences, Southwest Region, National Park Service, Santa Fe, NM.

McCoy, E.D., and H.R. Mushinsky. 1992. Rarity of organisms in the sand pine scrub habitat of Florida. Conservation Biology 6(4): 537-548.

McCullough, J. D. 1974. A Preliminary survey of the invertebrate fauna of Big Thicket National Preserve. National Park Service, Office of Natural Science, Southwest Region.

McGeen, D. S. 1972. Cowbird-host relationships. The Auk 89:360-380.

McGuffin, S.C. 1984. Community structure of the forest avifauna of the Loblolly Unit of the Big Thicket National Preserve. M.S. Thesis, Lamar University. Beaumont, TX. 84pp.

McMahan, C.A. & R.G. Frye. 1986. Bottomland Hardwoods in Texas. Proceedings of an Interagency Workshop on Status and Ecology, May 6-7, 1986. Texas Parks & Wildlife Department, Austin, TX.

McMahan, C.A., R.G. Frye, & K.L. Brown. 1984. The Vegetation Types of Texas including Cropland, An Illustrated Synopsis to Accompany the Map. Texas Parks & Wildlife Department, Wildlife Division. Austin, TX. 40 pp.

McMahon, T.E., G. Gebhart, O.E. Maughan, & P.C. Nelson. 1984. Habitat suitability index models and instream flow suitability curves: Spotted Bass. FWS/OBS - 82/10.72. U.S. Fish & Wildlife Service. 41 pp.

Mealey, S.P., J.F. Lipscomb, & K.N. Johnson. 1982. Solving the habitat dispersion problem in forest planning. In Transactions of the Forty-seventh Wildlife and Natural Resources Conference. Edited by K. Sabol. Wildlife Management Institute, Washington, D.C.

Meents, J. K, B. W. Anderson, & R. D. Ohmart. 1984. Sensitivity of riparian birds to habitat loss. In California Riparian Systems: Ecology, Conservation, and Productive Management. Edited by R.E. Warner & K. M. Hendrix. University of California Press, Berkeley, CA.

Merriam, G. 1991. Corridors and connectivity: animal populations in heterogeneous environments. In The role of corridors. Edited by D. A. Saunders & R. J. Hobbs. Surrey Beatty, Chipping Norton, New South Wales, Australia. pp. 133-142.

Merriam, G. & A. Lanoue. 1990. Corridor use by small mammals: field measurement for three experimental types of *Peromyscus leucopus*. Landscape Ecology 4:123-131.

Meyer, J.L. 1990. A blackwater perspective on riverine ecosystems. BioScience 40:643-651.

Meyer, J.L. 1992. Seasonal patterns of water quality in Blackwater Rivers of the Coastal Plain, Southeastern United States. In Water Quality in North American River Systems. Edited by C.D. Becker & D.A. Neitzel. Battelle Press. Columbus, OH.

Mirowsky, K. and P. Horner. 1997. 1996 Annual Report on Roosting of two rare vespertilionid bats, the southeastern myotis and Rafinesque's big-eared bat in East Texas. Texas Parks and Wildlife Department, Austin, TX.

Mitchell, M.R. 1992. Bald eagle nest survey and management. Performance report as required by Federal Aid in Wildlife Restoration Act. Texas Federal Aid Project No. W-125-R-3. Wildlife Research and Surveys, Job No. 30. Texas Parks and Wildlife Department, Austin, TX. 10pp.

Mitsch, W.J. 1992. Landscape design and the role of created, restored, and natural riparian wetlands in controlling nonpoint source pollution. Ecological Engineering 1:22-47.

Mitsch, W.J. & J.G. Gosselink. 1986. Wetlands. Van Norstrand Reinhold Co., New York, NY. 539pp.

Mohler, C.L. 1979. An analysis of floodplain vegetation of the lower Neches drainage, southeast Texas, with some considerations on the use of regression and correlation in plant genecology. Ph.D. dissertation, Cornell University, Ithaca, NY.

Montgomery, D.R. 1997. What's best on banks? Nature 388:328-329.

Moore, Roger G. and Saul Aronow. 1994. Archeological and Geomorphological Investigations of a Proposed Weems Geophysical, Inc. Seismic Line within the Beaumont Unit of the Big Thicket National Preserve, Hardin County, Texas. Moore Archeological Consulting, Houston, Texas.

Moriarty, Loren J. 1995. Spatial and Temporal Variation in Fish Assemblage Structure at Village Creek. Texas A&M University, College Station, TX.

Morreale, S. J. & J. W. Gibbons. 1986. Habitat suitability index models: slider turtle. U.S. Fish and Wildlife Service Biol. Rep. 82(10.125). 14 pp.

Morreale, S. J., J. W. Gibbons, & J. D. Congdon. 1984. Significance of activity and movement in the yellow-bellied slider turtle (*Pseudomys scripta*). Canadian Journal of Zoology 62:1038-1042.

Muncy, R. J., G.J. Atchison, R.V. Bulkley, B. W. Menzel, L.G. Perry & R. C. Summerfelt. 1979. Effects of suspended solids and sediment on reproduction and early life of warmwater fishes: a review. U.S. EPA. EPA -600/3-79-042. 101 pp.

Myers, R.L. 1985. Fire and the dynamic relationship between Florida sandhill and sand pine scrub vegetation. Bulletin of the Torrey Botanical Club 112(3):241-252.

Nailon, Robert W. (Entrix). 1995. Grass carp management and control, in Galveston Bay Foundation, Soundings, Vol. 7, No. 1, Spring 1995.

Nailon, Robert W. (Entrix) and Leslie Sanderson (National Association of Conservation Districts). 1994. Exotic species management and control (overview and focus on nutria), in Galveston Bay Foundation, Soundings, Vol. 6, No. 4, Winter 1994-1995 (originally published in GulfWatch, August 1994).

Naiman, R.J., H. Décamps, & M. Pollock. 1993. The role of riparian corridors in maintaining regional biodiversity. Ecological Applications 3:209-212.

National Park Service, U.S. Department of Interior. 1975. Big Thicket National Preserve Memorandum of Understanding with Texas Parks and Wildlife Department, June 26, 1975.

National Park Service, U.S. Department of Interior. 1976. Final Environmental Statement for Establishment of the Big Thicket National Preserve Texas.

National Park Service, U.S. Department of Interior. 1980. General Management Plan, Big Thicket National Preserve, September 1980.

National Park Service, U.S. Department of Interior. 1988a. Management Policies, U.S. Department of the Interior, National Park Service.

National Park Service, U.S. Department of Interior. 1988b. Big Thicket National Preserve Draft Statement for Management.

National Park Service, U.S. Department of Interior. 1989. River Use Management Plan, Ozark National Scenic Riverways. May 1989.

National Park Service, U.S. Department of Interior. 1994a. Superintendent's Orders: Big Thicket National Preserve Standard Operating Procedures.

National Park Service, U.S. Department of Interior. 1994b. Minutes of meeting with Bevil Oaks homeowners in files of Big Thicket National Preserve.

National Park Service, U.S. Department of Interior. 1995a. Big Thicket National Preserve Final Draft Statement for Management.

National Park Service, U.S. Department of Interior. 1995b. An Introduction to Selected Laws Important for Resources Management in the National Park Service. By Napier Shelton and Lissa Fox, Natural Resources Report NPS/NRPO/NRR-94/15.

National Park Service, U.S. Department of Interior. 1996a. Petroleum/Pipeline Information for Big Thicket National Preserve. Denver Service Center, National Park Service.

National Park Service, U.S. Department of Interior. 1996b. Land Protection Plan, Big Thicket National Preserve Addition Act of 1993, Amendment to Land Protection Plan for Big Thicket National Preserve Approved May 7, 1984. BTNP, National Park Service.

Neary, D.G., W.T. Swank, & H. Riekerk. 1989. An overview of nonpoint source pollution in the southern United States. In Proceedings of the symposium: The Forested Wetlands of the Southern United States. Edited by D.D. Hook & R. Lea. Forest Service, Ashville, SC. pp. 1-7.

Nelson, R., V. Anderson, L.J. Cote, & N. Horning. 1989. Large scale forest resource assessment using Landsat and airphotos. Journal of World Forest Resource Management 4: 21-36.

Nemani, R.R., and S.W. Running. 1989a. Estimation of regional surface resistance to evapotranspiration from NDVI and thermal-IR AVHRR data. Journal of Applied Meteorology 28: 276-294.

Nemani, R.R., and S.W. Running. 1989b. Testing a theoretical climate-soil-leaf area hydrologic equilibrium of forests using satellite data and ecosystem simulation. Agricultural and Forest Meteorology 44: 245-260.

Nesbitt, S.A. & M.J. Folk. 1992. Bald eagle management guidelines : implementation and effects, Final Report Study 7522. Florida Game and Freshwater Fish Commission. Tallahassee, FL

Newmark, W.D. 1985. Legal and biotic boundaries of western North American national parks: a problem of congruence. Biological Conservation 33: 197-208.

Newsom, J.D., T. Joanen & R.J. Howard. 1987. Habitat Suitability Index Models: American Alligator. U.S. Fish and Wildlife Service Biological Report 82(10.136). 14 pp.

