STATE OF THE RIVER REPORT FOR THE LOWER ST. JOHNS RIVER BASIN, FLORIDA: *WATER QUALITY, FISHERIES, AQUATIC LIFE, & CONTAMINANTS*

2008

Prepared for

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August 4, 2008

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Preface

The State of the River Report is the result of a collaborative effort of a team of academic researchers from Jacksonville University and the University of North Florida, Jacksonville, FL. The purpose of the project, funded primarily by the Environmental Protection Board of the City of Jacksonville, was to review various previously collected data and literature about the river and to place it into a format that was informative and readable to the general public. The report consisted of three parts---the brochure, the full report, and an appendix. The short brochure provides a brief summary of the status and trends of each item or indicator (i.e. water quality, fisheries, etc.) looked at for the river. The full report and appendix were produced to provide those interested with more detail regarding the results summarized in the brochure. In the development of these documents, many different sources of data were examined, including data from the Florida Department of Environmental Protection, St. Johns River Water Management District, Fish and Wildlife Commission, City of Jacksonville, individual researchers, and others. The researchers reviewed data addressing many different aspects of the Lower St. Johns River. The most legitimate and stringent research available was used to assemble the report. When a draft of all documents was produced, an extensive review process was undertaken to ensure accuracy, balance, and clarity. We are extremely grateful to the following scientists and interested parties who provided invaluable assistance in improving our document.

Vince Seibold, City of Jacksonville
Dana Morton, City of Jacksonville
Christi Veleta, City of Jacksonville
Kristen Beach, City of Jacksonville
John Hendrickson, SJRWMD
John Higman, SJRWMD
Dean Dobberfuhl, SJRWMD
Dean Campbell, SJRWMD
Teresa Monson, SJRWMD
Russ Brodie, FWRI
Justin Solomon, FWRI
Lee Banks, FL DEP
Patrick O'Connor, FL DEP
Neil Armingeon, St. Johns River Riverkeeper
Paul Steinbrecher, JEA
Tiffany Busby, Wildwood Consulting
Marcy Policastro, Wildwood Consulting
Mike McManus, The Nature Conservancy
Richard Bryant, National Park Service
Mark Middlebrook, The Middlebrook Company
Maria Mark, The Middlebrook Company
Stephan Nix, University of North Florida
Kelly Smith, University of North Florida
Dale Casamatta, University of North Florida
Robert Richardson, University of North Florida

We have appreciated the opportunity to work with the environmental community to educate the public about the unique problems of the Lower St. Johns River, and the efforts that are under way to restore our river to a healthy ecosystem.

We would also like to thank the following undergraduate students for their contributions toward the development of this report:

Laura Elston, Jacksonville University
Bobbi Estabrook, Jacksonville University
Jessica Goodman, Jacksonville University
Julia Goodman, Jacksonville University
Julie Hammon, Jacksonville University
Leon Huderson, III, Jacksonville University
Jingu Gene Kang, Jacksonville University
Ryan Keith, Jacksonville University
Rebecca Lucas, Jacksonville University
Andrea Pertoso, University of North Florida
David Roueche, Jacksonville University

Sincerely,

Dan McCarthy, Principal Investigator, JU
Heather McCarthy, JU
Gerry Pinto, JU
Lucy Sonnenberg, Millar Wilson Lab at JU
Quinton White, JU

Pat Welsh, Co-Principal Investigator, UNF
Gretchen Bielmyer, UNF
Stuart Chalk, UNF
Ray Bowman, UNF
April Moore, UNF

1. BACKGROUND

1.1. Introduction to the River Report

This *State of the River Report for the Lower St. Johns River Basin* is the result of a consolidated effort directed by a team of academic researchers from Jacksonville University (JU) and the University of North Florida (UNF) in Jacksonville, Florida. This Report has undergone an extensive review process including local stakeholders and an expert review panel with the expertise and experience in various disciplines to address the multi-faceted nature of the data.

The *State of the River Report* was funded through the Environmental Protection Board (EPB) of the City of Jacksonville, Florida, as one component of a range of far-reaching efforts initiated by Jacksonville Mayors John Delaney and John Peyton and the *River Accord* partners (including St. Johns River Water Management District, JEA, Jacksonville Water and Sewer Expansion Authority (WSEA), and the Florida Department of Environmental Protection (DEP)) to inform and educate the public regarding the status of the Lower St. Johns River Basin (LSJRB), Florida (Figure 1.1).

1.1.1. *Purpose*

The *State of the River Report's* purpose is to be a single clear, concise document that reduces a vast amount of scientific information and evaluates the current ecological status of the Lower St. Johns River Basin.

1.1.2. *Goals and Objectives*

The overarching goal of the *State of the River Report* is to summarize the status and trends in the health of the LSJRB through comprehensive, unbiased, and scientific methods.

The tangible objectives of the River Report project include the design, creation, and distribution of a concise, easy-to-understand, and graphically pleasing document for the general public that explains the current health of the LSJRB in terms of water quality, fisheries, aquatic life, and contaminants.

Secondary objectives include the production of a baseline record of the status of the St. Johns River that can serve as a benchmark for the public to compare the future health of the river. From this baseline, the public and policymakers can see the current health of the river in its historical context. This better ensures that management efforts and resources focus on areas that need the most improvement first, and there is a standard against which to gauge the success of current and future management practices.

1.1.3. *River Health Indicators and Evaluation*

The *State of the River Report* describes the health of the Lower St. Johns River Basin based on a number of broad indicators in four major categories:

- **WATER QUALITY**
  - Dissolved Oxygen (DO)
  - Nutrients (Nitrogen & Phosphorus)
  - Turbidity
  - Algal Blooms
  - Bacteria (Fecal Coliform)
- **FISHERIES**
  - Finfish Fisheries
  - Invertebrate Fisheries
- **AQUATIC LIFE**
  - Submerged Aquatic Vegetation
  - Wetlands
  - Macrobenthic Invertebrates
  - Threatened and Endangered Species
  - Nonindigenous Aquatic Species
- **CONTAMINANTS**
  - Metals
  - Polyaromatic Hydrocarbons (PAHs)
  - Polychlorinated Biphenyls (PCBs)
  - Organochlorine Pesticides (OCPs)

The *State of the River Report* is based on the best available data for each river health indicator listed above. How each indicator contributes to, or signals, overall river health is discussed in terms of its 1) *Current Status* in 2008 and 2) the *Trend* over time.

The *Current Status* for each indicator is based on the most recent data records and designated as "satisfactory" or "unsatisfactory." This designation often considers whether the indicator meets State and Federal minimum standards and guidelines.

The *Trend* is derived from statistical analyses of the best available scientific data for each indicator and reflects historical change over the time period analyzed. The *Trend* ratings for each indicator are designated as "conditions improving," "conditions stable," "conditions worsening," or "uncertain." The *Trend* rating does not consider initiated or planned management efforts that have not yet had a direct impact on the indicator.

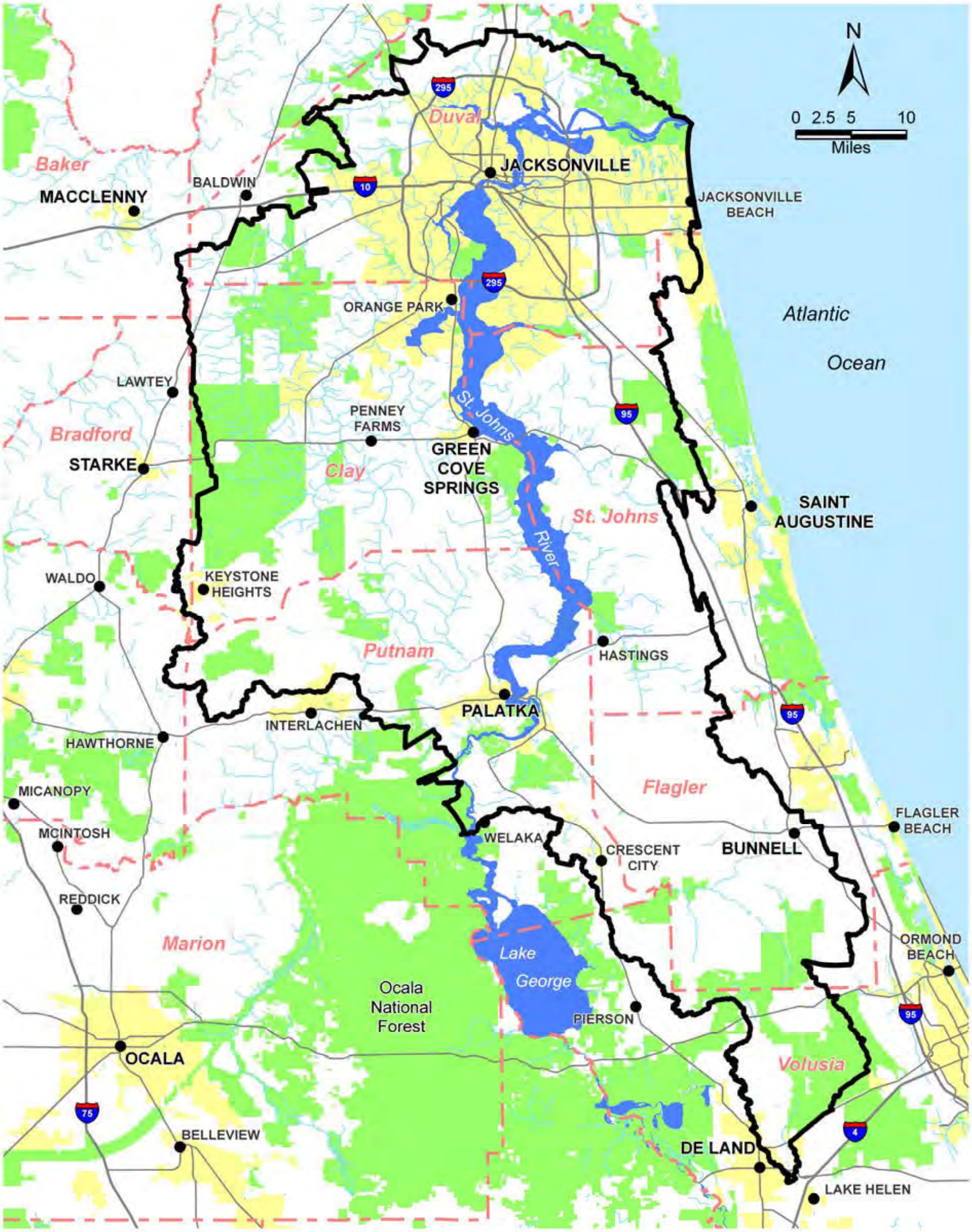


Figure 1.1 Geopolitical Map of the Lower St. Johns River Basin

1.2. St. Johns River Basin Landscape

The LSJRB in Northeast Florida has long been recognized as a treasured watershed- providing enormous ecological, recreational, socioeconomic, and aesthetic benefits. However, during recent years, it has also been recognized as a threatened watershed critically in need of resource conservation, water quality improvement, and careful management.

1.2.1. Geopolitical Boundaries

For management purposes, the entire St. Johns River watershed is commonly divided into five basins: the Upper Basin (southern, marshy headwaters in east central Florida), the Middle Basin (the area in central Florida where the river widens, forming Lakes Harney, Jesup, and Monroe), the Lake George Basin (the area between the confluence of the Wekiva and St. Johns and that of the Ocklawaha and the St. Johns), the Lower Basin (the area in Northeast Florida), and the Ocklawaha River Basin (the primary tributary for the St. Johns River). The health of the LSJRB is the focus of this State of the River Report.

As a constant, this Report defines the LSJRB in accordance with the SJRWMD definition: "the drainage area for the portion of the St. Johns River extending from the confluence of the St. Johns and Ocklawaha rivers near Welaka to the mouth of the St. Johns River at Mayport" (SJRWMD 1989; Figure 1.1).

The LSJRB includes portions of nine counties: Clay, Duval, Flagler, Putnam, St. Johns, and small portions of Volusia, Alachua, Baker, and Bradford Counties (Brody 1994). Notable municipalities within the Lower Basin include Jacksonville, Orange Park, Green Cove Springs, and Palatka (Figure 1.1).

The LSJRB covers a 1.8 million-acre drainage area, extends 101 miles in length, and has a surface area of water approximately equal to 115 square miles (Adamus, *et al.* 1997; USEPA 2008).

1.2.2. Existing Land Uses

The LSJRB consists of approximately 68% uplands and 32% wetlands and deepwater habitats (Figure 1.2, see Appendix 1.A.).

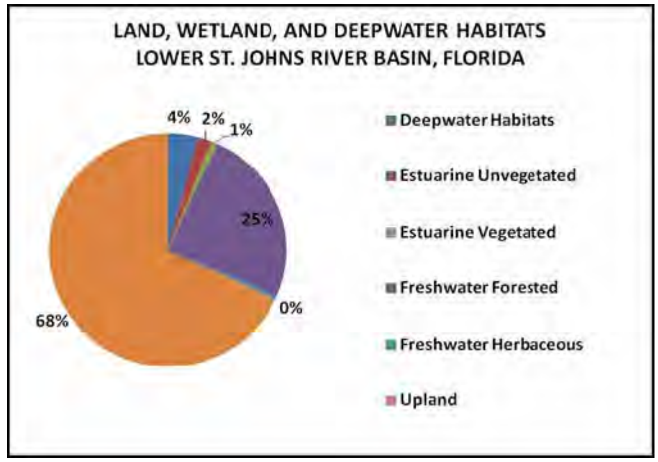


Figure 1.2 Total percentages for land, wetland, and deepwater habitats within the Lower St. Johns River Basin, Florida. (Source: SJRWMD Wetlands and Deep Water Habitats GIS Maps, 1972-1980; SJRWMD 2007a)

Within the LSJRB in 2004, the dominant land uses were upland forests (35%) and wetlands (24%), and 18% was considered urban and built-up (Figure 1.3). Since the 1970s, the proportion of the total basin designated as upland forests and agriculture have decreased, while the proportion designated as urban and built-up has increased (see Appendix 1.B.; SJRWMD 2007a).

1.2.3. Ecological Zones

The LSJRB is commonly divided into three ecological zones based on expected salinity differences (Figure 1.3; Hendrickson and Konwinski 1998). Malecki, *et al.* 2004 describes these zones in the quote below.

> *The freshwater lacustrine zone in the southern region stretches from south of Palatka to north of Green Cove Springs with an average salinity of 0.5 parts per thousand (ppt). The riverbed broadens into the tidal oligohaline lacustrine zone, with an extensive floodplain, which is shallow and slow-moving, spanning from Doctors Lake north to the Fuller Warren Bridge in Jacksonville with a mean salinity of 2.9 ppt. Finally, the northern region from the Fuller Warren Bridge north to the Atlantic Ocean is considered mesohaline riverine, becoming deeper, fast-moving, and well-mixed with a mean salinity of 14.5 ppt (Malecki, et al. 2004).*

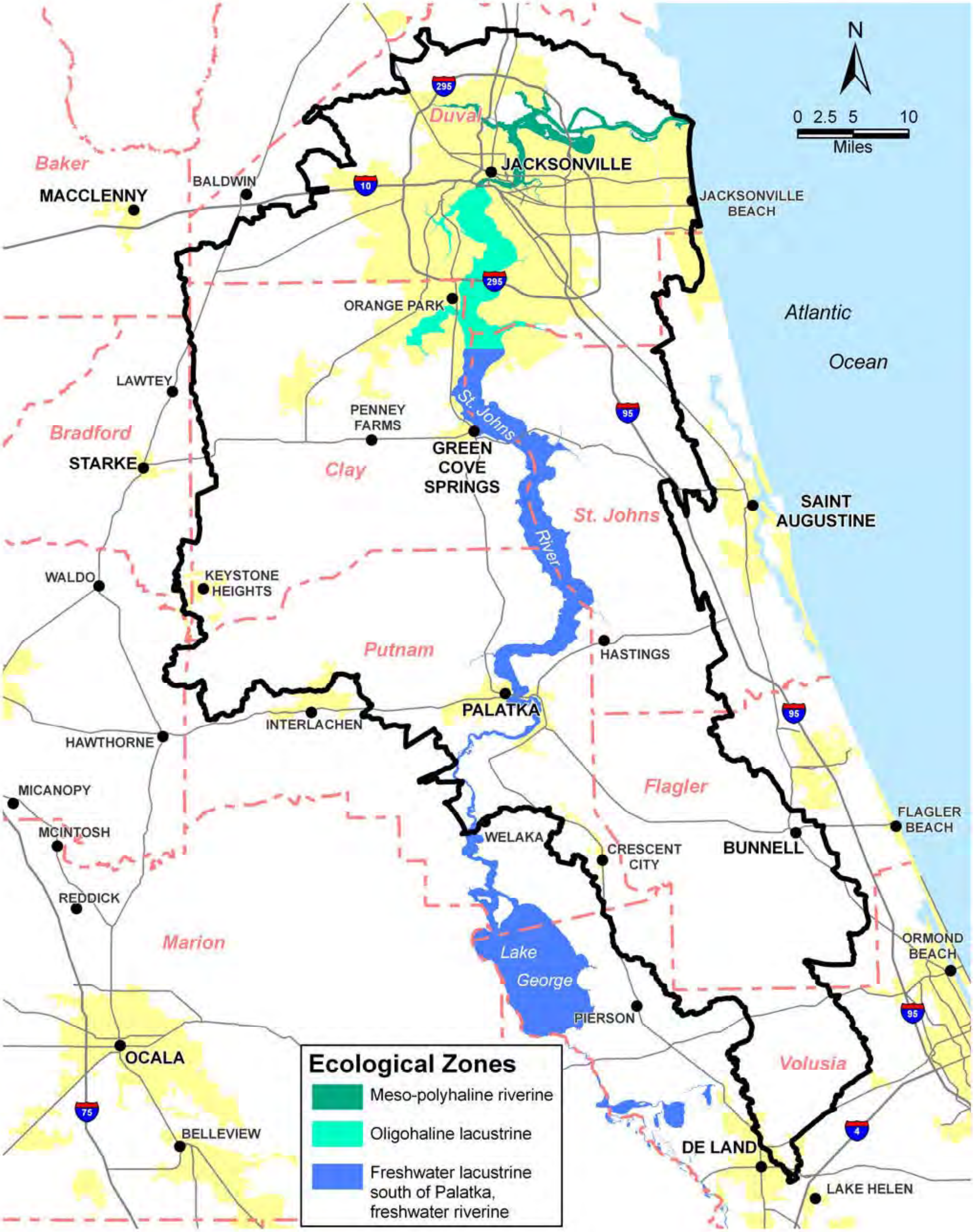


Figure 1.3 Map of the Ecological Zones of the Lower St. Johns River Basin

1.2.4. Unique Physical Features

The St. Johns River is unique and distinctive due to a number of exceptional physical features.

- ***The St. Johns River is the longest river in Florida.*** Stretching 310 miles and draining approximately 9,430 square miles, this extensive river basin drains about 16% of the total surface area of Florida (DeMort 1991; Morris IV 1995).

- ***The St. Johns River flows northward.*** Most major rivers in North America flow in a southward direction. This means that the Upper St. Johns actually lies south of the Lower St. Johns (DeMort 1991).

- ***The St. Johns River is one of the flattest major rivers in North America.*** The headwaters of the St. Johns River are less than 30 feet above sea level. The river flows downward on a slope ranging from as low as 0.002% (Benke and Cushing 2005) to about 1% (DeMort 1991). This slope is governed by the exceptionally flat terrain of the drainage basin. This extremely low gradient, about one inch per mile, causes the water of the St. Johns River to flow very slowly (DeMort 1991). This holds back drainage, slows flushing of pollutants, and intensifies flooding and pooling of water along the river creating numerous lakes and extensive wetlands throughout the drainage basin (Durako, *et al.* 1988). The retention time of the water (and its dissolved and suspended components) in river is on the order of three to four months (Benke and Cushing 2005). High retention times have severe impacts on water quality.

- ***The Lower St. Johns River is a broad, shallow system.*** The average width of the Lower St. Johns River from Lake George to Mayport is one mile, although the flood plain reaches a maximum width of ten miles (Miller 1998). The average depth of the river is 11 feet (Dame, *et al.* 2000).The wideness of the river can result in different water flow patterns and conditions on opposing banks of the river (Welsh 2008).

- ***The St. Johns River receives saltwater from springs.*** Major springs that feed into the St. Johns River Drainage Basin include Blue Springs, Salt Springs, and Silver Springs. Inputs from salty springs cause localized areas of elevated salinity (>5 ppt) in otherwise freshwater sections of the river (Benke and Cushing 2005). Such variations in salinity have profound hydrological and ecological effects. The amount of flow from springs is dramatically affected by droughts and is highly variable (Campbell 2008).

- ***The St. Johns River drains into the Atlantic Ocean.*** The average discharge of water at the mouth of the St. Johns River is 8,300 cubic feet per second (Miller 1998) or 5.4 billion gallons per day (Steinbrecher 2008). Natural water sources for the St. Johns River are rainfall, underground aquifers, and springs. Continual input from springs and aquifers supplies the river with water that discharges into the Atlantic Ocean, despite drought periods or seasonal declines in rainfall (Benke and Cushing 2005).

- ***The Lower St. Johns River is a tidal system with an extended estuary.*** The tidal range at the mouth of the river at Mayport, Florida is about six feet (McCully 2006). The Atlantic Ocean's tide heights are large compared to the slope of the St. Johns River, and at times, can produce strong tidal currents and mixing in the northernmost portion of the river. The St. Johns River is typically influenced by tides as far south as Lake George (106 miles upstream) (Durako, *et al.* 1988). During times of drought (when little rainwater enters the system) or extreme high tides, river flow-reversal can occur as far south as Lake Monroe (160 miles upstream) (Durako, *et al.* 1988). Tidal reverse flows occur daily in the LSJR, and net reverse flows can occur for weeks at a time (Morris IV 1995).

- ***The St. Johns River can be influenced by wind direction and wind speed.*** South winds (blowing to the north) accelerate the flow of water toward the ocean, if the flow is not opposed by a strong tidal current. Similarly, north winds can push river water back upstream (Welsh 2008). Strong sustained north winds (from fall nor'easters or summer hurricanes) can push saltwater up the river into areas that are usually fresh. Although considered a natural occurrence, reverse flow of the river can impact flora and fauna with low salinity tolerances and cause inland areas to flood.

- ***The St. Johns River is a dark, blackwater river***. Southern blackwater rivers are naturally colored by dissolved organic matter derived from their connections to swamps, where plant materials slowly decay and release these organic materials into the water (Brody 1994). The Dissolved Organic Matter limits light penetration (and, therefore, warming and photosynthesis) to a very shallow layer near the surface of the river.

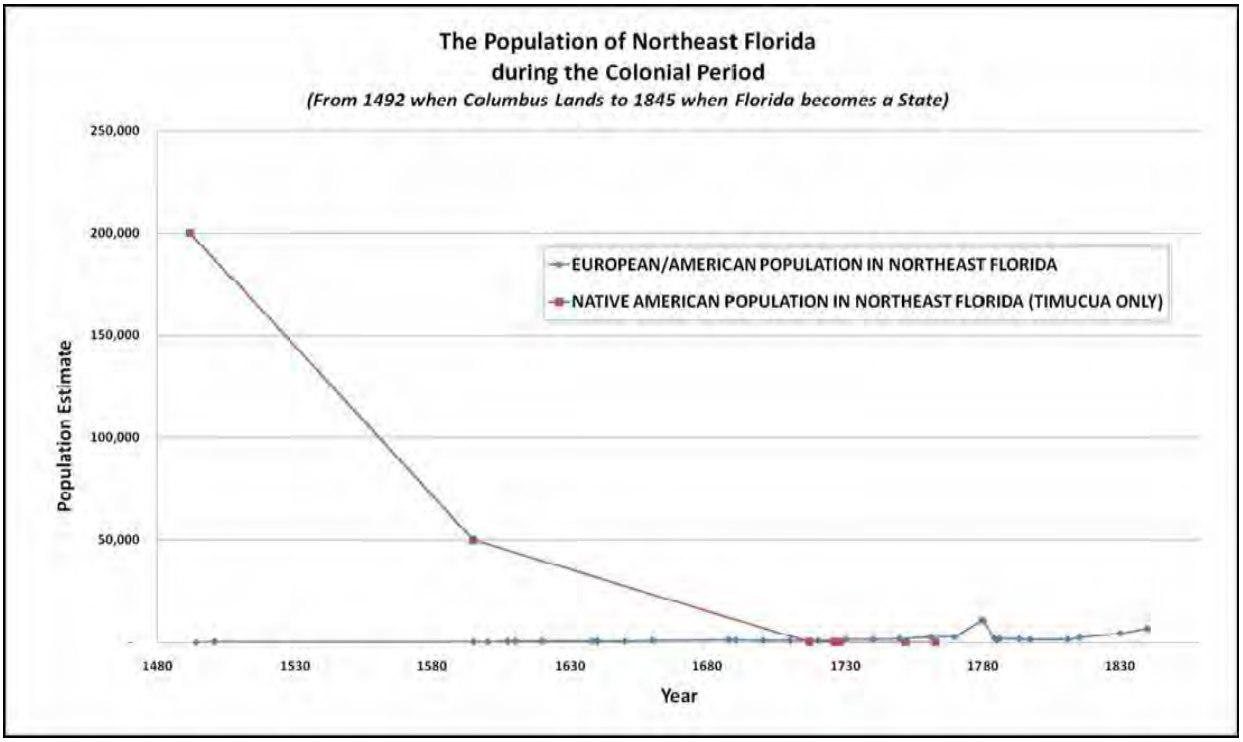


Figure 1.4 The Population of Northeast Florida during the Colonial Period, 1492 to 1845.(Sources: Population estimates for the Timucua Tribe in Northeast Florida were taken from Milanich 1997, and "Northeast Florida" is defined as all lands inhabited by Timucua. Population estimates for European Colonists were taken from Miller 1998, and "Northeast Florida" loosely includes settlers in "the basin of the northward-flowing St. Johns River from Lake George to the mouth, as well as the adjacent Atlantic Coast and the intervening coastal plain" (Miller 1998). Complete data table provided in Appendix 1.C.)

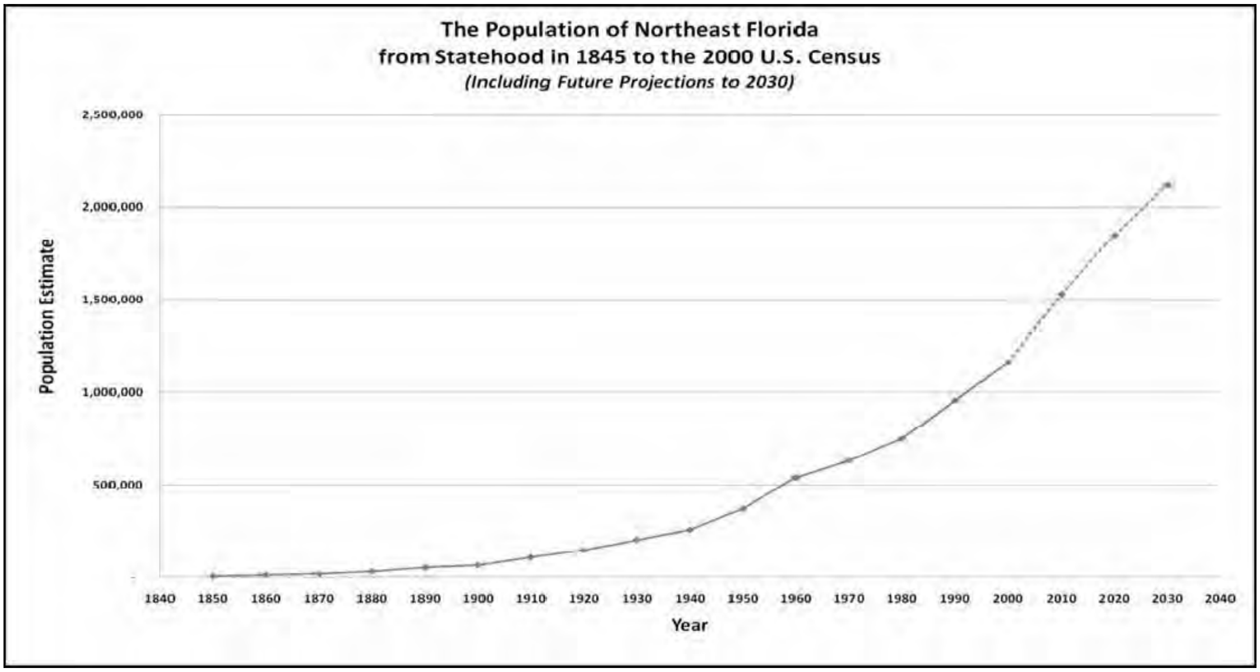


Figure 1.5 The Population of Northeast Florida from the time Florida was granted statehood to the 2000 U.S. Census including Future Population Projections to 2030. ("Northeast Florida" includes population counts from Clay, Duval, Flagler, Putnam, and St. Johns Counties. Sources: Population counts for the years 1850-1900 were provided by Miller 1998. Counts from 1900-1990 were extracted from Forstall 1995, and 2000 counts from the USCB 2000. Note: U.S. Census data was not available for Flagler County in 1900 and 1910.Population estimates for 2010, 2020, and 2030 were extracted from the Demographic Estimating Conference Database (EDR 2008), updated August 3007. Complete data table provided in Appendix 1.C.

1.3. Human Occupancy of the Region (pre-1800s)

1.3.1. Native Americans

The Lower Basin of the St. Johns River watershed has been occupied, utilized, and modified by humans for over 12,000 years (Miller 1998). As the Ice Age ended, the first Floridians, the Paleoindians, inhabited a dry, wide Florida hunting for food and searching for freshwater sources. Gradually, the glaciers melted, sea level rose, and Florida was transformed. By 3,000 B.C., the region resembled the Florida of today with a wet, mild climate and abundant freshwater lakes, rivers, and springs (Purdum 2002). The conditions were favorable for settlement, and early Indians occupied areas throughout the state. In fact, historians estimate that as many as 350,000 Native Americans were thriving in Florida (including 200,000 Timucuans in the Lower Basin of the St. Johns River), when the first French and Spanish explorers arrived in the 1500s (Figure 1.4; Milanich 1995, 1997).

Unlike the Native American groups to the south, the Timucua Indians in northern Florida began to cultivate crops such as corn, beans, and squash, in addition to traditional hunting and gathering (Purdum 2002). These Native Americans did modify the land to their advantage, such as burning and clearing land for agriculture and constructing drainage ditches and large shell middens (Milanich 1998). But, by today's standards, these impacts on the landscape were small in scale and spread out over a vast terrain.

The numbers of Native Americans in Florida plummeted during the 16^{th} and 17^{th} centuries, as many were killed by European diseases or conflicts (Davis and Arsenault 2005). By the 1700s, the original Native American population in Florida had virtually vanished (Figure 1.4).

1.3.2. Europeans

The first permanent European colony in North America was Fort Caroline, founded in 1564 by the French near the mouth of the St. Johns River (Miller 1998). One year later, the Spanish conquered the French, and from 1565 to 1763, the still-wild territory of Florida flew the flag of Spain (UNF 2007). The epicenter of the Spanish colony became St. Augustine, and few colonists ventured beyond the walls of the guarded city. In retrospect, the footprint of these Spanish settlers on Florida was light. Apart from introducing nonindigenous citrus, sugarcane, and pigs (the wild boars of today), they altered the environmental landscape very little along the St. Johns River watershed as compared to what was to come (UNF 2007; Warren 2005).

In 1763, the British took control of Florida. Immediately, John and William Bartram, serving as naturalists to King George III of England, were commissioned to survey the natural resources of Florida that were now available for English use and benefit. The writings of this father and son provide evidence that the First Spanish Period left behind a wild and largely untouched land full of untapped resources and potential (Bartram 1769; Bartram 1955; Harper 1998).

During the 20 years that the British occupied Florida, landscape modifications for colonization and agriculture were intensive. Large tracts of land were cleared for plantations intended for crop exportation, and timber was harvested and exported for the first time (Miller 1998). During the American Revolution, Florida became a haven for British loyalists, and the population of Florida ballooned from several thousand to 17,000 (Milanich 1997). The Spanish reacquired Florida in 1783, most of the British settlers left the area, and the state population declined again to several thousand (Figure 1.4). The Spanish continued plantation farming within the LSJRB, but did not as successfully exploit the land as the British (Miller 1998). Spain held Florida until the region was legally acquired by the United States in 1821. At this time, exploration and exploitation of the St. Johns River Basin began in earnest.

1.4. Early Environmental Management (1800s to 1970s)

The history of environmental management of the St. Johns River watershed, and water resources in Florida in general, is a complex, convoluted, but relatively short history. Major milestones of environmental management in Florida have taken place within just the last century, with much of the story occurring during our living memory (Table 1.1). The story of water management in Florida unfolds as a tale of lessons learned, a shift from reigning to restoring, from consuming to conserving.

Like the tides, management efforts in the watershed have surged and retracted over the last 100 years. Many landmark policies and programs have been initiated in response to environmental changes deemed intolerable to the public and the policymakers who represent them.

Noticeable, but small-scale changes occurred in the St. Johns River Basin during pre-Columbian times, when Northeast Florida was occupied by the Timucua Indians (Milanich 1998). However, it was not until the Colonial Period, particularly during the British occupation in the late 1700s, that the environment experienced larger-scale alterations. Such landscape modifications as the conversion of wetlands to agriculture and the clearing of forests for timber surged again in the mid-1800s after Florida was granted statehood (Davis and Arsenault 2005).

Most of the earliest changes to the landscape of the LSJRB were utilitarian in purpose, but the late 1800s and early 1900s were fraught with changes driven by the profitable, even whimsical, tourist industry. Tourists were fascinated with promotional accounts describing this land of eternal summer, filled with wild botanicals and beguiling beasts (Miller 1998). The growing village of Jacksonville became the initial portal to Florida, and a thriving tourist industry flourished as steamboats began to shuttle tourists down the St. Johns River. By 1875, Jacksonville was the most important town in Florida (Blake 1980). First tourists, and then developers and agricultural interests, were enticed to the rich and largely unexploited resource that was early Florida (Blake 1980). By the early 1900s, the population of Northeast Florida was increasing at a slow steady rate (see Figure 1.5).

Impacts to the environment mirrored the steady population growth during the early 1900s. Entrepreneurs, investors, and government officials in Florida at this time were thoroughly focused on the drainage and redirection of water through engineering works (Blake 1980).

The immigration of new settlers was moderate during Florida's first century as a state, because the region still proved inhospitable and rather uninhabitable to the unadventurous. Not only was the region full of irritating, disease-carrying mosquitoes, Florida was just too hot and humid. But, that all changed when air conditioners for residential use became affordable and widespread after WWII (Davis and Arsenault 2005). Florida's population exploded around the 1950s and has continued to skyrocket ever since (USCB 2000; Figure 1.5).

By the 1960s, a century of topographical tinkering was taking its toll. Ecosystems across Florida were beginning to show signs of stress. Sinkholes emerged in Central Florida (the Upper Basin of the St. Johns River) indicating a serious decline in the water table (SJRWMD 2007b). Flooding, particularly during storm events, was destructive and devastating. Loss of wetlands peaked during this time, as wet areas were rapidly converted to agriculture or urban land uses (Meindl 2005). Water works, such as the Kissimmee Canal and Cross Florida Barge Canal, continued into the 1960s, but public opposition against such projects was mounting (Purdum 2002).

During 1970-71, Florida experienced its worst drought in history, and the attitudes toward water began to shift from control and consumption to conservation (Purdum 2002). During 1972, the "Year of the Environment," the Federal and State governments passed a number of significant pieces of environmental legislation (see Table 1.1.). The laws of the early 1970s, such as the National Environmental Policy Act, Endangered Species Act, and Clean Water Act, showcase a turn in our approach to resource use and our attitudes regarding ecosystem services, nature, and the environment. From this time forward, environmental management began to take a shift towards consideration of the outcomes of our actions.