Niering, W.A. 1988. Endangered, threatened and rare wetland plants and animals of the continental United States. In The Ecology and Management of Wetlands Vol 1. Edited

by D.D. Hook, W.H. McKee, Jr., H.K. Smith, J. Gregory, V.G. Burrell, Jr., M.R. DeVoe, R.E. Sojka, S. Gilbert, R. Banks, L.H. Stolzy, C. Brooks, T.D. Matthews, & T.H. Shears. Croom Helm, London, England. pp. 227-238.

Nixon, S.W. & V. Lee. 1986. Wetlands and water quality, A regional review of recent research in the U.S. on the role of freshwater & saltwater wetlands as sources, sinks, & transformers of nitrogen, phosphorus, & various heavy metals. U.S. Dept. of the Army, Corps of Engineers. Washington, D.C.

Noss, R.F. 1983. A regional landscape approach to maintain diversity. BioScience 33: 700-706.

Nynan, J.A, R.H. Chebrek and N.W. Kinler. Some effects of weir management on emergent vegetation in brackish marsh. Wetlands 93:165-175.

Noss, R.F. 1987. Corridors in real landscapes: A reply to Simberloff and Cox. Conservation Biology 1:159-164.

Oberholser, H.C. 1974. The Bird Life of Texas. University of Texas, Austin, TX. 1069pp.

Ohlendorf, H. M., M. K. Saiki, C.M. Bunck, T. W. Aldrich, & J. F. Moore. 1986. Relationships between selenium concentrations and avian reproduction. Transactions of the North American Wildlife and Natural Resources Conference 51: 330-342.

Olson, R.K. Evaluating the role of created and natural wetlands in controlling nonpoint source pollution. Ecological Engineering 1:xi-xv.

Ormerod, S.J., S.D. Rundle, E.C. Lloyd, & A.A. Douglas. 1993. The influence of riparian management on the habitat structure and macroinvertebrate communities of upland streams draining plantation forests. Journal of Applied Ecology 30: 13-24.

Parker G. R., M. J. Petrie, & D. T. Sears. 1991. Waterfowl distribution relative to wetland acidity. Journal of Wildlife Management 56(2):268-174.

Parker, W.S. 1984. Immigration and dispersal of slider turtles (*Pseudemys scripta* ) in MIssissippi farm ponds. American Midland Naturalist 112:280-293.

Parker, W.T. & M.K. Phillips. 1991. Application of the experimental population designation to recovery of endangered red wolves. Wildlife Society Bulletin 19(1): 73-79.

Parmalee, W. P. 1953. Foods of the feral house cat in east-central Texas. Journal of Wildlife Management 17:375-376.

Parmenter, R. R. 1980. Effects of food availability and water temperature on the feeding ecology of pond sliders (*Chrysemys s. scripta* ). Copeia 1980(3):503-514.

Parsons, K. & C.H. Wharton. 1978. Macroinvertebrates of pools on a Piedmont river floodplain. Georgia Journal of Science 36:25-33.

Patrick, W.H., G. Dissmeyer, D.D. Hook, V.W. Lambou, H.M. Leitman & C.H. Wharton. 1981. Characteristics of wetlands ecosystems of southeastern bottomland hardwood forests. In Wetlands of Bottomland Hardwood Forests. Edited by J.R. Clark & J. Benforado. Elsevier Scientific: Amsterdam, The Netherlands. pp. 275-300.

Patterson, L.D. 1971. Physico-chemical conditions and community stucture of benthic macroinvertebrates in the Neches River in the vicinity of the salt water barrier. M.S. Thesis. Lamar University, Beaumont, TX. 51pp.

Paveglio, F. L., C.M. Bunck, & G.H. Heinz. 1992. Selenium and boron in aquatic birds from central California. Journal of Wildlife Management 56: 31-42.

Pearstine, L., H. McKellar, and W. Kitchens. 1985. Modelling the impacts of a river diversion on bottomland forest communities in the Santee River floodplain, South Carolina. Ecol. Modelling 29:281-302.

Pennak, R. W. 1989. Fresh-Water Invertebrates of the United States: Protozoa to Mollusca, 3rd ed. John Wiley & Sons, Inc., New York, NY.

Peterson, D.L., M.A. Spanner, S.W. Running, & K.B. Teuber. 1987. Relationship to Thematic Mapper simulator data to leaf area index of temperate coniferous forests. Remote Sensing of Environment 22: 323-341.

Peterson, R.O. 1988. The pit or the pendulum : issues in large carnivore management in natural ecosystems. In Ecosystem Management for Parks and Wilderness. Edited by J.K. Agee & D.L. Johnson. University of Washington Press. Seattle, WA. 237pp.

Peterson, R.T. 1967. A field guide to the birds of Texas. Houghton Mifflin Co. Boston, MA.

Phillips, K. 1990. Where have all the frogs and toads gone? BioScience 40(6): 422-424.

Pitman, V.M. 1991. Synopsis of Paddlefish Biology and Their Utilization and Management in Texas, Special Report. Texas Parks & Wildlife Department, Fisheries & Wildlife Division, Inland Fisheries Branch, Austin, TX. 70 pp.

Pitman, V.M. 1992. Texas Paddlefish Recovery Plan, Special Report. Texas Parks & Wildlife Department, Fisheries & Wildlife Division, Inland Fisheries Branch, Austin, TX. 30 pp.

Prasifka, P.M. 1976. Sociological, economic and biological ramifications of establishing the Big Thicket National Preserve. Manuscript (NSF grant to undergraduate students). Sam Houston State University, Huntsville, TX.

Pressey, R. L., C. J. Humphries, C. R. Margules, R. I. Vane-Wright , & P. H. Williams. 1993. Beyond opportunism: key principles for systematic reserve selection. Tree 8(4):124-128.

Radian Corporation. 1985. Location and characterization of active and abandoned oil and gas activity in Big Thicket National Preserve. Report to National Park Service, Energy, Mining, and Mineral Division, Denver, CO.

Rainwater, F. L. 1974. A preliminary survey of the amphibians and reptiles of the Big Thicket National Preserve. Stephen F. Austin State University, Nacogdoches, TX.

Ramsey, J.J. 1980. A survey of the avifauna of the Beaumont Unit, Big Thicket National Preserve. Texas Ornithological Society Bulletin 13: 14-19.

Robb, D.M. 1992. The role of wetland water quality standards in nonpoint source pollution control strategies. Ecological Engineering 1:143-148.

Rodgers, Jr., J.H. & A. Dunn. 1992. Developing design guidelines for constructed wetlands to remove pesticides from agricultural runoff. Ecological Engineering 1:83-95.

Rogers, D.S. & D.J. Schmidly. 1978. Game Mammals of Big Thicket National Preserve (unpublished). Texas A&M Universi ty, College Station, TX. 24 pp.

Rohwer, F. C. & H. W. Heusmann. 1991. Effects of brood size and age on survival of female wood ducks. The Condor 93:817-824.

Roland, J. 1993. Large-scale forest fragmentation increases the duration of tent caterpillar outbreak. Oecologia 93(1): 25-30.

Rootes, W.L. & R.H. Chabreck. 1992. Cannibalism in the American alligator. Herpetologica 49:99-107.

Rosen, R.A. & D.C. Hales. 1981. Feeding of paddlefish, Polyodon spathula. Copeia 1981 (2): 441-445.

Rudolph, D.C. & J.G. Dickson. 1990. Streamside zone width and amphibian and reptile abundance. The Southwestern Naturalist 35:472-476.

Salafsky, N. 1993. Mammalian use of a buffer zone agroforestry system bordering Gunung Palung National Park, West Kalimantan, Indonesia.

Salwasser, H. 1988. Managing ecosystems for viable populations of vertebrates : a focus for diversity. In Ecosystem Management for Parks and Wilderness. Edited by J.K. Agee & D.L. Johnson. University of Washington Press. Seattle, WA. 237pp.

Samson, F. B. 1980. Island biogeography and the conservation of nongame birds. In Transactions of the Forty-fifth North American Wildlife and Natural Resources Conference. Edited by K. Sabol. Wildlife Management Institute, Washington, D. C. pp. 245-251.

Saunders, D. A. & C. P. de Rebeira. 1991. Values of corridors to avian populations in a fragmented landscape. In Nature Conservation 2: The Role of Corridors. Edited by D.A. Saunders & R.J. Hobbs. Surrey Beatty & Sons Pty Limited. Norton, New South Wales, Australia. pp. 221-240.

Schedbauer, M.D. 1974. Botanical survey of the non-flowering plants of the Big Thicket National Preserve. PX7029-6-0544. Texas A&M University, College Station, TX.

Schiemer, F. & M. Zalewski. 1992. The importance of riparian ecotones for diversity and productivity of riverine fish communities. Netherlands Journal of Zoology 42:323-335.

Schmidly, D.J. 1974. A preliminary survey of mammalian fauna of Big Thicket National Preserve. Texas A&M University, College Station, Texas.

Schmidly, D.J. 1983. Texas Mammals East of the Balcones Fault Zone. Texas A&M University Press, College Station, TX.

Schmidly, D.J., B.R. Barnette, & J.A. Read. 1979. The mammals of Big Thicket National Preserve and East Texas. Manuscript. Texas A&M University, Department of Wildlife and Fisheries Sciences. College Station, TX. 345 pp.

Schwartz, M.W. 1993. Modeling effects of habitat fragmentation on the ability of trees to respond to climatic warming. Biodiversity and Conservation 2(1): 51-61.

Scott, J.A. 1986. The butterflies of North America: a natural history and field guide. Stanford University Press, Stanford, CA.

Scott, J.M., F. Davis, B. Csuti, R. Noss, B. Butterfield, C. Groves, H. Anderson, S. Caicco, F. D'erchia, T.C. Edwards, Jr., J. Ullman & R.G. Wright. 1993. Gap analysis: a geographic approach to protection of biological diversity. Wildlife Monographs 123: 1-41.

Sedell, J. and Chris Maser. 1994. From forest to sea: the ecology of wood in streams, rivers, estuaries, and oceans. Delray Beach: St. Lucie Press.

Seidensticker, P. 1994. Performance Report as required by Federal Aid in Fisheries Restoration Act, Federal Aid Project F-30-R-20, Job A: Existing reservoir and stream management recommendations, Neches River. Texas Parks and Wildlife Department, Austin, TX.

Shafer, C. L. 1991. Help for nature reserve designers. Ecology 72(6):2301-2302.

Shafer, H.J., E.P. Baxter, T.B. Stearns, & J.P. Dering. 1975. An archeological assessment of the Big Thicket National Preserve. Report to the Office of Archeological Resources, Southwestern Region, National Park Service, Santa Fe, NM.

Sharitz, R.R. & L.C. Lee. 1985. Limits on regeneration processes in southeastern riverine wetlands. In Riparian ecosystems and their management : reconciling conflicting uses. First North American Conference, April 16-18,1985. Tucson, Arizona. General Technical Report RM-120, Rocky Mountain Forest and Range Experiment Station, Forest Service, USDA, Ft. Collins, CO.

Sharitz, R.R. & W.J. Mitsch. 1993. Southern Floodplain Forests. In Biodiversity of the Southeastern United States/Lowland Terrestrial Communities. Edited by W.H. Martin, S.G. Boyce, & A.C. Echternacht. John Wiley & Sons, Inc. New York, NY.

Shaw, Chad. 1995. Timber Effects on Water Quality. Appendix D in Hall and Bruce, 1996.

Shirley, M. G, R.G. Linscombe, N.W. Kinler, R.M. Knaus, V.L. Wright. 1988 Population Estimates of River Otter in a Louisiana Coastal Marshland. Journal of Wildlife Management 52:512-515.

Simberloff, D. and J. Cox. 1987. Consequences and costs of conservation corridors. Conservation Biology 1:63-71.

Simberloff, D., J.A. Farr, J. Cox, & D.W. Mehlman. 1992. Movement corridors: conservation bargains or poor investments? Conservation Biology 6(4): 493-504.

Sinsch, U. 1990. Migration and orientation in anuran amphibians. Ethology, Ecolgoy & Evolution 2:65-79

Smock, L.A. & E. Gilinsky. 1992. Coastal plain blackwater streams. In Biodiversity of the Southeastern United States Aquatic Communities. Edited by C. T. Hackney, S. M. Adams, & W.H. Martin. Wiley, New York, NY. pp. 271-311.

Smock, L.A., E. Gilinsky, & D.L. Stoneburner. 1985. Macroinvertebrate production in a southeastern United States blackwater stream. Ecology 66: 1491-1503.

Soulé, M., editor. 1987. Viable Population for Conservation. Cambridge University Press. New York, NY.

Stanturf, J.A., S.B. Jones, & W.D. Ticknor. 1993. Managing industrial forestsland in a changing society. Journal of Forestry. Nov. pp. 6-11.

State of Texas. 1994a. Official Texas Administrative Code, Title 30, Environmental Quality, 1994-Part Two. State of Texas, Austin, TX.

State of Texas. 1994b. Official Texas Administrative Code, Title 31, Natural Resources and Conservation. State of Texas, Austin, TX.

State of Texas. 1994c. Official Texas Administrative Code, Title 16, Economic Regulation. State of Texas, Austin, TX.

Steiner, F.R. and D.A. Osterman. 1988. Landscape planning: a working method applied to a case study of soil conservation. Landscape Ecology 1: 213-226.

Strahan, R.F., C.M. Boettcher, & R.R. Switzer. 1993. Superintendent's Orders, SOP 90-7140-02, Big Thicket National Preserve, North and South Districts. U.S. Department of the Interior, National Park Service, Big Thicket National Preserve. Beaumont, TX.

Stranksy, J.J. 1969. Deer habitat quality of major forest types in the south. p. 42 - 45 in White Talied Deer in the southern forest habitat. Proc. Symp. USDA Forest Service, Nacogdoches, Texas. 130 pp.

Stuber, R.J., G. Gebhart, & O.E. Maughan. 1982. Habitat suitability index models: Largemouth bass. FWS/OBS - 82/10.16. U.S. Dept.of the Interior, Fish & WIldlife Service 32 pp.

Suttkus, R.D. & G.H. Clemmer. 1979. The Fishes of Big Thicket National Preserve. Manuscript. U.S. Dept. of Interior, National Park Service, Big Thicket National Preserve, Beaumont, TX. 244 pp.

Swank, G.W. 1990. Streamside management units in the Pacific Northwest. Forest Ecology and Management 33/34: 419-424.

Swift, C.C., C.R. Gilbert, S.A. Bortoner, G.H. Burgess, & R.W. Yerger. 1986. Zoogeography of freshwater fishes of the Southeastern United States: Savannah River to Lake Ponchartrain. In The Zoogeography of North American Freshwater Fishes. Edited by Hocutt, C.H. & E.O. Wiley. Wiley & Sons, NY, NY. pp. 213-265.

Swift, L. W. & W. T. Swank. 1981. Long term responses of streamflow following clearcutting and regrowth. Hydrological Sciences Bulletin 26: 245-256.

Tatum, J.W. & D. Commander. 1971. Water quality study of Village Creek, Hardin County, Texas. Manuscript. Texas Water Quality Board. 40 pp.

Tennant, A. 1984. Snakes of Texas. Texas Monthly Press, Austin, TX.

Terborgh, J. 1989. Where Have All the Birds Gone? Essays on the Biology and Conservation of Birds that Migrate to the American Tropics. Princeton: Princeton, NJ. USA.

Teskey, R.O., T.M. Hinckley, & J.M. Brown. 1977a. Impact of water level changes on woody riparian and wetland communities, Vol.1, Plant and soil responses. U.S. Dept. of the Interior, U.S. Fish & Wildlife Service. Washington, D.C.

Teskey, R.O., T.M. Hinckley, & J.M. Brown. 1977b. Impact of water level changes on woody riparian and wetland communities, Vol.II, The Southern Forest Region. U.S. Dept. of the Interior, U.S. Fish & Wildlife Service. Washington, D.C.

Teskey, R.O., T.M. Hinckley, & J.M. Brown. 1977c. Impact of water level changes on woody riparian and wetland communities, Vol.III, The Central Forest Region. U.S. Dept. of the Interior, U.S. Fish & Wildlife Service. Washington, D.C.

Teskey, R.O., T.M. Hinckley, & J.M. Brown. 1978a. Impact of water level changes on woody riparian and wetland communities, Vol. IV, Eastern Deciduous Forest Region. U.S. Dept. of the Interior, U.S. Fish & Wildlife Service. Washington, D.C.

Teskey, R.O., T.M. Hinckley, & J.M. Brown. 1978b. Impact of water level changes on woody riparian and wetland communities, Vol. V, Northern Forest Region. U.S. Dept. of the Interior, U.S. Fish & Wildlife Service. Washington, D.C.

Teskey, R.O., T.M. Hinckley, & J.M. Brown. 1978c. Impact of water level changes on woody riparian and wetland communities, Vol. VI, Plains Grassland Region. U.S. Dept. of the Interior, U.S. Fish & Wildlife Service. Washington, D.C.

Texas Department of Health. 1990. Health commissioner warns of dioxin hazards in three areas. News Release, Texas Department of Health. Austin, TX.

Texas Department of Health. 1994. Bioaccumulant Pollutant Study, Lower Neches River Study. Internal Documents. Texas Department of Texas. Austin, TX.

Texas Department of Health, Seafood Safety Division. 1995. Fish Advisories and Bans.

Texas Forestry Association. 1989. Texas Best Management Practices for Silviculture. Lufkin, Texas, USA. 65 pp.

Texas Natural Resources Conservation Commission. 1996. Texas Water Quality, A Summary of River Basin Assessments. Prepared by Texas Clean Rivers Program, TNRCC. Austin, TX. December 1996.

Texas Parks and Wildlife Department. 1990. 1990 Texas Outdoor Recreation Plan: Assessment and Policy Plan. Report prepared by James A. DeLoney (dir.), Maria I. Araujo, Andrew Goldbloom, Kathryn Nichols, Joel S. Seffel, Consumer Planning Section, Comprehensive Planning Branch, Parks Division, Texas Parks and Wildlife Department, Austin, TX..

Texas Parks & Wildlife Department. 1991. Endangered Resources Annual Status Report. Austin, TX.