The Clean Water Act (CWA) has been one of the most enduring and influential pieces of legislation from the 1970s. The CWA addressed key elements that affect the long-term health of the nation's rivers and streams. The CWA required states to submit a list of their "impaired" (polluted) waters to the U.S. Environmental Protection Agency (EPA) every two years (or the EPA will develop the list for them). States determine impairment primarily by assessing whether water bodies meet specific chemical and biological standards or exhibit safety risks to people. Once a state has an approved (or "verified 303(d)") list of impaired waters, it must develop a management plan to address the issues that are causing the impairment. This process of identifying and improving impaired waters through the CWA has played a major role in modern environmental management from the 1980s through the 2000s.

1.5. Modern Environmental Management (1980s to 2000s)

The deluge of new environmental legislation in the 1970s caused a backlash during the 1980s from a property rights perspective (Davis and Arsenault 2005). At the same time, readily observable symptoms of environmental degradation continued to surface. The St. Johns River began having periodic blooms of blue-green algae, lesions in fish, and fish kills (FDEP 2002). Each of these conditions was a visible expression of degraded water quality in the river and represented changes that were not acceptable to the public and policymakers.

Since the 1990s, water quality improvements have been achieved in Florida through the seesawing efforts of policymakers and public and private stakeholders. The policymakers push on the legislative side (via governmental regulatory agencies), while public/private interests push on the judicial side (via lawsuits in the Courts). Back and forth, these groups seesaw on this long (and often costly) ride, forging 1970s laws to fit modern conditions and circumstances. Consequently, the last two decades are marked by this zigzag between lawsuits and laws. The result has been incremental and adaptive water quality management.

For years one aspect of the CWA was overlooked until an influential court decision in 1999. Several Florida environmental groups won a significant lawsuit against the U.S. EPA, pushing the agency to enforce the Total Maximum Daily Load (TMDL) provisions in the Federal CWA. For many water bodies, including the LSJR, the development and implementation of a TMDL is required by the CWA as a means to reverse water quality degradation. In the TMDL approach, state agencies must determine for each impaired water body: 1) the sources of the pollutants that could contribute to the impairment 2) the capacity of the water body to assimilate the pollutant without degradation and 3) how much pollutant from all possible sources, including future sources, can be allowed while attaining and maintaining compliance with water quality standards. From this information, agency scientists determine how much of a pollutant may be discharged by individual sources, and calculate how much of a load reduction is required by that source (Pollutant Load Reduction Goal or "PLRG"). Once the required load reductions are determined, then a Basin Management Action Plan ("BMAP") must be developed to implement those reductions. Monitoring programs must also be designed to evaluate the effectiveness of load reduction on water quality.

Since 1999, the U.S. EPA, Florida DEP, SJRWMD, and numerous public and private stakeholders have been working through this TMDL/BMAP process slowly to reduce pollution into the LSJR and its tributaries. As of July 2008, the verified 303(d) list of LSJR impairments requiring TMDLs consists of a total of 153 impairments in 89 water bodies (some water bodies have multiple parameters identified as impaired; (FDEP 2004). These impaired statuses are due primarily to unsatisfactory levels of dissolved oxygen, coliforms, nutrients, and metals. In response to these impaired water body designations, several TMDLs have already been adopted in the LSJRB, including those for nutrients in the main stem and fecal coliforms in the tributaries. Where TMDLs have been adopted, BMAPs are in currently in development. A main stem nutrient BMAP and the tributary coliform BMAP are due for completion in 2008. Additional TMDLs are scheduled for adoption within the next few years (FDEP 2008b).

Current and future efforts to improve the health of the LSJR (and other water bodies in Florida) will continue to focus on implementation of the TMDL provisions of the CWA. As this process presses forward, Florida's public and policymakers may continue to find themselves on the litigation-legislation seesaw, as both groups attempt to balance environmental concerns with an exploding population's desire to dwell and prosper in the Sunshine State.

Table 1.1 Timeline of environmental milestones, lower St. Johns river basin, Florida: From European colonization to 2008

DATE	EVENT
1765-1766	During the British occupation of Florida, John Bartram, the "Botanist to the King," and his son William Bartram toured the St. Johns River (Davis and Arsenault 2005).
1773-1777	Naturalist William Bartram chronicled his travels up the St. Johns River producing detailed descriptions of pre-statehood, Northeast Florida. "Bartram's observations remain an invaluable tool for environmental planning—restoring paradise—in northeastern Florida" (Davis and Arsenault 2005).
1821	Adams-Onis Treaty: United States legally acquired Florida (Blake 1980).
1835-1842	Second Seminole War: Many steamboats were first brought to the St. Johns River for combat with the Indians, but continued to operate out of Jacksonville for civilian purposes after the war (Buker 1992).
1845	Florida granted statehood.
1850	Swamp and Overflowed Lands Act: stated that Florida could have from the Federal government any swamp or submerged lands that they successfully drained (Leal and Meiners 2002).
1868	Florida's first water pollution law established a penalty for degrading springs and water supplies (SJRWMD 2007b).
1870-1884	Famed author of *Uncle Tom's Cabin*, Harriet Beecher Stowe, wintered in Mandarin and wrote essays extolling the beauties of the St. Johns River and attracting tourists to Florida (Blake 1980).
1870s	Increasing number of tourists visited Florida via steamboats up the St. Johns River.
1875	Jacksonville was the most important city in Florida (Blake 1980).
1884	Water hyacinth introduced into the St. Johns River near Palatka (McCann*, et al.* 1996b).
1896	Water hyacinth had spread throughout most the St. Johns River Lower Basin and was hindering steamboat navigation, causing changes in water quality and biotic communities by severely curtailing oxygen and light diffusion, and reducing water movement by 40-95% in Palatka (McCann*, et al.* 1996b).
1912	Intracoastal Waterway from Jacksonville to Miami was completed (SJRWMD 2007b)
1950s	Bacteria pollution was first documented in the St. Johns River (largely due to the direct discharge of untreated sewage into the river).
1966-1967	Sinkholes occurring in Central Florida (within the Upper Basin of the St. Johns River) indicating a serious drop in the water table (Purdum 2002).
Dec. 5, 1967	The City of Jacksonville received a letter from the Florida Air and Water Pollution Control Commission and State Board of Health, who "ordered the City within 90 days to furnish plans and an implementation schedule to end the disposal of 15 million gallons per day of raw sewage into the St. Johns River and its tributaries" (Crooks 2004).
1967-1968	Voters approved the consolidation of the Jacksonville and Duval County local governments.
1968	Initial flooding of the Rodman Reservoir. The Rodman Dam was completed and dammed the lower Ocklawaha River.
1970	National Environmental Policy Act: requires Federal agencies to consider the environmental impacts and reasonable alternatives of their proposed actions.
1970s	"Cleanup of the St. Johns River was impressive, but many of its tributaries remained heavily polluted; landfills were opened, but indiscriminate littering of wastes continued; polluting power plants and fertilizer factories closed, but other odors remained" (Crooks 2004). "Discharges occur to river of primary treated effluent or raw sewage. Periodic blue-green algal blooms and fish kills" (FDEP 2002).
1970-1971	Florida experiences its worst drought in history (Purdum 2002).
1972	Florida Water Resources Act: established regional water management districts and created a permit system for allocating water use.
1972	Federal Clean Water Act: required that all U.S. waters be swimmable and fishable.
1972	Land Conservation Act: authorized the sale of state bonds to purchase environmentally imperiled lands.
1972	Environmental Land and Water Management Act: initiated the "Development of Regional Impact" program and the "Area of Critical State Concern" program.
1972	Comprehensive Planning Act: called for the development of a state comprehensive plan.

DATE	EVENT
1972	Marine Mammal Protection Act: generally prohibits the killing or hurting of marine mammals in U.S. waters.
1973	Endangered Species Act: conservation of threatened and endangered plants and animals and their habitats.
Mar. 1973	"Press release announced that the St. Johns River south of the Naval Air Station to the Duval County Line at Julington Creek had been deemed safe for water contact sports" (Crooks 2004).
1973-1974	The U.S. Army Corps of Engineers and FDEP (then the Dept. of Natural Resources) implemented "maintenance control" of invasive aquatic plants (namely water hyacinth). Maintenance control replaced crisis management and kept water hyacinth populations at the lowest feasible level.
1977	The Federal government funded a shipping terminal on Blount Island (Crooks 2004). Completion of this Jacksonville Harbor Deepening Project (involved disposal of gravel and rock).
1977	Seventy seven sewage outfalls closed, and the St. Johns River became safe for recreational use again (Crooks 2004). Movement to regional wastewater treatment systems providing higher levels of treatment than before.
Jun. 18, 1977	St. Johns River Day Festival marked the completion of the St. Johns River cleanup, with reports of some types of aquatic life returning to the river (Crooks 2004).
Mid - late 1980s	"Outbreak of Ulcerative Disease Syndrome in fish occurs from Lake George to mouth of river. Exhaustive studies are conducted, but specific cause is not determined" (FDEP 2002).
1987	Surface Water Improvement and Management (SWIM) Act: Recognized the LSJRB as an area in need of special protection and restoration (SJRWMD 2007b).
1988	"The Florida Department of Environmental Regulation delegated authority to permit dredging and filling of wetlands to the St. Johns River Water Management District" (SJRWMD 2007b).
1988	"With funding from the SWIM program, the St. Johns River Water Management District began restoration of the Upper Ocklawaha River Basin and the Lower St. Johns River Basin" (SJRWMD 2007b).
1990s	"Blue-green algal blooms occur in freshwater portion of the river" (FDEP 2002).
1991	The Florida Times-Union began a monthly series of investigative reports entitled "A River in Decline. "This series reported: 17% of septic tanks were failing. In 1990, 47% of tributaries failed to meet appropriate health standards for fecal coliform. In 1990, 50% of privately owned sewage treatment plants violated local regulations. Eighty percent of pollutants in Jacksonville's waterways could be attributed to storm water runoff (Crooks 2004).
Early 1990s	The Florida Department of Environmental Regulation "downgraded formerly pristine areas of Julington and Durbin Creeks in southern Duval County from GOOD to FAIR water quality due to storm water, sewage, and other runoffs from the rapidly growing suburb of Mandarin." Half of the wetlands in this area were destroyed during this time period (Crooks 2004).
Late 1990s	Blooms of an exotic freshwater, toxin-producing, blue-green algae called *Cylindrospermopsis* occurred (FDEP 2002).
1997	The Lower St. Johns River Basin Strategic Planning Session (the "River Summit") led to the development of a 5-year "River Agenda" plan.
Sept. 17, 1998	FDEP submitted the 1998 303(d) List of Impaired Water bodies to the U.S. EPA for approval. The 1998 303(d) list included 53 water bodies in the LSJR.
1998	Several Florida environmental groups brought a lawsuit against the U.S. Environmental Protection Agency (EPA) for its failure to enforce the Total Maximum Daily Load (TMDL) provisions in the Federal Clean Water Act (Florida Wildlife Federation, Inc., *et al.* v. Browner, No. 4:98CV356 (N.D. Fla.)).
July 30, 1998	St. Johns River is designated as an American Heritage River (FDEP 2002).
Nov. 24, 1998	The U.S. EPA Region 4 approved the Florida 1998 303(d) List of Impaired Waters.
1999	Lawsuit against the U.S. EPA settled with a Consent Decree, which required the EPA and the Florida Department of Environmental Protection (FDEP) to begin implementation of the TMDL provisions of the CWA. The Consent Decree requires EPA to establish TMDLs if the State of Florida does not (13-year schedule to establish TMDLs).
1999	Florida Legislature enacted the Watershed Restoration Act (Florida Statutes, § 403.067) to provide for the establishment of Total Maximum Daily Loads (TMDLs) for pollutants of impaired waters as required by the CWA.
1999	FDEP formed a local stakeholders group to review the TMDL model inputs.

DATE	EVENT
April 26, 2001	Florida adopted a new science-based methodology to identify impaired waters as c. 62-303, F.A.C. (Identification of Impaired Surface Waters Rule).
June 10, 2002	Following an unsuccessful rule challenge by various individuals and environmental groups (Fla. DOAH case No. 01-1332R), the Impaired Surface Waters Rule (c. 62-303, F.A.C.) became effective.
July 2002	FDEP appointed the Lower St. Johns River TMDL Executive Committee to advise the Department on the development of TMDLs and a Basin Management Action Plan (BMAP) for the nutrient impairments in the Main Stem of the LSJR.
Dec. 3, 2002	Four Florida environmental groups filed suit in Federal Court against the U. S. EPA for failure of EPA to approve/disapprove Florida's Impaired Waters Rule as being consistent with the Clean Water Act (Florida Public Interest Research Group Citizen Lobby, Inc., *et al.,* v U.S. EPA *et al*.)
2002	FDEP appointed a Technical Advisory Committee (TAC) and officially began to identify impaired waters.
2002	The U.S. Army Corps of Engineers began the St. Johns River Harbor Deepening Project. The project initially "deepened about 14 miles of Jacksonville's main shipping channel from the mouth of the river to Drummond Point to a maintained depth of 40 feet" (JAXPORT 2008b).
2003	"River Summit 2003" takes place, and the River Agenda is revised. (FDEP 2003)
Sept.4, 2003	FDEP determined that most of the freshwater and estuarine segments of the LSJR were impaired by nutrients, and a verified list of impaired waters for the LSJR was adopted by Secretarial Order.
Sept. 30, 2003	The nutrient TMDL for the LSJR was originally adopted by Florida (Rule 62-304.415, F.A.C.).
April 27, 2004	Florida's nutrient TMDL was initially approved by the U.S. EPA Region 4.
Aug. 18, 2004	St. Johns Riverkeeper and Linda Young (Southeast Clean Water Network) filed suit against the U.S. EPA on the basis that the Class III marine daily average dissolved oxygen criterion would not be met at all times under the TMDL.
Oct. 21, 2004	U.S. EPA found that the nutrient TMDL for the LSJR did not implement the applicable water quality standards for dissolved oxygen and rescinded its previous approval of the nutrient TMDL for the LSJR.
May 24, 2005	The Executive Committee identified the water quality credit trading approach for the Basin Management Action Plan (BMAP).
June-July 2005	FDEP developed draft TMDL documents for Butcher Pen Creek Fecal Coliform TMDL, Durbin Creek Fecal Coliform TMDL, Cedar River Fecal and Total Coliform TMDL, Goodbys Creek Fecal Coliform TMDL, Hogan Creek Fecal Coliform TMDL, Miramar Creek Fecal Coliform TMDL, Moncrief Creek Fecal and Total Coliform TMDL, Ribault River Fecal Coliform TMDL, Williamson Creek Fecal Coliform and Total Coliform TMDL, and Wills Branch Fecal and Total Coliform TMDL.
July 2005	The Tributaries Assessment Team was formed to assess potential sources of fecal coliform in the tributaries.
Early fall 2005	Large clumps of surface scum, caused by the toxic blue-green algae *Microcystis aeruginosa*, bloomed from Lake George to Jacksonville. Some samples exceeded World Health Organization recommended guidelines (SJRWMD 2007b).
2005-2008	U.S. Army Corps of Engineers is extending the harbor deepening from Drummond Point to JAXPORT's Talleyrand Marine Terminal from 38 ft to a maintained depth of 40 ft.
2006	Blooms of algae continue in the St. Johns River."Algal blooms are caused by a combination of hot, overcast days, calm wind and excessive nutrients in the water, such as fertilizer runoff, storm water runoff and wastewater" (SJRWMD 2007b).
Jan. 23, 2006	U.S. EPA established a new nutrient TMDL for the LSJR that would meet the dissolved oxygen criteria.
May 25, 2006	Site Specific Alternative Criteria (SSAC) for dissolved oxygen in the LSJR (Florida Administrative Code 62-302.800(5)) was adopted by the Florida Environmental Regulation Commission and submitted to the U.S. EPA for approval. The SSAC was developed by FDEP in cooperation with the SJRWMD.
July 6, 2006	The monitoring plan discussions for the LSJR Main Stem BMAP began.
July 13, 2006	St. Johns River Riverkeeper and Clean Water Network filed a suit in federal court challenging the U.S. EPA's approval of Rule 62-302.800 (in effect, the Site Specific Alternative Criteria). (St. Johns River Riverkeeper, Inc., *et al.* v. United States Environmental Protection Agency, *et al.*, No. 4:2006-CV-00332 (N.D. Fla.))
July 28, 2006	The Tributaries Technical Working Group was formed to address fecal coliform impairments in 55 LSJR water bodies.
July 2006	The River Accord: A Partnership for the St. Johns is established.

DATE	EVENT
Sept. 2006	The project collection process for the LSJR Main Stem BMAP started, which provided the list of efforts that will implement the TMDL reductions and restore the river to water quality standards.
Oct. 10,2006	U.S. EPA approved Site Specific Alternative Criteria (SSAC) for dissolved oxygen in the marine portion of the St. Johns River.
2007	The U.S. Army Corps studied the impacts of blasting and dredging to deepen the navigation channel to a maintained 45 feet from the mouth of the river to Tallyrand terminals (USACE 2007a). Completion of the study is expected in 2010.
Feb. 1, 2007	The Executive Committee determined the LSJR Main Stem BMAP load allocation approach, which assigned reduction responsibilities to wastewater plants, industries, agriculture, cities and counties with urban storm water sources, and military bases with storm water sources.
April 2007	The St. Johns River Water Management District launched the LSJRB public awareness initiative, “The St. Johns: It’s Your River,” in order to help the public understand their personal impacts to the river and their responsibility for the river’s condition (SJRWMD 2007b).
August 3007	Urban storm water loads were identified and quantified by local jurisdictions for the LSJR Main Stem BMAP.
Oct. 2007	The first draft of the LSJR Main Stem BMAP was completed and presented to the Executive Committee and stakeholders group.
2008	U.S. EPA and FDEP are expected to develop TMDLs for a number of verified impaired segments of the LSJR Main Stem for several parameters (including nutrients, iron, lead, copper, nickel, cadmium, and silver).
Jan. 17, 2008	U.S. EPA approved/established the following TMDL for nutrients in the LSJR: “The dissolved oxygen shall not average less than 5.0 in a 24-hour period and shall never be less than 4.0. Normal daily fluctuations above these levels shall be maintained. The total nitrogen TMDL for the marine water segments is 1,376,855 kg/year. The total nitrogen TMDL for the freshwater segments is 8,571,563 kg/year.” The total phosphorus TMDL for the freshwater portion of the LSJR is 500,325 kg/year. These TMDLs represent a reassessment of EPA’s January 2006 TMDLs, based on the Site Specific Alternative Criterion (SSAC) for dissolved oxygen for the marine portion of the LSJR that was adopted by the State and approved by the U.S. EPA.
Feb. 2008	FDEP released the Lower St. Johns River Nutrient TMDL - Revised Draft.
April 2, 2008	FDEP revised the Surface Water Quality Standards (c. 62-302.530, F.A.C.) to match the U.S. EPA approved/established the following TMDL for nutrients in the LSJR (outlined above).
July 17, 2008	Earthjustice (representing the Florida Wildlife Federation, Conservancy of Southwest Florida, Environmental Confederation of Southwest Florida, St. Johns River Riverkeeper, and Sierra Club) filed a lawsuit against the U.S. EPA “for failing to comply with their nondiscretionary duty to promptly set numeric nutrient criteria for the state of Florida as directed by section 303(c)(4)(B) of the Clean Water Act” (Earthjustice 2008; (Florida Wildlife Federation, Inc., *et al.* v. Johnson *et al.*, 4:2008-CV-00324 (N.D. Fla.)).

2. WATER QUALITY

2.1. Overview

Water quality, more than any other measure of river health, is difficult (if not impossible) to reduce to a single factor, much less a single number. Each tributary, and even different sections of a tributary, or the main stem of the LSJRB are characteristically different and unique. To identify characteristically similar segments in each separate water body, under the CWA process, Florida DEP has assigned a water body identification number (WBID).

WBIDs are unique identifiers that offer an unambiguous method of referencing water bodies within the State of Florida. The CWA process mandates that each water body must be assessed for impairments for its stated uses, and if it is determined to be impaired for those uses, a TMDL standard must be established. The LSJR is a Florida Class III water body, with designated use(s) of recreation, propagation, and maintenance of a healthy, well-balanced population of fish and wildlife. For assessment purposes, FDEP has divided the LSJRB into assessment geographic polygons with a unique WBID for each watershed or stream reach. For example, the main stem of the LSJRB is divided into multiple segments. See Figure 3, page 5 in http://www.epa.gov/region4/water/tmdl/florida/documents/LSJR_Nutrient_Final_TMDL_0108.pdf.

In certain cases, the type and character of a water body may make it necessary to establish a special criterion for assessing the water quality of that water body. Florida's water quality standards also provide that a Site-Specific Alternative Criterion (SSAC) may be established where that alternative criterion is demonstrated, based on scientific methods, to protect existing and designated uses for a particular water body. As discussed in the background section and below, such a criterion has been established and EPA approved for Dissolved Oxygen (DO) in the predominantly marine portion of the LSJRB.

The Water Quality of each tributary is strongly impacted by both the land use surrounding the tributary and the nature and extent of human impact. Thus the tributaries of the LSJR vary in water quality impacts from agricultural to industrial, and urban to suburban to rural. Often different parts of the same tributary will have changes in water quality that reflect changes in land use, industry and population along it. Part of the TMDL analysis is the identification of sources and categories of nutrients or pollutants in the watershed and the amount of pollutant loading contributed by each of these sources. Sources are broadly classified as either "point sources" or "nonpoint sources". Historically, point sources mean discharges that typically have a continuous flow via a specific source such as a pipe. Domestic and industrial wastewater treatment facilities (WWTFs) are examples of point sources. In contrast, the term "nonpoint sources" has been used to describe other intermittent, often rainfall-driven, diffuse sources of pollution, including runoff from urban land uses, runoff from agriculture, runoff from tree farming (silviculture), runoff from roads and suburban yards, discharges from failing septic systems, and even atmospheric dust and rain deposition. Point sources are registered and permitted under the EPA's National Pollutant Discharge Elimination Program (NPDES), and the 1987 changes to the Clean Water Act included a redefinition which now includes storm water and drainage systems which were previously considered nonpoint sources under the permitted NPDES program. The Florida Legislature created the Surface Water Improvement and Management program (SWIM) as a way to manage and address nonpoint pollution sources, the program is outlined at http://www.dep.state.fl.us/water/watersheds/swim.htm.

The required TMDL process for impaired waters considers, and can require reductions to both these pollution source types in order to achieve water quality goals. For more about Florida's Watershed Management system see http://www.dep.state.fl.us/water/watersheds/index.htm.

A description of the BMAP which detail actions to be taken in a specific basin can be found at http://www.dep.state.fl.us/water/watersheds/bmap.htm.

The status of Northeast District BMAP plans can be found at http://www.dep.state.fl.us/water/watersheds/docs/bmap/BMAPStatusNED.pdf.

Due to resource constraints several of the more complex aspects of water quality have not been covered in this year's report, among these are characteristic variation among tributaries of the LSJR the impact of salinity on water quality parameters and the complex interaction of biology and water quality (specifically of algal blooms and water quality parameters). Additionally, the relationships noted here have been derived largely from existing reports in the scientific literature and data from the EPA's national database known as STORET. We acknowledge that there are distinct differences between the Florida and EPA versions of the STORET database, further complicated by disparate methods, spatial and temporal biases, and changing methodologies used to measure these water quality parameters, and thus, many of our conclusions and opinions (particularly about trends) are still debatable.

We have also not considered upstream sources in this years report. For these and other reasons, we recommend more continuous real-time data collection efforts be funded as a top priority over the next decade as the CWA mandated mitigation efforts begin to improve the water quality of the LSJR.

We have endeavored to provide the best, and yet still clear and straightforward public presentation that we can offer. We also applaud the efforts at all levels of state and local government, public environmental organizations, and the commitment of the public toward continually improving the water quality of the LSJR.

2.2. Dissolved Oxygen

2.2.1. Description and Significance: DO and BOD

Dissolved oxygen (DO) is defined as the concentration of oxygen that is soluble in water at a given altitude and temperature (Mortimer 1981). The concentration of oxygen dissolved in water is far less than that in air; therefore, subtle changes may drastically impact the amount of oxygen available to support many aquatic plants and animals. The dynamics of oxygen distribution, particularly in inland waters, are essential in understanding the distribution, growth, and behavior of aquatic organisms (Wetzel 2001). Many factors affect the DO in an aquatic system, several of them natural. Temperature, salinity, sediments and organic matter from erosion, runoff from agricultural and industrial sources, wastewater inputs, and excess nutrients from various sources may all potentially impact DO. In general, the more organic matter in a system, the less dissolved oxygen available. DO levels in a water body are dependent on physical, chemical, and biochemical characteristics (Clesceri 1989).

The St. Johns River is classified as a class III water body (used for recreation, propagation and maintenance of a healthy, well-balanced population of fish and wildlife**)** under the U.S. Environmental Protection Agency (USEPA) guidelines. The USEPA class III Freshwater Quality Criterion for dissolved oxygen is 5.0 mg/L (FDEP 2006a). This implies that normal daily and seasonal fluctuations must be maintained above 5.0 mg/L to protect aquatic wildlife. The predominantly freshwater part of the LSJR extends north from the city of Palatka to the mouth of Julington Creek. In marine waters, the DO average should not be less than 5.0 mg/L in a 24 hour period with a minimum DO concentration of 4.0 mg/L. The Florida Department of Environmental Protection (FDEP) has developed Site Specific Alternative criteria for the predominantly marine portion of the St. Johns River between Julington Creek and the mouth of the river which requires that DO concentrations not drop below a minimum of 4.0 mg/L however, DO concentrations between 4.0 and 5.0 mg/L are considered acceptable over short time periods extending up to 55 days (FDEP 2006b). For more details on the calculation of the Site Specific Alternative criteria, please visit the FDEP website (http://www.dep.state.fl.us).

Biological oxygen demand (BOD) is an index of the biodegradable organics in a water body (Clesceri 1989). Simply, it is the amount of oxygen used by bacteria to break down detritus and other organic material at a specified temperature and duration. Higher BOD is accompanied by lower dissolved oxygen. The EPA suggests that the BOD not exceed values, which would cause DO to decrease below the criterion, nor should BOD be great enough to cause nuisance conditions (FDEP 2006a). Bacterial growth requires nutrients such as nitrogen, phosphorus, and trace metals. Nutrients, in particular, may contribute to the overgrowth of phytoplankton, periphyton, and macrophytes, which then in turn die. Therefore, nutrient inputs into the river can increase the BOD, thereby decreasing the DO. Population responses to the increased nutrients in a system may be only temporary. However, if nutrient inputs are sustained for long periods, oxygen distribution will change, and the overall productivity of the water body can be altered (Wetzel 2001).

2.2.2. *Factors that Affect DO and BOD*

Warmer temperatures influence DO by decreasing its solubility (Mortimer 1981). Increasing temperatures also increase metabolism by causing an increase in respiration in aquatic organisms, which is a process that requires oxygen. Increased metabolism and production of bacteria and phytoplankton contribute to a higher BOD. Therefore, when the temperature increases, the BOD increases, and DO availability is reduced. Shallow areas and tributaries of the LSJR that are without shade have particularly elevated temperatures in the summer months. Correspondingly, DO concentration decreases during those times. The DO changes are compounded in waters with little movement, so turbulence is also a pertinent parameter in the system. Turbulence causes more water to come in contact with the air and thus more oxygen diffuses into the water from the atmosphere.

Salinity is another factor that affects DO concentrations in the LSJRB. Saline and brackish waters can decrease the DO in an aquatic system. Normal seawater has about 20% less oxygen than freshwater (Green and Carritt 1967; Weiss 1970). Factors influencing DO, such as increasing temperatures and BOD, will be compounded in saltwater as compared to freshwater.

2.2.3. *Data Sources*

All data used for the DO and BOD analyses were from the FDEP STORET database. STORET is a computerized environmental data system containing water quality, biological, and physical data. DO and BOD were measured using methods USEPA 360.1 and USEPA 405.1, respectively. Data points that had a 'V' qualifier were removed from the analyses and values below the detection limit were set to zero.

Data is presented in box and whisker plots, which consist of a five number summary including: a minimum value; value at the first quartile; the median value; the value at the third quartile; and the maximum value. The size of the box is a measure of the spread of the data with the minimum and maximum values indicated by the whiskers. The median value is the value of the data that splits the data in half and is indicated by the horizontal blue line in the center of the boxes.

2.2.4. *Limitations*

DO usually exhibits a diurnal (24-hour) pattern in eutrophic or highly productive aquatic systems. This pattern is the result of plant photosynthesis during the day which produces oxygen; such that the maximum DO concentration will be observed following peak productivity, often occurring just prior to sunset. Conversely, at night, plants respire and consume oxygen, resulting in an oxygen minimum, which often occurs just before sunrise (Laane, *et al.* 1985; Wetzel and Likens 2000). The LSJR is highly productive; however, it is a blackwater river, which influences the diurnal pattern typical to most rivers. The time of day in which water quality is measured can strongly influence the result. Additionally, some of the more historic data lacks pertinent corresponding water quality characteristics (i.e. tides), which may have impacted the measurements.

2.2.5. *Current Status and Trends*

The overall trend in the yearly DO values in the LSJRB from 1982 to 2007 appears fairly stable and generally stays within acceptable limits (Figure 2.1). Yearly data alone can be misleading. A clear seasonal trend is demonstrated in Figure 2.2A, with the lowest concentrations observed in the summer months. The seasonality of DO concentration was even more apparent over the years of 2000 through 2007 where a higher proportion of DO values in the summer months were below acceptable limits, as compared to winter months (Figure 2.2B).

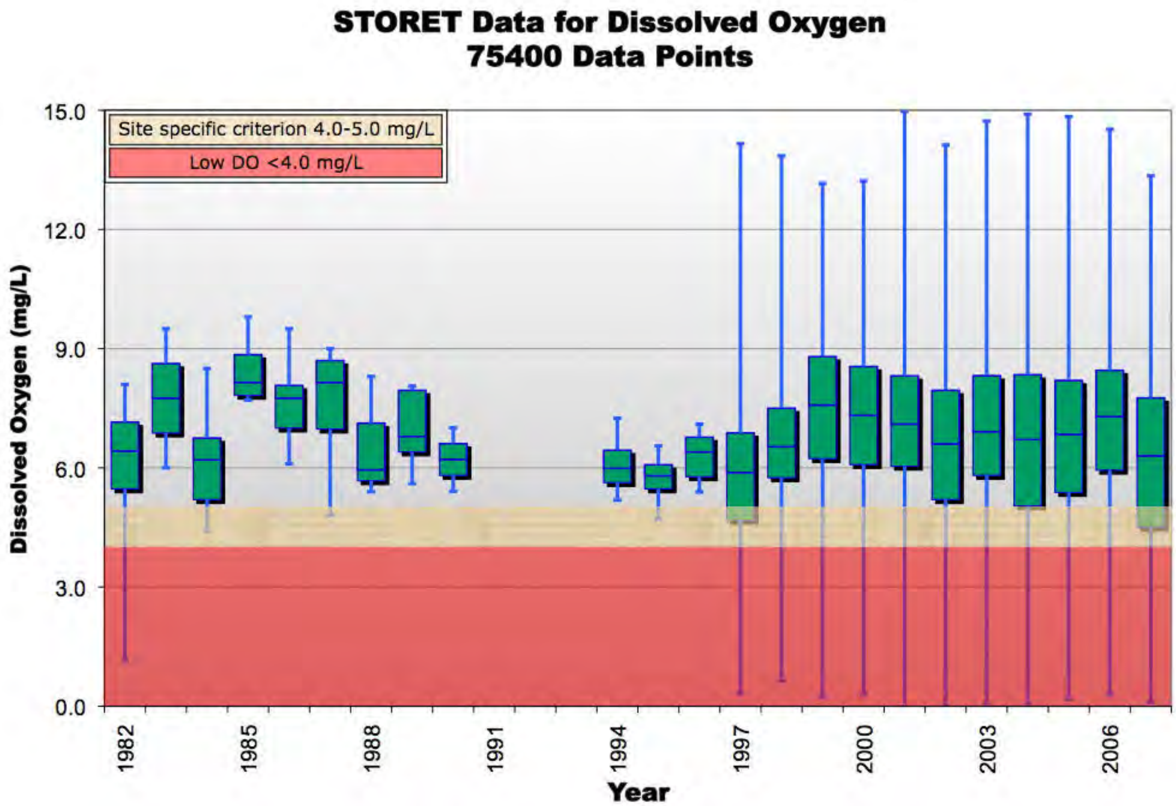
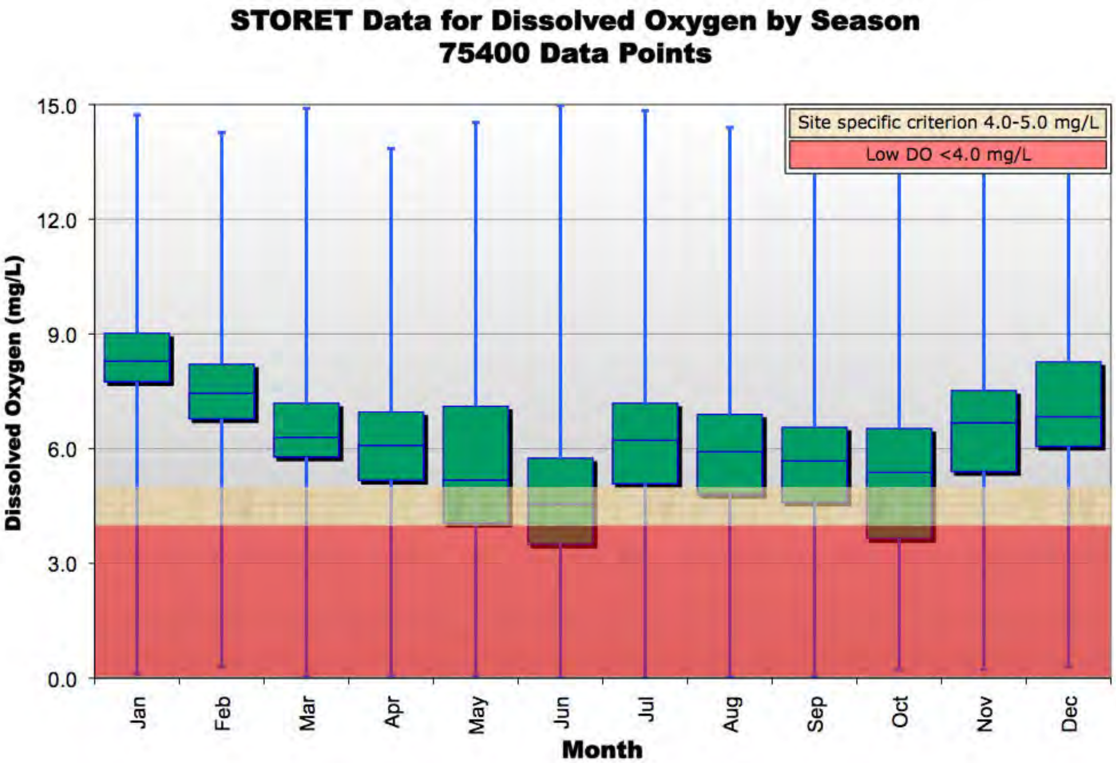


Figure 2.1 The yearly DO from 1982 to 2007 in the LSJRB. Data is presented as a box-and-whiskers plot with the green boxes indicating the median ±25% (middle 50% of the data) and the blue whiskers indicating the minimum and maximum values in the data set. The blue horizontal lines indicate the median values. The site-specific water quality standard range is given in the yellow box overlay. DO values under 4.0 mg/L (pink box overlay) are considered unacceptable.

A.



B.