Texas Parks & Wildlife Department. 1993a. Big game harvest results 1983-84 thru 1992-93 : white-tailed deer, turkey, mule deer, javelina. Texas Parks & Wildlife Department. Austin, TX.

Texas Parks & Wildlife Department. 1993b. Small game harvest results 1981-82 thru 1992-93 : quail, rabbit, squirrel, mourning dove, pheasant, spring turkey. Texas Parks & Wildlife Department. Austin, TX.

Texas Parks & Wildlife Department. 1993c. Special Aminal List. Texas Parks & Wildlife Department, Texas Natural Heritage Program. Austin, Texas.

Texas Parks & Wildlife Department. 1993d. Special Plant List. Texas Parks & Wildlife Department, Texas Natural Heritage Program. Austin, Texas.

Texas Parks & Wildlife Department. 1993e. Texas Hunting Guide, 1993-1994. Texas Parks & Wildlife Department. Austin, TX.

Texas Parks & Wildlife Department. 1993f. Texas Inland Fishery Assessment Procedures : Stream Survey Procedures. Texas Parks & Wildlife Department. Austin, TX.

Texas Parks & Wildlife Department. 1993g. White-tailed deer harvest (major ecological areas) 1972-1992 (unpublished). Texas Parks & Wildlife Department. Austin, TX.

Texas Parks & Wildlife Department. 1994. Texas Natural Heritage Program, Descriptions of locations of state and federally listed species. Texas Parks & Wildlife Department, Texas Natural Heritage Program. Austin, TX.

Texas Parks and Wildlife Department. 1997. Wildlife Research Highlights, 1997: Vol. 2. Wildlife Division, Texas Parks and Wildlife Department, Austin, TX.

Texas Parks & Wildlife Department & U.S. Fish & Wildlife Service. 1993. Habitat Management Guidelines for Bald Eagles in Texas. Texas Parks & Wildlife Department. Austin, TX.

Thomas, J.K., C.E. Adams, & J. Thigpen. 1990. Texas Hunting Leases : Statewide and Regional Summary. Texas Agricultural Experiment Station. Texas A&M University. College Station, TX.

Thompson, F. R., W. D. Dijak, T. G. Kolowiec, & D. A. Hamilton. 1991. Breeding bird populations in Missouri Ozark forests with and without clearcutting. Journal of Wildlife Management 56(1):23-30.

Thornes, J.B., editor. 1990. Vegetation and erosion. NY: John Wiley.

Thorp, J. H. & A. P. Covich. 1991. An Overview of Freshwater Habitats. In Ecology and Classification of North American Freshwater Invertebrates. Academic Press, Inc. pp. 17-36.

Trans-Texas Water Program. 1994. Phase I Report for the Southeast Area of the Trans-Texas Water Program. Prepared by Brown & Root Inc. and Freese & Nichols, March 1994.

Treat, V.H. & H.C. Detloff. 1978. Historic resources study, Big Thicket National Preserve, Texas. Report to the Office of Cultural Resources, Southwest Region. National Park Service, Santa Fe, NM.

Trenchard, M.H. 1977. Baseline climatological data for the Big Thicket National Preserve. Report to the Office of Natural Sciences, Southwest Region. National Park Service, Santa Fe, NM.

Turner, M.G. & R.H. Gardner, editors. 1990. Quantitative Methods in Landscape Ecology. Springer-Verlag, New York, New York, USA.

Twomey, K.A., G. Gebhart, O.E. Maughan, & P.C. Nelson. 1984. Habitat suitability index models and instream flow suitability curves: red-ear sunfish. FWS/OBS - 82/10.79. U.S. Fish & Wildlife Service 29 pp.

Tyser, R. W. & C. A. Worley. 1992. Alien flora in grasslands adjacent to road and trail corridors in Glacier National Park, Montana (U.S.A.). Conservation Biology 6(2):253-262.

U. S. Department of Agriculture Forest Service. 1985. Insects of Eastern Forests. U.S. Government Printing Office, Washington, D.C.

U.S. Department of Agriculture, Forest Service & U.S. Department of Interior, Bureau of Land Management. 1994a. Environmental Assessment for the Implementation of Interim Strategies for Managing Anadromous Fish-producing Watersheds in Eastern Oregon and Washington, Idaho, and Portions of California. U.S. Department of Agriculture, Forest Service & U.S. Department of Interior, Bureau of Land Management. Washington, D.C.

U.S. Department of the Army, Corps of Engineers, Fort Worth District. 1976. Final Environmental Impact Statement on the Operation and Mainteanance Programs for the Town Bluff Dam-B. A. Steinhagen Lake, Sam Rayburn Dam and Reservoir, Neches-Angelina Rivers Basin, Texas.

U.S. Department of the Army, Corps of Engineers, Galveston District. 1974. Salt water barrier at Beaumont, Texas. In Interim Review of Reports. U.S. Army, Corps of Engineers, Galveston District, Galveston, TX.

U.S. Department. of the Army, Corps of Engineers, Galveston District. 1975. Neches River and Tributaries, Texas: Saltwater Barrier on Neches River at Beaumont, Texas, Final Environmental Impact Statement. U.S. Dept. of the Army, Corps of Engineers, Galveston District, Galveston, TX.

U.S. Department of the Army, Corps of Engineers, Galveston District. 1976. Neches River and Tributaries, Texas: Reconnaissance Report on Flood Problem at Pinewood Estates Subdivision, Hardin County, Texas. October 1976.

U.S. Department of the Army, Corps of Engineers, Galveston District. 1985. Feasibility Report: Pine Island Bayou Watershed, Texas: Flood Damage Prevention. Galveston District, Galveston, TX. June 1985.

U.S. Department of the Army, Corps of Engineers, Galveston District. 1992. Notice of Public Hearing, CESWG-CO-RN, Permit Application 19611.

U.S. Department of the Army, Corps of Engineers, Galveston District. 1994. Environmental Assessment and statement of findings on permit application 19611 for applicant, Lower Neches River Valley Authority, subject is temporary salt water barriers (internal document). Martinez / 3095, CESWG-CO-RN. Galveston District, Galveston, TX.

U.S. Department of the Interior, National Biological Survey. 1994. Isolation of Aeromonas salmonicida from Paddlefishes. U.S. Department of the Interior, National Biological Survey. Research Information Bulletin No. 7.

U.S. Department of Interior, National Park Service. 1993. National Park Service Regulations, 36 CFR Ch. 1.

U.S. Department of State, Biosphere Reserve Directorate, US. Man and the Biosphere Program. 1994. Strategic Plan for the U.S. Biosphere Reserve Program. Department of State Publication 10186, December 1994.

U.S. Environmental Protection Agency. 1993. Summary of current state nonpoint source control practices for forestry. Report Number EPA-841/S-93-001. Office of Water, Nonpoint Source Control Branch 4503-F. Washington, D.C.

U.S. Environmental Protection Agency. 1993. Water quality effects and nonpoint source control practices for forestry : an annotated bibliography. Report Number EPA-841/B-93-005. Office of Water, Nonpoint Source Control Branch 4503-F. Washington, D.C.

U.S. Fish & Wildlife Service. 1987a. Endangered and Threatened Species of Texas and Oklahoma. 50 CFR 17.11 & 17.12. Albuquerque Regional Office, U.S. Department of the Interior, Fish & Wildlife Service, Washington, D.C. 128 pp.

U.S. Fish and Wildlife Service. 1987b. Habitat management for the bald eagle in the southeast region. U.S. Fish and Wildlife Service. Atlanta, GA. 9pp.

U.S. Fish & Wildlife Service. 1987. Habitat management guidelines for the bald eagle in the southeast region, thrid revision. U.S. Fish & Wildlife Service, Ecological Services. Atlanta, GA.

U.S. Fish & Wildlife Service. 1989. Endangered & Threatened Wildlife & Plants. 50 CFR 17.11 & 17.12. U.S. Department of the Interior, Fish & Wildlife Service, Washington, D.C. 34 pp.

U.S. Fish & Wildlife Service. 1990. Report to Congress: Endangered and Threatened Species Recovery Program. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. 406 pp.

U.S. Fish & Wildlife Service. 1992. Federally listed threatened and endangered species occurring in Texas. Texas State Office. Austin, TX.

U.S. Fish & Wildlife Service. 1993a. Federally Endangered and Threatened Species for the Counties of Texas. U.S. Fish & Wildlife Service, Clear Lake Field Office, Houston, TX.

U.S. Fish & Wildlife Service. 1993b. Point counts in bottomland hardwood forests: points versus visits. Research Information Bulletin. No. 46. U.S. Department of the Interior, Fish & Wildlife Service.

U.S. Fish & Wildlife Service. 1994. Technical/Agency Draft Louisiana Black Bear Recovery Plan. Bob Bowker, Southeast Region, Atlanta Georgia. 34 pp.

Valentine, J.M., J. R. Walther, K.M. McCartney, & L.M. Ivy. 1972. Alligator diets in the Sabine National WildlifeRefuge, Louisiana. Journal of Wildlife Management 36:809-815.

Van der Valk, A.G. & R.W. Jolly. 1992. Recommendations for research to develop guidelines for the use of wetlands to control rural nonpoint source pollution. Ecological Engineering 1:115-134.

Viles, H.A., editor. 1988. Biogeomorphology. Basil Blackwell.

Walker, L.C. 1976. Fire in the Big Thicket area of Texas. Report to the Office of Natural Sciences, Southwest Region. National Park Service, Santa Fe, NM.

Ward, A.K., G.M. Ward, & S.C. Harris. 1992. Water quality and biological communities of the Mobile River Drainage, Eastern Gulf of Mexico Region. In Water Quality in North American River Systems. Edited by C.D. Becker & D.A. Neitzel. Battelle Press. Columbus, OH.

Watson, G. 1979. Big Thicket Plant Ecology: An Introduction. Big Thicket Museum Publishing Ser. No. 5, second edition, Saratoga, TX.

Watson, G.E. 1982. Vegetational survey of Big Thicket National Preserve. Report to the Office of Natural Resources, Southwest Region. National Park Service, Santa Fe, NM.

Watson, G.E. 1986. Influence of fire on longleaf pine-bluestem range in the Big Thicket region. In Wilderness and Natural Areas in the Eastern United States : A Management Challenge, Symposium Proceedings. Edited by D.L. Kulhavy & R.N. Conner. Center for Applied Studies, School of Forestry, Stephen F. Austin State University, Nacogdoches, TX.

Wayne, R. K. & S.M. Jenks. 1991. Mitochondrial DNA analysis implying extensive hybridization of the endangered red wolf, Canis rufus. Nature 351: 565-568.

Weller, M. W. 1978. Management of freshwater marshes for wildlife. In Freshwater Wetlands: Ecological Processes and Management Potential. Edited by R. E. Good, D. F. Whigham, & R. L. Simpson. Academic Press, New York, NY. pp. 267-284.

Wells, F.C. & K.C. Bourdon. 1985. Summary of statistical and trend analysis of selected water-quality data collected near the Big Thicket National Preserve, southeast Texas. United States Geological Survey Open-file Report 85-183. Austin, TX.

Wharton, C.H. & M.M. Brinson. 1974. Characteristics of southeastern river systems. In Strategies for protection and management of floodplain wetlands and other riparian ecosystems. General Technical Report WO-12. R.R. Johnson & J.F. McCormick, technical coordinators. U.S. Department of Agriculture, Forest Service. Washington, D.C.

Wharton, C. H., V.W. Lambour, J. Newsom, P.V. Winger, L.L. Gaddy & R. Manke. 1981. The fauna of bottomland hardwoods in southeastern United States. Pages 87-133. In Wetlands of Bottomland Hardwood Forests. Edited by J.R. Clark & J. Benforado. Elsevier Scientific: Amsterdam, The Netherlands.

Wharton, C.H., W.M. Kitchens, E.C. Pendleton, & T.W. Sipe. 1982. The ecology of bottomland hardwood swamps of the southeast: A community profile. FWS/OBS-81/37. U.S. Fish & Wildlife Service, Biological Services Program, Washington, D.C.

Wharton, C. W. 1980. Values and functions of bottomland hardwoods. In 1980. Transactions of the Forty-fifth North American Wildlife and Natural Resources Conference. Edited by K. Sabol. Wildlife Management Institute, Washington, D. C. pp. 387-391.

Whitaker, G. & C.R. Terrell. 1992. Federal programs for wetland restoration and use of wetlands for nonpoint source pollution control. Ecological Engineering 1:157-170.

Wilcove, D.S. 1985. Nest predation in forest tracts and the decline of migratory songbirds. Ecology 66:1211-1214.

Wilcove, D.S., C. H., McLellan, & A. P. Dobson. 1986. Habitat fragmentation in the temperate zone. In Conservation Biology. Edited by M. Soulé. Sinauer Assoc. Sunderland, MA. pp. 237-256.

Wilkinson, D.L., K. Schneller-McDonald, R.W. Olsen, & G.T. Auble. 1987. Synopsis of Wetland Functions and Values: Bottomland Hardwoods with Special Emphasis on Eastern Texas and Oklahoma. Biological Report 87(12). U.S. Dept. of the Interior, U.S. Fish & Wildlife Service. Washington, D.C.

Williams, K.L.P. 1981. A census of the avian fauna of the Dujay Sanctuary, Hardin County, Texas. Masters Thesis. Lamar University. Beaumont, TX. 82 pp.

Wilson, E. O. & E. O. Willis. 1975. Applied biogeography. In Ecology and evolution of communities. Edited by M. L. Cody & J. M. Diamond. Harvard University Press, Cambridge, MA. pp. 523-534.

Wilson, Paul C., Jr. 1981. History of the saltwater barrier on the Neches River. The Texas Gulf Historical and Biographical Record 17:29-37.

Wren, C.D. 1991. Cause-Effect linkages between chamicals and populations of mink (Mustela vison) and otter (Lutra canadensis) in the Great Lakes Basin. Journal of Toxicology and Environmental Health 33:549-585.

# APPENDICES

# APPENDIX A

## DESCRIPTION OF LAND COVER/LAND USE MAP

Report prepared by
Rosine W. Hall and P. A. Harcombe
Department of Ecology and Evolutionary Biology
Rice University, Houston TX

Under Cooperative Agreement with
National Park Service
Big Thicket National Preserve
Mr. Pete Peterson, Superintendent

July 1997

# 1.0 Description of Land Cover/Land Use Map

## 1.1 Introduction

The Big Thicket National Preserve (BTNP) has several stream and river corridor units within its boundaries. A Water Corridor Management Assessment is being prepared in order to assist National Park Service (NPS) managers in making management decisions which directly affect these corridors. One type of data which can assist managers and decision-makers in planning for stream and river corridors is land use and land cover data on the watersheds which are drained by the rivers and streams and which contain the corridors. In combination with other data layers in a Geographic Information System (GIS), land cover/land use data can be used to quantify the potential influence of human disturbance by assessing its location, extent, and proximity to the watercourses. Such data can also be used to characterize types and extent of certain habitat types within watersheds and along corridors. As part of the characterization of resources, we classified satellite imagery of the BTNP to identify various vegetation types, producing a raster map layer suitable for import into GRASS, the GIS system used by NPS.

## 1.2 Methods

A LANDSAT Thematic Mapper TM image from 10 February 1991 was obtained from EOSAT which contained the entire Preserve in one scene (path 25, row 39). This image provided 1) lack of obscuring clouds, which is a problem with this region; 2) leaf-off condition for most deciduous forest types; and 3) lack of excessive rain within the previous six weeks. A supervised classification of the image was implemented using ERDAS (v. 7.5) image processing software. Because of our knowledge of the vegetation patterns of east Texas, we opted to conduct a supervised classification of the image.

Before analysis, the image was cut to exclude areas outside the Big Thicket area of eastern Texas. The analyzed area consisted of the region between the Neches and Trinity Rivers, north of Beaumont, and south of Steinhagen Lake. TM imagery consists of a raster of 30 m x 30 m pixels from seven bands of sensor data (each band represents remotely sensed reflectance in a particular region of the electromagnetic spectrum). The TM bands are visible (blue, green, and

red), reflective infra-red, middle-infra-red (two bands), and thermal infra-red (ERDAS, 1991). The thermal band was eliminated, and two additional transformations of the data were added as two additional bands: the mid-infrared index (MIRI), which is the ratio of the two mid-infra-red bands to each other, and the Normalized Difference Vegetation Index (NDVI), which is the ratio between the difference and the sum of the reflectances from the near infrared and the visible red bands (Tucker, 1979).

Six subsets of the scene were used to locate training sites: Livingston and Beaumont were used to generate signatures for the urban and developed classes (transportation, residential, commercial and industrial), based on land use maps. Areas centered on Peach Tree Point (on the Neches River), the Turkey Creek Unit, the Lance Rosier Unit, and Labelle, Texas were used to generate the signatures for the various vegetation classes. The original vegetation/land cover classes selected were based on the eleven potential natural vegetation classes of Marks and Harcombe (1981), with additional disturbance classes including pasture, clearcut, open water, pine plantation, and agriculture (rice) (Table 1) for a total of 20 classes. Almost immediately, the two floodplain hardwood forest types were combined into one class, as were the upland and sandhill pine forest types because the classes were judged to be insufficiently separable with vegetation in winter condition, for a total of 18 classes.

Classification was done using the minimum distance algorithm (ERDAS, 1991). While this algorithm is less accurate than the maximum likelihood (Bayesian) algorithm (ERDAS, 1991), it was used because of the lack of normality of the data in all bands. The maximum likelihood algorithm is parametric and is extremely sensitive to violations of the assumption of normally distributed data. Examination of the distributions revealed apparent severe deviations from the normal. Of the eight bands, three (4,5,7) were bimodal, three had long tails (1,3,8) and two were platykurtic (very flat - 2,6). Therefore, the maximum likelihood algorithm was not appropriate for this dataset without some form of data reduction (e.g., PCA) or enhancement (e.g., transformation). Another algorithm, the minimum distance algorithm, was selected. The selected algorithm always assigns every pixel to one of the signature classes. Several rounds of adjustments were made to the signatures which made the individual classes larger or smaller. Such adjustments allowed better discrimination among classes.