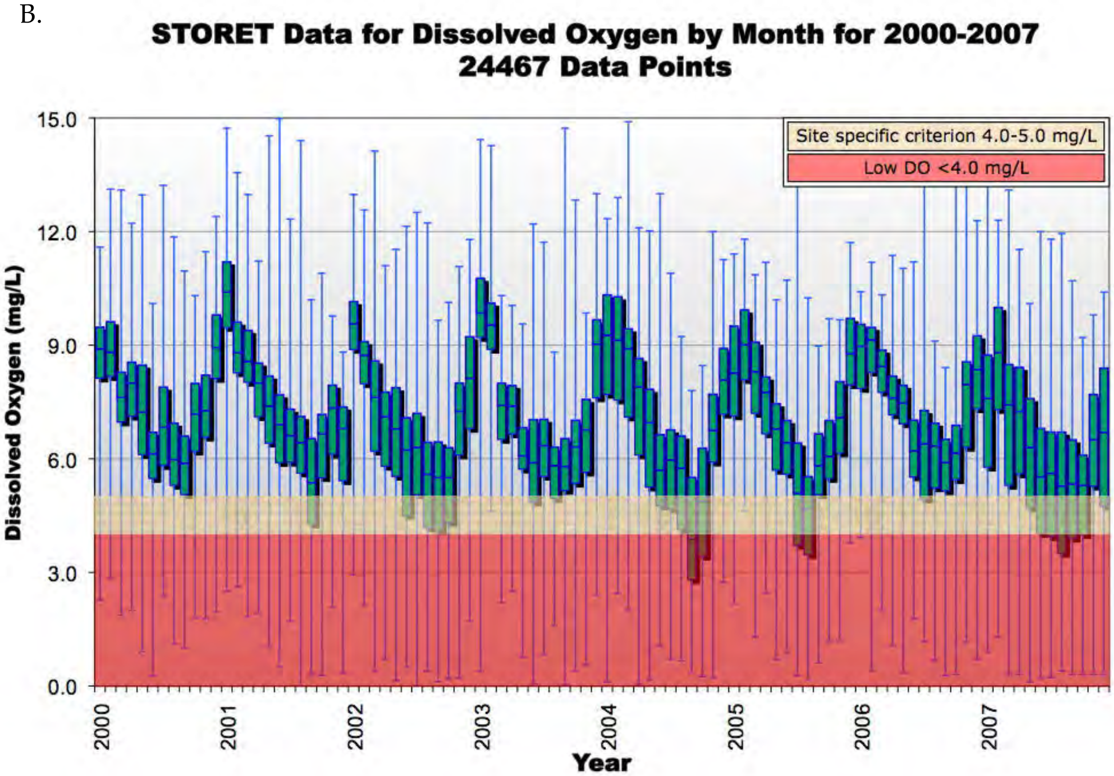


Figure 2.2 The monthly DO concentrations from A., 1967 to 2006 and B., from 2000 to 2007 in the LSJRB. Data is presented as a box-and-whiskers plot with the green boxes indicating the median ±25% (middle 50% of the data) and the blue whiskers indicating the minimum and maximum values in the data set. The blue horizontal lines indicate the median values. The site-specific water quality standard range is given in the yellow box overlay. DO values under 4.0 mg/L (pink box overlay) are considered unacceptable.

Correspondingly, as DO concentrations decreased in summer months, BOD levels slightly increased (Figure 2.3).

Seasonal DO fluctuation is not as problematic in the main stem of the LSJR (Figure 2.4A) as compared to the tributaries and creeks (Figure 2.4B and C). Measured DO values in the main stem of the LSJR were within acceptable limits. Alternatively, in the tributaries and creeks, several DO values were below the site specific minimum standard of 4.0 mg/L (Figure 2.4B and C). DO concentrations can also vary between tributaries, depending on the surrounding land use. Deep Creek is a tributary of the LSJR which drains the eastern banks around Hastings and Spuds, receiving substantial agricultural inputs, such as nutrients. Black Creek is a less impacted tributary as compared to Deep Creek and measured DO concentrations in these areas reflect the different conditions, with lower DO values observed in Deep Creek (Figure 2.4B and C). Nutrients, organic matter, temperature and community structure (i.e. number and types of plants and animal species), among other biotic factors, may contribute to the lower DO concentrations in these tributaries.

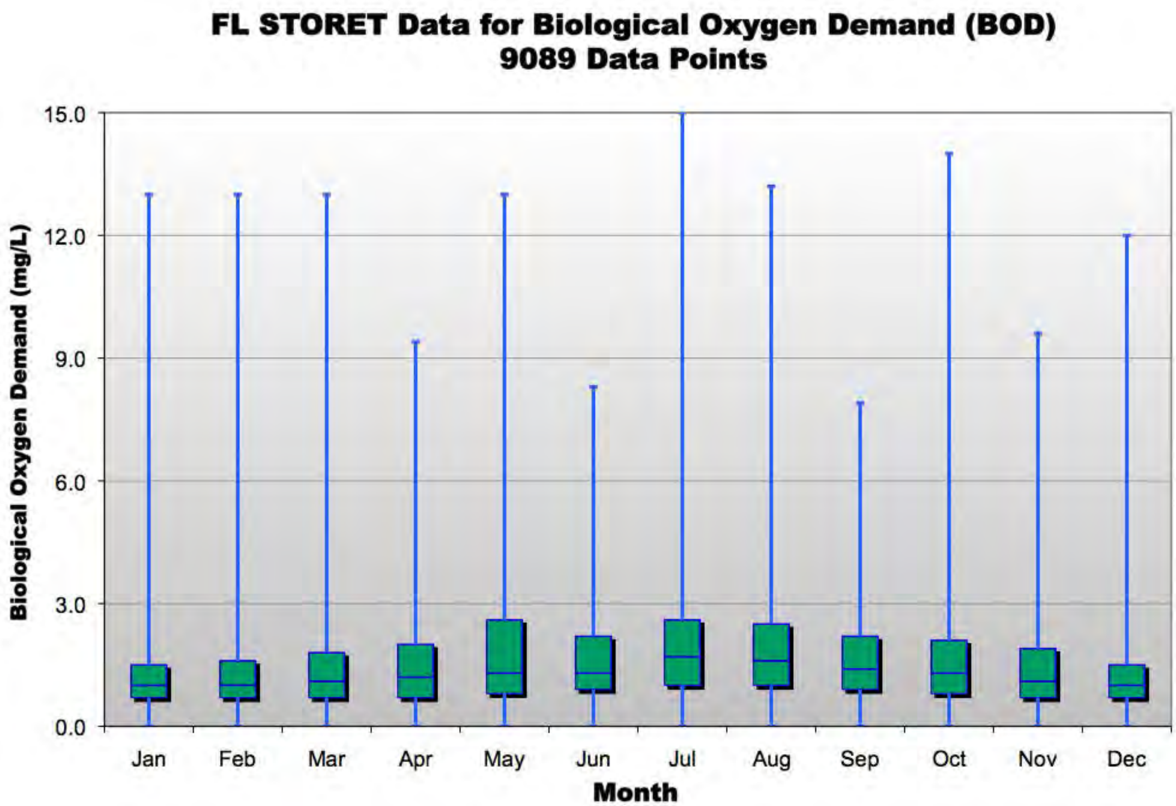


Figure 2.3 The monthly BOD (data from 1983 to 2007) in the LSJRB. Data is presented as a box-and-whiskers plot with the green boxes indicating the median ±25% (middle 50% of the data) and the blue whiskers indicating the minimum and maximum values in the data set. The blue horizontal lines indicate the median values.

A. B. C.

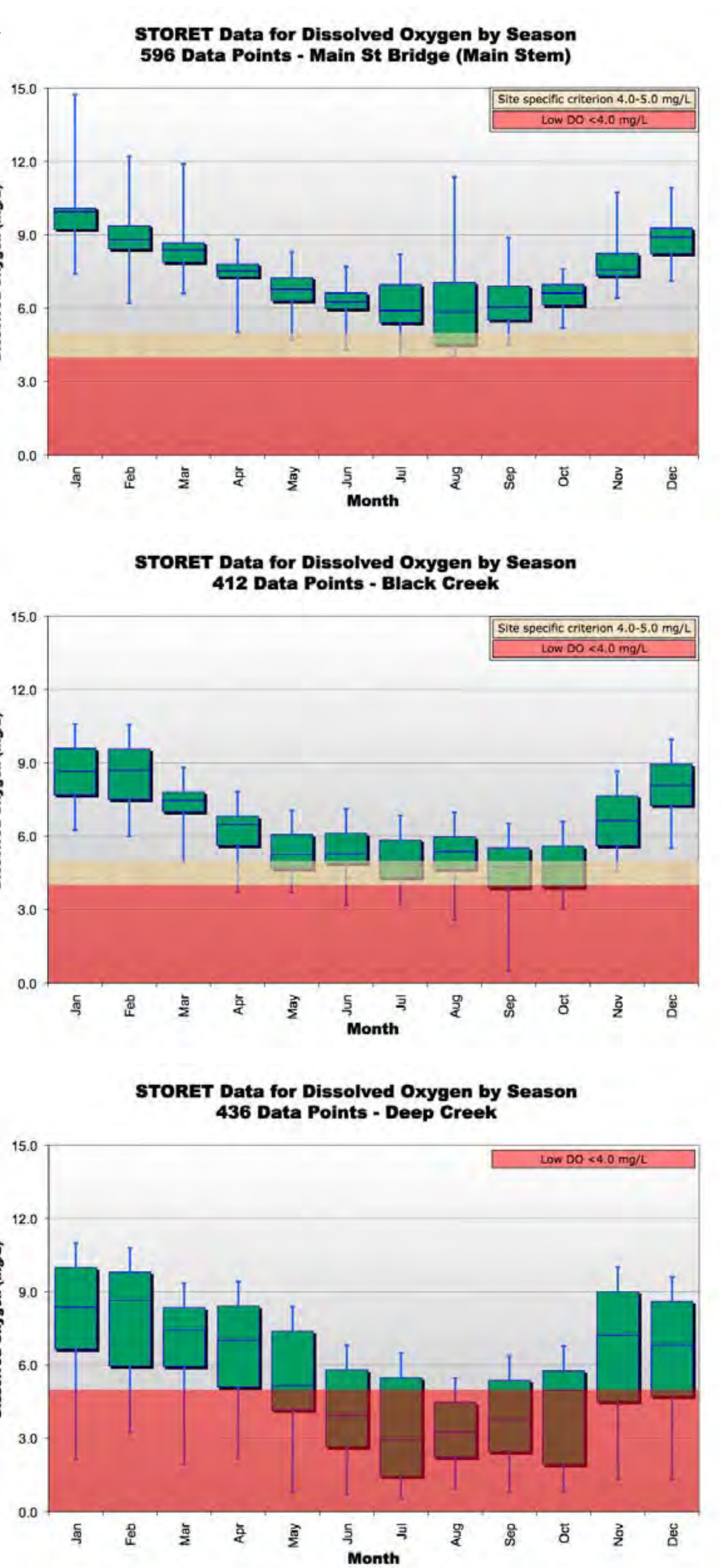


Figure 2.4 The monthly DO concentrations (data from 1967 to 2007) A. The main stem of the Lower St. Johns River near the Main Street Bridge; B. Black Creek; and, C. Deep Creek. Data is presented as a box-and-whiskers plot with the green boxes indicating the median ±25% (middle 50% of the data) and the blue whiskers indicating the minimum and maximum values in the data set. The blue horizontal lines indicate the median values. The site-specific water quality standard range is given in the yellow box overlay. DO values under 4.0 mg/L (pink box overlay) are considered unacceptable.

2.2.6. *Future Outlook*

Analysis of available data indicates that the average DO levels in the LSJRB are most problematic during summer months with many of the lowest DO measurements occurring in tributaries and creeks. Based on data from 1967 to 2007, the average DO concentration in the LSJR during the month of June was 4.5 mg/L, ranging from 0.0 to 14.9 mg/L, with several measurements below the site specific minimum standard of 4.0 mg/L. Unacceptable DO concentrations occurred intermittently during every month of the year. DO concentrations below 5.0 mg/L for prolonged periods may be too low to support the many aquatic animals that require oxygen (USEPA 2002a, 2002b). Maintenance above minimum DO levels is critical to the health of the St. Johns River and the organisms that depend on it. Nutrient reduction strategies (discussed in the next section) have recently been formulated by government agencies and may combat the low DO concentrations observed in the LSJR to some extent. Additionally, monitoring agencies are now making efforts to collect data which better represent the variable DO conditions and to concurrently document other important water quality characteristics for an improved assessment of the river's health.

2.3. Nutrients

2.3.1. *Description and Significance: Phosphorus*

Phosphorus and nitrogen are important and required nutrients for many aquatic organisms, such as phytoplankton (e.g., algae). If all other conditions (light, water quality, etc.) are sufficient, nutrients stimulate immediate algal growth and alternatively, if absent, can limit algal abundance. In excess, either phosphorus or nitrogen can cause the overgrowth of phytoplankton to nuisance levels. If the nutrient concentration in a system remains high for extended periods of time, eutrophic conditions may result, potentially changing the entire ecosystem by favoring the growth of some organisms and changing the optimal water quality conditions for other organisms. The term "eutrophic" generally signifies a nutrient-rich condition, resulting in a high concentration of phytoplankton (Naumann 1929) The more recent definition characterizes eutrophication as an increase in organic matter loading to a system (Nixon 1995). Eutrophication is a natural process, predominantly occurring in small enclosed water bodies like ponds and lakes. However, eutrophication is not a process commonly observed in river systems, like the St. Johns. The presence of eutrophication in these types of river systems is an identifying characteristic of significant anthropogenic (man-made) nutrient inputs.

Phosphorus predominately occurs in natural freshwater areas as organically bound phosphate, within aquatic biota, or adsorbed to particles and dead organic matter (Clesceri 1989; Wetzel 2001); whereas, the dominant inorganic species, orthophosphate, accounts for about 10% of the total phosphorus in the system (Clesceri 1989). Orthophosphate is released by the breakdown of rock and soils and is then quickly used by aquatic biota, particularly bacteria and algae, and incorporated as organic phosphate (Newbold 1992). Phosphorus can be released from biota by excretion and by the decaying of matter.

Humans add to the naturally occurring phosphorus in aquatic systems. In Florida, phosphorus is mined quite extensively, and is used in fertilizers, commercial cleaners and detergents, animal feeds, and in water treatment, among other purposes, many of which end up in local waterways (Clesceri 1989; Wright and Nebel 2008). In the past, phosphorus was also often used in laundry detergents. Orthophosphate generally averages 0.010 mg/L whereas total dissolved phosphorus averages about 0.025 mg/L in unpolluted rivers worldwide (Meybeck 1982). Orthophosphate concentrations in rivers can increase substantially following a rainwater event to as high as 0.050-0.100 mg/L from agricultural runoff and over 1.0 mg/L from municipal sewage sources (Meybeck 1982, 1993).

The USEPA established a Recommended Water Quality Criterion of 0.040 mg/L, for total phosphorus in the St. Johns River (USEPA 2000). Drainage basins and have been shown to largely impact the chemical characteristics of surface waters (Keup 1968; Lal 1998; Vollenweider 1968). The drainage basin for the river consists of agricultural lands, golf courses, and urban areas, all of which add to the phosphorus loading in the river. Those inputs, in addition to inputs from municipal wastewater treatment plants and other point sources may contribute to eutrophic conditions in the Lower St. Johns River.

Generally, sediments act as a reservoir for phosphorus; however, many factors, such as wind, turbulence, DO, water hardness and alkalinity, and benthic (bottom dwelling) organisms may potentially re-mobilize phosphorus into the water column (Boström, *et al.* 1988; Boström, *et al.* 1982; Wetzel 1999).

2.3.2. *Description and Significance: Nitrogen*

The atmosphere is the main reservoir for nitrogen, as it contains 78% nitrogen gas. This form of nitrogen is unreactive and unavailable to most organisms, with the exception of a few microbes. Other forms of nitrogen include nitrate, nitrite, ammonia and organic nitrogen, such as protein and urea, all of which can move freely between organisms and the environment (Wright and Nebel 2008). Nitrate is found in the effluent of biological wastewater treatment and nitrite is used as a corrosion inhibitor in industry and as such is found in industrial effluent (Clesceri 1989). Nitrite and nitrate are microbially converted from one to the other, depending on the availability of oxygen and pH. Ammonia is a waste product of aquatic organisms and naturally occurs in surface and wastewaters at concentrations ranging from 0.010 mg/L in some natural surface waters and groundwater, to 30 mg/L in some wastewaters (Clesceri 1989). Plants take up inorganic reactive nitrogen and incorporate it into essential organic compounds like proteins. It is then passed up the food chain, during which time nitrogen wastes can be given off, as ammonium compounds. The decay of organisms also liberates nitrogen (Hutchinson 1944; Wetzel 2001). The USEPA Recommended Water Quality Criterion for total nitrogen is 0.90 mg/L (USEPA 2000). The USEPA class III Water Quality Criterion for nitrogen, as ammonia is 0.02 mg/L (FDEP 2006a).

Human processes that produce nitrogen compounds primarily include industrial fixation in the manufacturer of fertilizers, in which nitrogen gas is converted to ammonia, and the combustion of fossil fuels, during which nitrogen from coal and oil is oxidized, thereby liberating nitrogen oxide into the atmosphere. In the first process, nitrogen can pollute waterways from agricultural and urban runoff of fertilizer. In the later process, nitrogen oxides in the atmosphere are converted to nitric or nitrous acids and brought down to waterways by precipitation. The form of nitrogen that enters a waterway can give an indication of its source. However, in aquatic systems, several abiotic (pH, complexation) and biotic (nitrification, dentrification, nitrogen fixation) processes can change the speciation or form of nitrogen. Sediments act as a major reservoir of nitrogen, just as they do for phosphorus (Levine and Schindler 1992).

Excessive total nitrogen in a system can have severe impacts on the community structure. Nitrogen can markedly alter the community distribution of phytoplankton. Cyanobacteria, for example, are capable of nitrogen fixation (converting inert N_2 to reactive nitrogen), which allows them to grow rapidly, thus out-competing other species when inorganic nitrogen levels are low (Smith 1983). Repetitive nitrogen and phosphorus overloading can be detrimental to aquatic systems.

2.3.3. *Data Sources*

All data were obtained from the FDEP STORET database except data used for Figures 2.5A, 2.5B, 2.6A, 2.6B, 2.11A, 2.11B, and 2.12, which were obtained from the USEPA STORET database. The USEPA database was only used if there was insufficient data in the FDEP STORET database for this analysis. STORET is a computerized environmental data system containing water quality, biological, and physical data. Phosphorus, as orthophosphate, and nitrogen, as kjeldahl, ammonia, and nitrate plus nitrite were measured from surface waters using U.S. Environmental Protection Agency methods USEPA 365.1, 351.2, 350.1, and 353.2, respectively. Data points that had a 'V' qualifier were removed from the analyses and values below the detection limit were used as zero. Since the nutrient criteria for the state of Florida has not yet been implemented, the USEPA Recommended Ecoregional Nutrient criteria for Ecoregion XII Rivers and Streams (USEPA 2000) were used for comparison with measured total phosphorus and nitrogen values in the LSJR to assess impairment as was the USEPA class III Water Quality Criterion for nitrogen, as ammonia (FDEP 2006a). Data is presented in box and whisker plots, which consist of a five number summary including: a minimum value, value at the first quartile, the median value, the value at the third quartile, and the maximum value. The size of the box is a measure of the spread of the data with the minimum and maximum values indicated by the whiskers. The median value is the value of the data that splits the data in half and is indicated by the horizontal blue line in the center of the boxes.

2.3.4. *Limitations*

Data used from the USEPA STORET database prior to 1998 are of undocumented quality and no analysis procedure was listed.

2.3.5. *Current Status and Trends: Phosphorus*

Total phosphorus concentrations in the LSJR were generally higher in the 1970s (Figure 2.5A, B), which largely occurred from the increasing use of phosphorus in fertilizers, manure, and laundry detergents. Even though Florida contains a higher background phosphorus concentration than many states due to its geological composition (rocks and soils), the anthropogenic inputs of phosphorus in the river have been much more substantial. The use of phosphorus in laundry detergents was banned in Florida, December 31st, 1972 and the use of phosphorus in fertilizers did not considerably increase after 1980. The decreasing use of phosphorus in detergent manufacturing also led to a decrease in the amount of phosphorus in wastewater effluent.

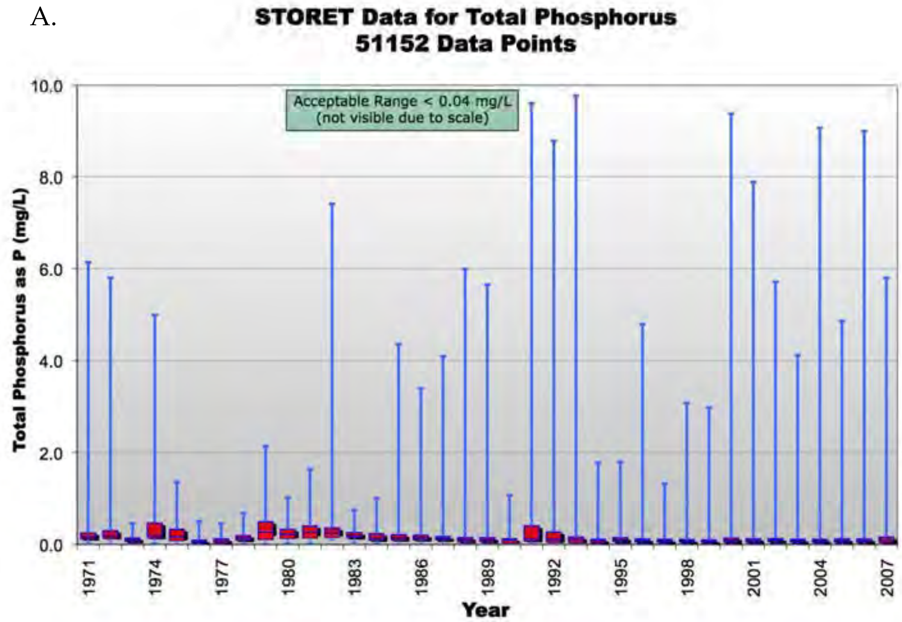
In further efforts to improve water quality and reduce eutrophication, the Federal Water Pollution Control Act of 1972 (CWA) was implemented. One of the main objectives of the CWA was to upgrade wastewater-treatment plants by implementing technology-based limits and including tertiary treatment, which would reduce phosphorus and nitrogen, among other things, from wastewater effluent. Several wastewater treatment plants were upgraded in the 1990s. Total phosphorus concentrations in the LSJR appear to have decreased in the 1980s and have remained fairly stabile since 1992 (Figure 2.5A, B), possibly reflecting the point source reduction efforts.

Even with the phosphorus reductions from point sources, phosphorus in the LSJR still exceeds the USEPA Recommended Ecoregional Nutrient standard of 0.04 mg/L (Figure 2.5A, B). Efforts over the last decade or so have been to reduce nonpoint sources of phosphorus, particularly from agricultural rainwater runoff and the use of fertilizers.

Deep Creek is a tributary of the LSJR with substantial nutrient input from agricultural lands (eastern banks around Hastings and Spuds). In general, lower phosphorus concentrations have been observed in the main stem of the LSJR (Figure 2.6A) as compared to several of the creeks and tributaries (Figure 2.6B); however, all areas sampled have phosphorus concentrations higher than the USEPA recommended water quality standard. Nutrients are most concentrated in tributaries of the LSJR that receive substantial point and non-point source inputs from more developed watersheds. The main stem is deeper with more vertical mixing, so the nutrient input is diluted, to some extent.

No seasonal fluctuation of phosphorus concentration in the LSJR was observed from the data analyzed (Figure 2.7). Fertilizers containing phosphorus are used on crops primarily during the winter; however, increased storm water runoff during the summer liberates phosphorus from the soils resulting in a continuous input into the LSJR.

A.



B.

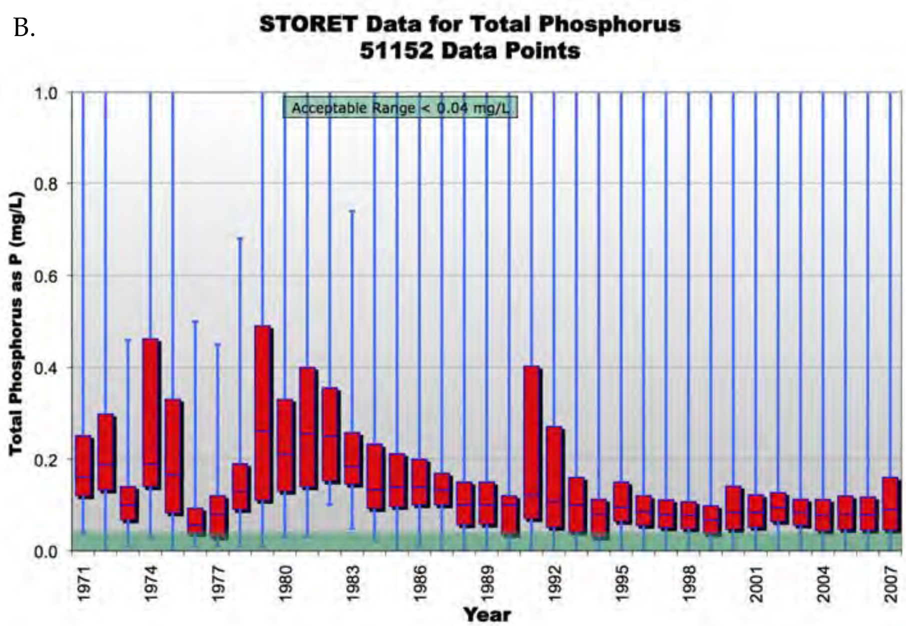
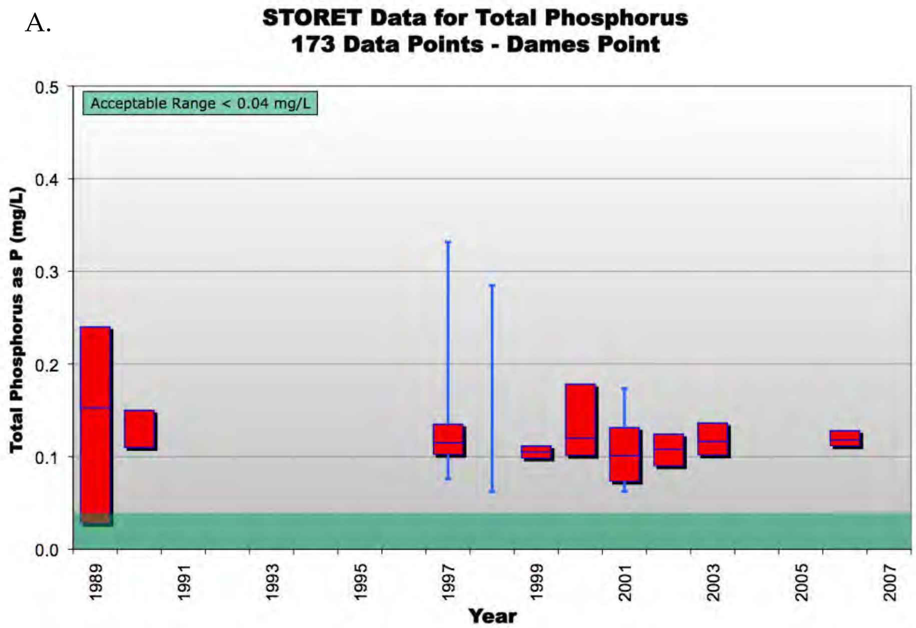


Figure 2.5 The yearly total phosphorus concentration from 1971 to 2007 in the Lower St. Johns River. In A., all data is presented as a box-and-whiskers plot with the red boxes indicating the median±25% (middle 50% of the data) and the blue whiskers indicating the minimum and maximum values in the data set and in B, the vertical scale has been expanded to more clearly show the acceptable range. The blue horizontal lines indicate the median values. The USEPA recommended water quality standard is given in the green box and overlay.

A.



B.

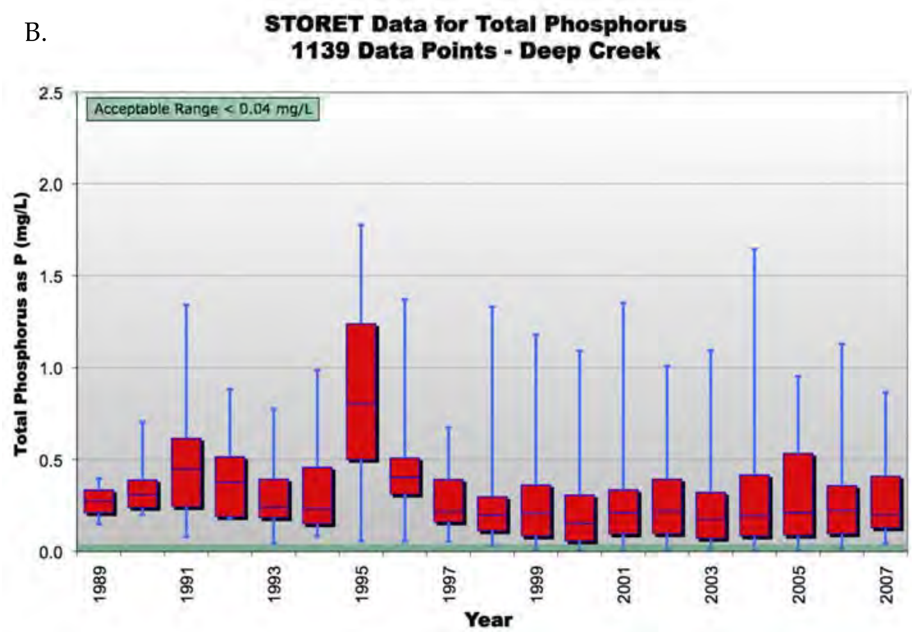


Figure 2.6 Yearly total phosphorus concentrations in A., the main stem of the Lower St. Johns River near Dames Point and B., in Deep Creek, a tributary of the Lower St. Johns River. All data is presented as a box-and-whiskers plot with the red boxes indicating the median ±25% (middle 50% of the data) and the blue whiskers indicating the minimum and maximum values in the data set. The blue horizontal lines indicate the median values. The USEPA recommended water quality standard is given in the green box and overlay. Note the change of scale between the two graphs.

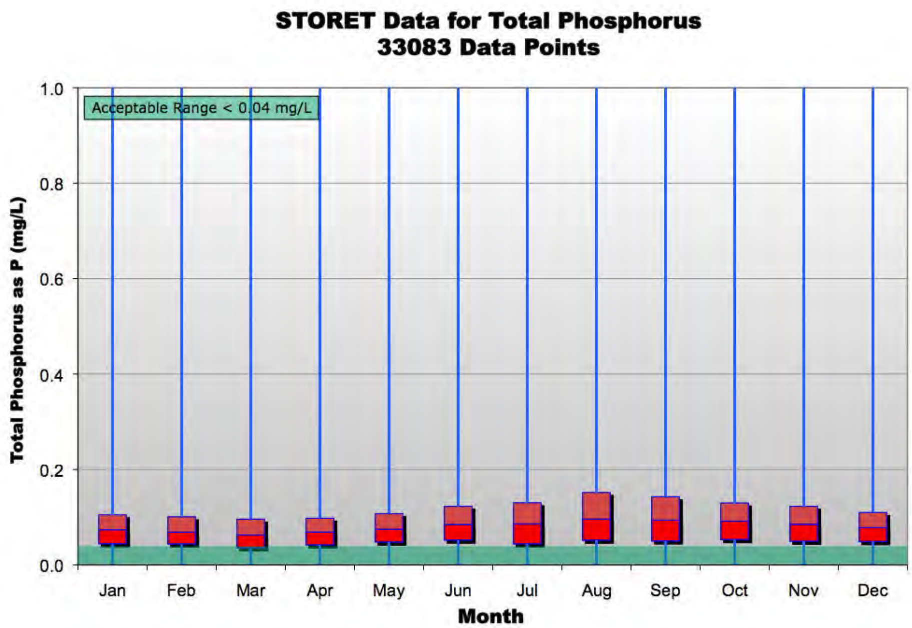


Figure 2.7 Monthly total phosphorus concentrations in the Lower St. Johns River. All data is presented as a box-and-whiskers plot with the red boxes indicating the median ±25% (middle 50% of the data) and the blue whiskers indicating the minimum and maximum values in the data set. The blue horizontal lines indicate the median values. The USEPA recommended water quality standard is given in the green box and overlay.

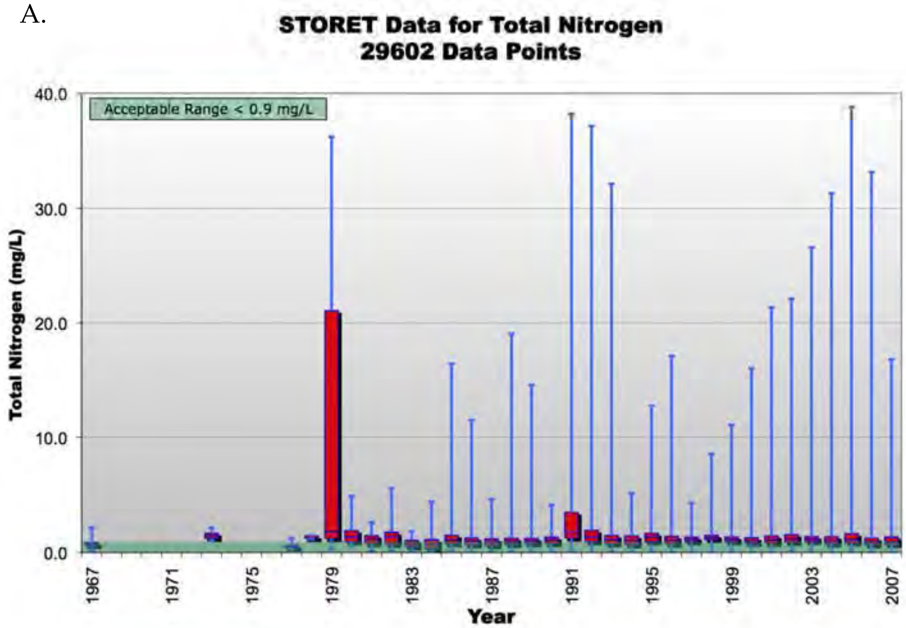
2.3.6. *Current Status and Trends: Nitrogen*

Overall, the total nitrogen concentration has been stable since 1981; however, most of the recorded measurements have exceeded the USEPA Recommended Ecoregional Nutrient criteria of 0.9 mg/L (Figure 2.8A, B). Relatively elevated levels of nitrogen have been measured in several creeks including: Julington Creek, Rice Creek, and Deep Creek, although levels have decreased slightly since 2004 in Julington Creek (Figure 2.9A-C). The shores of Julington Creek are occupied by private residences and commercial development. Moving southward, however, development decreases and wetlands increase. Rice Creek is predominantly surrounded by wetlands, forests, The Rice Creek Wildlife Management Area, and a pulp mill; whereas, the land use surrounding Deep Creek is mostly agricultural. Non-point source rainwater runoff is likely the major cause of the increased nitrogen concentrations in these areas. Nitrogen concentrations were most elevated in Deep Creek, which receives significant agricultural inputs (Figure 2.9C). Relatively elevated levels of nitrogen were also observed in the main stem of the LSJR near the Main St. Bridge, which receives a substantial upstream contribution as well as city storm drainage inputs and power plant effluent, making it difficult to identify a predominant source.

Nitrogen, as ammonia, has generally decreased from 1968 to 1982, and has been stable until the present time (Figure 2.11A, B). Like total nitrogen, ammonia concentrations exceed the USEPA class III Water Quality Criterion for nitrogen, as ammonia of 0.02 mg/L. Julington Creek is an area in which relatively high ammonia levels have been measured.