**Table 1. List of classes used in supervised classification**

| Potential natural vegetation* | Land use classes |
|---|---|
| Cypress-tupelo | Pine plantation |
| Floodplain hardwoods | Open water |
| Baygall | Rice/agriculture |
| Flatland hardwood forest | Pasture |
| Lower-slope hardwoods-pine | Clearcut |
| Mid-slope oak-pine | Residential |
| Upper-slope pine-oak | Commercial |
| Wetland pine savanna | Industrial |
| Upland/Sandhill pine | Transportation |

*From Marks and Harcombe 1981.

### 1.3 Results

No data were collected which could serve as independent verification of the classified image. Therefore, ground-truthing was not attempted. In light of this, the classification should be considered provisional. Nevertheless, the resulting land-use/land-cover map reflects broad landscape patterns which we know to occur. For instance, we know the BTNP to have proportionally more bottomland forests than the region as a whole (Table 2). Combined, these classes (1-5 in Table 2) account for nearly forty percent (38.73%) of the acreage in the BTNP, while accounting for less than twenty percent (18.98%) of the study region. Based on the methods used to select land for inclusion in BTNP, we also know it to contain relatively little developed or urbanized area, and little pasture or clearcut. For areas within the BTNP, these classes account for less than one percent (0.84%) of the area, while for the region as a whole, these types account for more than a quarter of the acreage (25.2%). It is reassuring that the classified image reveals these expected overall patterns.

**Table 2. Comparison of frequency of cover classes in BTNP versus the entire study region.**

| # | description | BTNP hectares | BTNP % cover | STUDY REGION hectares | STUDY REGION % cover |
|---|---|---|---|---|---|
| 1 | Baygall | 1360 | 3.79 | 16,611 | 2.03 |
| 2 | Cypress-tupelo | 1994 | 5.55 | 14,328 | 1.75 |
| 3 | Open water | 1093 | 3.04 | 9,944 | 1.22 |
| 4 | Flatland hardwoods forest | 1928 | 5.37 | 43,351 | 5.30 |
| 5 | Floodplain hardwoods | 7535 | 20.97 | 71,039 | 8.68 |
| 6 | Upper-slope pine-oak | 86 | 0.24 | 30,704 | 3.75 |
| 7 | Pine plantation | 1078 | 3.00 | 68,816 | 8.41 |
| 8 | Wetland pine savanna | 826 | 2.30 | 82,101 | 10.04 |
| 9 | Mid-slope oak-pine | 6634 | 18.47 | 109,591 | 13.40 |
| 10 | Lower-slope hardwoods-pine | 9631 | 26.81 | 165,301 | 20.21 |
| 11 | Upland/Sandhill Pine | 3464 | 9.64 | 52,349 | 6.40 |
| 12 | Residential | 39 | 0.11 | 6,316 | 0.77 |
| 13 | Industrial | 3 | 0.01 | 2,871 | 0.35 |
| 14 | Commercial | 6 | 0.02 | 10,998 | 1.34 |
| 15 | Transportation | 6 | 0.02 | 4,880 | 0.60 |
| 16 | Rice / Agriculture | 151 | 0.42 | 35,519 | 4.34 |
| 17 | Pasture. | 31 | 0.09 | 53,577 | 6.55 |
| 18 | Clearcut | 61 | 0.17 | 39,662 | 4.85 |
| | TOTAL | 35,926 | 100.00 | 817,958 | 100.00 |

Inspection of individual class acreages suggests problems with certain classes. The wetland pine savanna class is seriously over-represented in the classified image compared to its actual frequency in the landscape. This suggests that the signature of this type is confounded with an unmapped type, possibly an open pine overstory over graminoids. Both abandoned pastures and young successional stands could fit this description. Similarly, the community type labeled "flatland hardwood forest" represents a problem type. While it is clearly a wetland hardwood class, its prevalence in both the upper Neches River floodplain and in the coastal prairie south of the Big Thicket (where recent forests of Chinese tallow are known to occur commonly) suggests that this class is also confounded with one or more other (possibly wetland) hardwood types. It does not reflect the limited vegetation class identified by Marks and Harcombe. In recognition of these problems, the class names were changed from "wetland pine savanna" to "woodland/pasture" and from "flatland hardwood forest" to simply "hardwood forest".

Using the GIS, we can also perform a rough evaluation of the classification by comparing percentage frequencies of image classes to percentage frequencies of the Harcombe-Marks potential natural vegetation classes mapped for areas within the preserve (Table 3). While the Harcombe-Marks vegetation map is meant to represent potential natural vegetation (PNV) and the classified image is meant to represent actual vegetation, a comparison between the two should agree in overall pattern. Prior to comparison, several PNV classes were combined in recognition that they were not identified separately in the remote sensing exercise. Specifically, the "Floodplain Hardwoods" class is compared to the sum of two PNV classes: the "Floodplain Hardwood Forest" and "Floodplain Hardwood Pine Forest" of Marks and Harcombe (1981). Likewise, the Upland/Sandhill pine class is compared to the sum of two Harcombe-Marks PNV classes: "Upland Pine Forest" and "Sandhill Pine".

The rankings of the types are consistent for the top two classes, which account for 50-60% of the land cover, though the classified image under-represents the amount of Lower-slope hardwood-pine by a substantial amount. Rankings for all other types are within 2 places of their HM ranking, except for Upper-slope pine-oak, Tallow (hardwood) forest, and Upland/Sandhill Pine. The Upper-slope pine-oak class and the Flatland hardwood class are seriously under-represented in the classified image. Mid-slope oak pine, Cypress-tupelo, and Upland/Sandhill pine are significantly over-represented in the final classification.

The Tallow forest:Flatland hardwoods discrepancy is not difficult to explain: it is likely that they actually represent two different classes, one a successional class not mapped by Marks and Harcombe and the other a rare class not distinguishable on the basis of remote sensing data. Other differences could result from inability to distinguish among classes because of the time of year of the photo (winter, with deciduous trees lacking their leaves), successional status of current vegetation (e.g. too recently disturbed to reflect their eventual condition as reflected in the PNV map), or because of harvesting impacts (high-graded stands, or stands with pine removed). Nevertheless, comparison of the overall concordance between the two data sets suggests that the classification fairly represents expected vegetation patterns in the landscape at the most general level.

**Table 3. Comparison of frequency of image classes to frequency of Harcombe-Marks potential natural vegetation classes within BTNP boundaries**

| # | description | Image classes % cover | Harcombe-Marks PNV classes % cover |
|---|---|---|---|
| 10 | Lower-slope hardwoods-pine | 26.8 | 34.2 |
| 5 | Floodplain hardwoods[1] | 21.0 | 25.0 |
| 4 | Tallow forest[2] | 5.4 | 15.2 |
| 6 | Upper-slope pine-oak | 0.2 | 11.8 |
| 9 | Mid-slope oak-pine | 18.5 | 5.0 |
| 8 | Wetland pine savanna[3] | 2.3 | 2.5 |
| 2 | Cypress-tupelo | 5.6 | 1.5 |
| 11 | Upland/Sandhill Pine[4] | 9.6 | 1.4 |
| 1 | Baygall | 3.8 | 1.6 |
| 7 | Pine plantation[5] | 3.0 | 0.0 |

1. For comparison, the PNV class combines "Floodplain Hardwood Forest" and "Floodplain Hardwood Pine Forest" of Harcombe and Marks.
2. Note that this class was modified to "Hardwood forest": it is compared to the "Flatland hardwoods" type of Harcombe and Marks.
3. This class was modified to "Woodland/Pasture", but is compared here to the "Wetland pine savanna" type of Harcombe and Marks.
4. This class contains a combination of "Upland Pine Forest" and "Sandhill Pine Forest".
5. Pine plantation is not a natural vegetation type, and was not mapped by Harcombe and Marks.

## 2.0 References Cited


ERDAS. 1991. ERDAS Field Guide, 2nd Edition. ERDAS, Inc., Atlanta, GA.

Harcombe, P.A. and P. L. Marks. 1979. Forest Vegetation of the Big Thicket National Preserve. Report to Office of Natural Resources, Southwestern Region, National Park Service.

Marks, P. L., and P. A. Harcombe. 1981. Forest Vegetation of the Big Thicket, Southeast Texas. Ecological Monographs 51:287-305.

Tucker, C. J. 1979. Red and photographic infrared linear combinations for monitoring vegetation. Remote Sensing of Environment 8:127-150.

## APPENDIX B

## METHODOLOGY FOR LAND OWNERSHIP AND LAND USE MAPPING

This appendix briefly describes the methods followed to build a data base and generate maps on a Geographic Information System (GIS) of type of land ownership and type of land uses neighboring the Big Thicket National Preserve (BTNP) water corridors.

Two sets of maps provided the basic information to begin this task: Tobin Research Inc. (1" = 1000') Maps prepared in September 1961, and U.S. Department of the Interior, National Park Service Division of Land Acquisition Maps (1" = 400') prepared by Tobin Research, San Antonio, Texas in September 1977. Tracts that bordered the Preserve's water corridor units were digitized from those maps and assigned polygon numbers.

Land ownership information contained on the maps was recorded in spreadsheet format (Lotus 1-2-3) noting survey, last known owner, land use and acreage. This information was reviewed and updated by BTNP real estate personnel. A polygon number linking the ownership and use information to the GIS map was assigned to each parcel. Preliminary maps were prepared using ArcInfo GIS and an initial examination of the data indicated that there were approximately 2,000 acres for which the type of land use was not known (Figure B-1). Field reconnaissance by BTNP staff and project staff in 1996 enabled the identification of land use types for about 1,500 acres of that amount, leaving about 500 acres for which the land use type has not be recorded.

Because of the tremendous variation in size of tracts included in the data base, the concept of a "buffer" was adopted for analyses. The table below sets out the acres of several land use types within a buffer of one mile from the center of the stream for Preserve units associated with the Neches River.

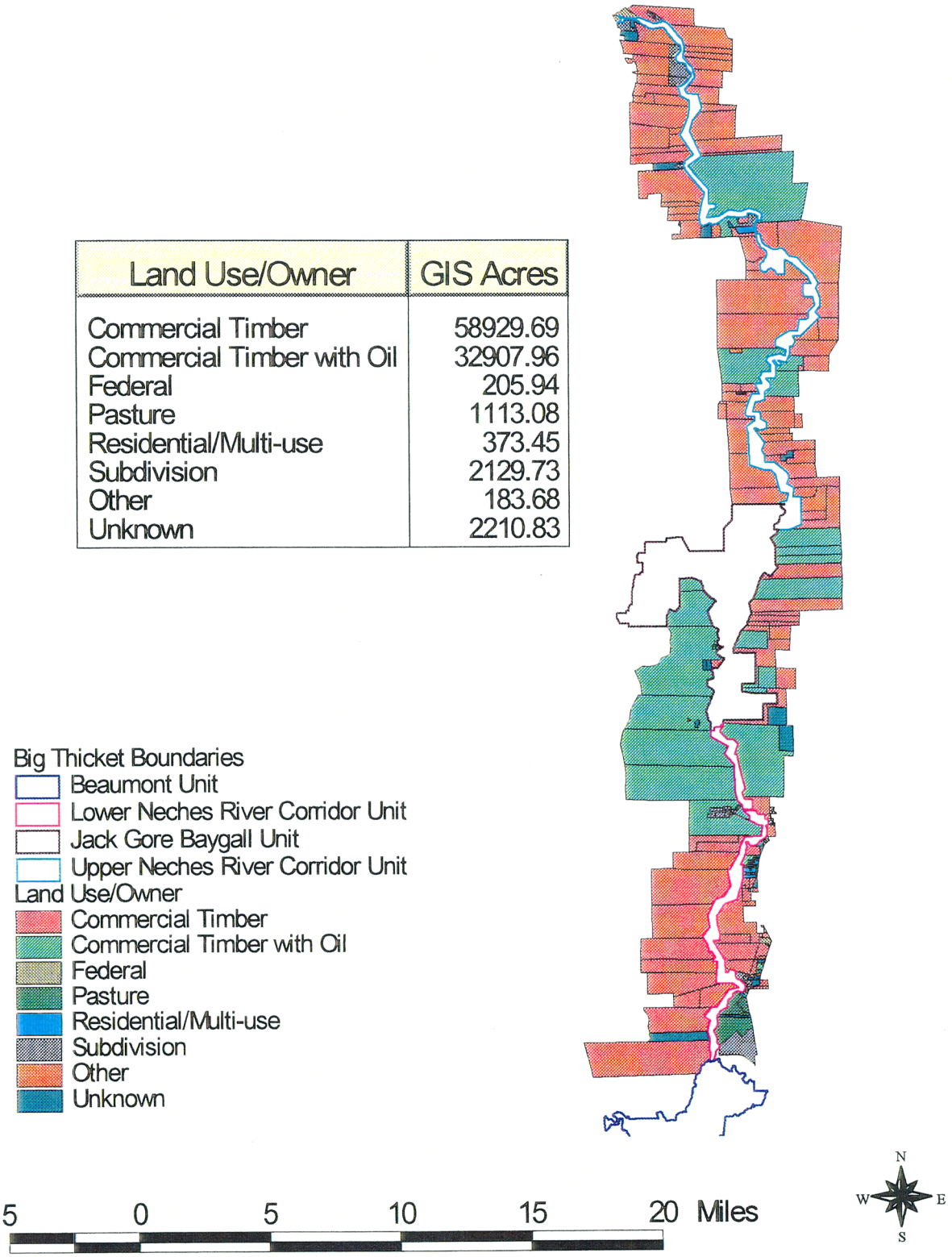
**Table B-1. Land Use Types Neighboring the Big Thicket National Preserve along the Neches River**

| Land Use Type | Acres in One Mile Buffer | Percent of Total Acreage in Buffer |
|---|---|---|
| Commercial Timber | 39,421 | 67 |
| Commercial Timber with Oil | 14,177 | 24 |
| Federal | 137 | <1 |
| Pasture | 1,021 | 2 |
| Residential/Multi-Use | 1,396 | 2 |
| Subdivision | 1,934 | 3 |
| Other | 518 | 1 |
| Total | 58,604 | 100 |

Figure B-1

# Neighboring Land Use Types Along the Neches River

| Land Use/Owner | GIS Acres |
|---|---|
| Commercial Timber | 58929.69 |
| Commercial Timber with Oil | 32907.96 |
| Federal | 205.94 |
| Pasture | 1113.08 |
| Residential/Multi-use | 373.45 |
| Subdivision | 2129.73 |
| Other | 183.68 |
| Unknown | 2210.83 |



## APPENDIX C
## Rare Species of Big Thicket National Preserve (BTNP) followed by State and Federal Agencies

The following pages contain a list of rare species of the BTNP that was constructed as follows:

(1) State and/or federally listed (endangered, threatened, or candidate status) species thought to occur in the seven county area around the BTNP were selected (TPWD 1993,1995,1996, USFWS 1996a,b).

(2) State and federally listed species present or potentially present in the BTNP according to species lists in each chapter of this report were added; species occupying habitats not represented in BTNP were removed.

(3) 'Bottomland hardwood forest' (BLHF) status (references in footnotes of species lists in each chapter of this report) was included to indicate likelihood of presence in the water corridors.

(4) Descriptions of specific locations in the BTNP provided by Texas Natural Heritage Program in 1994 were added.

(5) Relevant G. Watson notes (1982) on species locations in BTNP units were added.

**Legend**

**Status or rank codes**:

**E** = endangered
**T** = threatened
**T(SA)** = threatened by virtue of similarity
**C** = candidate species for federal listing (approximately equivalent to former Category 1; substantial data supports state of vulnerability)
**SC** = species of concern, an informal category of endemic or rare species, many of which were formerly Category 2 species
**3C** = species no longer being considered for federal listing; formerly Category 3 species
**S1** = < 6 occurrences in Texas, critically imperiled in the state
**S2** = 6-20 occurrences in Texas, imperiled
**S3** = 21-100 occurrences in Texas, rare or uncommon
**X** = presumed extirpated from Texas.

**County codes** :

**H** = Hardin, **Ja** = Jasper, **Je** = Jefferson, **P** = Polk, **T** = Tyler, **O** = Orange, **L** = Liberty

**Bottomland hardwood forests (BLHF) status codes** :

**O** = Obligate inhabitant, **F** = Facultative inhabitant, **V** = Occasional visitor.

**Appendix C: Rare Species of Big Thicket National Preserve (BTNP) followed by State and Federal Agencies (continued)**

**Sources**

TPWD 1993. Special Plant List. Texas Parks & Wildlife Department, Texas Natural Heritage Program. Austin, Texas.

TPWD 1995. A Plan for Action to Conserve Rare Resources in Texas. Second Review Draft. October 16, 1995. Texas Parks & Wildlife Department, Endangered Resources Branch, Austin, TX.

TPWD 1996. Texas Threatened and Endangered Species. Texas Parks & Wildlife Department, Endangered Species Branch, Austin, TX.

USFWS 1996a. Federally Listed Threatened and Endangered Species within Clear Lake Field Office Area of Responsibility. U.S. Fish & Wildlife Service, Clear Lake Field Office, Houston, TX.

USFWS 1996b. Candidates or Species of Concern within Clear Lake Field Office Area of Responsibility. U.S. Fish & Wildlife Service, Clear Lake Field Office, Houston, TX.