Nitrogen, as nitrate plus nitrite, has been fairly stable since 1983 (Figure 2.12). There does appear to be a seasonal trend in the levels of nitrate and nitrite, with the highest concentrations occurring in the winter (Figure 2.13). This may be a result of nitrate liberation from the flood plain in winter months. This pattern has been demonstrated in two Delaware salt marshes (Aurand and Daiber 1973). Additionally, in the winter less nitrate and nitrite is taken up as particulate organic matter (POM) (i.e., into algae) because the phytoplankton density is lower. Relatively high nitrate and nitrite concentrations have been detected in Deep Creek, particularly between the years of 2001 and 2007 (Figure 2.14). These high concentrations are again likely consistent with the agricultural land use surrounding Deep Creek.

A.



B.

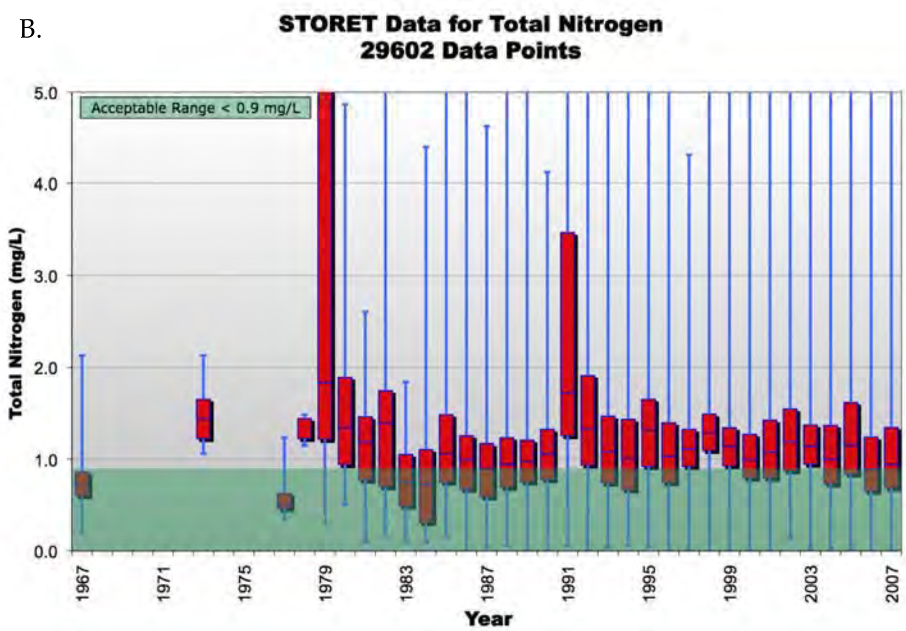


Figure 2.8 The yearly total nitrogen concentration from 1967to 2007 in the Lower St. Johns River. In A., all data is presented as a box-and-whiskers plot with the red boxes indicating the median ±25% (middle 50% of the data) and the blue whiskers indicating the minimum and maximum values in the data set and in B, the vertical scale has been expanded. The blue horizontal lines indicate the median values. The USEPA Recommended Ecoregional Nutrient standard is given in the green box and overlay.

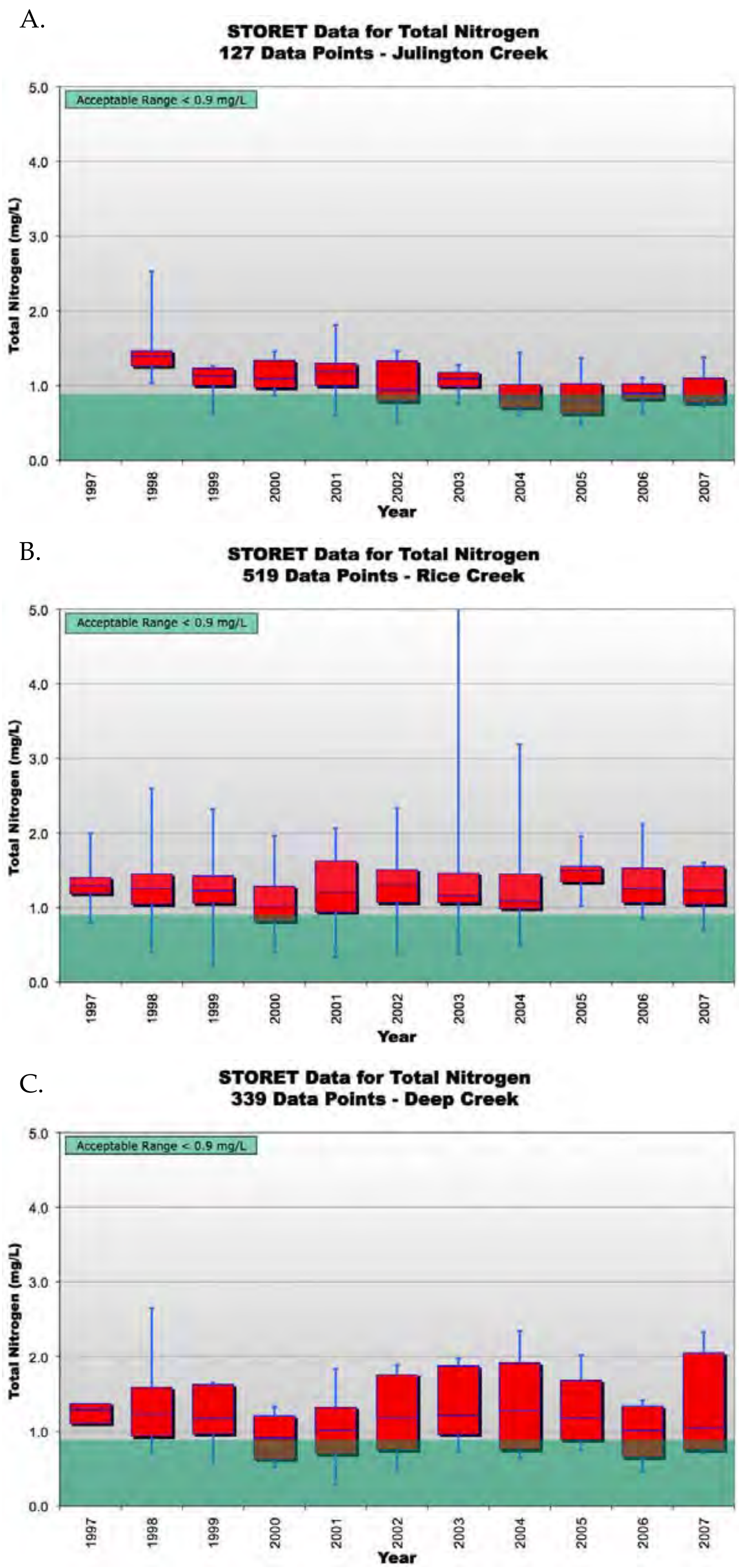


Figure 2.9 The yearly total nitrogen concentration in A. Julington Creek; B. Rice Creek; and, C. Deep Creek, all tributaries of the Lower St. Johns River. All data is presented as a box-and-whiskers plot with the red boxes indicating the median ±25% (middle 50% of the data) and the blue whiskers indicating the minimum and maximum values in the data set. The blue horizontal lines indicate the median values. The USEPA Recommended Ecoregional Nutrient standard is given in the green box and overlay

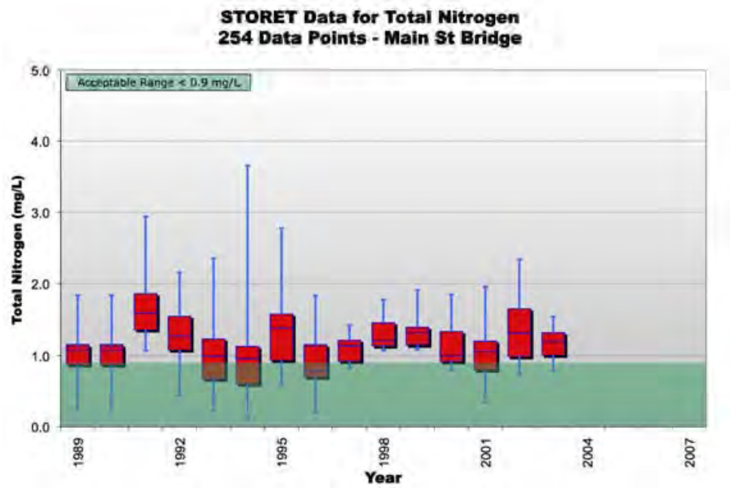
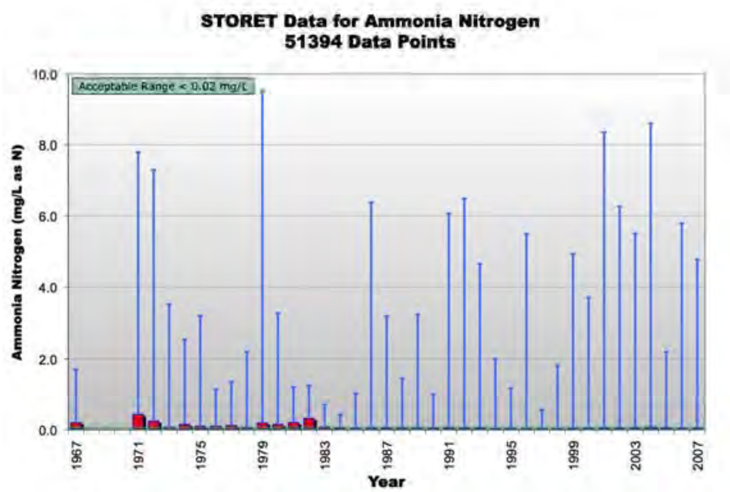


Figure 2.10 The yearly total nitrogen concentration in the main stem of the Lower St. Johns River near the Main Street Bridge. All data is presented as a box-and-whiskers plot with the red boxes indicating the median ±25% (middle 50% of the data) and the blue whiskers indicating the minimum and maximum values in the data set. The blue horizontal lines indicate the median values. The USEPA Recommended Ecoregional Nutrient standard is given in the green box and overlay.

A.



B.

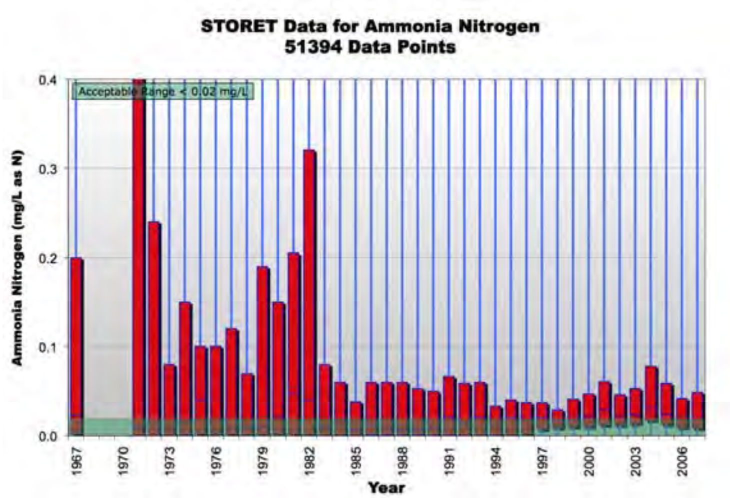


Figure 2.11 The yearly nitrogen concentration, as ammonia, from 1967 to 2007 in the Lower St. Johns River. In A., all data is presented as a box-and-whiskers plot with the red boxes indicating the median ±25% (middle 50% of the data) and the blue whiskers indicating the minimum and maximum values in the data set and in B, the vertical scale has been expanded. The blue horizontal lines indicate the median values. The USEPA class III Water Quality Criterion for nitrogen, as ammonia is given in the green box and overlay.

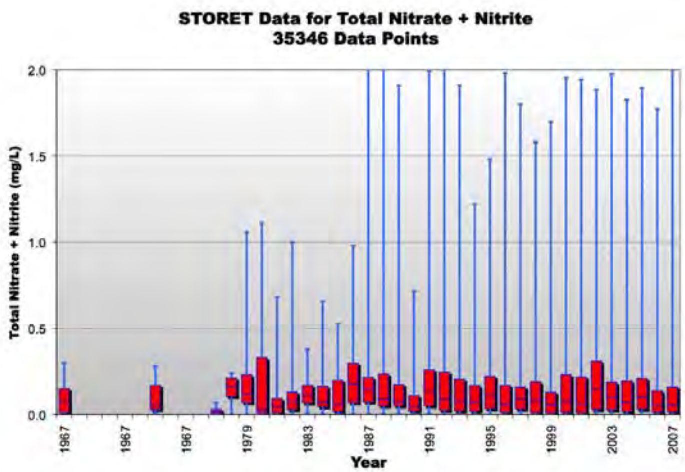


Figure 2.12 The yearly nitrogen concentration, as nitrate + nitrite, from 1966 to 2007 in the Lower St. Johns River. All data is presented as a box-and-whiskers plot with the red boxes indicating the median ±25% (middle 50% of the data) and the blue whiskers indicating the minimum and maximum values in the data set. The blue horizontal lines indicate the median values.

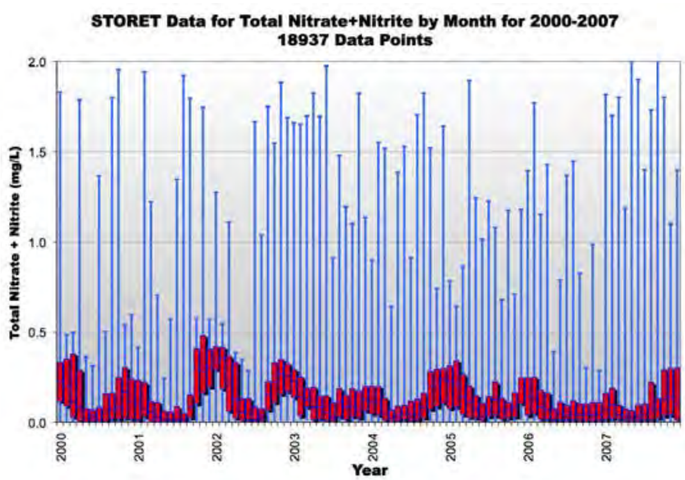


Figure 2.13 Monthly nitrogen concentration, as nitrate + nitrite, from 2000 to 2007 in the Lower St. Johns River. All data is presented as a box-and-whiskers plot with the red boxes indicating the median ±25% (middle 50% of the data) and the blue whiskers indicating the minimum and maximum values in the data set. The blue horizontal lines indicate the median values.

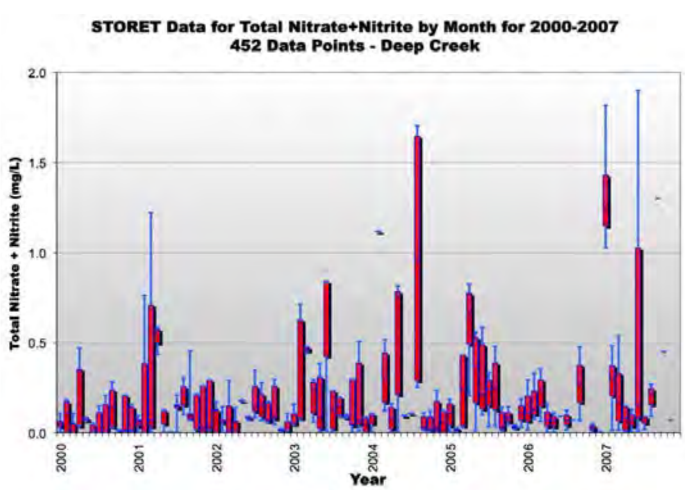


Figure 2.14 Monthly nitrogen concentration, as nitrate + nitrite, from 2000 to 2007 in Deep Creek, a tributary of the Lower St. Johns River. All data is presented as a box-and-whiskers plot with the red boxes indicating the median ±25% (middle 50% of the data) and the blue whiskers indicating the minimum and maximum values in the data set. The blue horizontal lines indicate the median values.

2.3.7. *Future Outlook*

Phosphorus and nitrogen inputs from multiple sources should be reduced. Even though levels are fairly stable, they far exceed the USEPA recommended standards, particularly in the smaller tributaries and creeks. Phosphorus concentrations generally follow a seasonal pattern similar to DO, and are therefore higher and more problematic in the summer months. Total nitrogen concentrations typically do not follow a seasonal trend; however, nitrate plus nitrite concentrations are higher in the winter months. In creeks and tributaries as well as in the main stem of the LSJR, total nitrogen and ammonia are generally higher than the Recommended Ecoregion XII Nutrient standard and Surface Water Quality Class III standard, respectively. Monitoring specific chemical species of nitrogen may give some indication of the source. Increases in phosphorus and nitrogen concentrations to eutrophic conditions are highly linked to changes in the relative abundance of phytoplankton, favoring growth of potentially harmful species (Kilham 1990; Kilham and Hecky 1988; Smith 1983; Tilman 1982). Decreasing phosphorus loading has been shown to decrease productivity (Vollenweider 1968) and may reduce the occurrence of harmful algal and cyanobacteria blooms. Further, decreasing nutrient levels would contribute to better water quality in the LSJR, as DO, biological oxygen demand, and the availability of other contaminants to aquatic organisms, have been associated with nutrient levels. Best Management Practices, reducing fertilizer use and further improving wastewater treatment systems would help to reduce nutrient inputs into the river.

A TMDL document was drafted this year by the FDEP in efforts to reduce nutrient inputs into the LSJR. A TMDL is a scientific determination of the maximum amount of a given pollutant that a surface water can absorb and still meet the water quality standards that protect human health and aquatic life (USEPA 2008). The Nutrient TMDL indicates the necessary nutrient reduction to meet water quality standards in the LSJR and the restoration strategies required to achieve it. Government agencies are working with industries and agriculture to reduce nutrient inputs and meet projected future goals. Local utilities and government agencies have voluntarily made efforts to reduce nutrients since 2000 and a large public outreach campaign is under way to reduce fertilizer use by homeowners. In addition to reducing sources of nutrients, nutrient-rich waters coming from standard secondary water treatment plants may be recycled. These recycled waters can and have recently been used as a means to irrigate favorable plants, however, the effluent must not be contaminated with toxic materials. This practice has been recently utilized in Clay County, within the LSJRB as well as other areas of the U.S., such as Bakersfield, California; Clayton County, Georgia; and St. Petersburg, Florida, mostly for irrigation of urban open spaces like parks, residential lawns and golf courses. A similar practice has been used in agriculture. These methods among others have been included in the FDEP Nutrient TMDL and have wide spread implications in reducing inputs of nutrients into the St. Johns River.

2.4. Turbidity

2.4.1. *Description and Significance:*

In its natural state, the St. Johns River, like other blackwater rivers, swamps and sloughs, has a high concentration of colored dissolved organic material (CDOM) that stains the water a dark brown color. The natural decay of plant materials (particularly oak leaves which produce tannins) stain the water to appear somewhat like tea in color. This water color can indicate a very healthy condition, or it may not. The St. Johns River, in particular, has a varied mix of dark-stained water from rainwater flow through the slow moving backwaters, and nearly clear contributions from large springs such as Blue Spring, De Leon Springs, Silver Springs (through the Ocklawaha River) and others. Heavy rains flush tannin-stained waters out of the slow-moving sloughs, swamps and backwaters and into the tributaries and main stem of the LSJR.

Turbidity is described on the Florida DEP website as:

> *Turbidity is a measure of the suspended particles in water. Several types of material cause water turbidity, these include: silt or soil particles, tiny floating organisms, and fragments of dead plants. Human activities can be the cause of turbidity as well. Runoff from farm fields, storm water from construction sites and urban areas, shoreline erosion and heavy boat traffic all contribute to high levels of turbidity in natural waters. These high levels can greatly diminish the health and productivity of estuarine ecosystems. (FDEP 2008a)*

Turbidity is a measure of the light scattered by particulate materials within the water column which reflect and scatter light. Both high levels of suspended solids and particles of algal origin are optically active as scatterers and to a lesser extent, high levels of CDOM contain micron-sized scattering particles. All are present in the dominantly freshwater portion of the LSJR. (Gallegos 2005). In the LSJR system, turbidity is dominated by both phytoplankton (mostly single-cell plants) and suspended solids from human impact (most often sediment or industrial waste) called Non-Algal Particulates (NAP). NAP comes from such activities as sediment erosion from construction, land clearing and timber harvesting sites; storm water runoff in urban and industrial areas, dredging, and solids from industrial outfalls (Gallegos 2005). During heavy rains, these sources may input a large volume of NAP into tributaries of the river that can both cover aquatic life and effectively block sunlight from reaching the Submerged Aquatic Vegetation (SAV). Turbidity gives a good measure of the amount of sunlight that cannot penetrate the waters to support aquatic photosynthesis. Small plants and plantlike bacteria have evolved to float or suspend themselves in the upper levels of the water column to remain in the sunlight. At high concentration their combined scattering may only pass insufficient light to large plants attached to the bottom, like the river grasses that feed and serve as nursery habitat for juvenile fish and shrimp. SAV can suffer from a lack of light due to high turbidity and from sediment cover, or by small plants coating their leaf surfaces, or masking by floating algae. This has a large impact on the other species, which depend on the grasses for food and shelter.

Florida has an extensive storm water permitting program to limit storm water impact. For further information see http://www.dep.state.fl.us/water/stormwater/npdes/index.htm.

During periods of drought a paradoxical condition can occur in which rainfall flow from the backwaters decreases dramatically but the flow from springs diminishes less. When this happens, the water may become significantly clearer and optical absorption by CDOM diminishes to below normal levels. During drought conditions, with decreased CDOM and higher light penetration, phytoplankton are able to take advantage of the high nutrient concentrations and more readily form algal blooms. In rainy periods after a drought, the St. Johns River may actually become darker stained from CDOM than usual, as rainfall moves the stalled and tannin-stained waters into the main stem of the LSJR again. In these conditions, CDOM absorption is the most influential optical property in a blackwater system such as the LSJR (Phlips, *et al.* 2000). In other events, and at specific locations and times, phytoplankton or NAP will dominate light extinction in the water column and can be assessed by comparing turbidity levels with Chlorophyll-a levels, which indicate algal content.

A background turbidity level in the LSJR varies from single digit values to 12-15 Nephelometric Turbidity Units (NTUs) along the main stem. (Armingeon 2008), and anything over 29 NTUs above background is considered to exceed Florida state standards. Turbidity levels in tributaries can be higher in either drought when near constant industrial and WWTF output may be dominant, or more commonly after episodic rain events, when sediment from construction, land clearing and timber harvesting sites, coupled with storm water runoff, can overwhelm the other components. The latter should happen much less often with strong enforcement of good engineering practices at work sites and continuing improvements to storm water practices. Episodic monitoring of work sites specifically after heavy rain events could provide needed help with enforcement. Public vigilance in reporting turbidity events in tributaries will help lessen the total impact of spills and runoff sediment. It is not difficult to spot sediment laden water due to its appearance, often having a resemblance to “coffee with cream” (Figure 2.15 is an extreme example).

In the more haline portions of the LSJR scattering of light is dominantly from materials which are of larger size such as sediment (Gallegos 2005).

Figure 2.15 Turbid water from McCoys Creek entering the LSJR on 17 July 2008. Courtesy of Christopher Ball.

The following four graphs (Figure 2.16A - D) show the steady progress that has been made since the 1970s in reducing turbidity in the LSJR. Over this period there have been changes in measurement techniques, spatial sampling changes and many other factors that make it difficult or impossible to determine the validity of this trend. Additional effort to provide a more verifiable and valid trend will be included in the next report. The box indicates the median +/- 25% of the data points (middle 50%). The total number of points for the decade is in the second line of the title. Note that there is improvement each decade. While the state criterion for turbitdity is 29 NTU above background, we have used 29 NTU as the threshold in the graphs, due to variation in background levels in the LSJR.

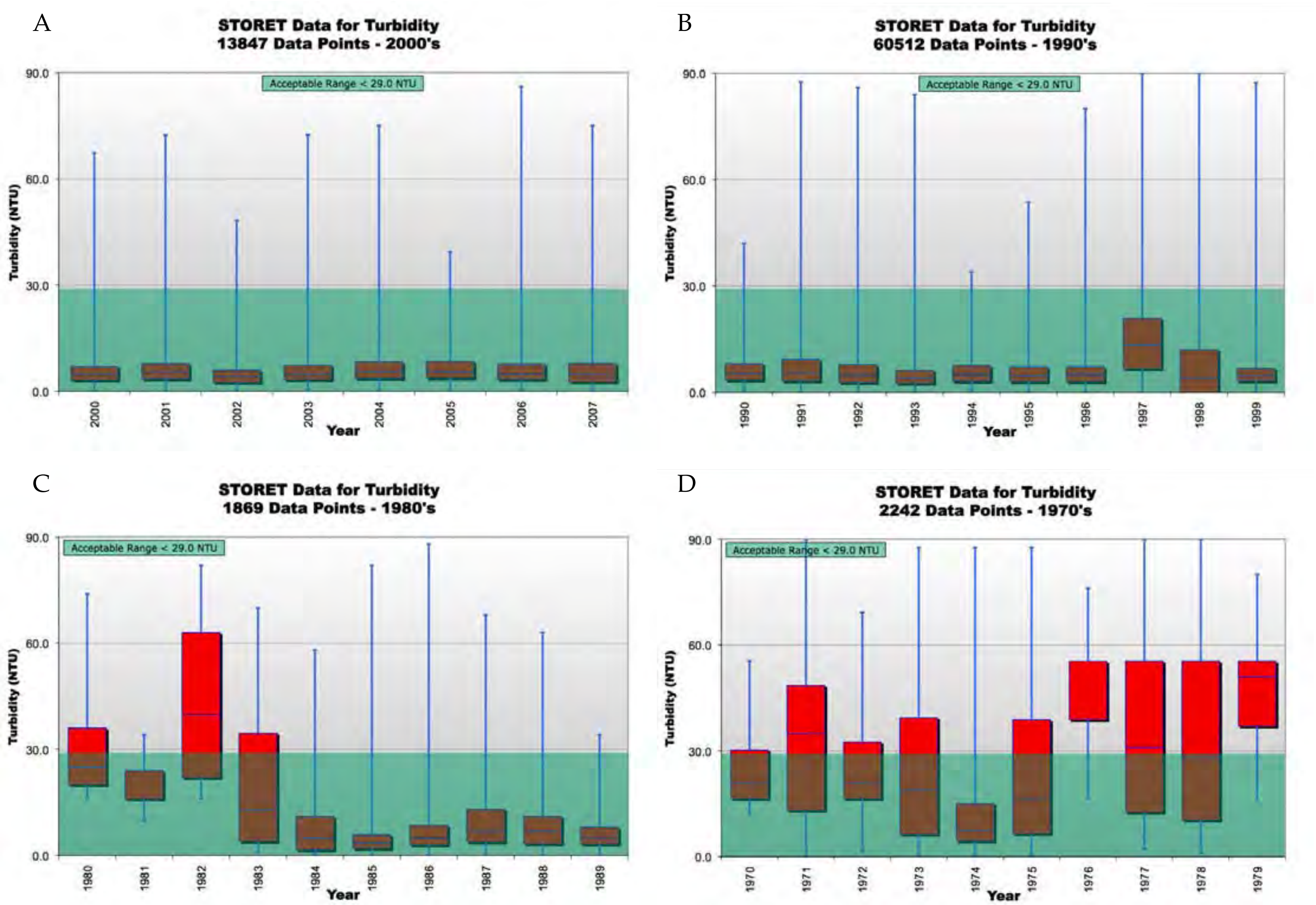


Figure 2.16 Yearly turbidity in the Lower St. Johns River Basin; A. Since 2000; B. From 1990-1999; C. From 1980-1989; and, D. From 1970-1979. Data is presented as a box-and-whiskers decadal plot with the red/brown boxes indicating the median value ±25% (middle 50%of data) and the blue whiskers indicating the minimum and maximum values in the data set. The water quality criterion is 29 NTU above background (see text), but we use 29 NTU in the green box overlay for uniformity.

2.4.2. *Data Sources*

The primary source for this evaluation is the STORET database and the EPA-mandated reports required by the CWA such as the Florida 303(d) report of impaired waters. These reports become the basis for future water quality management and restoration efforts. These are publicly available online at http://www.dep.state.fl.us/water/tmdl/adopted_gp2.htm and http://www.dep.state.fl.us/water/tmdl/docs/303d_lists/group2/adopted/LSJRverified5-13-04.pdf.

2.4.3. *Limitations*

In 1998, under the EPA standards, 16 water bodies in the Lower St. Johns River basin were listed as impaired for turbidity. Many (but not all) of these were urban streams between the city of Jacksonville and Mayport, areas where urban runoff may have been a problem. Many have since been "delisted" in the CWA process. This may truly indicate substantial improvements, but it may also have been partly a function of the sampling timing during pre-hurricane drought conditions in 2004 which greatly reduced runoff and associated turbidity. For example: the earlier 303(d) report listed Cedar River and Goodbys Creek, as well as the main stem of the river above the Dames Point area, at high risk of turbidity impairment. Later sampling in 2004 did not. Additionally, we have chosen to use virtually all the STORET data in spite of changes in methodology, uneven spatial and temporal sampling, and other issues that limit both the validity and generalization of the trend.

2.4.4. *Current Conditions*

Based on the STORET data available from the current CWA sampling, turbidity conditions are improving for the main stem of the LSJR. In the tributaries however, too many reported violations of sediment control practices from work sites resulting in high turbidity events still exist.

2.4.5. *Trend and Future Outlook*

Heightened awareness of the public and improved engineering sediment control practices are bringing improvements in this area. A few recent finable events and the press they received will help keep the pressure on proper engineering practices. Vigilance in design of retention and detention ponds, sediment fences and public monitoring all can help. Reporting of turbidity events and sediment discharges near land-clearing and construction projects, particularly future Developments of Regional Impact (DRI) should help ensure the best outcomes for the LSJR. Tributaries are particularly prone to turbidity events after a heavy rainfall.

2.4.6. *Recommendation*

Model prediction of substantial rainfall is now sufficient so that one to two day forecasts are reliable. Scheduling of event-based monitoring of sediment control practices based on forecast rain events is feasible. Rainfall event-based monitoring of turbidity in tributaries near major construction or development should be established in the LSJRB basin as a standard. Strong enforcement of existing engineering standards for sediment control as well as increased training is recommended, particularly in areas where DRIs exist.

2.5. Algal Blooms

2.5.1. *Description and Significance*

Pristine blackwater river systems usually have low levels of planktonic primary producers (as measured by chlorophyll a concentration) since the available nutrient and light levels in black water systems are low. Rapid growth of cyanobacteria (AKA blue-green algae), which are chlorophyll producing bacteria, have occurred in disturbed blackwater streams in the Carolinas, (Mallin, *et al.* 2001) and in the St. Johns River. These organisms can tolerate lower light levels than most other aquatic plants, and under the right conditions of nutrient and light, can propagate profusely, called a bloom (see the Dissolved Oxygen and Nutrient sections above).

The St. Johns River and particularly its tributaries, are impacted by excess nutrients in runoff and wastewater (see nitrogen and phosphorus section above), with high levels of coliform bacteria which indicate nutrient sources from human or animal fecal contamination. High levels of nutrients and phytoplankton can indicate a danger of eutrophication, in which the ecosystem becomes unbalanced with an increase in organic matter loading to the system. (NRC 2000). Where these conditions are present in the St. Johns River, high primary productivity by phytoplankton, may dominate the biotic processes in the aquatic ecosystem, referred to as a plankton “bloom”. “Blue green algae” blooms in addition to being clearly visible events, often induce high oxygen production during the daylight hours when the cyanobacteria and other algal plants produce oxygen, followed at night by very low oxygen levels due to oxygen consumption from nocturnal plant respiration and the decay of dead biomass (see Dissolved Oxygen and Nutrient sections above). This can result in low oxygen levels making it difficult for fish and other animals to thrive. Such blooms can also be so dense as to prevent sunlight from reaching the native submerged rooted plants (SAV) that are essential for the survival of juvenile fish and other aquatic organisms (see Turbidity and SAV sections). Algal blooms may have increased after successful eradication efforts to control the water hyacinth, which in the past shaded much of the water column. Reduction in the water hyacinth may have had the effect of changing the LSJR from a floating aquatic plant system to an algal-dominated system (Hendrickson 2006, 2008).

Some algal species also produce toxins which can reach higher levels in a bloom, and these are collectively known as Harmful Algal Blooms (HAB). Two summary references on HAB by Steidinger, *et al.* 1999, and Burns Jr 2008 are recommended reading on this subject. There is a valid question about whether harmful algal blooms are even a natural occurrence. Burns has this to say:

> *Although there is little doubt that the phenomenon of cyanobacterial blooms predates human development in Florida, the recent acceleration in population growth and associated changes to surrounding landscapes has contributed to the increased frequency, duration, and intensity of cyanobacterial blooms and precipitated*

public concern over their possible harmful effects to aquatic ecosystems and human health. Toxic cyanobacterial blooms in Florida waters represent a major threat to water quality, ecosystem stability, surface drinking water supplies, and public health.

In our region, two primary HAB organisms dominate. Microcystis species are common in the freshwater portion of the St. Johns River (Phlips and Cichra 1998) though only a few produce HAB. M*icrocystis species* are actually bacteria with photosynthetic ability and are members of the cyanobacteria. *Anabaena circinalis* and *Microcystis aeruginosa* are two of the most widely distributed freshwater cyanobacteria HAB generating species in Florida. (Steidinger, *et al.* 1999).

The World Health Organization has set a separate drinking water "provisional consumption" limit of 1 µg/L for microcystin-LR (WHO 1998), but up to 12.5 µg/L were detected in drinking water samples collected in a 2000 survey (Burns Jr 2008). An oceanic dinoflagellate, *Karenia brevis*, a common component of red tides, dominates HAB events in the coastal waters offshore but may be influenced by nutrients from the LSJR and other coastal estuaries. Certain types of HAB may be harmful to human skin and animals. Swimmers and anglers have complained of rashes after coming into contact with the bloom, which often form extensive surface scum in eutrophic waters during calm wind and hot weather conditions. The saltwater "red tide" has been known to produce respiratory problems in humans who only visited the coast, without direct contact with the water, though it is seldom reported in the LSJR estuary (Steidinger, *et al.* 1973).

Microcystis species also have been reported as dominant phytoplankton in the fresh water section of the Lower St. Johns River during all seasons (Phlips and Cichra 1998). Some of the other potentially toxic cyanobacteria that are known to bloom in Florida waters (in addition to *Microcystis aeruginosa,* and *Anabaena circinalis)* include *A. flos-aquae, Aphanizomenon flos-aquae, Cylindrospermopsis raciborskii* (reported as possibly a recent invasive import, Chapman and Schelske 1997), and *Lyngbya wollei.* (Steidinger, *et al.* 1999). Extensive statewide sampling reports showing that *Cylindrospermopsis* accounted for nearly 40% of 88 samples containing cyanotoxins (Burns Jr 2008), casts doubt on the recent introduction idea. Other potentially toxic species have also been identified, such as the *Pfiesteria*-like *Crytoperidiniopsoids* (Burkholder and Glasgow Jr 1997a, 1997b and *Prorocentrum minimum* (Phlips, *et al.* 2000), and often co-occur with fish kills or ulcerative disease syndrome in fish (Steidinger, *et al.* 1999).

Nutrients, which include the same nitrogen-based chemicals and phosphorus-based chemicals in garden fertilizer, are a common cause of impaired waters in the Lower St. Johns River and they are a crucial component of algal blooms. Much of this nutrient comes from leaking septic systems, livestock, industry and runoff during and after heavy rain events. Recent work by Hendrickson, *et al.* 2007 indicates that anthropogenic nutrient enrichment has tripled the total nitrogen load in the St. Johns River, but has even greater increases in the nitrogen components linked to HAB. The weather also influences HAB, with low flow or periods of drought conditions increasing the likelihood of algal bloom events; while high flow and hurricane rain events decrease the likelihood of algal bloom events (Phlips, *et al.* 2007).