## Appendix C: Rare Species of Big Thicket National Preserve (BTNP) followed by State and Federal Agencies (continued)

| Scientific name | Common name | BLHF status | Fed./State status | County distrib. |
|---|---|---|---|---|
| **PLANTS** | | | | |
| Family Apiaceae | | | | |
| *Oxypolis ternata* | three-leaf cowbane | | 3C,S1 | H,T |
| Family Apocynaceae | | | | |
| *Amsonia glabberima* | smooth blue-star | | 3C,S2 | H |
| | BTNP location - Beaumont Unit, 1.0 air miles north of the Lower Neches Valley Authority Canal Pumping Station along Pine Island Bayou. | | | |
| Family Asteraceae | | | | |
| *Gaillardia aestivalis* var. *winkleri* | white firewheel | | SC,S1 | H |
| *Prenanthes barbata* | rattlesnake root | | SC,S2 | H,Ja |
| | BTNP location - Neches Bottom & Jack Gore Baygall Units, Sally Withers Lake area, sandy slope in mixed woods. | | | |
| *Liatris tenuis* | slender gay-feather | | SC,S3 | Ja,T |
| | G. Watson - few found in Big Sandy Unit | | | |
| *Rudbeckia scabrifolia* | bog coneflower | | SC,S2 | Ja |
| Family Brassicaceae | | | | |
| *Armoracia lacustris* | lady cress | F | 3C,S1 | T |
| Family Caryophyllaceae | | | | |
| *Silene subciliata* | scarlet catchfly | | SC,S3 | H,Ja,Je, L,P,T |
| | BTNP locations:<br>(1) Menard Creek Corridor Unit, Big Sandy Creek Unit, between 2 bridges over Menard Creek on FM 943,<br>(2) Lance Rosier Unit, exposed sand surfaces of old stream levee deposits,<br>(3) near Big Sandy Creek Unit-ca. 300' west of NW corner of BSC unit in Alabama-Coushatta Indian Reservation, along foot trail through dense re-growth from clear-cut,<br>(4) Menard Creek Corridor Unit, near parking lot on SE bank of Menard Creek, both sides of unnamed road that crosses creek near Hardin-Liberty county line, fairly well-drained sandy flat at margin of forest,<br>(5) Turkey Creek Unit, both sides of Hester Bridge Road, 0.5 miles west of its crossing of Turkey Creek,<br>(6) Menard Creek Unit, east side of north-south road to Fuqua, just south of bridge over Menard Creek,<br>(7) Big Sandy Creek Unit, along "Woodlands Trail" ca. 1/10 mile east of parking lot on FM 1276.<br>G. Watson - At edge of sandhills and terraces. Few individuals widely scattered in Turkey Creek & Big Sandy Units. Once in Lance Rosier Unit. Locations in Big Sandy & Lance Rosier Units now gone (fire responsive, must have open sun). | | | |

## Appendix C: Rare Species of Big Thicket National Preserve (BTNP) followed by State and Federal Agencies (continued)

| Scientific name | Common name | BLHF status | Fed./State status | County distrib. |
|---|---|---|---|---|
| **Family Cyperaceae** | | | | |
| *Cyperus grayoides* | Mohlenbrock's umbrella sedge | F | 3C,S3 | H,T |
| | BTNP location - Turkey Creek Unit, w/in 20' of property fence line at 75° angle from fence. ca. 0.5 air mile due east of junction of Turkey & Village Creeks. | | | |
| **Family Eriocaulaceae** | | | | |
| *Lachnocaulon digynum* | bog buttons | F | 3C,S1 | Ja |
| *Eriocaulon kornickianum* | small-headed pipewort | F | 3C,S1 | T |
| | G. Watson - found in Turkey Creek Unit in 1960's, not seen since. | | | |
| **Family Gentianaceae** | | | | |
| *Bartonia texana* | Texas screwstem | O | 3C,S2 | H,Ja,P,T |
| | BTNP locations - | | | |
| | (1) Neches Bottom & Jack Gore Baygall Units, NNE of Silsbee, | | | |
| | (2) Turkey Creek Unit, edge of savannah. | | | |
| **Family Labiatae** | | | | |
| *Physostegia longisepala* | long-sepaled false dragonhead | F | SC,S2 | H,Ja,O |
| **Family Liliaceae** | | | | |
| *Trillium pusillum* var. *texanum* | Texas (least) trillium | O | 3C,S3 | T |
| **Family Orchidaceae** | | | | |
| *Spiranthes parksii* | Navasota ladies-tresses | F | E,E(S2) | Ja |
| *Cypripedium kentuckiense* | southern lady's slipper | F | SC,S1 | T |
| **Family Polemoniaceae** | | | | |
| *Phlox nivalis* ssp. *texensis* | Texas trailing phlox | | E,E(S2) | H,P,T |
| | BTNP locations- | | | |
| | (1) Big Sandy Creek Unit, sandy uplands, | | | |
| | (2) Turkey Creek Unit, NNE of confluence of Village & Turkey Creeks, & east of Turkey Creek. | | | |
| | G. Watson- Sandhills in Turkey Creek & Big Sandy Units | | | |
| **Family Rosaceae** | | | | |
| *Agrimonia incisa* | harvest lice | F | SC,S1 | Ja |
| **Family Xyridaceae** | | | | |
| *Xyris drummondii* | Drummond's yellow-eyed grass | F | SC,S2 | Ja |
| *Xyris scabrifolia* | rough-leaf yelllow-eyed grass | F | SC,S2 | Ja |

**Appendix C: Rare Species of Big Thicket National Preserve (BTNP) followed by State and Federal Agencies (continued)**

| Scientific name | Common name | BLHF status | Fed./State status | County distrib. |
|---|---|---|---|---|
| **BIRDS** | | | | |
| Family Threskiornithidae | | | | |
| *Plegadis chihi* | white-faced ibis | V | 3C,T | Je,O |
| Family Ciconiidae | | | | |
| *Mycteria americana* | wood stork | F | -,T | |
| Family Pelecanidae | | | | |
| *Pelecanus occidentalis* | brown pelican | V | E,E | Je |
| Family Scolopacidae | | | | |
| *Numenius borealis* | eskimo curlew | V | E,E | |
| Family Laridae | | | | |
| *Sterna antillarum athalassus* | interior least tern | V | E,E | |
| Family Accipitridae | | | | |
| *Haliaeetus leucocephalus* | bald eagle | F | T,T | H,Ja,Je,L,O,P,T |
| *Elanoides forficatus* | swallowtail kite | F | 3C,T | |
| Family Falconidae | | | | |
| *Falco peregrinus tundrius* | Arctic peregrine falcon | V | T(SA),T | Je |
| Family Picidae | | | | |
| *Campephilus principalis* | ivory-billed woodpecker | O | X | |
| *Picoides borealis* | red-cockaded woodpecker | V | E,E | H,Ja,L,P,T |
| | BTNP location - Big Sandy Creek Unit - 4.2 km. south of dam at Lake Tombigbee, Polk Co. | | | |
| Family Vireonidae | | | | |
| *Vermivora bachmanii* | Bachman's warbler | O | X | |
| Family Fringillidae | | | | |
| *Aimophila aestivalis* | Bachman's sparrow | V | SC,T | H,Ja,Je,L,O,P,T |

**Appendix C: Rare Species of Big Thicket National Preserve (BTNP) followed by State and Federal Agencies (continued)**

| Scientific name | Common name | BLHF status | Fed./State status | County distrib. |
|---|---|---|---|---|
| **MAMMALS** | | | | |
| Order Chiroptera | | | | |
| Family Vespertilionidae | | | | |
| *Myotis austroriparius* | southeastern bat | O | SC,T | H, L,T |
| *Corynorhinus rafinesquii* | Rafinesque's big-eared bat | F | SC,T | H,P |
| Order Carnivora | | | | |
| Family Mustelidae | | | | |
| *Conepatus mesoleucus telmalestes* | Big Thicket hog-nosed skunk | F | C,S1 | H,L |
| Family Ursidae | | | | |
| *Ursus americanus luteolus* | Louisiana black bear | F | T,E | |
| Family Canidae | | | | |
| *Canis rufus* | Red wolf | F | X | |
| **REPTILES** | | | | |
| Order Squamata | | | | |
| Suborder Serpentes | | | | |
| Family Colubridae | | | | |
| *Pituophis melanoleucus ruthveni* | Louisiana pine snake<br>BTNP location - Menard Creek & Big Sandy Creek Units | | SC,E | H,Ja,P,T |
| Family Viperidae | | | | |
| *Crotalus horridus* | timber/canebreak rattlesnake | F | -,T | |
| Suborder Lacertilia | | | | |
| Family Phrynosomatidae | | | | |
| *Phrynosoma cornutum* | Texas horned lizard | | 3C,T | Je,L,O |

**Appendix C: Rare Species of Big Thicket National Preserve (BTNP) followed by State and Federal Agencies (continued)**

| Scientific name | Common name | BLHF status | Fed./State status | County distrib. |
|---|---|---|---|---|
| Order Chelonia, Suborder Cryptodira | | | | |
| Family Chelydridae | | | | |
| *Macroclemys temmincki* | Alligator snapping turtle | F | SC,T(S3) | H,Ja,Je,L,O,P,T |
| Family Emydidae | | | | |
| *Malaclemys terrapin littoralis* | Texas diamondback terrapin | F? | SC,S3 | Je,L,O |
| **FISH** | | | | |
| Order Acipenseriformes | | | | |
| Family Poltodontidae | | | | |
| *Polyodon spathula* | paddlefish | O | SC,E | |
| Order Cypriniformes | | | | |
| Family Catostomidae | | | | |
| *Erimyzon oblongus* | creek chubsucker | F | -,T | |
| *Cycleptus elongatus* | blue sucker | O | -,T | |
| **INVERTEBRATES** | | | | |
| Phylum Arthropoda, Class Insecta | | | | |
| Order Coleoptera, Family Sylphidae | | | | |
| *Nicrophorus americanus* | American burying beetle | F | E,S1 | |
| Order Odonata, Family Corduliidae | | | | |
| *Somatochlora margarita* | Big Thicket emerald dragonfly | F | -,S3 | |
| Phylum Mollusca, Class Bivalvia, Order ?, Family Unionidae | | | | |
| *Potamilius amphichaenus* | Texas heelsplitter | O | SC,S1 | |