Florida biologists in collected a total of 167 samples throughout Florida; 88 of these samples, representing 75 individual water bodies, were found to contain HAB cyanotoxins. Most bloom-forming cyanobacteria genera were distributed throughout the state, but water bodies such as Lake Okeechobee, the Lower St. Johns River, the Calooshatchee River, Lake George, Crescent Lake, Doctors Lake, and the St. Lucie River (among others) were water bodies that supported extensive cyanobacterial biomass. Seven genera of cyanobacteria were identified in the samples, with Microcystis (43.1%), Cylindrospermopsis (39.5%), and Anabaena (28.7%) the most frequently observed, and in greatest concentration (Burns Jr 2008).

Mean Chlorophyll *a* levels for some sections of the LSJR remain at relatively low levels, some as low as 3-6 µg/L [or parts per billion] (FDEP 2008c) compared to the very high levels during HAB events. Current standards are 11 µg/L for saltwater and generally 20 µg/L for fresh water, but the latter is exceeded during natural algal increases each summer in eutrophic blackwater systems, and greatly exceeded in the HAB events. A TMDL limit of "40 µg/L for not more than 40 continuous days" was proposed for algal biomass in the LSJR, but has not been adopted.

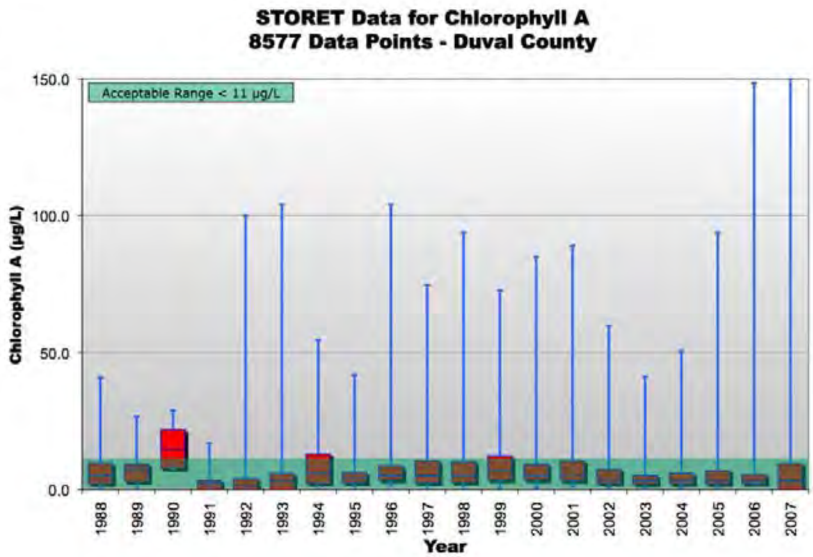


Figure 2.17 Chlorophyll a data for Duval County from 1988- 2006. Note the use of the estuarine standard of 11 µg/L.

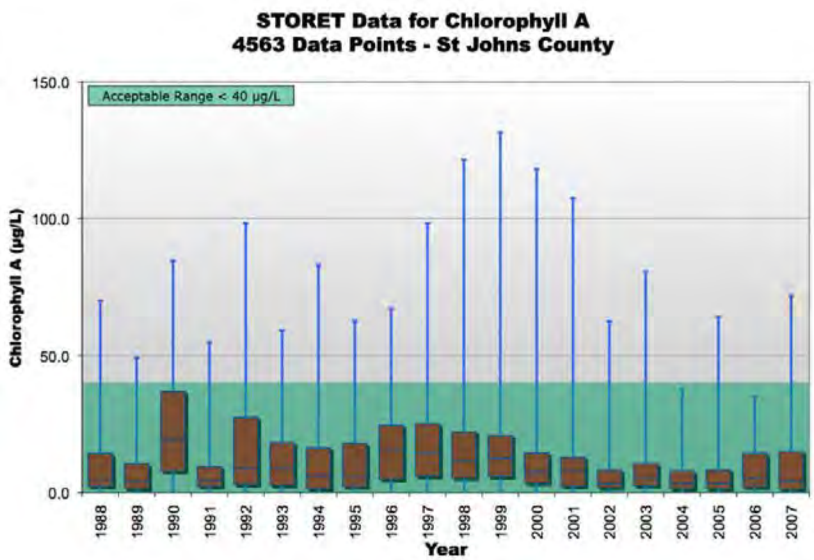


Figure 2.18 Chlorophyll a data for St. Johns County from 1988-2006. Note the use of the proposed Florida freshwater standard of 40 µg/L.

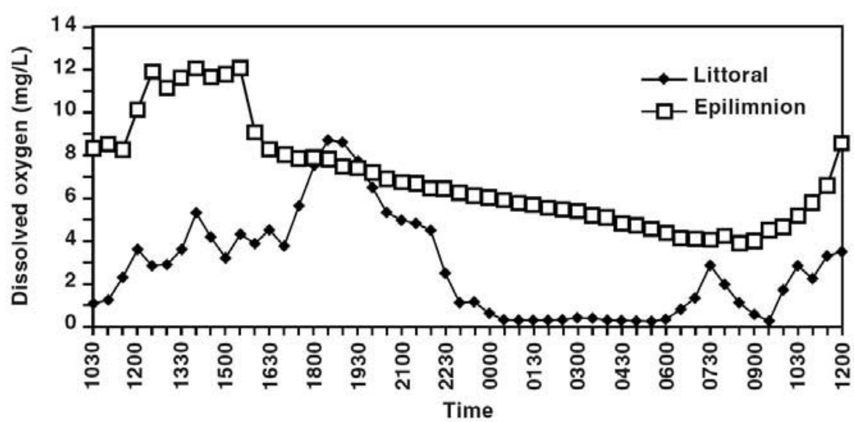


Figure 2.19 Littoral and deeper water Dissolved Oxygen during LSJR HAB event after Steidinger, et al., 1999

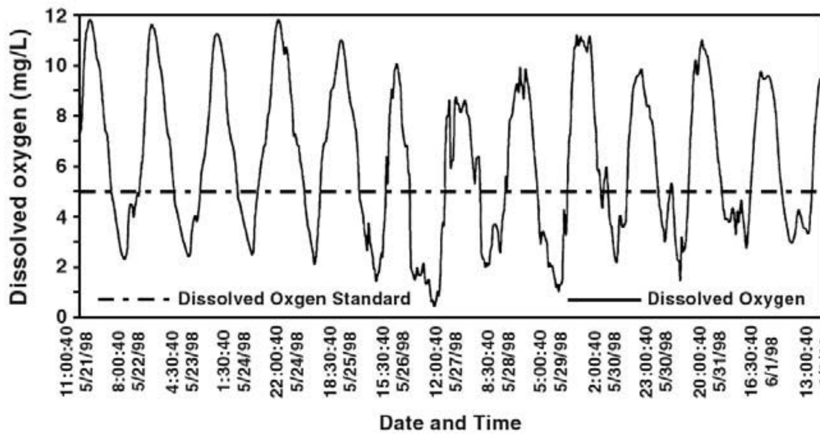


Figure 2.20 Diurnal cycles of Dissolved Oxygen during Doctors Lake HAB event in 1997 from Steidinger, et al., 1999 page 23.

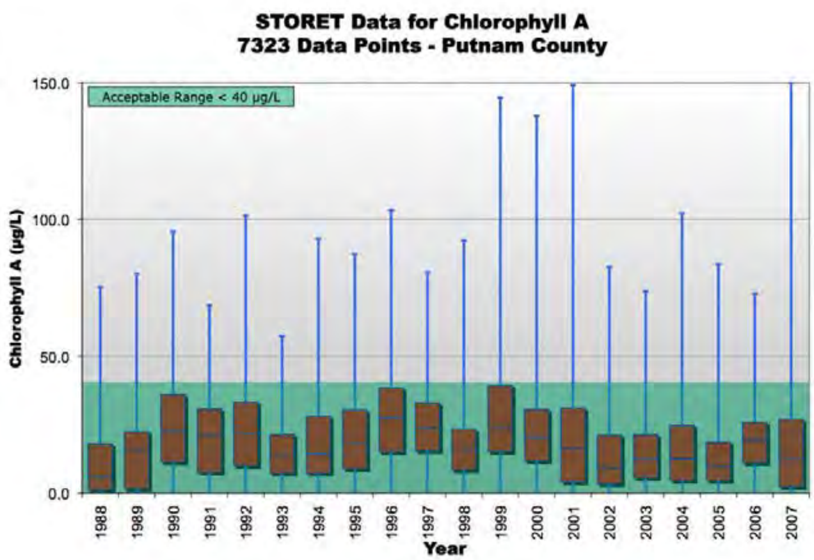


Figure 2.21 Chlorophyll a data for Putnam County from 1988-2006. Note the use of the proposed Florida freshwater standard of 40 µg/L.

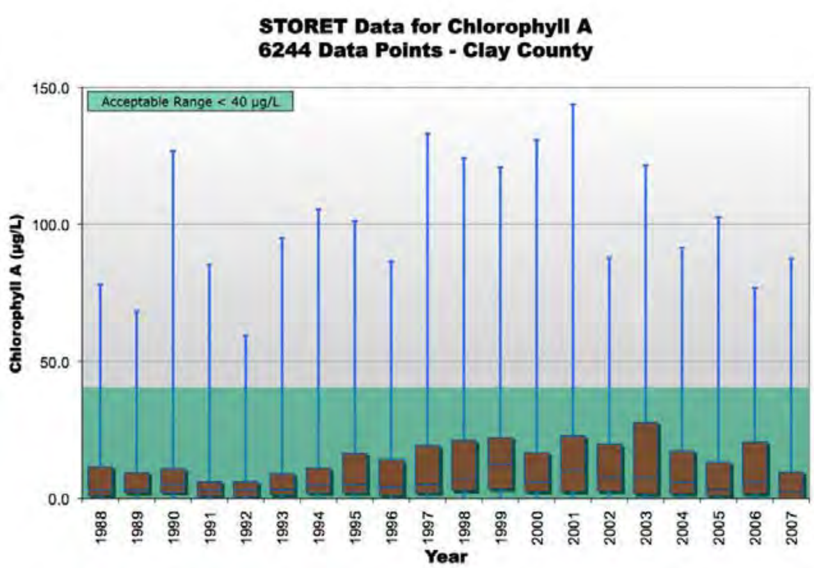


Figure 2.22 Chlorophyll a data for Clay County from 1988-2006 Note the lower average, but unusually high maxima compared to adjacent Putnam County

During cyanobacteria blooms in the lower St. Johns River, organisms such as juvenile fish that are unable to escape to deeper offshore, more oxygenated water (Figure 2.19) may not survive. Typical diurnal DO cycles (over a period of 24 hours) show that DO measurements tend to increase during the day (Figure 2.20) because of photosynthesis by the primary producers (cyanobacters), and diminish at night due to cyanobacterial oxygen depletion by respiration coupled with the additional oxygen consumption by the decaying biomass of the bloom (Steidinger, *et al.* 1999).

2.5.2. *Limitations*

While there is a long history of *chlorophyll a* sampling in the LSJR, the data is highly variable. The real-time monitoring of *chlorophyll a* in the LSJR system proposed by the City of Jacksonville could provide early alerts to potential algal bloom events, and increased sampling could then be triggered to study these events in detail. There are many complex and unanswered questions that would benefit from more data and further research. While we know high levels of nutrients in the river have fostered "blooms" of cyanobacteria, and other algae that can sometimes be toxic to animals and humans, the specifics of toxin production are not well understood. For example, while we know which genes in specific algal species can actually lead to toxin production, there are many genetic questions about when and why toxins are triggered and produced. Similarly, additional near-shore coastal data is required help us understand how much the St. Johns River nutrient load may or may not contribute to "Red Tide" blooms along our beaches.

2.5.3. *Current Conditions*

High levels of nutrients in the river have fostered "blooms" of primitive cyanobacteria, and other algae which (though native) can sometimes be toxic to animals and humans. Excess nutrients and summer sunlight can encourage these normally infrequent growth events. Nutrient from the St. Johns River may also increase the likelihood of "Red Tide" blooms along the coast, but this is an aspect that requires research confirmation.

2.5.4. *Trend*

While minor algal bloom events (such as might occur near a large bird rookery) have probably occurred since formation of the LSJR (thousands of years ago), the increases in nutrient concentration over the last few decades has increased algal blooms significantly. Recent improvements in nutrient levels since 2000 indicate current nutrient reduction progress that needs to be continued.

2.5.5. *Future Outlook*

Reduction of HAB events is highly linked to continued progress in nutrient reduction. Continued funding of the River Accord adopted by the City of Jacksonville and its partners as announced in July 2006 will certainly help. How much the nutrients from the St. Johns and other Northeast Florida rivers contributes to coastal "Red Tide" is currently not known. Likewise, little is known about what triggers toxin production in either the fresh water or salt water HAB species.

2.5.6. *Recommendations*

Sophisticated DNA studies of the various cyanobacterial genomes previously mentioned, their gene products, and protein structures as well as studies of their toxins are recommended. A long term study of cyanobacterial growth rates coupled with bioassay studies under varied nutrient loading is essential to understand algal bloom phenomena in the LSJR. Further research into the role of upstream algal seeding is needed to understand its impact on the LSJR.

2.6. Bacteria (Fecal Coliform)

2.6.1. *Description and Significance*

Fecal coliform bacteria are a natural component of digestive systems of birds and mammals. They aid in digestion, and are not normally considered harmful. Rather, they are used as water quality measures of water contamination by feces, which may indicate potential presence of disease causing organisms such as pathogenic bacteria and viruses. The EPA has set standards (EPA440/5-84-002) for recreational water quality after earlier studies by the CDC determined that few people become sick with gastroenteritis by accidentally ingesting water with 200 coliform bacteria units per 100 milliliters of water while engaged in recreational activities (Dufour 1984). This document can be found at http://www.epa.gov/waterscience/beaches/files/1986crit.pdf.

Florida fecal coliform exceedance criteria standards for recreational contact are:

> *Exceeding 800 colonies/100 milliliters for any single sample and a 30 day geometric mean exceeding 200 colonies/100 milliliters indicates that the water body sampled does not meet recreational water quality standards and contact should be avoided. Exceeding 400 colonies/100 milliliters in 10% of samples taken in a 30 day period indicates that the waterbody does not meet recreational water quality standards and caution should be exercised (FDEP 2008a).*

Fecal coliform bacteria reach the river from natural sources such as free-roaming wildlife and birds. Other major sources include domestic animal contamination from poor agricultural practices, human contamination from failing septic tanks, sewer line breaks, and wastewater treatment facilities overflows. These latter sources are often called point sources because large amounts of waste can enter the river or tributary at a single point such as an outfall pipe. Non-point sources in contrast, enter the watershed from a broad area such as wildlife excrement, runoff and agricultural wastes from pasturelands.

2.6.2. *History*

Conceptually, the reuse of sewage wastewater and recycling by land based application is not new. Use of human sewage wastes in agriculture to fertilize crops and replenish nutrients from depleted soils has been practiced by the Chinese since ancient times (Shuval, *et al.* 1990). The First Royal Commission on Sewage Disposal in England of 1865 stated "The right way to dispose of town sewage is to apply it continuously to the land and it is by such application that the pollution of the rivers can be avoided."

Modern methods of sewage disposal involve treating human sewage in wastewater treatment plants before discharging it into local waterways or the ocean. Over the last three decades, the standards for sewage treatment have become ever more stringent, particularly with the passage of the CWA in 1977. As the U.S. EPA website notes:

> *Growing public awareness and concern for controlling water pollution led to enactment of the Federal Water Pollution Control Act Amendments of 1972. As amended in 1977, this law became commonly known as the Clean Water Act. The Act established the basic structure for regulating discharges of pollutants into the waters of the United States. It gave EPA the authority to implement pollution control programs such as setting wastewater standards for industry. The Clean Water Act also continued requirements to set water quality standards for all contaminants in surface waters (EPA 2008).*

This law required the nation's publicly owned sewer systems to remove 90% of the solid matter, and to disinfect the effluent (Shabecoff 1988), which was usually done with chlorine, to protect streams and rivers. Recently there has been a trend to move from chlorine to other oxidants (such as peroxides, oxygen, or ultraviolet light) because chlorine by-products may be harmful (Jolley, *et al.* 1982). The City of Jacksonville passed **Environmental Protection Board (EPB) Rule 3** to improve water quality in Duval County (1987). This led to phase-out of the existing but less reliable local wastewater treatment plants; many of which were unable to meet the higher standards. Consolidation into larger regional treatment plants helped meet the higher standards. Yet, when fecal coliform levels were measured in order to comply with the EPA process, many of the tributaries in the LSJR were out of compliance. Jacksonville made the news when the FDEP and the The St. Johns Riverkeeper noted that "the ocean would be closed to swimmers" at those contamination levels. The 50 water bodies that were so listed had measured above an average of 400 bacterial colony forming units per 100 milliliters of water. Several sites had count levels in the thousands and a few in tens of thousands. The St. Johns Riverkeeper's website lists the impaired streams (FDEP 2004): http://www.stjohnsriverkeeper.org/river_ImpairedWaters.asp.

Many of these have been traced to leaking or failed septic systems. Actions are under way to more intensely monitor and correct these problems in LSJR tributaries, and establishment of TMDLs and BMAPs for the tributaries of the coliform-impaired tributaries are under way.

The City of Jacksonville is monitoring water quality in Duval County at over 100 sites in the Tributary Program which provides a list of sites and photos at http://www.coj.net/Departments/Environmental+and+C ompliance/Environmental+Quality/Surface+Water+Quality/Tributary+Program+Monitoring+Sites.htm.

The most current fecal coliform data for Duval County streams is located on the city website and uses the single sample standard of 800 coliform units per sample http://www.coj.net/Departments/Environmental+and+Compliance/Environmental+Quality/Surface+Water+Quality/Tributary+Basin+Tables+April-June+2005.htm.

Data from January to March 2008, the most current periods available, and back one year (2007) indicate that individual tributaries along the Cedar River, Arlington River, Southside (San Jose Blvd) area, Pablo Creek/Mt. Pleasant Creek, and the downtown area are occasionally in violation of the fecal coliform standard (depicted in RED). Rural tributaries like Deep Creek, Julington-Durbin Creeks, and Yellow Water Creek are generally within standard. The latest data show improvement in the Ortega River area, Trout River, and Mill Cove.

Comparison of the graphs for the entire LSJR dataset, and two tributaries, Black Creek and Cedar River clearly show the differences in proportion of the datasets with over 800 fecal coliform counts (the single sample exceedance criterion) and those below 200 counts per sample. These graphs only include 2000-2007 data, so the number of samples is limited (Figure 2.23).

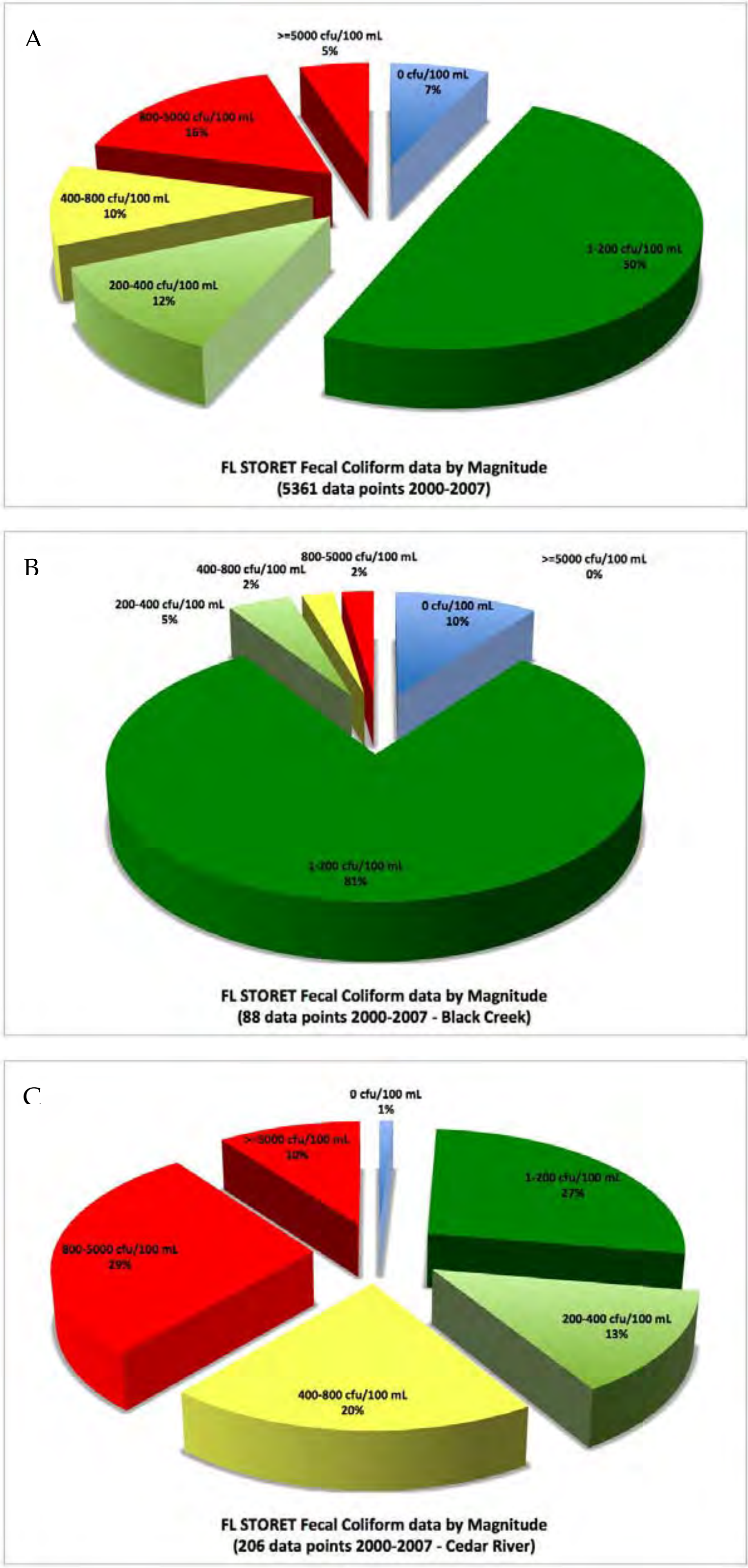


Figure 2.23 Distribution (as %) of fecal coliform counts (2000-2007) for A. The LSJRB, B. Black Creek, and C. Cedar River

In contrast, the main stem of the LSJR is monitored for fecal coliform and other water quality parameters at several sites from Welaka to Arlington (Jacksonville) under the "River–at-a-Glance" program, and shows that the main stem of the LSJR is clearly in compliance for fecal coliform http://www.dep.state.fl.us/northeast/RAAG/default.htm.

2.6.3. *Data Sources*

The primary source for this evaluation is the STORET database and the EPA-mandated statewide TMDL assessment reports required by the CWA such as the Florida 303(d) report of impaired waters and other data on the FDEP website. These reports become the basis for future water quality management and restoration efforts. These are publicly available online at websites listed above. Additional sources for the Duval County tributaries include the City of Jacksonville website (above).

2.6.4. *Limitations*

Infrequent monitoring of fecal coliform levels limits assessment of trends.

2.6.5. *Current Conditions:*

Tributaries: **UNSATISFACTORY**
Main Stem: **SATISFACTORY**

2.6.6. *Future Outlook*

The future outlook is unable to be determined, but is promising due to The River Accord and other public efforts such as the JEA/SWEA consolidation of WWTFs (Figure 2.24) and public monitoring on the Riverkeeper website.

2.6.7. *Recommendation*

More frequent (monthly) monitoring results of problem urban watersheds should be posted on the city website.

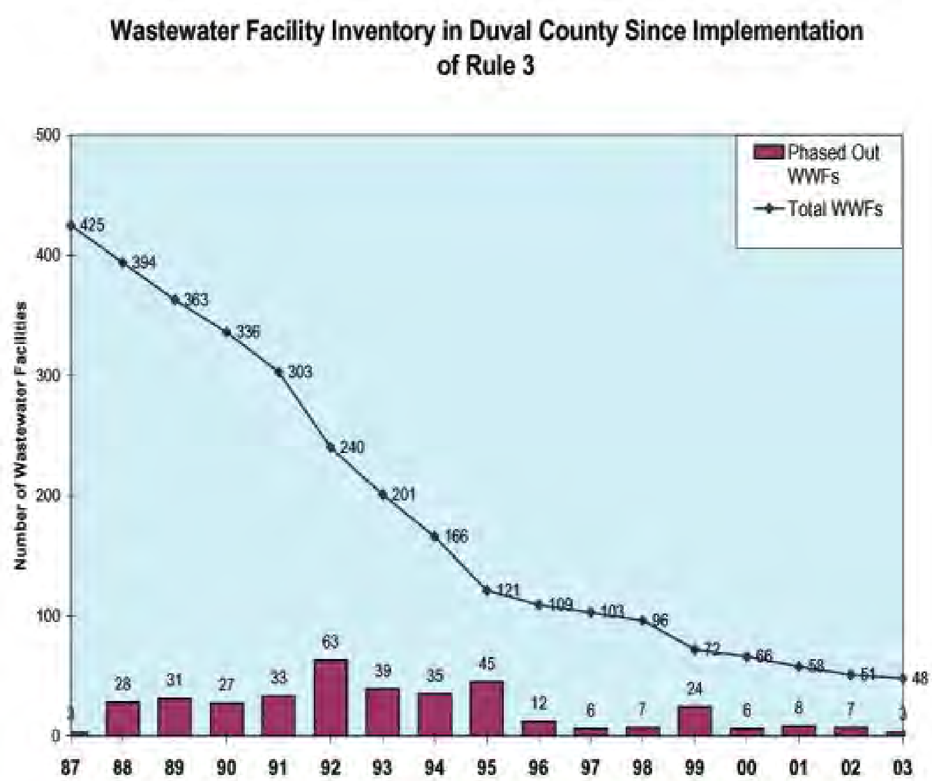
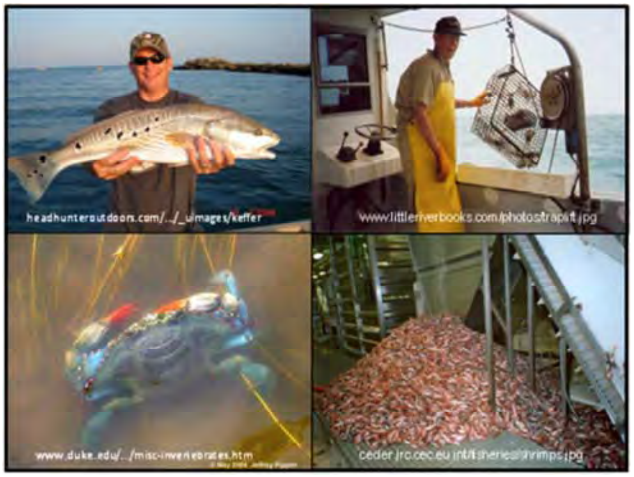


Figure 2.24 Waste Water Treatment Facilities in Duval County by Year. Since the Implementation of EPB Rule 3. Source: City of Jacksonville

3. Fisheries



3.1. Introduction

3.1.1. General Description

The lower basin of the St. Johns River supports a diverse and abundant fish and invertebrate community of commercial and recreational value to the public. Invertebrate commercial fisheries account for the largest percentage of landings with blue crabs comprising 63% of the total landings for 2006 (http://www.floridamarine.org/features/). In the same year, finfish fisheries accounted for 35% of the total catch with striped mullet, whiting and flounder being the most commonly caught species in the five counties associated with the lower basin of the St. John River (Figure 3.1). Recreationally, the St. Johns area supports high numbers of red drum, spotted sea trout, croaker, sheepshead, flounder, largemouth bass, and bluegill that are sought by both local and visiting anglers.

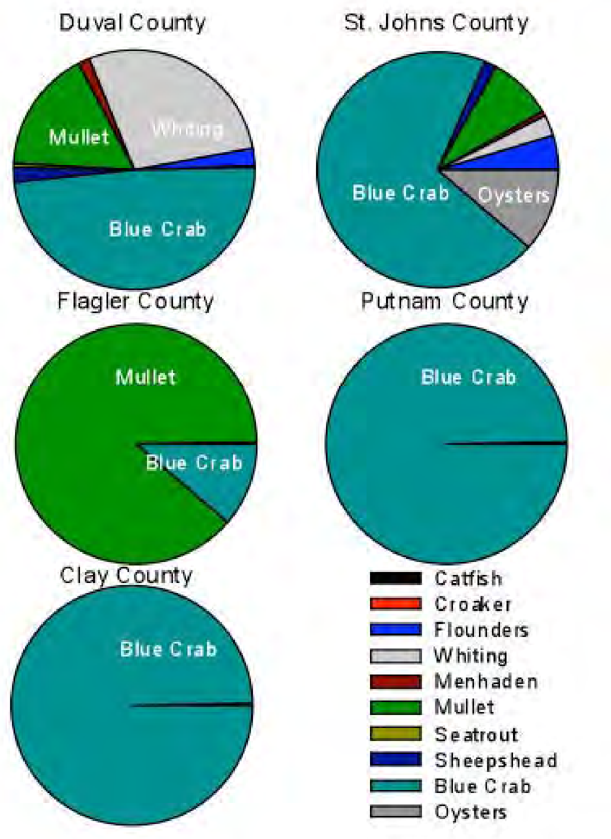


Figure 3.1 Percent comparison of commercially important fish and invertebrates caught by five counties associated with the lower basin of the St. Johns River in 2006. These data do not differentiate between fish and invertebrates caught in the St. Johns River or the Intracoastal Waterway (ICW).

3.1.2. Data Sources &Limitations

Four sources of data were referenced in interpreting status and trends of fish and invertebrates. All available literature was used to examine potential long-term trends (1955-2007) in fish communities via the presence or absence of species encountered in the particular study. Such comparisons may give insight into whether the overall fish community was the same for the time periods compared. A major weakness of this comparison is that it gives no information on how the numbers of a given species may have changed with time. In most cases, the collection methods in the studies were not the same. Consequently, the conclusions that can be drawn from these kinds of comparisons are limited.

The status and trends documented for species in this section are derived from the three remaining sources of data. The focal datasets come from recreational landings estimates (1982-2007) and commercial landings reports

(1994-2007) obtained from the Fish and Wildlife Research Institute (FWRI) and the National Oceanic and Atmospheric Administration (NOAA), respectively. Generally, data are analyzed separately for the north (Duval County), south (St. Johns, Flagler, Putnam & Clay Counties) and whole lower St. Johns River. It should be noted, that there are uncertainties associated with either the exact location of where a fish was caught and/or the method of estimating total number of landings for a given area. In particular, these data do not differentiate between fish and invertebrates caught in the St. Johns River or in the Intracoastal Waterway (ICW). Additionally, changes in fishery regulations through the years limit what can be said of landings between certain time periods. In most cases, total landings are graphed. However, in order to best assess comparison of landings over the years, landings per trip are calculated for the north and south sections of the river, and trends investigated using nonparametric correlation analysis. Graphs using these values are located in the Appendix.

The most statistically reliable data used in this report come from ongoing research conducted by the FWRI (see Appendix 3.1.1a & b for river areas sampled). However, they have only been collecting information since 2001. Finally, scientific literature was used where appropriate to supplement these data, and to form our conclusions on trends and statuses.

3.1.3. Health of Fish and Invertebrates

There is not much information on the health of fish and invertebrates from the lower basin of the St. Johns River. In the mid-1980s, there were concerns with fish health in the St. Johns River when high numbers of fish with external lesions (called ulcerative disease syndrome—UDS) were reported by local fishermen. A comprehensive 1987 study (CSA 1988) from Clapboard Creek to Lake George revealed only 73 lesioned fish out of 69,510 (0.11%). However, this study also observed a higher percentage (5 %) of lesioned fish in the Tallyrand area with the main affected fish being southern flounder, weakfish, yellowfin menhaden, southern stingray and Atlantic croaker. FWRI research suggested that a major cause of the lesions is a water mold (*Aphanomyces invadans*) that is more likely to infect stressed fish. Fish can be stressed when exposed to unusual changes in salinity, temperature and water quality.

The FWRI investigated external abnormalities such as lesions in fish since 2000. They surveyed fish and invertebrates for the presence of abnormal growths, colors and ulcers or gross external abnormalities (GEA). They also sampled mercury levels in muscle tissue from the shoulder area in similar sized (generally larger) spotted sea trout, red drum, southern flounder, southern kingfish, and blue crabs.

The incidence of GEAs was found to be less than one percent in 2000 and 2005 (http://research.myfwc.com/features/view_article.asp?id=24885). In 2005, less than one percent (19 fish) of 18,413 fish (> 75 mm in length) surveyed in Northeast Florida had GEAs (FWRI 2006b). The consumable fish that had some kind of abnormality were striped mullet (5), southern flounder (2), channel catfish (1), black drum (1), largemouth bass (2), bluegill (2), and Florida pompano (1). In most case, several hundred individuals of each of the above species were sampled allowing for a more reliable assessment of frequency of abnormality (Figure 3.2). The one exception is the Florida pompano where only one individual was encountered rendering health interpretation for this species not possible. Over 150 species of fish were surveyed.

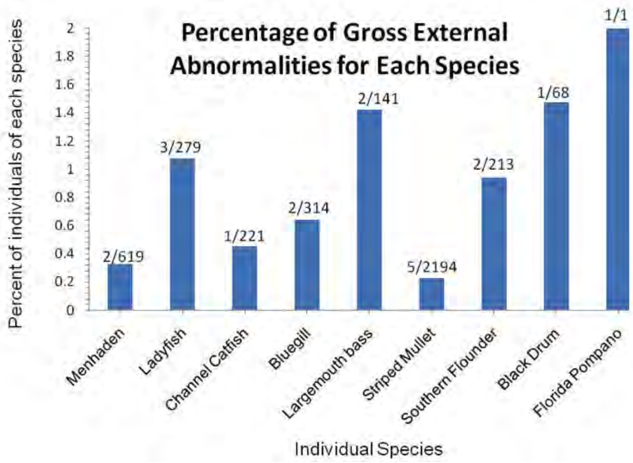


Figure 3.2 The percent of each fish encountered with gross external abnormalities (GEAs). Fractions over each column represent the number of GEA over total number sampled.

Mercury has been encountered in southern flounder, spotted sea trout, red drum and southern kingfish, as well as, blue crabs although not at levels that prohibit human consumption (Figure 3.3). The values in FWRI's study varied between 0.05 and 0.15 mg/L with the Spotted Seatrout having the statistically highest mercury levels (Figure 3.3). The Department of Health advises limited consumption (1-2 meals/week) of brown bullhead, Red breast sunfish, bluegill, black crappie, warmouth, largemouth bass, bowfin, gar, Atlantic croaker, Atlantic thread herring, Atlantic weakfish, black drum, Gulf and southern flounder, Jack crevalle, hardhead catfish, red drum, sand seatrout, sheepshead, spotted seatrout, southern kingfish, striped and white mullet, and spot.

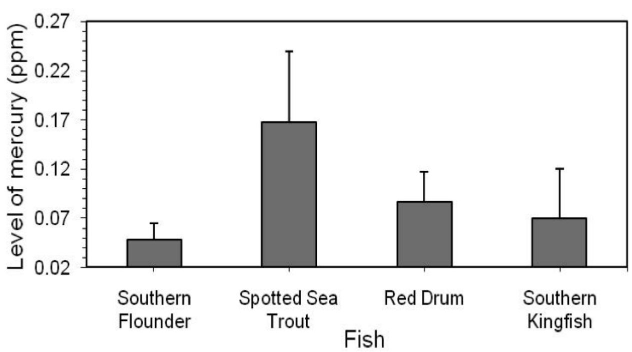


Figure 3.3 The average level of mercury encountered in four selected fish species collected in the lower St. Johns Rive from 2005 to 2006.

3.2. Finfish Fishery

3.2.1. General Description

The St. Johns River lower basin supports a fish community of great ecological, commercial and recreational value to the public. Most of the fish sought after are predaceous fish that are important in maintaining community balance in the areas where they occur. Historically, American eel and shad were huge fisheries in the St. Johns, although populations have decreased to such low levels that they are now not the focus of most commercial fisherman (McBride 2000). Currently, the premier commercially harvested estuarine or marine fish in the lower basin are striped mullet, flounder, sheepshead, menhaden, black drum, croaker and whiting. However, American eels, spotted Seatrout, and weakfish are also commercially harvested. In freshwater sections of the river, important species commercially harvested include non-native tilapia, catfish, gar, bluegill/redear sunfish, shad, and American eels. Of the five counties studied, Duval County catches the highest landings (1,194,330 lbs in 2006) and species of fish per year (only includes fish caught within the river and ICW).

The St. Johns River supports a diverse recreational fishery in the lower basin. Within the different sections of the river, significant fisheries exist for freshwater, estuarine or saltwater fish. A saltwater license is required if fishing from a vessel, floating object or if wading in deeper than 4 ft. of water. Premier saltwater species sought after are red drum, spotted Seatrout, flounder and sheepshead. A freshwater license is required for land or vessel fishing. Premier freshwater species include largemouth bass, blue gill and catfish. The abundance of some of these fish species in the river has resulted in a number of very high profile fishing tournaments occurring each year---red drum and bass tournaments being among the most popular.

3.2.2. Long-term trends

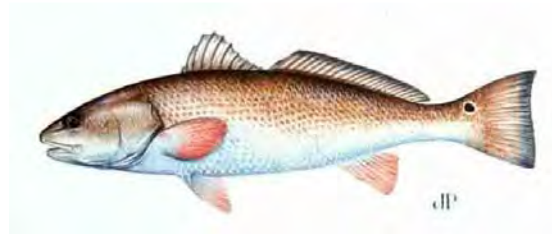
For many years, humans have benefited from the thriving fish communities that utilize the lower basin of the St. Johns River. Indeed, a number of the same species sought after today, such as spotted Seatrout and sheepshead, were commented on by the naturalist

William Bartram as far back as the late 1700s. However, despite the importance of river fisheries over the years, only a few studies have rigorously sampled fish populations in the St. Johns River. In response to this need for more information, the FWRI started an ongoing monthly fish sampling program in 2001 that is designed to understand fish population changes with time in estuarine areas of Northeast Florida.

The available long-term research suggests that many of the same species present today (~170 species total) were present in the river back in the late 1960s (FWRI 2007c; McLane 1955; Tagatz 1968c). However, it is unclear whether the numbers of individual species have changed during this time period because of different sampling methods used in these studies. Currently, the most numerically dominant species in the lower basin include anchovy, striped mullet, killifish, menhaden, Atlantic croaker, spot, silversides, and silver perch.

A preliminary study by McCloud 2008 with St. Johns River Water Management District (SJRWMD) compared current FWRI fish data with that collected by M. Tagatz in 1968. Her research suggested that at some areas of the river, observed fish communities were 50% different between 1968 and the 2001-2006 time period. She further suggests that the observed differences in fish communities in these areas may have been the result of a transition zone between marine and freshwater moving further upstream. One of the unique aspects of the St. Johns Estuary is the ability of some marine fish to ascend far upstream into freshwater. For instance, stingrays are abundant in a number of freshwater areas in the river. However, most fish are sensitive to their environment, and can move from an area in response to unsuitable changes in important environmental factors such salinity, dissolved oxygen, and temperature.

3.2.3. *Red Drum (Sciaenops ocellatus)*



http://myfwc.com/marine/fish/reddrum.jpg

3.2.3.1. General Life History

Red drum (also called puppy drum, channel bass, spottail bass and redfish) are predatory fish that are found in the estuarine sections of the St. Johns River. During the fall and winter, they spawn at dusk in coastal waters near passes, inlets and bays. Newly hatched young live in the water column for 20 days before settling to the sea floor bottom. Young fish will become reproductively mature fish at around three years of age, and may ultimately live to be approximately 40 years (Murphy and Taylor 1990), and reach a maximum length of five feet.

3.2.3.2. Significance

Red drum are ecologically important as both a predator and prey in the food web of the St. Johns River. They are bottom feeders that eat crabs, shrimp, worms and small fish. Their predators include larger fish, birds, and turtles.

A strong recreational fishery exists for red drum. The recreational fishery for red drum is an estuarine and near-shore fishery, targeting small, "puppy drum" and large trophy fish. Trophy-size fish are caught along the mid- and south coastal barrier islands, while smaller red drum are taken in shallow estuarine waters. Red drum have not been commercially harvested since 1988 to minimize impacts to natural populations.

3.2.3.3. Trend

Both NOAA and FWRI data sets show recreational landings of red drum decreased substantially during the mid-1980s, but have been consistent since then (Figure 3.4). This trend is evident in both the northern and southern sections of the river although far more red drum are landed in the northern river sections. FWRI research data shows similar trends for the 2001-2005 time periods (Appendix 3.2.3a and 3.2.3b).

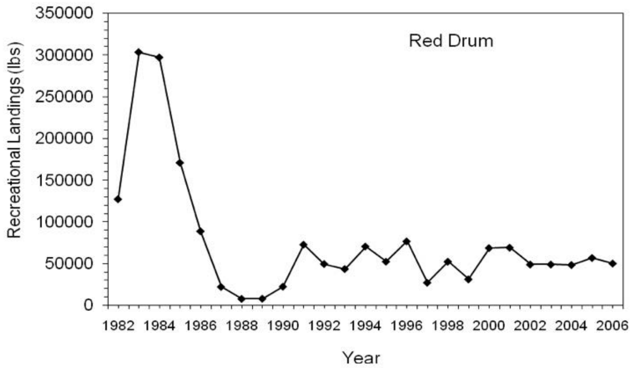


Figure 3.4 Recreational landings (in lbs) of red drum within the lower basin of the St. Johns River from 1982 to 2007. Note that the gill net ban went into effect in 1995.

3.2.3.4. Current Status and Outlook

Red drum are a very important recreational fishery in the lower St. Johns River. It appears they are safe from overexploitation (Murphy 2005). There is concern that increased fishing activity may in the future cause decreases in fish numbers through direct loss of fish captured, and mortality of "returned" fish. Consequently, close monitoring of reproduction and abundance in local populations is essential for ensuring the long-term maintenance of red drum in the LSJRB.

Recreationally, one red drum can be caught per day throughout the year. Individual fish must be within 18 and 27" in length. No red drum can be sold for profit (http://myfwc.com/marine/docs/07FLSalt_webregs.pdf).

3.2.4. Spotted Seatrout (Cynoscion nebulosus)

http://www.floridasportfishing.com/magazine/images

3.2.4.1. General Life History

The spotted Seatrout is a bottom-dwelling predator that is common in estuarine and shallow coastal habitats in Northeast Florida. They are carnivores that prey on a number of small fish species such as anchovies, pinfish and menhaden. Reproduction tends to occur during the night within the river from spring through fall with a peak during April through July. The young often form schools of up to 30-50 individuals. Individual fish will become sexually mature in two to three years. Their expected lifespan is eight to ten years. They may reach a maximum length of three feet.

3.2.4.2. Significance

Spotted Seatrout are very important in both the benthic and planktonic food webs in the St. Johns River. As newly hatched young they are planktivores, feeding primarily on copepods within the plankton. As they grow, they shift to larger prey including shrimp, and eventually a number of smaller fish within the river. A number of predators feed on Seatrout including Atlantic croaker, cormorants, brown pelicans, porpoises, and sharks.

There are recreational and commercial spotted Seatrout fisheries within the St. Johns River. Recreationally, the fish is the premier game fish in the area for visiting and local anglers. Annual commercial landings for the state of Florida were over four million pounds in the 1950s and 1960s, and down to 45,000 lbs in 2006 (Murphy, *et al.* 2006). Out of this value, the lower St. Johns River (and the neighboring ICW) accounts for approximately 5,000 lbs. harvested annually.

3.2.4.3. Trend

Recreational and commercial landings data show similar trends for the comparable time periods. Recreational landings data decreased substantially once in the mid-1980s, and again to even lower levels in the mid-1990s. However, landings have been somewhat stable since 1996 (Figure 3.5; Appendix 3.2.4a & b). Commercial landings of spotted Seatrout similarly decreased in the mid-1990s and appear to be declining since then. The substantial mid 1990s decrease may be due to the impact of the gill net ban (Murphy, *et al.* 2006). Finally, the NOAA and FWRI commercial and research data sets all reveal higher numbers of spotted Seatrout in the northern versus southern sections of the lower St. Johns River (Appendix 3.2.4c).

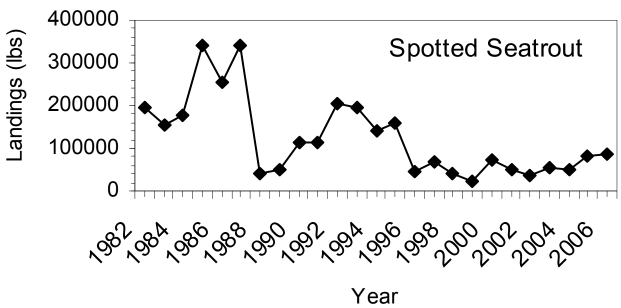


Figure 3.5 Recreational landings (in lbs) of spotted Seatrout within the lower basin of the St. Johns River from 1982 to 2007. Note that gill nets were banned in 1995.

3.2.4.4. Current Status & Outlook

The spotted Seatrout recreational fishery has grown in the last 15 years while the commercial fishery has decreased. However, both fisheries appear to be declining. The decrease in landings may be related to: 1) changes in fishing regulations; 2) coastal development; and 3) fishing pressure (Murphy, *et al.* 2006). Despite these trends, a recent FWRI stock assessment suggests that spotted Seatrout are not being overfished within the Northeast Florida region (Murphy, *et al.* 2006).

Recreationally, spotted Seatrout are considered a restricted species (Murphy, *et al.* 2006). However, they can be caught in the Northeast Florida region during all months of the year, except during February (when keeping spotted Seatrout is prohibited). The legal size range is 15 to 20 inches with a daily limit of five per person (includes one larger fish) (http://myfwc.com/marine/docs/07FLSalt_webregs.pdf).

3.2.5. ***Largemouth Bass*** (Micropterus.salmoides)

http://www.usbr.gov/.../activities_largemouth_bass.jpg

3.2.5.1. General Life History

Largemouth bass are predatory fish that occupy shallow brackish water to freshwater habitats, including upper estuaries, rivers, ponds and lakes. When young, they are carnivores feeding on zooplankton, crustaceans, insects and crayfish. As they get older, they feed on a variety of organisms such as larger fish, crayfish, crabs, frogs, and salamanders. They reproduce from December through May. The male builds nests in hard-bottom areas along shallow shorelines. The female then lays her eggs in the nest, where they are fertilized as they enter the nest. The male will guard the nest and later, the young fry. The fry initially swim in tight schools, and then disperse when they reach about one inch in size. Largemouth bass may live up to 16 years growing in excess of 22 inches in length (http://floridafisheries.com/Fishes/bass.html).

3.2.5.2. Significance

Largemouth bass are very important in freshwater benthic food webs in the lower St. Johns River. Their willingness and aggressiveness to feed on any appropriately sized prey is significant in affecting the abundance of many organisms in the same habitat. Recreationally, bass are a premier game fish in the area for visiting and local anglers.

3.2.5.3. Trend

FWRI research in the past six years suggests a slight increase in abundance of bass in the middle sections of the St. Johns River since 2002 (Figure 3.6). As expected, bass were also encountered in the more southern area of the river. However, sampling in this section of the river was terminated by 2003. There is no data available on recreational landings of largemouth bass.

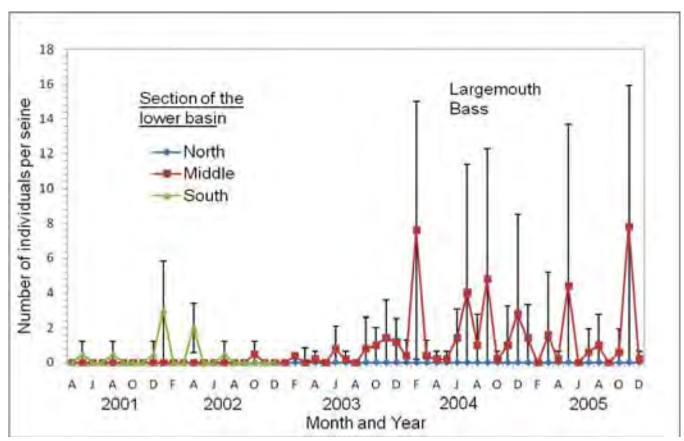


Figure 3.6 Mean number of largemouth bass collected per seine within the upper, middle and lower sections of the lower basin of the St. Johns River from 2001-2005. Vertical bars at each point represent degree of variability around each value.

3.2.5.4. Current Status & Outlook

There is not enough information to assess the status of the recreational fishery associated with largemouth bass in the lower St. Johns River. However, they are not likely to be overfished in the near future. Bass are commonly raised in hatcheries and stocked in lakes and ponds throughout Florida.

Recreational fishermen are permitted to take largemouth bass all months of the year. A daily limit of five per person is allowed with minimum size of 14 inches and only one of the five being more than 22 inches (http://www.floridaconservation.org/fishing/rules.html).

3.2.6. *Channel & White Catfish*
(Ictalurus punctatus & Ameiurus catus)

http://myfwc.com/.../images/raverart/White-Catfish.jpg

3.2.6.1. General Life History

Channel and white catfish are omnivorous fish that can be found in primarily freshwater rivers, streams, ponds and lakes. During their lifetime, they may feed on insects, crustaceans, crayfish, mollusks and fish. They reproduce in the river in the spring and summer months. The male builds nests where the eggs are laid by the female and fertilization occurs. The male will guard the nest and later the young fry. The fry will leave the nest one week after hatching. As they mature, catfish will tend to occupy bottom areas with slow moving currents. Individuals may live 11-14 years.

3.2.6.2. Significance

Both catfish species are very important in benthic food webs in the more freshwater sections of the lower St. Johns River. They are abundant, and feed on a wide variety of organisms during their lifetime (DeMort 1991). There has been a sizeable commercial catfish fishery associated with white and channel catfish for many years, yet there is little data available on annual recreational landings for the Northeast Florida area. There is also a large recreational catfish fishery within the river. Channel catfish are often stocked in ponds and lakes to maintain population numbers.

3.2.6.3. Trend

Commercial landings decreased substantially in the mid-1990s (Figure 3.7). This mid-1990s decrease may be due to the impact of the Florida gill net ban. Since this time period, landings have been decreasing in the north (landings mostly likely from tributaries in this area) and consistently low in the south sections of the river (Appendix 3.2.6a). However, the more recent FWRI data shows a consistent trend with both species being more common in the southern sections of the river, and white catfish generally being more abundant than channel catfish (Appendix 3.2.6b). There is no data available on the recreational catfish fishery.

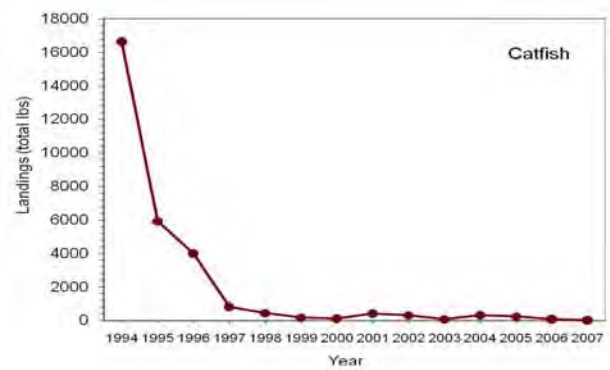


Figure 3.7 Commercial landings (in lbs) of catfish within the lower basin of the St. Johns River from 1994 to 2007. Note that the gill net ban went into effect in 1995.

3.2.6.4. Current Status and Future Outlook

Both species of catfish are generally common in the St. Johns River. The decrease in commercial landings of catfish may be more related to changes in fishing regulations over the years, although this is not known for sure. It may also be a result of a recent increase in farm-raised catfish in the southeast United States (http://news.ufl.edu/1999/08/13/catfish-2/). FWRI is in process of implementing freshwater species into their marine trip ticket program to more effectively assess freshwater landings in various parts of Florida. With the exception of Fish Management Areas, there are no bag or possession limits on either species of catfish (http://www.floridaconservation.org/fishing/rules.html).

3.2.7. *Striped Mullet (Mugil cephalus)*

http://www.floridafishandhunt.com/.../stripemul.jpg

3.2.7.1. General Life History

Striped mullet (also known as black mullet) are detritivores that have a wide salinity range. They are abundant in freshwater and inshore coastal environments often being found near mud bottoms feeding on algae, and decaying plant material. Mullet migrate offshore to spawn with their resultant larvae eventually drifting back to coastal waters and marsh estuaries. Developing individuals will become sexually mature at three years and live from four to 16 years. Older fish may ultimately reach lengths of up to three feet.

3.2.7.2. Significance

Mullet are considered extremely important in benthic food webs in all sections of the lower St. Johns River. They are abundant and significant in the transfer of energy from the detrital matter they feed on to their predators such as birds, Seatrout, sharks and marine mammals. The commercial mullet fishery has been the largest among all fisheries in the St. Johns for many years with over 100,000 lbs. harvested annually. Additionally, mullet are sought after recreationally for their food and bait value.

3.2.7.3. Trend

Both recreational and commercial landings have been highly variable since the 1980s (Figure 3.8). Commercially and recreationally, more mullet are harvested in the southern section of the river (Appendix 3.2.7a & b). The northern section has been somewhat more consistent with a slight decreasing trend while landings in the south fluctuate more drastically from year to year. The FWRI data reveals consistent trends in abundance for both zones from 2001 to 2005 (Appendix 3.2.7c).

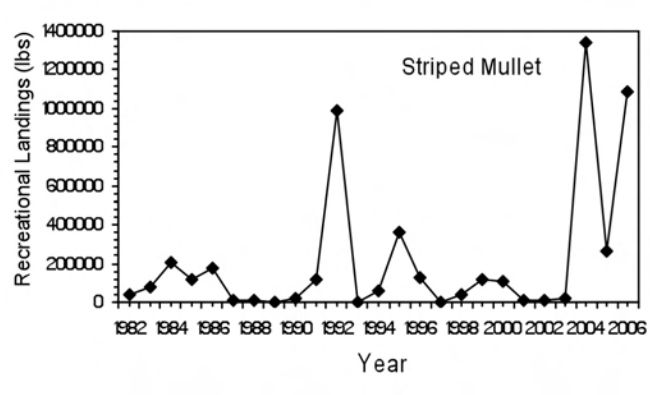
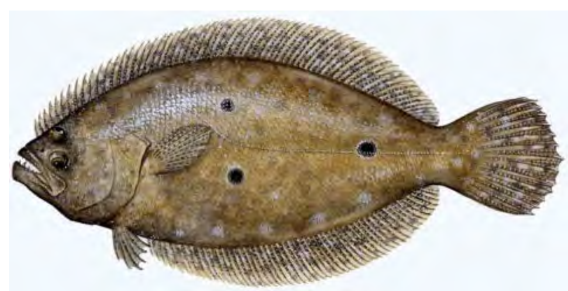


Figure 3.8 Recreational landings (in lbs) of striped mullet within the lower basin of the St. Johns River from 1982 to 2007.

3.2.7.4. Current Status & Future Outlook

Striped mullet in the St. Johns River continue to be important commercially and recreationally. Populations appear to be healthy and sustainable into the foreseeable future along the east coast of Florida (Mahmoudi 2005). Recreational fishing limitations are 50 fish maximum (includes striped and silver mullet) per harvester per day. There is no closed season (http://myfwc.com/marine/docs/07FLSalt_webregs.pdf).

3.2.8. *Southern Flounder (Paralichthyes lethstigma)*



http://www.floridasportfishing.com/magazine/images

3.2.8.1. General Life History

The southern flounder is a common flounder in inshore channels and estuaries associated with the St. Johns River. It is a bottom-dwelling predator that feed on shrimp, crabs, snails, bivalves and small fish. During the fall and winter it moves offshore to spawn. Larvae will develop and drift in the plankton while being transported (via wind driven currents) back to estuaries and lagoons where they will settle and develop into juveniles and then adults. The southern flounder may grow up to 36 inches, and live to approximately three years of age.

3.2.8.2. Significance

Flounder are important ecologically, recreationally and commercially to humans in the lower St. Johns River area. They are abundant and important in maintaining ecological balance in their roles as both predator and prey. The commercial flounder fishery is one of the larger ones in Northeast Florida. Flounder are also highly sought after recreationally for their excellent food value.

3.2.8.3. Trend

Recreationally, southern flounder landings decreased dramatically in the early 1980s but have since been appeared stable with slight fluctuations (Figure 3.9). Less drastic fluctuations in landings have occurred more to the south where landings generally are the largest (Appendix 3.2.8a). Commercially, landings of all flounders have decreased significantly after 1995 but have since been consistent (Appendix 3.2.8b). However, it is unclear whether this trend applies specifically to the southern flounder. The mid-1990s decrease in commercial landings of all flounders may be due to the impact of the gill net ban. FWRI data for southern flounder show similar trends in abundance between north and south sections of the river but no observable trends from 2001 to 2005 (Appendix 3.2.8c).

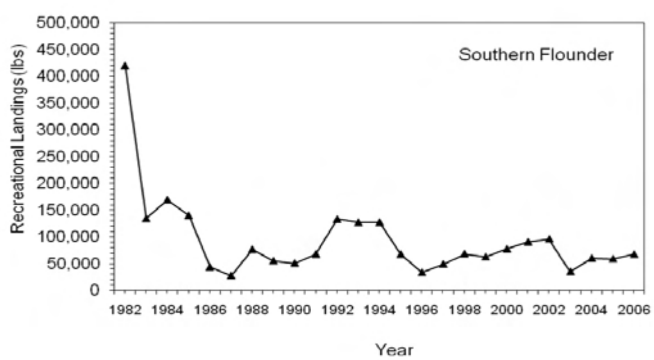


Figure 3.9 Recreational landings (in lbs) of southern flounder within the Lower Basin of the St. Johns River from 1982 to 2007.

3.2.8.4. Current Status & Future Outlook

The southern flounder continues to be important recreationally and commercially in the lower St. Johns River. While commercial landings data lacks specific information on southern flounder, they are fairly common in the St. Johns River, and appear to have no short term risk of being overfished along the Florida east coast (FWRI 2006d). However, to help ensure their maintenance, it is important to have a better understanding of the reproductive and life history ecology of populations within the river. Recreationally, flounder can be caught all months of the year. Legal size range is 12 inches with a daily limit of ten fish per person (http://myfwc.com/marine/docs/07FLSalt_webregs.pdf).

3.2.9. *Sheepshead (Archosargus probatocephalus)*

http://myfwc.com/marine/fish/sheepshead.jpg

3.2.9.1. General Life History

Sheepshead are common near-shore and estuarine fish that are very often associated with pilings, docks and jetties. They have a very impressive and strong set of incisor teeth that are used to break apart prey such as bivalves, crabs and barnacles. Adults will migrate offshore during the spring to spawn. Fertilized eggs will develop into larvae offshore and be carried towards the coast by currents primarily driven by the wind. The larvae will enter the mouths of inlets and settle in shallow grassy areas. Developing individuals may reach a maximum length of three feet.

3.2.9.2. Significance

Sheepshead are ecologically, recreationally and commercially important in Northeast Florida. They are important in maintaining the estuarine and coastal food web as both a predator and prey. The commercial fishery is one of the larger ones within the river. Recreationally, sheepshead are highly valued by fisherman in the area for their high food value.

3.2.9.3. Trend

Overall, recreational landings have been stable with occasional fluctuations (Figure 3.10). Landings have been more stable to the north and somewhat decreasing in the south sections of the river (Appendix 3.2.9a). Commercially, landings have been stable yet fluctuating for both sections of the river (Appendix 3.2.9b). However, data from the southern counties most likely includes a significant number of fish caught in the ICW. The FWRI data shows no trend from 2001 to 2005 but does suggest higher number of sheepshead in the north sections of the river (Appendix 3.2.9c).

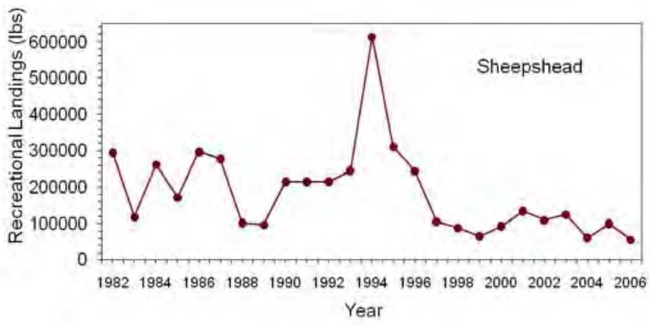


Figure 3.10 Recreational landings (in lbs) of sheepshead within the lower basin of the St. Johns River from 1982 to 2006.

3.2.9.4. Current Status & Future Outlook

Sheepshead continue to be important as both recreational and commercial fisheries. They are common in the St. Johns River, and appear abundant enough along the Florida east coast to produce an adequate number of new fish to the populations at current levels of harvest (Muyandorero, *et al.* 2006). They can be caught all months of the year. Legal minimum size is 15 inches with a daily limit of ten fish per person (http://myfwc.com/marine/docs/07FLSalt_webregs.pdf).

3.2.10. Atlantic Croaker (Micropogonias undulatus)

http://www.floridafishandhunt.com/.../atlcroaker.jpg

3.2.10.1. General Life History

The Atlantic croaker is a bottom-dwelling predator that is commonly encountered around rocks and pilings in estuarine habitats. They are named for the croaking sound they make which is accomplished by raping muscles against their swim bladder. They use their barbells to sense prey such as large invertebrates and fish. Adults will migrate offshore during winter and spring to spawn. Their offspring will develop in the plankton and be transported back inshore, where they will settle in vegetated shallow marsh areas. They grow rapidly and may attain a maximum length of 20 inches.

3.2.10.2. Significance

Croakers are important to the St. Johns area in a number of ways. They are very abundant and consequently extremely important in the food web as both predator and particularly as prey. For many years, their commercial fishery has been one of the biggest in the St. Johns. Additionally, they are recreationally caught for their food value.

3.2.10.3. Trend

Both commercial and recreational croaker landings have been consistent since 1988 (Figure 3.11; Appendix 3.2.10a & b). In both sets of data, landings are lower in the southern sections of the river. The FWRI dataset reflects the same trends from 2001-2005 (Appendix 3.2.10c). However, smaller fish (not accounted for in this study) have been observed in the more freshwater areas of the lower St. Johns River. They appear to transit to estuarine areas of the river as they get larger (Brodie 2008).

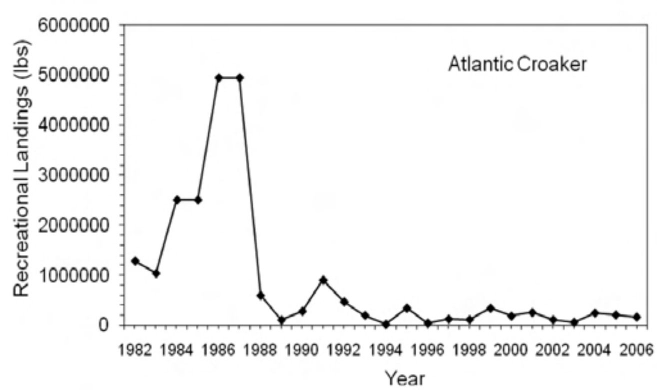


Figure 3.11 Recreational landings (in lbs) of Atlantic croaker within the lower basin of the St. Johns River from 1994 to 2007.

3.2.10.4. Current Status & Future Outlook

Atlantic Croaker are common in the St. Johns River, and continue to be important commercially and recreationally. While there does not appear to be major risk of landings decreasing significantly in the next few years, there has never been a stock assessment performed on any Florida population (FWRI 2006c). Recreationally, they can be caught all months of the year. There is no legal size limit (http://myfwc.com/marine/docs/07FLSalt_webregs.pdf).

3.2.11. Baitfish

http://floridasportfishing.com/magazine/baifish

3.2.11.1. General Life History

Baitfish encompass the multitude of small schooling fish that are the most abundant fishes in the lower St. Johns River. There are at least two dozen baitfish in Florida which include anchovy, menhaden, herring, killifish, sheepshead minnows and sardines. Many of the baitfish species such as Spanish sardines and thread herring are planktivores. However, many may also eat small animals such as crabs, worms, shrimp and fish.

There is high diversity in life history patterns among baitfish species in the lower St. Johns River. However, most migrate seasonally either along the coast and/or away from shore. Many become sexually mature at about one year reproducing by spawning externally at either the mouth of estuaries (menhaden) or offshore (sardines, anchovy). In both cases, larvae hatch out, and are carried by currents to estuaries where the young will eventually join large schools of juvenile and adult fish. In most cases, individuals do not live longer than four years.

3.2.11.2. Significance

Baitfish are very important to the lower St. Johns area. Because they are very abundant, baitfish are extremely important in the food web as prey for a number of larger fish species. They are also important as predators that recycle plant and/or animal material that is then available for higher trophic levels. They are commercially and recreationally caught for their bait value. They are caught for recreational use as bait but also are used commercially in various products such as fertilizers, fish meal, oil and pet food. The primary fisheries in this group are focused on anchovy, menhaden, sardines, and herring (Sea Stats 2000). However, smaller fisheries catch killifish, sheepshead minnows and sardines.

3.2.11.3. Trends

Commercial landings decreased in the mid-1990s and have been highly sporadic since then (Figure 3.13; Appendix 3.2.11). The decrease during the mid-1990s may have been due to the Florida gill net ban. Generally, baitfish landings are lower in the southern sections of the river. There is no data available on the recreational baitfish fishery.

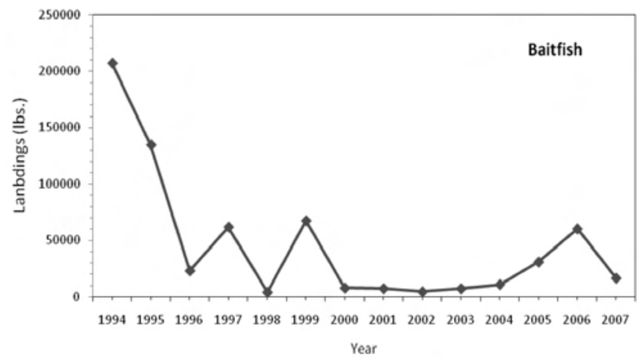


Figure 3.12 Commercial landings (in lbs) of baitfish within the lower basin of the St. Johns River from 1994 to 2007.

3.2.11.4. Current Status & Future Outlook

Baitfish are very abundant in the St. Johns River, and continue to be important commercially and recreationally. They are likely to be sustainable into the foreseeable future. However, true trends are uncertain because of the lack of specific information on the species and location of baitfish reported in the commercial landings data. However, future analysis of data from the ongoing FWRI research program may allow for a more clear understanding of temporal trends of baitfish within the lower St. Johns River. Recreationally, they can be caught all months of the year. There is no legal size limit (http://myfwc.com/marine/docs/07FLSalt_webregs.pdf).

3.3. Invertebrate Fishery

3.3.1. General Description

The invertebrate community is very important to the overall ecology of the LSJRB. It is also important economically for commercial and recreational fisheries. Commercially harvested invertebrates in the lower basin include blue crabs, bait shrimp and stones crabs. Of the five counties studied, Duval County generally reports the highest catch of crabs (generally over 600,000 lbs per year). Recreational fisheries in the area are probably significant for the species mentioned although the level of significance is unclear since there are few reports on recreational landings.

3.3.2. Blue Crab (Callinectes sapidus)

http://www.jacqueauger.com/.../natural/blue_crab.jpg

3.3.2.1. General Life History

The blue crab is a very common benthic predator that inhabits estuarine and near-shore coastal habitats in Northeast Florida. They are general feeders (omnivores) that will eat fish, aquatic vegetation, molluscs, crustaceans and worms (FWRI 2007a). In the St. Johns River, they reproduce from March to July, and then again from October to December (Tagatz 1968b, 1968a). Females carry fertilized eggs and migrate towards the more marine waters near the mouth of the river, where they will release their eggs into the water. At this point, the young are called zoea, and they drift and develop along the continental shelf for 30-45 days. Wind and currents eventually transport the larger megalope back to the estuarine parts of the river where they will settle in submerged aquatic vegetation (SAV) that serves as a nursery for them. Within six to 20 days of landing at this location, the young will molt and become what is a recognizable blue crab. In 12-18 months, young crabs will then become sexually mature, ultimately reaching a width of eight inches.

3.3.2.2. Significance

Blue crabs are very important in both the benthic and planktonic food webs in the St. Johns. They are important predators that can affect the abundance of many macroinvertebrates such as bivalves, smaller crabs, and worms. They are also important prey for many species. Smaller individuals provide food for drum, spot, croaker, Seatrout and catfish, while larger crabs are eaten by sharks and rays.

A strong recreational blue crab fishery exists, although there is relatively little data on it. The blue crab fishery is the largest commercial fishery in the lower St. Johns River. It easily accounts for over 60 percent of commercial fisheries in the river with over one million lbs. harvested annually. Duval County typically reports the highest number of crab landings of the five counties associated with the lower basin of the river with values often over 500,000 lbs harvested annually.

3.3.2.3. Data Sources

Blue crab data was collected from commercial reports (1994 to 2007) of landings made to the state, and research (2001-2005) from the FWRI. There were no available recreational landings data.

3.3.2.4. Limitations

The primary limitation with the commercial landing data is that it does not account for young crabs that are too small to be harvested. Additionally, there may be uncertainties regarding location of where the crabs are collected. For instance, fisherman (crabbers) landings reports are made from their home counties, although it is uncertain what part of the river the crabs were actually caught. Changes in harvesting regulations through the years limit what can be said of landings between certain time periods. In this report, total landings are graphed. However, in order to best assess comparison of landings over the years, landings per trip are calculated, and trends investigated using regression analysis. Graphs using these values are located in the Appendix. In terms of the FWRI data set, the collection methods assessed in this study are likely to not have caught the complete size range of crabs that exist within the river.

3.3.2.5. Trend

Commercial landings of blue crabs have been variable with no upward or downward trend from 1994 to 2007 (Figure 3.13). Additionally, more landings occur in the southern versus northern section of the river (Appendix 3.3.2a). The FWRI data set shows no trend from 2001 to

2005 but does show higher blue crab abundances in the southern sections of the river (Appendix 3.3.2b).

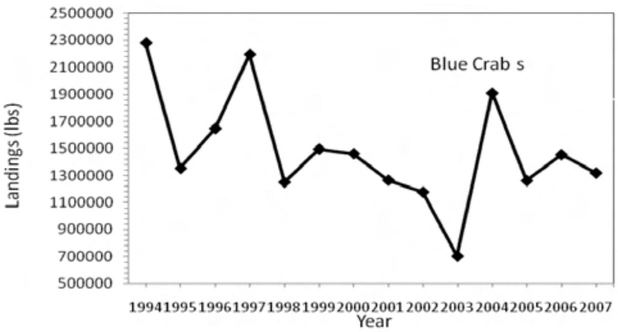


Figure 3.13 Commercial landings (in lbs) of blue crabs within the lower basin of the St. Johns River from 1994 to 2007.

3.3.2.6. Current Status & Future Outlook

The blue crab commercial fishery continues to be the premier invertebrate fishery within the lower basin of the St. Johns River. The recreational fishery is also likely to be very large, although there is no information available on it.

While common within the river, there is uncertainty regarding whether blue crabs are being overfished or not in Florida. This uncertainty is because the maximum age of blue crabs in Florida is not known. Maximum age is one component that is used in a stock assessment model. Depending on the value used, it can affect whether the model suggests crabs are overharvested or not (Murphy, *et al.* 2007). Consequently, this piece of information is needed to more accurately assess blue crab stocks in Florida. Currently, crabs may be caught recreationally using five or fewer traps. Crabs can also be caught (must be in whole condition and not carrying eggs) using dip nets, crab pots, and handlines.

3.3.3. Penaeid shrimp (White, pink & brown) (Litopenaeus setiferus, Farfantepenaeus duorarum & F. aztecus)

3.3.3.1. General Life History

There are three penaeid shrimp species that exist within the estuaries and near-shore waters of the Northeast Florida region. They are the white, pink, and brown shrimp. The white shrimp is the most common species in local waters. All three are omnivorous predators feeding on worms, amphipods, molluscs, copepods, isopods and organic detritus. White shrimp reproduce during April to October, whereas pink and brown shrimp can spawn year round (FWRI 2006a). However, peak spawning for brown shrimp is from February to March and from spring through fall for pink shrimp. All species spawn offshore in deeper waters with larvae developing in the plankton and eventually settling in salt marsh tidal creeks within estuaries. From there, young will develop for approximately two to three months. As they get larger, they start to migrate towards the more marine waters of the ocean where they will become sexually mature when they reach lengths between three to five inches. While they generally do not live long (a maximum 1.5 years), they may reach maximum lengths of up to seven inches.

3.3.3.2. Significance

Penaeid shrimp are very important in both the benthic and planktonic food webs in the St. Johns. They are important predators that can affect the abundance of many small macroinvertebrates (see list above). They are also important prey for many species. As smaller individuals such as post-larvae and juveniles, they provide food for sheepshead minnows, insect larvae, killifish and blue crabs. As adult shrimp, they are preyed on by a number of the finfish found within the river.

The lower St. Johns River supports both recreational and commercial shrimp fisheries. The recreational fishery is likely to be large although there is relatively little information on it. In contrast, the commercial shrimp fishery is one of the largest fisheries in the region. However, most shrimp obtained for human consumption are caught by trawlers offshore. The commercial shrimp trawled for within the lower St. Johns River is a much smaller fishery.

3.3.3.3. Data Sources

Penaeid shrimp data were collected from commercial reportings (1994 to 2007) of total bait shrimp landings (generally collected within the river) made to the State. These data likely include white, brown and pink shrimp, although their relative proportions are unknown. Data was also collected and assessed from research (2001-2006) from the FWRI. There were no available recreational landings data.

3.3.3.4. Limitations

The primary limitation with the commercial landing data is there are uncertainties regarding the location of where shrimp are collected. For instance, shrimp fisherman landings reports are made from their home counties although it is sometimes uncertain what part of the river shrimp were actually caught in. Additionally, changes in harvesting regulations through the years may limit what can be said of landings between certain time periods. In this report, total landings are graphed. However, in order to best assess comparison of landings over the years, landings per trip are calculated, and trends investigated using regression analysis (see Appendices 3.3.3a, b & c). In terms of the FWRI data set, the collection methods assessed in this study may not have caught the complete size range of shrimp that exist within the river.

3.3.3.5. Trend

The commercial bait shrimp data set suggests that penaeid shrimp landings have been variable with no upward or downward trend (Figure 3.15). However, from 2001 to 2007 there have been drastic fluctuations among the years with a peak landings occurring in 2004. Far more bait shrimp are reported in the northern versus southern sections of the lower St. Johns River (Appendix 3.3.3a). The FWRI data also shows no temporal trends, as well as higher abundances in the northern sections of the river for white or pink shrimp (Appendix 3.3.3b & c). However, the low numbers of individuals encountered in their research (most likely because of net type used) make assessment of true temporal trends uncertain.

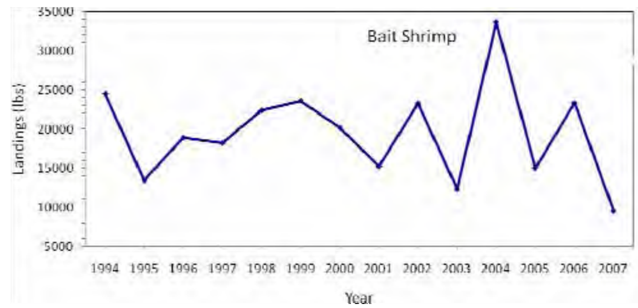


Figure 3.14 Commercial landings (in lbs) of bait shrimp within the lower basin of the St. Johns River from 1994 to 2007.

3.3.3.6. Current Status & Future Outlook

Commercial harvesting of penaeid shrimp is a relatively small fishery in the St. Johns River. The recreational fishery is probably moderately sized, although there is no available data on it. Generally, penaeid shrimp are very abundant in the region. They may be at slight risk of being overfished in the south Atlantic region (see FWRI 2006a for a review). However, the South Atlantic Fishery Management Council and Gulf of Mexico Fishery Management Council have established fishery management plans for shrimp to try to ensure they are not overharvested (FWRI 2006a).

Recreationally, shrimp can be harvested (five gallons per person per day) via dip net, cast net, push net, or one frame net. When fishing from a boat, a license is required and there is a limit of five gallons per day per vessel. The season is closed during April and May (http://myfwc.com/marine/docs/07FLSalt_webregs.pdf).

3.3.4. Stone Crabs (Menippe mercenaria)

http://www.ocean.udel.edu/.../species_stonecr.gif

3.3.4.1. General Life History

The stone crab is a fairly common benthic predator that inhabits hard bottoms (such as oyster reefs) and grass beds in the Northeast Florida area. Stone crabs are opportunistic carnivores feeding on oysters, barnacles, snails, clams, etc. In Florida, stone crabs reproduce from April through September (Muller, *et al.* 2006). It is unclear where stone crabs sexually reproduce, and females will carry eggs for approximately two weeks before the eggs hatch. The larvae will drift in the plankton and settle and metamorphose into juvenile forms of the adult in about four weeks. In approximately two years, the crabs will then become sexually mature and reach a width of 2.5 inches. They may live as long as seven years.

3.3.4.2. Significance

Stone crabs are important predators and prey in the estuarine community in the St. Johns River. As important predators, they can affect the abundance of many macroinvertebrates such as bivalves, smaller crabs, and worms. They are also important prey when both young and old. As larvae in the plankton, they are preyed on by filter-feeding fish, larval fish and other zooplankton. As adults, they are preyed on by many larger fish predators in the river.

The stone crab fishery is unique in that the crab is not killed. The two claws are removed (it is recommended to only take one claw so the animal has a better chance of survival) and the animal is returned to its habitat. While there probably is a recreational stone crab fishery in the area, there is relatively little information on it. The stone crab commercial fishery is relatively new and small in the lower St. Johns River. The highest number of claw landings within the river basin likely come from Duval County. Claw landings from other counties of the lower St. Johns River most likely come from collections made in the Intracoastal Waterway (ICW).

3.3.4.3. Data Sources

Stone crab data were collected from commercial reportings of landings made to the State between 1994 and 2007. There were no available recreational landings data.

3.3.4.4. Limitations

The primary limitation with the commercial landing data is it does not account for young crabs that are too small to be harvested. Additionally, there are uncertainties regarding location of where crab claws are collected. For instance, fisherman (crabbers) landings reports are made from their home counties although the crab claws may have been collected elsewhere. For stone crabs reported by southern counties of the lower basin, it is more likely that the claws were collected in the ICW than the river itself. Additionally, changes in harvesting regulations through the years may limit what can be said of landings between certain time periods. Total landings are shown in this report. However, in order to best assess comparison of landings over the years, landings per trip are calculated, and trends investigated using regression analysis. Graphs using these values are located in Appendix 3.3.4a.

3.3.4.5. Trend

Commercial landings of stone crabs in Florida have been highly variable despite an increase in the number of deployed traps (Muller, *et al.* 2006). In Northeast Florida, peak landings occurred in 2001 and 2007 with low landings occurring from 1998-1999 and 2004-2006 (Figure 3.15). Most landings generally were reported by the more southern counties of the lower St. Johns River basin (Appendix 3.3.4a). However, this is most likely a reflection of crab claws caught in the ICW of the more southern counties than in the river itself. Consequently, landings reported for the north section (Duval County), probably more accurately reflect trends in river. In this area, landings have been somewhat stable during the time period assessed (Appendix 3.3.4a).

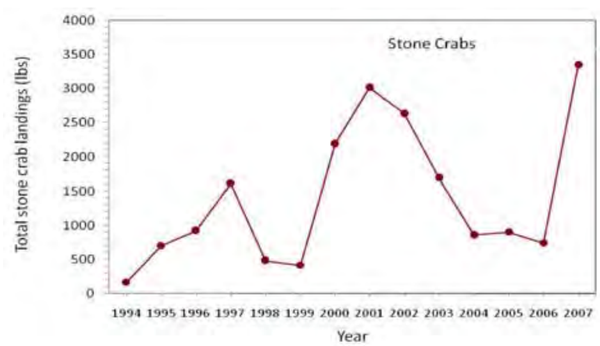


Figure 3.15 Commercial landings (in lbs) of stone crab claws within the lower basin of the St. Johns River from 1994 to 2007.

3.3.4.6. Current Status & Future Outlook

Stone crabs are not currently at risk of being overfished but are probably now at a level of landings that is all that can be harvested under current conditions along the Florida east coast (Muller, *et al.* 2006). To minimize negative impacts from commercial fisherman, the Florida state legislature implemented a crab trap reduction program in 2002. Currently, there is a daily limit of one gallon of minimum-sized 2 ¾-inch claws from non-egg carrying crabs. The season is closed from from May 16 to October 14 (http://myfwc.com/marine/docs/07FLSalt_webregs.pdf).

4. AQUATIC LIFE

4.1. Submerged Aquatic Vegetation (SAV)

4.1.1. Description

Dating back to 1773, records indicating that extensive Submerged Aquatic Vegetation (SAV) beds have existed in the river are mentioned in Bartram 1928. Since that time, people have altered the natural system by dredging, constructing seawalls, contributing chemical contamination, and sediment and nutrient loading (DeMort 1991; Dobberfuhl 2007).

Submerged aquatic macrophytes (aquatic plants, growing in or near water that are emergent, submergent, or floating) found in the LSJRB are primarily freshwater and brackish water species. Commonly found species include: tape grass (*Vallisneria americana*), wigeon grass (*Ruppia maritime*), sago pondweed (*Potamogeton pectinatus*) and coontail (*Ceratophyllum demersum*). Tape grass and wigeon grass are submerged grasses which form extensive beds when conditions are favorable. Tape grass is a freshwater species that tolerates brackish conditions, while wigeon grass is a brackish water species (White, *et al.* 2002). Other freshwater species include: muskgrass (*Chara* spp.); spikerush (*Eleocharis* sp.); water thyme (*Hydrilla verticillata*, an invasive non-native weed); baby's-tears (*Micranthemum* sp.); southern naiad (*Najas guadalupensis*); small pondweed (*Potamogeton pusillus*); awl-leaf arrowhead (*Sagittaria sublata*) and horned pondweed (*Zannichellia palustris*)(IFAS 2007; Sagan 2006; USDA 2007). DeMort 1991 surveyed four locations for submerged macrophytes in the Lower St. Johns River and indicated that greater consistency in species occurred south of Hallowes Cove (St. Johns County) with tape grass being the dominant species. North of this location wigeon grass and sago pondweed were the dominant species; however, tape grass coverage increased 30% from 1982-1987.

The greatest distribution of submerged macrophytes in Duval County is in waters south of the Fuller Warren Bridge (Kinnaird 1983aSubmerged aquatic vegetation in the tannin-rich, black water LSJR is found exclusively in four feet or less of water depth. Poor sunlight penetration prevents the growth of SAV in deeper waters. Dobberfuhl 2007 confirmed that the deeper outer edge of the grass beds occurs at about three feet in the LSJRB. Rapid regeneration of grass beds occurs annually in late winter and spring when water temperatures become more favorable for plant growth and is robust from April through September (Dobberfuhl 2007; Thayer, *et al.* 1984).

Submerged vegetation provides nurseries for a variety of aquatic life, helps to prevent erosion, and reduces turbidity by trapping sediment. Sunlight is vital for good growth of submerged grasses. Sunlight penetration may be reduced because of increased turbidity, pollution from upland development and/or disturbance of soils. Deteriorating water quality has been shown to cause a reduction in the amount of viable, submerged vegetation. This leads to erosion and further deterioration of water quality. Tape grass grows well from 0-12 parts per thousand of salinity and can tolerate waters with salinities up to 15-20 parts per thousand for short periods of time (Twilly and Barko 1990). Also, SAV requires more light in a higher salinity environment because of increased metabolic demands (Dobberfuhl 2007). Evidence suggests that greater light availability can lessen the impact of high salinity effects on SAV (French and Moore 2003; Kraemer, *et al.* 1999). Dobberfuhl 2007 noted that, during drought conditions, there is an increase in light availability that likely causes specific competition between the grasses and organisms growing on the surface of the grasses. Too many of these epiphytic organisms block light and can be detrimental to normal growth of the tape grass. As a result, this fouling causes an increase in light requirements for the SAV (Dunn, *et al.* 2008).

4.1.2. Significance

SAV is important ecologically and economically to the LSJRB. SAV persists year round in the LSJRB and forms extensive beds which carry out the ecological role of “nursery area” for many important invertebrates and fish species, including the endangered West Indian manatee (*Trichechus manatus*) (White, *et al.* 2002). Commercial and recreational fisheries, including largemouth bass, catfish, blue crabs and shrimp, are sustained by healthy SAV habitat (Watkins 1995). Sagan 2006 noted that SAV adds oxygen to the water column in the littoral zones (shallow banks), takes up nutrients that might otherwise be used by bloom-forming algae or epiphytic algae (plants that grow on top of other plants), reduces sediment suspension, and reduces shoreline erosion. Scientists have used SAV distribution and abundance as major indicators of ecosystem health (Dennison, *et al.* 1993).

Over the years dredging to deepen the channel for commercial and naval shipping has led to some salt water intrusion upstream. Further deepening could be detrimental to the grass beds especially if this were to occur in conjunction with a water withdrawal.

Manatees consume from four to 11% of their body weight in SAV daily (Bengtson 1981; Best 1981; Burns Jr, *et al.* 1997; Lomolino 1977). Fish and insects forage and avoid predation within the cover of the grass beds (Batzer and Wissinger 1996; Jordan, *et al.* 1996). For example, Jordan 2000 mentioned that SAV beds in the Lower Basin have three times greater fish abundance and 15 times greater invertebrate abundance than do adjacent sand flats.

4.1.3. Data Sources & Limitations

The SJRWMD conducts year-round sampling of SAV at numerous stations along line transacts of St. Johns River that are about 1.25 miles apart (1998-2006). The routine field sampling performed does not lend itself to real coverage estimates but only provides for inter-annual relative change analysis by site or region. For maps of the transect locations see Appendix: 4.1.7.1.A-D.

The parameters used were (1) Grass bed length, (2) Shannon-Weiner Diversity Index, (3) Total percent cover and (4) Proportional percent covered by tape grass. The data set includes one of the most intense El Nino years (1998) followed by one of the most intense drought periods (1999-2001) in Florida history, which exaggerates the normal cycle. Also, the data tends to be biased by the fact that grass length on western shorelines is longer than that which grows on eastern shore lines. Therefore, the shore-to-shore bias would be most pronounced in Clay-western shore sites and St. Johns-eastern shore sites (Dobberfuhl 2008).

Salinity data was provided by the Environmental Quality Division, City of Jacksonville. Water quality parameters are measured monthly at ten stations in the main stem of the St. Johns River at the bottom, middle and surface depths. These data are presented in the endangered species section under manatees (Figure 4.10).

4.1.4. Current Status

The section of the St. Johns River north of Palatka had relatively stable trends with normal seasonal fluctuations, with regards to the following parameters: (1) Grass bed length, (2) Shannon-Weiner Diversity Index, (3) Total percent cover and (4) Proportional percent covered by tape grass (Appendix: 4.1.7.2.A-D). Initially, a declining trend in all the same parameters was apparent south of Palatka and in Crescent Lake (Appendix: 4.1.7.2.E-F). However, the most recent data suggests that the trend is increasing again (Dobberfuhl 2008).

The availability of tape grass decreased significantly in the LSJRB during 2000-2001, because the drought caused higher than usual salinity values. In 2003, environmental conditions returned to a more normal rainfall pattern. As a result, lower salinity values favored tape grass growth again. In 2004, salinities were initially higher than in 2003 but decreased significantly after August with the arrival of heavy rainfall associated with four hurricanes that skirted Florida (Hurricanes Charley, Francis, Ivan and Jeanne). Grass beds north of the Buckman Bridge regenerated from 2002-2006 and then declined again in 2007 due to the onset of renewed drought conditions (White and Pinto 2006a). Declining SAV in the river south of Palatka and Crescent Lake is highly influenced by runoff and consequent increases in color of the water. More recent data, not as yet available for this report, suggest that the SAV in this area is rebounding and relatively stable (Dobberfuhl 2008).

4.1.5. Future Outlook

Continuation of long-term monitoring of SAV is essential to detect changes over time. Grass bed indices, along with water quality parameters, should be used to determine restoration goals for the health and state of the habitat available to invertebrates, fish, wildlife and people that rely on the resource for food, shelter and livelihood. Moreover, further indices of the health and status of grass beds should be developed that express the economic value of the resource as it pertains to fisheries and other quality of life indices such as aesthetics, recreation, and public health.

SAV response to drought and/or periods of reduced flow can provide crucial understanding as to how a water withdrawal and/or the issue of future sea level rise will affect the health of the ecosystem by adversely altering salinity profiles.

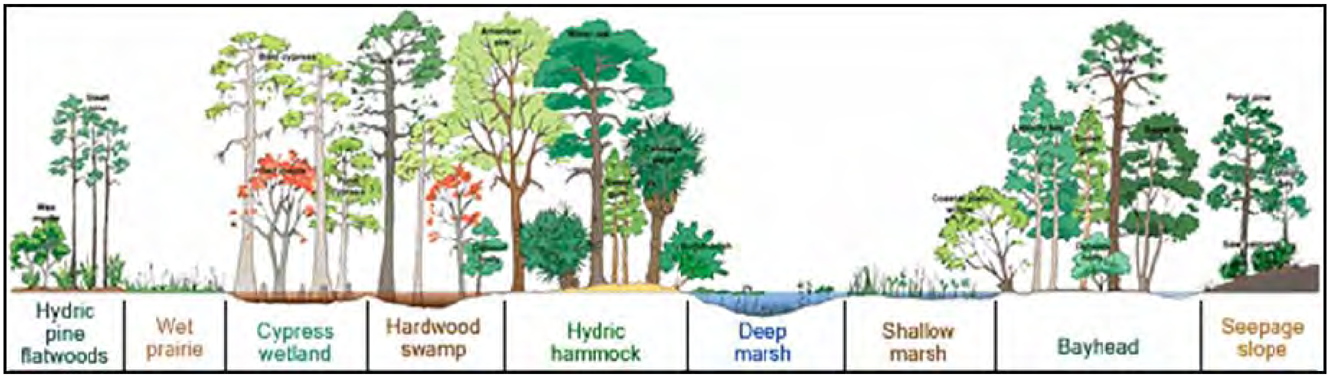


Figure 4.1 Types of wetlands common within the Lower St. Johns River Basin.(Illustration: SJRWMD StreamLines Publication, Spring 2006)

4.2. WETLANDS

4.2.1. Description

Wetlands are areas that are partially or periodically inundated with water (Myers and Ewel 1990). Wetland vegetation types in the LSJRB include freshwater marshes, bayheads, bogs, riverine hardwood swamps, cabbage palm savannahs, coastal hammocks, cypress domes, wet prairies, salt marshes, and similar areas (Figure 4.1).

4.2.2. Significance

Wetlands perform a number of crucial ecosystem functions including assimilation of nutrients and other non-point source pollutants from upland sources. Additionally, recent studies have shown that wetlands serve as natural flood mitigation devices, minimize local flooding, and, thereby, reduce property loss and the external cost of floods to communities. A study examining wetland permits granted by the Army Corps of Engineers in Florida between 1997 and 2001 determined that "one wetland permit increased the average cost of each flood in Florida by $989.62" (Brody, *et al.* 2007). Wetlands also provide nursery grounds for many commercially and recreationally important fish, supply refuge, nesting, and forage areas for migratory birds, bank stabilization, and habitat for a wide variety of aquatic and terrestrial wildlife (Meffe and Carroll 1997; Mitsch and Gosselink 2000).

Extensive, functional wetlands are essential for both saltwater fishing and wildlife viewing. Studies have estimated that the economic value of such wildlife-related recreation in Northeast Florida (Duval, St. Johns, Clay, and Putnam Counties) is in the range of $700 million per year (Kiker and Hodges 2002). The activities with the greatest economic value to Northeast Florida are recreational saltwater fishing ($301.6 million per year), followed by wildlife viewing ($226.5 million per year).

4.2.3. Data Sources

4.2.3.1. Data Sources for Wetland Spatial Trends

A total of nine GIS (Geographic Information System) maps that contain data on wetlands vegetation were available and analyzed. The GIS maps were created by either the Department of Interior U.S. Fish & Wildlife Service or the SJRWMD from high-altitude aerial photographs (color infrared or black-and–white photos) with varying degrees of consideration of soil type, topographical and hydrologic features, and ground-truthing. Each parcel of land or water was outlined and assigned a category, creating distinct polygons for which area (i.e., number of acres) can be calculated. These areas were used to calculate wetland and land/water totals within the LSJRB for each year available (Table 4.1).

4.2.3.2. Data Sources for Wetland Permit Trends

Within the LSJRB, there are two governmental entities that grant permits for the destruction, alteration, and mitigation of wetlands: 1) SJRWMD, and 2) U.S. Army

Corps of Engineers (USACE). The differing regulatory definitions of wetlands used by Federal and State agencies are outlined in Appendix 4.2.A.

The wetland permit analysis conducted for this report reveals how the acreage of wetlands has changed over time according to the historical wetland permits granted through the SJRWMD Environmental Resource Permitting Program. Records of permits granted by the USACE were not analyzed for this report.

Table 4.1. Comparison of Wetland Maps - Lower St. Johns River Basin, Florida.

GIS MAP ANALYZED	TOTAL WETLAND AREA IN LSJRB (ACRES)	TOTAL LAND/WATER AREA IN LSJRB (ACRES)
Just-released National Wetlands Inventory map (produced from 1977-2006 lumped data, produced by Dept. of Interior U.S. Fish & Wildlife, available from Florida Geo Data Library)	5,572,098 Erroneous result - unknown problems with freshwater wetlands data.	5,595,239 ACRES INCLUDING DEEPWATER. Erroneous result - there are only about 1,800,000 acres total in LSJRB.
SJRWMD-corrected National Wetlands Inventory map (produced from 1971-1992 lumped data, processed by SJRWMD in 2001, 2003)	727,631	849,512 ACRES INCLUDING DEEPWATER. Non-wetland upland acres not specified in this map.
SJRWMD Wetland & Deep Water Habitats map (based on National Wetlands Reconnaissance Survey maps from 1972-1980, processed 1996 by SJRWMD, dated 2001)	870,576	3,110,209
SJRWMD Wetlands & Vegetation Inventory map (based on District's Wetlands Mapping Project 1984-2002, finished 2002, accuracy of wetland boundaries estimated at 80-95%)	441,072	2,208,172
SJRWMD Land Use/Land Cover map (based on 1973 data)	440,048	2,100,552
SJRWMD Land Use/Land Cover map (based on 1990 data)	435,662	2,605,247
SJRWMD Land Use/Land Cover map (based on 1995 data)	450,595	1,910,422
SJRWMD Land Use/Land Cover map (based on 2000 data)	444,467	1,851,447
SJRWMD Land Use/Land Cover map (based on 2004 data)	451,702	1,868,003
** Lumped dates for maps result from the consolidation of aerial photographs taken during different years.*		** 1.8 million acres is considered the accurate area of the LSJRB (according to the SJRWMD). Demonstrates that maps are not statistically comparable for total wetland area.*

4.2.4. *Limitations*

4.2.4.1. Limitations of Wetland Spatial Analyses

The identification of vegetation type from an aerial photograph is an imperfect process, and any errors generated during the initial phases of GIS map production are perpetuated in this report. The metadata associated with the SJRWMD Wetlands & Vegetation Inventory map estimates the margin of error in wetlands delineation from aerial photographs to vary according to the type of vegetation being identified and range from five to 20% (SJRWMD 2007c). The metadata states: "The main source of positional error, in general, is due to the difficulty of delineating wetland boundaries in transitional areas. Thematic accuracy: correct differentiation of wetlands from uplands: 95%; correct differentiation of saline wetlands from freshwater or transitional wetlands: 95%; correct differentiation of forested, shrub, herbaceous, or other group forms: 90%; correct differentiation of specific types within classes: 80%. Accuracy varies for different locations, dates, and interpreters.

In addition to interpretation errors, wetland maps do not accurately reflect wetlands habitats that vary seasonally or annually (e.g., the spatial extent of floating vegetation or cleared areas can be dramatically different depending on the day the aerial photo was taken). Aerial photographs pieced together to create wetlands maps may be of different types (high altitude vs. low altitude, color infrared, black-and-white, varying resolutions and varying dates). Sometimes satellite imagery is used to create wetlands maps, which is considered less accurate for wetland identification (USGS 1992).

Analyses are further limited by inconsistencies and shortcomings in the wetland classification codes used (e.g., wetland codes used in the SJRWMD Land Use/Land Cover map of 1973 were markedly different than codes used since 1990). Additionally, wetland classification codes do not always address whether a wetland area has been diked/impounded, partially drained/ditched, excavated, or if the vegetation is dead (although the National Wetlands Inventory adds code modifiers to address the impacts of man). Further, wetland mapping classification categories often do not differentiate between natural and manmade wetlands. For example, naturally occurring freshwater ponds may be coded identically with ponds created for storm water retention, golf courses, fishing, aesthetics, water management, or aquaculture. Some maps classify drained or farmed wetlands as uplands, while others classify them as wetlands. An unknown number of additional discrepancies may exist between maps.

Lastly, most of the spatial information in wetlands maps has not been ground-truthed or verified in the field, but is based on analyses of aerial photographs and other maps.

4.2.4.2. Limitations of Wetland Permit Analyses

A shortcoming of the records of wetlands impacted through regulatory permitting processes is that they do not address total wetland acres in the region. Permit records only attempt to report the relative gain/loss of wetlands each year.

Additionally, acres recorded as mitigated wetlands do not always represent an actual gain of new wetland acres (e.g., mitigation acres may represent preexisting wetlands in a mitigation bank or formerly existing wetland acres that are restored or enhanced). Thus, a true net change in wetlands (annually or cumulatively) cannot be calculated from permit numbers with certainty.

Further, changing environmental conditions require that field verification of mitigated wetlands occur on a regular basis over long time periods. The actual spatial extent, functional success, health of vegetation, saturation of soil, water flow, etc. of mitigated wetlands can change over time. On-ground site visits can verify that the spatial extent of anticipated wetlands impacted (as recorded on permits) equals actual wetlands impacted and confirm the ecological functionality of mitigated wetlands.

The wetland permit analyses presented in this report are limited, because: 1) the analyses include all wetland permits granted within the entire SJRWMD region (time did not permit an extraction of only those permits that fall within the LSJRB boundaries), and 2) the analyses do not include the wetland gains and losses as granted by the USACE. The historical records of USACE permits will be analyzed for the second River Report.

Although there are considerable limitations associated with the analysis of wetland permit records, they may be a more accurate tool to assess the status and trends of wetlands in the LSJRB than wetlands GIS maps. Permit records will be the focus of the wetlands analyses in the second River Report.

4.2.5. *Current Status*

4.2.5.1. Current Status of Wetlands in the Lower Basin

The conclusions on the current status of wetlands in the LSJRB that can be gleaned from GIS maps are limited. Total wetland acres in the LSJRB cannot be determined with certainty from available data. The high margin of error associated with the delineation of wetlands from aerial photographs renders the wetlands maps unsuitable for total acreage calculations (see differences in total wetlands areas and total land/water areas calculated from maps listed in Table 4.1).

Based on one wetlands map (thought to be most accurate and complete for this kind of information), 83% of all wetlands and deepwater habitats in the LSJRB are freshwater, and three percent are estuarine and marine wetlands (Figure 4.2, based on SJRWMD-corrected National Wetlands Inventory Map). Freshwater wetlands are dominated mostly by freshwater forests, followed by freshwater unconsolidated bottoms and shores (ponds).

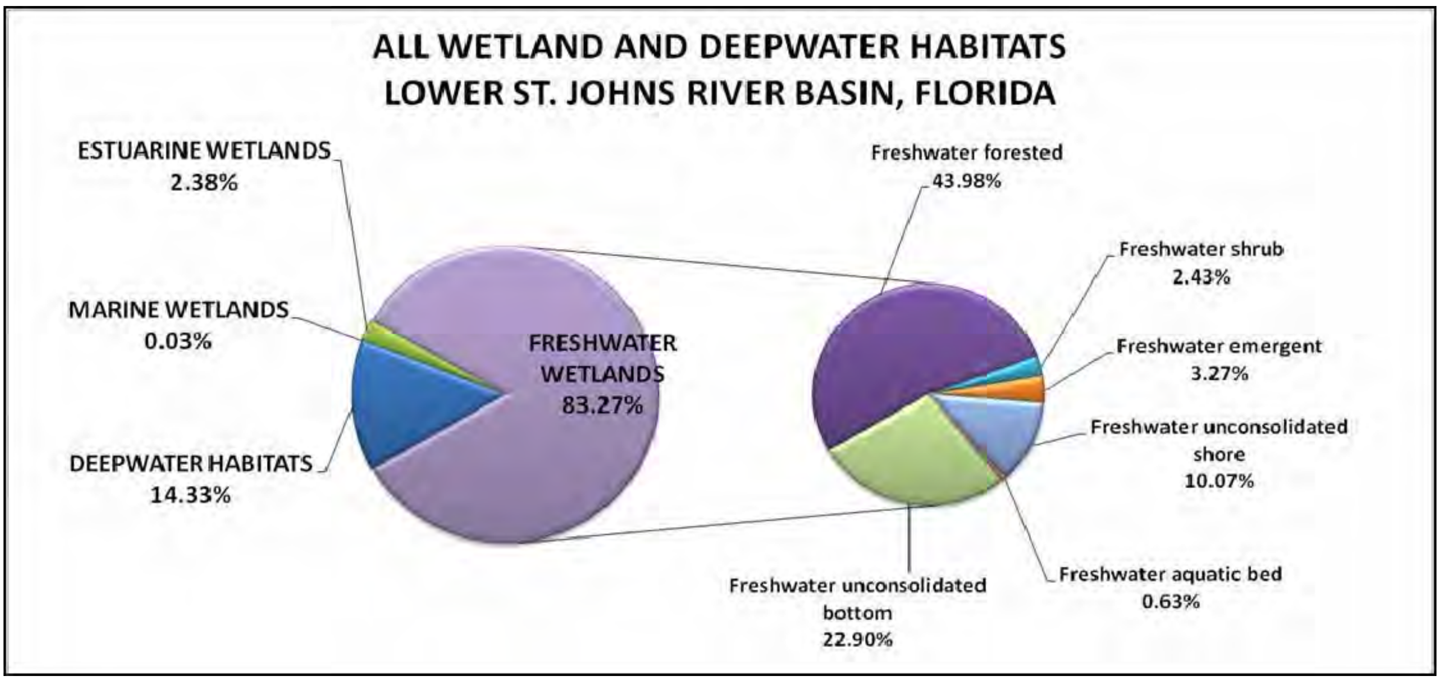


Figure 4.2 The percentages of each wetland type in the Lower St. Johns River Basin, Florida (Source: SJRWMD-corrected National Wetlands Inventory Maps, 1971-1992

4.2.6. *Historical Perspective of the Wetland Status*

Although wetlands maps do not reveal (with any statistical certainty) how many acres of wetlands in the LSJRB have been gained or lost over time, there are historical records in the literature that estimate how many wetland acres have been lost throughout the state of Florida over time. A discussion of wetland status in the LSJRB is incomplete without an evaluation of wetlands within a historical context.

A literature search was conducted to compile comparable and quantifiable estimates of historical wetland change over time. Because data occurring within just the Lower Basin could not be extracted from statewide data, information for the whole state of Florida is compiled in Appendix 4.2.B. and explained below.

4.2.6.1. Historical Data on Florida's Wetlands.

Prior to 1907, there were over 20 million acres of wetlands in Florida, which comprised 54.2% of the state's total surface area (Figure 4.3). By the mid-1950s, the total area of wetlands had declined to almost 15 million acres. The fastest rate of wetland destruction occurred between the 1950s and 1970s, as the total area of wetlands dropped down to 10.3 million acres. Since the mid-1970s, total wetland area in Florida appears to have risen at a slight rate. Net increases in total statewide wetlands are attributed to increases in freshwater ponds, such manmade ponds created for fishing, artificial water detention or retention, aesthetics, water management, and aquaculture (Dahl 2006).

The average of all compiled wetlands data in Florida revealed that the state retained a total of 11,371,900 acres by the mid-1990s (occupying 30.3% percent of state's surface area). This translates into a cumulative net loss of an estimated 8,940,607 acres of wetlands in Florida since the early 1900s (a loss of 44% of its original wetlands).

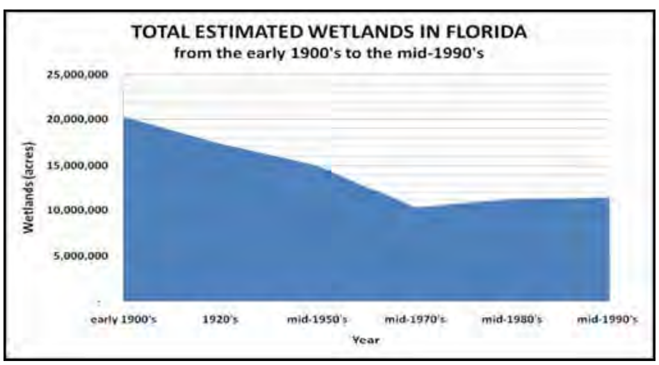


Figure 4.3 Total estimated wetlands per generalized time period in Florida.Based on averages calculated from a literature search (complete data table with references in Appendix 4.2.B.)

4.2.6.2. Historical Data on Wetlands in the LSJRB

Some literature references and anecdotal evidence suggest incomplete, but notable, trends in wetlands within Florida and or certain sections of the LSJRB.

- In Florida, the conversion of wetlands for agriculture, followed by urbanization, has contributed to the greatest wetland losses (Dahl 2005).
- The Upper Basin (the marshy headwaters of the St. Johns River) has experienced substantial historical wetland loss, and by 1983, it was estimated that only 65% of the original floodplain remained (SJRWMD 2000).
- Dahl 2005 states "modest estuarine salt marsh gains were observed in the counties of ... Duval and St. Johns counties" between 1985 and 1996.
- Hefner 1986 state that "over a 50-year period in Northeast Florida, 62 percent of the 289,200 acres of wetlands in the St. Johns River floodplain were ditched, drained, and diked for pasture and crop production (Fernald and Patton 1984)."
- According to FDEP 2002 "the 1999 District Water Management Plan notes seven to 14 percent losses of wetlands in Duval County from 1984 to 1995, according to National Wetlands Inventory maps."

Because a decrease in wetlands has been documented throughout Florida, the current status of wetlands in Florida is considered UNSATISFACTORY. Because such losses cannot be calculated with certainty for just the LSJRB, the current status of wetlands in the LSJRB is considered UNCERTAIN.

4.2.7. *Current Trend*

The only sequential, time-series spatial data on wetlands within the LSJRB are contained within Land Use/Land Cover maps from the SJRWMD (dated 1973, 1990, 1995, 2000, and 2004).

4.2.7.1. Trend in Total Wetlands Acreage

Acres per year of wetlands derived from the SJRWMD Land Use/Land Cover maps are not comparable enough or statistically robust enough to establish trends in total wetland acreage over time. The lack of comparability between the years stems from differences in the techniques, scale, and wetlands interpretation. The lack of statistical strength stems from a number of problems associated with the data, most importantly is the small sample size (n=5). Therefore, the current trend in total wetland acreage within the LSJRB is considered UNCERTAIN.

4.2.7.2. Trends in Wetland Vegetation

Although the total wetland acreage cannot be statistically compared from year to year, the relative contribution of different wetland types can be statistically compared with an acceptable degree of reliability. These comparisons attempt to assess how the quality of wetlands in the LSJRB might have changed over time.

Most categories of wetlands used in the SJRWMD Land Use/Land Cover maps were not consistent over the years. Notably, the categories used in 1973 were markedly different from the categories used in the 1990-2004 maps. In order to statistically compare between wetland types, categories were consolidated into several levels of groupings (see Appendix 4.2.C.).

When wetland codes are grouped into two broad categories (forested wetlands and non-forested wetlands), significant trends are noted. There appears to have been a shift in the composition of wetland communities over time from forested to non-forested wetlands (Figure 4.4). Forested wetlands comprised 91% of the total wetlands in 1973, and constituted only 75% of total wetlands in 2004 (see Table 4.2).

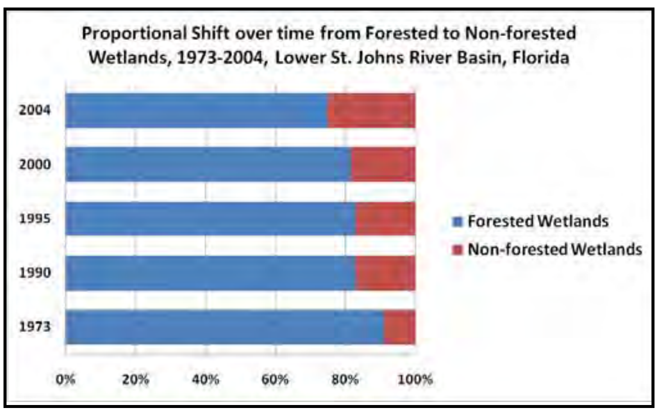


Figure 4.4 Percent of Forested Wetlands and Non-forested Wetlands in the Lower St. Johns River Basin based on Land Use/Land Cover Maps (SJRWMD).

Table 4.2. Yearly Total of Forested Wetlands, Non-forested Wetlands, and Total Wetlands in the Lower St. Johns River Basin based on Land Use/Land Cover Maps (SJRWMD 2007c).

WETLAND CATEGORY	LAND AREA (acres) (% of total)				
	1973	1990	1995	2000	2004
Forested Wetlands	400,060 (91%)	360,937 (83%)	373,568 (83%)	362,071 (81%)	336,898 (75%)
Non-forested Wetlands	39,988 (9%)	74,725 (17%)	77,027 (17%)	82,396 (19%)	114,804 (25%)
Total Wetlands	440,048 (100%)	435,662 (100%)	450,595 (100%)	444,467 (100%)	451,702 (100%)

Non-parametric statistics were used to examine whether the proportion of forested versus non-forested wetlands was significantly different between sequential years (Chi-Square Goodness-of-Fit Test results provided in Appendix 4.2.D.). The differences between the years were *statistically significant at the 0.05 level* for all years, except between 1990 and 1995.

Furthermore, regression analyses also revealed that the observed increase in non-forested wetlands was statistically significant at the 0.05 level (r2 = 0.88, p-value = 0.019). The decrease in forested wetlands was also statistically significant at the 0.05 level (r2 = 0.81, p-value = 0.028; regression plots in Appendix 4.2.E.).

Both of these types of statistical analyses are provided as support that the shift from forested to non-forested wetlands is a significant 30-year trend (according to the SJRWMD Land Use/Land Cover maps analyzed).

Supplemental graphs are provided in Appendices 4.2.F. and 4.2.G. These graphs examine how additional finer categorical groupings of wetlands appear to have changed over time (no significant trends).

4.2.8. Wetland Permit Trends

4.2.8.1. <u>Trends in Wetland Acreage Impacted/Mitigated</u>

According to the Environmental Resource Permits granted by SJRWMD during the fiscal years examined, annual losses (acres of wetlands negatively impacted) and gains (acres of wetland mitigation required) have both increased over time (Figure 4.5; Appendix 4.2.H.; SJRWMD 2006). That is, wetlands are being mitigated (i.e., created, restored, enhanced, or preserved in upland/wetland areas) at a rate greater than they are being destroyed.

The increasing trend for wetlands impacted was *statistically significant at the 0.001 level* (r^2 = 0.93, p-value = 0.0000017). Likewise, the increasing trend for total wetlands mitigation was also *statistically significant at the 0.001 level* (r^2 = 0.93, p-value = 0.0000017). Regression plots for both are provided in Appendix 4.2.I.

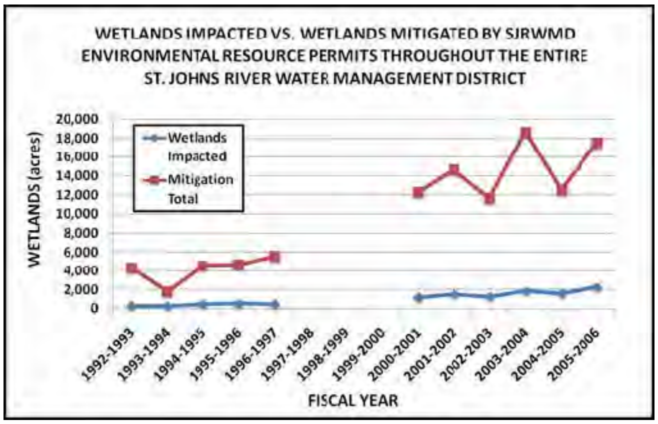


Figure 4.5 The acres of wetlands impacted and mitigation required by the SJRWMD Environmental Resource Permitting Program throughout the entire SJRWMD.

The effects of the permitting process on wetlands are generally permanent changes. In fact, permits usually require that mitigation be sustained in perpetuity. Because changes build upon one another, it may be more appropriate to view annual data cumulatively, rather than year-to-year (Figure 4.6 displays the cumulative impacts since Fiscal Year 2000-2001).

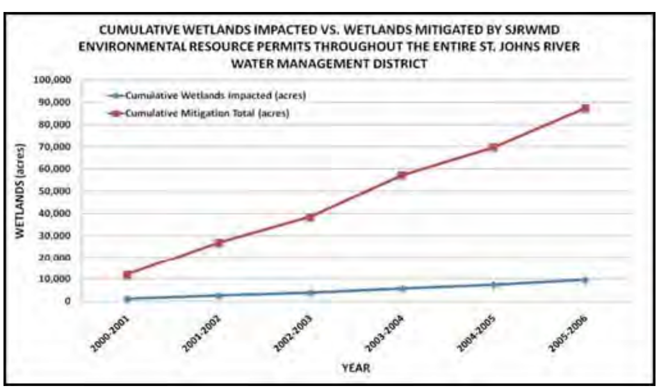


Figure 4.6 The cumulative wetlands impacted and mitigated by the SJRWMD Environmental Resource Permitting Program throughout the entire SJRWMD from Fiscal Year 2000-2001 to Fiscal Year 2005-2006.

As expected, cumulative increases in both wetlands impacted and wetlands mitigated are highly significant trends. The increasing trend of cumulative wetlands impacted was *statistically significant at the 0.001 level* (r^2 = 0.992, p-value = 0.00002). The increasing trend of cumulative wetlands mitigated was *statistically significant at the 0.001 level* (r^2 = 0.997, p-value = 0.000004).

4.2.8.2. <u>Trends in Wetland Mitigation</u>

According to SJRWMD permit records, the methods used to mitigate wetlands have changed over time (Figure 4.7). During the early 1990s, wetland areas were most commonly mitigated by the creation of new wetlands or through wetland restoration. During the 2000s, very few wetlands were created or restored—most mitigation occurred through the preservation of uplands/wetlands.

Some of this preservation of uplands/wetlands has occurred in mitigation banks. Wetland mitigation banks are designed to compensate for unavoidable impacts to wetlands that occur as a result of Federal or state permitting processes (NRC 2001). In 2007, there were six FDEP-approved mitigation banks with service areas that fall within the LSJRB boundaries (Table 4.3). The SJRWMD may allow the purchase of compensatory mitigation credits from a mitigation bank to offset impacts of a permitted activity. Ecological assessment techniques are used to certify that those credits provide the ecological functions that they are intended to replace. The price that a permit-holder pays varies by bank and time. For example, in October 2007, SJRWMD approved the Florida Department of Transportation (FDOT) to purchase 55 mitigation bank credits from the East Central Florida Mitigation Bank at a purchase price of $32,000 per credit with up to ten additional credits for $38,000 each for unexpected impacts (SJRWMD 2007c).

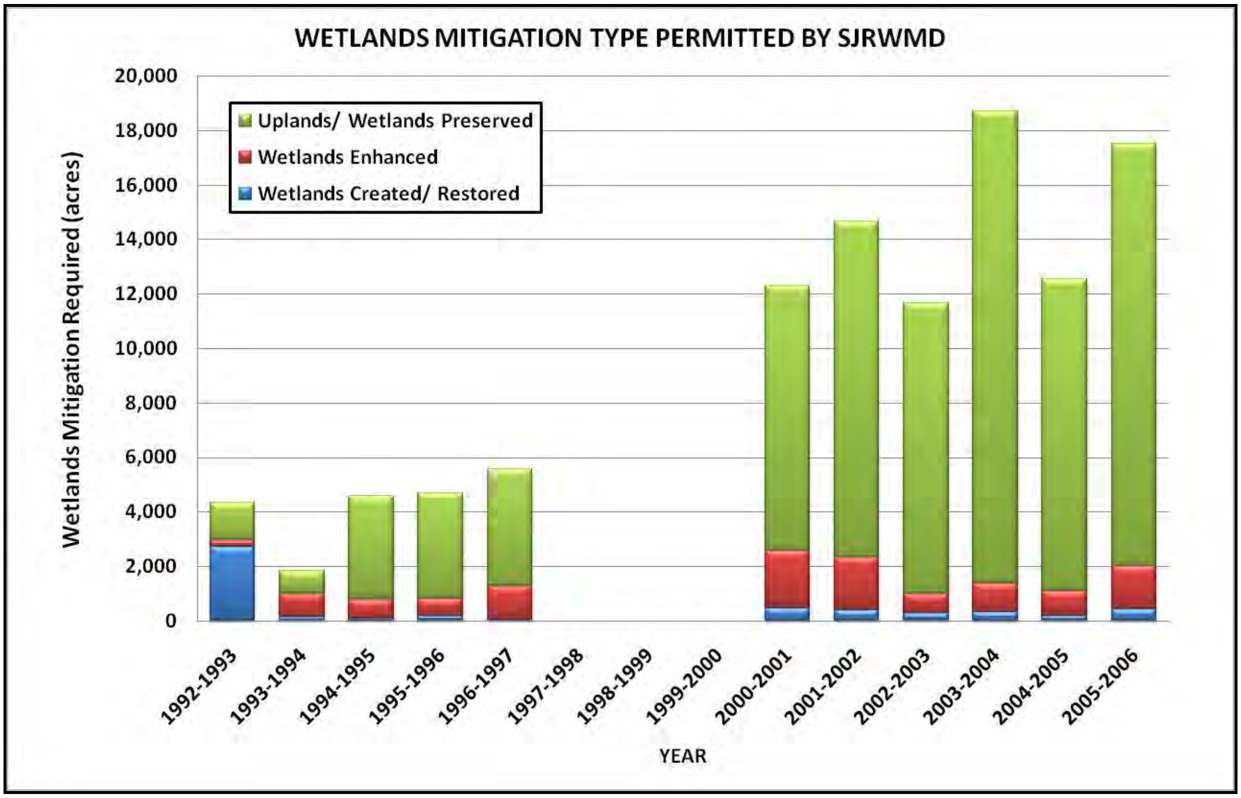


Figure 4.7 The types of mitigation permitted through the SJRWMD Environmental Resource Permitting Program throughout the entire SJRWMD from Fiscal Year 2000-2001 to Fiscal Year 2005-2006 (some data missing due to SJRWMD database problems).

Table 4.3. Wetland Mitigation Banks in Northeast Florida (Source: FDEP 2005).

MITIGATION BANK NAME	ACREAGE	CREDIT TYPE, POTENTIAL CREDITS FOR SALE	COUNTIES of SERVICE AREA
Barberville Conservation Area Mitigation Bank	366 acres (in Volusia County)	Freshwater herbaceous/ forested, 84.3	Volusia, Flagler, Putnam, Marion, Lake
Northeast Florida Wetland Mitigation Bank	630 acres (in Duval County)	Freshwater, 371.6	Duval, Nassau
Longleaf Mitigation Bank	3,017 acres (in Nassau County)	Freshwater, 813.8	Nassau, Baker, Duval
Loblolly Mitigation Bank	6,247 acres (in Duval County)	Freshwater, 2,034.0	Duval, Baker, Clay, St. Johns
Tupelo Mitigation Bank	1,525 acres (in St. Johns County)	Freshwater, 459.7	St. Johns, Duval, Clay
Sundew Mitigation Bank	2,104 acres (in Clay County)	Freshwater, 698.0	Clay, St. Johns, Putnam

4.2.9. Future Outlook

WETLANDS IMPACTS DATABASE NEEDED. During the development of this report, it became clear that wetlands data for Northeast Florida is disconnected, incomplete, and has not been recorded with the precision needed to accurately assess trends over time. It is not even possible to determine with statistical certainty whether the total acres of wetlands in the LSJRB has gone up or down during recent decades. One consolidated database pulling together records of wetlands permits granted by both State and Federal agencies is needed. Such a database could be available online and be queried by the public, so they can see when, where, and how wetlands are being impacted and mitigated. Additionally, project-specific and/or summary reports could be provided to local, State, and Federal agencies which play an advisory or decision-making role in wetlands permitting and management.

HIGH VULNERABILITY. Many remaining wetlands are susceptible to alteration and fragmentation due to growing population pressures in Northeast Florida. The total spatial extent of wetlands negatively impacted through the SJRWMD permit process is increasing each fiscal year. These impacts are magnified by the addition of wetland alteration permitted by the USACE (these permits were not evaluated in this study). This might represent a cumulative, gradual loss of wetland ecosystem functions. Additionally, the environmental consequences of the gradual shift from forested wetlands to non-forested wetlands require attention and further study.

QUESTIONABLE QUALITY. Further investigation is needed to determine the quality and longevity of mitigated wetlands and their ability to actually perform the ecosystem functions of the wetlands they “replace.” An increasing proportion of these mitigation wetlands represent uplands/wetlands preserved elsewhere, including many acres in wetland mitigation banks. If preserved wetlands represent already functional wetlands, then they do not replace the ecosystem services lost. The USACE and the EPA have released new rules regarding compensatory mitigation of wetlands impacted by USACE permits (took effect on June 9, 2008). According to the Federal Register, the new rule emphasizes “a watershed approach” and requires “measurable, enforceable ecological performance standards and regular monitoring for all types of compensation” (USACE 2008b). How these rule changes may or may not affect wetlands mitigation in the LSJRB warrants future investigation.

In summary, the future outlook for the health of the LSJRB depends upon detailed, accurate, consolidated record-keeping of wetlands impacts, the cumulative impact of parcel-by-parcel loss of wetland ecosystem services, and the success of wetlands enhanced, created, or restored.

4.3. Macroinvertebrates

4.3.1. *Description*

Benthic macroinvertebrates include invertebrates (animals without a backbone) that live on or in the sediment. This includes a variety of relatively small organisms such as crabs (decapods), snails (gastropods), shrimp, clams (bivalves), insects (mostly flies), segmented worms (polychaetes), nonsegmented worms (nemerteans and platyhelminthes), barnacles (cirripedians), and some others. In many cases, these organisms are extremely abundant. For instance, a one square meter area of mud can have as many as 40,000 organisms living within it.

There is high diversity in how long these organisms live and how they reproduce. In many areas of the St. Johns River, there is relatively high turnover of individuals with life spans of a few years at most. Most of these organisms produce young that spend some time drifting as microscopic organisms (larvae) in the plankton, before settling to the bottom where they will eventually become sexually mature adults. Other species either brood their young or lay egg cases.

4.3.2. *Significance*

There are multiple reasons why benthic macroinvertebrates are important in the LSJRB. First, because many of these organisms are so plentiful, they are an important component of the river's food web. Indeed, many of the adults of these species serve as food for commercially and recreationally important fish and invertebrate species. Their microscopic young can also be very abundant, providing food resources for smaller organisms such as important larval and juvenile fish species.

Macroinvertebrates are also important because they can exert a strong influence on their environment by affecting the aeration and sediment size of the river bottom. In high abundances, they can literally change the sediment to accommodate other animals that live on or near the sediment.

Finally, the assemblage of macroinvertebrates can provide insight into the degree of stress or pollution that is occurring in a given area of the river (Gray, *et al.* 1979; Pearson and Rosenberg 1978). Consequently, they can serve as a good biological indicator of the health of a river or estuary.

4.3.3. *Data Sources*

Macroinvertebrate community data used to assess long-term trends was obtained from the FDEP. The primary data set (1974-1995) was provided courtesy of the Jacksonville DEP office. Supplemental data from DEP's "Fifth-Year" assessments were obtained online (http://www.dep.state.fl.us/northeast/), and combined with the former dataset to increase the strength of the analyses. Macroinvertebrates were assessed for the north (Duval County) and south (St. Johns, Flagler, Clay & Putnam Counties) sections of the lower St. Johns River. Within each section of these sections of the river, the community of the macroinvertebrates was assessed by using collected data in a Shannon-Wiener diversity index. Diversity Indices have the value of mathematically accounting for both the number and abundance of each species encountered in a sample (Evans and Higman 2001 classify moderate diversity at index values of two to three, and low diversity at values less than two). Finally, scientific literature supplemented these data sets to strengthen insight on long-term patterns for macroinvertebrate communities within the river.

4.3.4. *Limitations*

While the dataset covers a long time period (~30 years), a few important limitations exist. First, similar regions were not sampled throughout the entire time period. In particular, the southern areas of the lower basin were less often visited than northern sections of the river. Further, because of the natural variability when sampling, there probably were not enough replicates to accurately assess potential differences. Often microhabitat variability can be as high as site variability. Finally, the dataset assesses macroinvertebrates in deeper sections of the river, because sampling did not occur in shallow areas where boat access was limited.

4.3.5. *Trend*

Macroinvertebrate diversity was highly variable during the time period (1974-1999) of the study (Figure 4.8). The species diversity varied from a value of 1.3 to 2.9 (1-29 species). There was a similar lack of trend in diversity for both the northern (τ=0.317; not significant) and southern (τ=0.250; not significant) sections of the river (Figure 4.8). However, there were drastic changes in what types of macroinvertebrates dominated an area in both river sections during the course of the study (Figure 4.9). In the 1970s, the northern river section was dominated by barnacles, polychaetes, and amphipods. In contrast, the southern river area was dominated by molluscs, amphipods, polychaetes, oligochaetes, and fly larvae. In the 1980s, the north section was dominated by polychaetes and barnacles, and the south river was mostly oligochaetes and fly larvae. By the 1990s, another shift had occurred with the north being mostly amphipods, molluscs, polychaetes, and barnacles. The southern parts of the river also shifted with dominant species being molluscs (mostly bivalves and snails.

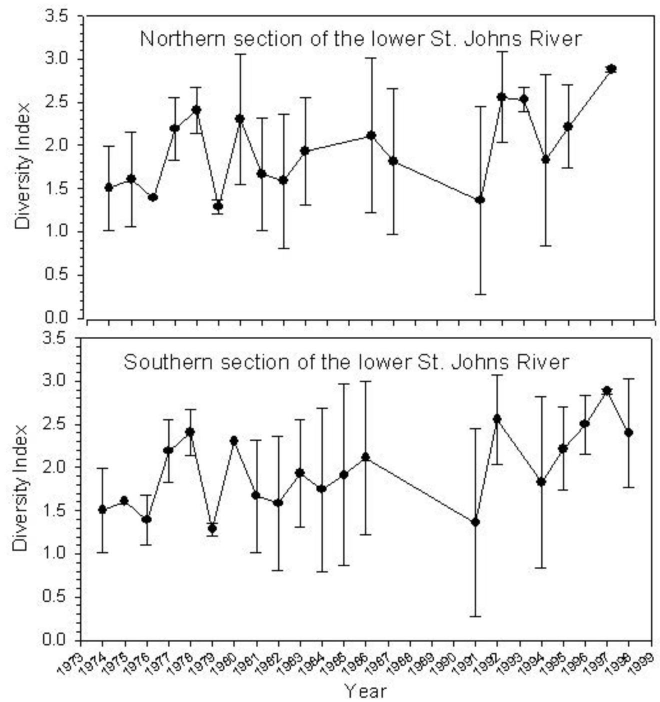


Figure 4.8 A comparison of the diversity of macroinvertebrates between the northern and southern sections of the Lower Basin of the St. Johns River. Evans and Higman 2001 classify moderate diversity at index values of two to three, and low diversity at values less than two. The vertical bars of each point indicate the degree of variability (standard deviation) for each date.

4.3.6. *Current Status*

Macroinvertebrates encountered in the St. Johns River are highly variable in diversity and abundance. The number of species in a single sample can vary from one to over 20 while the number of individuals of a given species could vary from none to as high as forty thousand per meter squared! As might be expected, the species encountered in our study change as one transitions from the saltwater dominated northern sections of the river to the freshwater areas in the south (For a complete list of species see Appendix 4.3.6). Certainly, community shifts are expected in response to the natural changes in environmental factors.

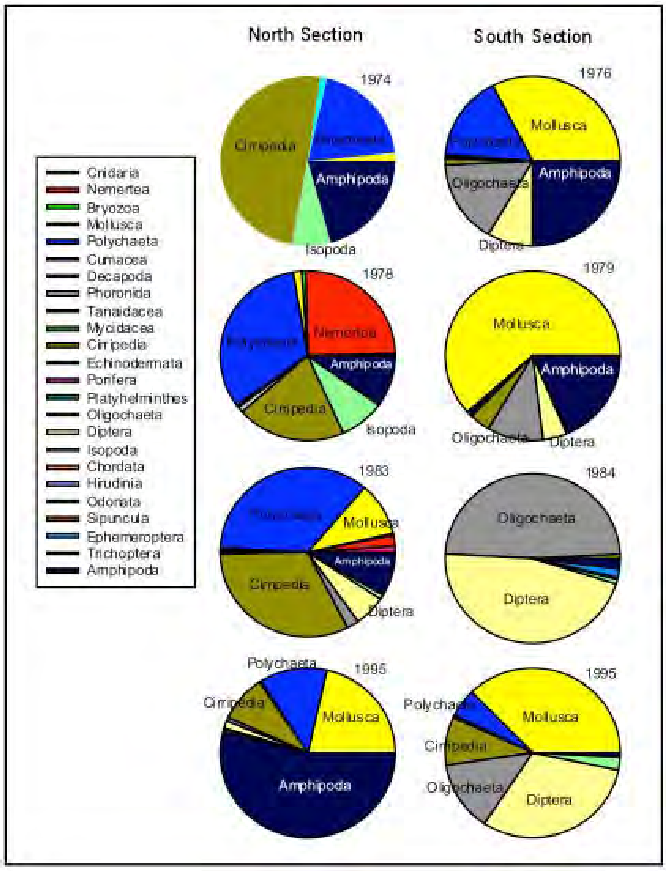


Figure 4.9 A comparison of the percentage of macroinvertebrate groups encountered between northern and southern sections of the Lower Basin of the St. Johns River from the 1970s-1990s.

In the 1990s, the dominant animal groups were primarily pollution-tolerant species in both north and south sections of the St. Johns River. To the north, the dominant species were primarily pollution-tolerant bivalves (dominated by the clam *Rangia cuneata*), polychaete worms (dominated by *Strebliospio spp*.), and amphipods (several species). Similar trends were found from 2000 to 2002 in St. Johns River studies by Cooksey and Hyland 2007; Evans and Higman 2001; Mason Jr 1998, and Vittor 2001, 2003). Evans and Higman 2001 encountered high number so abnormalities in insect larvae in the Cedar-Ortega River basin and Julington Creek. Towards the south of the lower basin, dominant taxa are more freshwater-tolerant (as expected) but still pollution-tolerant. In these southern areas, dominant taxa included snails (primarily *Littoridinops sp*.), oligochaetes (earthworm group), insects (primarily fly larvae), and amphipods (primarily *Corophium lacustre*).

It is expected that high abundances of macroinvertebrates will persist within the St. Johns River. However, the types of organisms that make up these communities can shift significantly - often in response to changes in water quality, salinity or temperature. Indeed, some of these shifts in the community are likely a result of the dynamic nature of the St. Johns River. For instance, Cichra 1998 suggests that freshwater areas of the river may often be affected by increased salinity. However, a potential concern is if macroinvertebrate communities change in a large area within the river, then species that feed on these organisms may be positively or negatively affected. Such changes could therefore have profound effects up the food chain and affect on abundances of ecologically, commercially or recreationally important species (for example red drum, spotted Seatrout, or flounder).

4.4. Threatened & Endangered Species

The species examined in this section are Federally listed threatened and endangered species that occur in Duval, Clay, St. Johns, Putnam, Flagler and Volusia counties (USFWS 2008d) and that are within the LSJRB. These animals are protected under the Endangered Species Act of 1973. The West Indian Manatee, Bald Eagle and Wood Stork are considered primary indicators of ecosystem health because of their proximity to and use of the St. Johns River. In addition, the data available for these species was relatively more robust than data on the Shortnose sturgeon, Piping Plover, Florida Scrub-jay, and Eastern Indigo Snake. These examples convey in part the diverse nature of endangered wildlife within, adjacent to, or directly affected by people's activities in the LSJRB. These species, and many more, add to the overall diversity and quality of life we enjoy and should strive to protect and conserve for the future. It is important to remember that human actions within the LSJRB affect the health of the entire ecosystem of which the St. Johns River is an integral part. Research, education and public awareness are key steps to understanding the implications of our actions towards the environment. The list of species examined here does not include all species protected under Florida State and Federal Laws (see Appendix 4.4.1). It is likely that in the future this list will need to be periodically updated as changes occur over time or indicator species /data are identified. For additional supporting information the reader is asked to refer to the appendices section of the report.

4.4.1. *The Florida Manatee (Endangered)*


Source: FWC

4.4.1.1. Description

In 1967, under a law that preceded the Endangered Species Act of 1973 the manatee was listed as an endangered species. Manatees are also protected at the Federal level under the Marine Mammal Protection Act of 1972 (http://www.fws.gov/laws/lawsdigest/marmam.html) and at the State level under the Florida Manatee Sanctuary Act of 1978 (http://www.leg.state.fl.us/statutes/index.cfm?mode=View%20Statutes&SubMenu=1&App_mode=Display_Statute&Search_String=manatee+sanctuary+act&URL=CH0379/Sec2431.HTM).

The Florida manatee *(Trichechus manatus latirostris)* inhabits the waters of the St. Johns River year round and may reach a possible length of 12 feet and a weight of 3,000 lbs (USFWS 2001). They are generally gray to dark-brown in color. Few manatees are observed during winter (December-February). Manatees are generally most abundant in the St. Johns River from late April through August. In 1989, Florida's Governor and Cabinet identified 13 "Key" counties experiencing excessive watercraft-related mortality of manatees and mandated that these counties develop County Manatee Protection Plans (MPPs). Currently, all the "Key" Counties have a state-approved manatee protection plan (Brevard, Broward, Citrus, Collier, Dade, Duval, Indian River, Lee, Martin, Palm Beach, Sarasota, St. Lucie, and Volusia) (FWRI 2008a). In 2006, although not one of the original 13 "Key" counties, Clay County voluntarily developed a State-approved MPP. St. Johns County also voluntarily developed a manatee plan, but it is has not been approved by State or Federal agencies. Putnam and Flagler Counties have not developed MPPs.

Jacksonville University has conducted some 548 aerial surveys with over 11,614 manatee sightings (1994–2008). These surveys covered the shorelines of the St. Johns River, its tributaries (Jacksonville to Black Creek), and the Atlantic ICW (Nassau Sound to Palm Valley). During the winter, industrial warm water sources were also monitored for manatee presence (aerial and ground surveys). When water temperatures decrease (December through March), the majority of manatees in the LSJRB migrate to warmer South Florida waters.

Within the St. Johns River, survey data indicates that manatees feed, rest and mate in greater numbers south of the Fuller Warren Bridge where their food supply is greatest relative to other areas in Duval County. Sightings in remaining waters have consisted mostly of manatees traveling or resting. Manatees use the ICW as a travel corridor during their seasonal (north/south) migrations along the east coast of Florida. Data indicate that manatees stay close to the shore, utilizing small tributaries for feeding when in these waters (White, *et al.* 2002). Aerial surveys of manatees, by various organizations and individuals, in Northeast Florida have occurred prior to 1994 and are listed in Ackerman 1995.

There are two sub-populations of manatees that use the LSJRB. A few manatees from the Blue Spring sub-population, which currently consists of a total of about 265 manatees (Hartley 2007), visit the LSJRB, though exact numbers are not known (Ross 2008). Most of the animals in the LSJRB (about 260 manatees) (White and Pinto 2006a, 2006b) are members of the greater Atlantic region sub-population, which averages about 1,400 manatees along the entire east coast of Florida (FWRI 2008a). This information is based on the results of long-term radio tracking and photo-identification studies (Beck and Reid 1995; Reid, *et al.* 1995). Deutsch, *et al.* 2003 reported that the lower St. Johns River south of Jacksonville was an important area visited by 18 tagged manatees that were part of a 12-year study of 78 radio-tagged and tracked manatees from 1986 to 1998. Satellite telemetry data supports the fact that most animals come into the LSJRB as a result of south Florida east coast animals migrating north/south each year (Deutsch, *et al.* 2000). Scar pattern identification suggested that significant numbers of manatees are part of the Atlantic sub-population and, that only three manatee carcasses (1988, 1989, and 1991) have been recovered in LSJRB that have been identified as animals that came from the Blue Springs sub-population (Beck 2008).

4.4.1.2. Significance

The St. Johns River provides habitat for the manatee along with supporting tremendous recreational and industrial vessel usage. Watercraft deaths of manatees continue to be the most significant threat to survival. Boat traffic in the river is diverse and includes port facilities for large industrial and commercial shippers, commercial fishing, sport fishing and recreational activity. Florida Department of Highway Safety and Motor Vehicles (FDHSMV 2008) estimated that there were 34,008 registered boaters in Duval County in 2002 and this increased to 34,494 by 2007. Recent port statistics indicated that about 3,342 vessels use the Port each year (JAXPORT 2008a). In addition to this, in 2004 there were 100 cruise ship passages to and from the Port and by 2007 this number rose to 160. Large commercial vessel calls and departures are projected to increase significantly when TraPac, owned by the Japanese steamship company Mitsui O.S.K. Lines (MOL), expects to double JAXPORT's yearly container traffic (JAXPORT 2007). Also, in order to accommodate larger ships significant dredging by the port is expected in 2008 which can change vessel traffic patterns and increase noise in the aquatic environment that can potentially harm manatees because they cannot hear oncoming vessels (Gerstein, *et al.* 2006). Dredging a deeper channel can also affect the salinity conditions in the estuary by causing the salt water wedge to move further upstream (Sucsy 2008), negatively impact biological communities like the tape grass beds on which manatees rely for food (Twilly and Barko 1990).

4.4.1.3. Data Sources & Limitations

Aerial survey data collected by Jacksonville University (Duval County 1994-2007, and Clay County 2002-2003) was used in addition to historic surveys by Florida Fish and Wildlife Conservation Commission (FWC) (Putnam 1994-1995). Ground survey data came from Blue Springs State Park (1970-2007). The FWC and the FWRI provided manatee mortality data. Other data sources include the U.S.G.S. Sirenia Project's radio and satellite tracking program, manatee photo id catalogue, tracking work by Wildlife Trust and various books, periodicals, reports and web sites.

Aerial survey counts of manatees are considered to be conservative measures of abundance (Irvine 1980) and consist of slow speed flying in a Cessna high-wing aircraft at altitudes of 500-1000 ft (Jacksonville University data - http://www.ju.edu/marco). The survey path was the same for each survey and followed the shore lines of the St. Johns River and tributaries, about every two weeks. Survey time varied according to how many manatees were observed. The quality of a survey is hampered by a number of factors including weather conditions, dark nature of the water, and the sun's glare off the water surface, water's surface condition and observer bias. The units of aerial surveys presented here are the average number of manatees observed, and the Single Highest Day Count of manatees, per survey each year. The number of surveys each year averaged 20 ± 3 S.D. (range 18-26/yr).

The actual location that a watercraft related mortality occurred can be difficult to determine because animals are transported by currents or injured animals continue to drift or swim for some time before being reported. In addition, the size of the vessel involved in a watercraft fatality is often difficult to determine with frequency and consistency.

Salinity data (Figure 4.10) was provided by Dana Morton (Environmental Quality Division, City of Jacksonville). Water quality parameters are measured monthly at ten stations in the main stem of the St. Johns River at the bottom, middle and surface depths.

4.4.1.4. Current Status

Aerial surveys: The average numbers of manatees observed on aerial surveys in Duval County and adjacent waters decreased prior to the drought (2000-2001) and then increased again after the drought (Figure 4.11). The longer term trend appears to be stable, when excluding the variation caused by the drought.

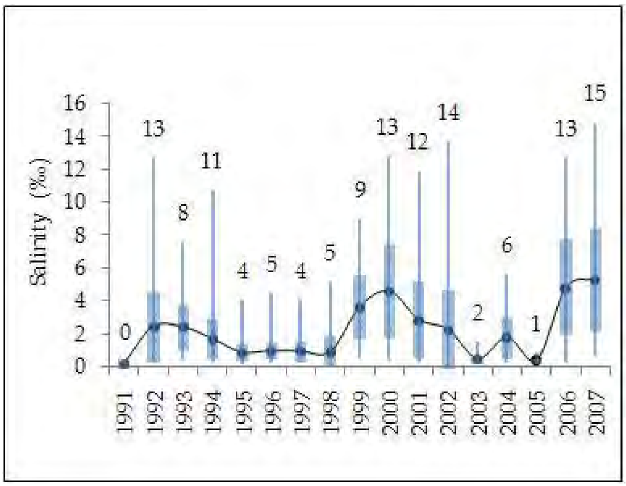


Figure 4.10 Salinity on the bottom of SJR (west bank ~1000m south of Doctors Lake). Solid line (mean), vertical lines (maximum and minimum), and bars (95% Confidence Interval of the mean). Data source: Dana Morton, Environmental Quality Division, City of Jacksonville.

Single Highest Day Counts of manatees appear to have increased to a level slightly higher than prior to the drought but the increase is not statistically significant. The large dip in numbers in 2000-2001 can be attributed to the effects of the drought that caused manatees to move further south out of the Duval County survey area in search of food (Figure 4.12 and Appendix 4.4.1.A).

"Single Highest Day Count" of manatees is defined as the record highest total number of manatees observed on a single aerial survey day during the year.

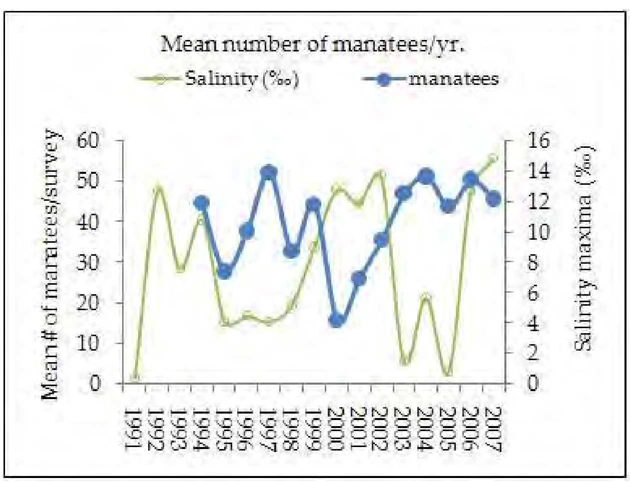


Figure 4.11 Mean numbers of manatees per survey in Duval Co., FL and adjacent waters 1994-2008. (Source: Jacksonville University and City of Jacksonville) (Appendix 4.4.1.A).

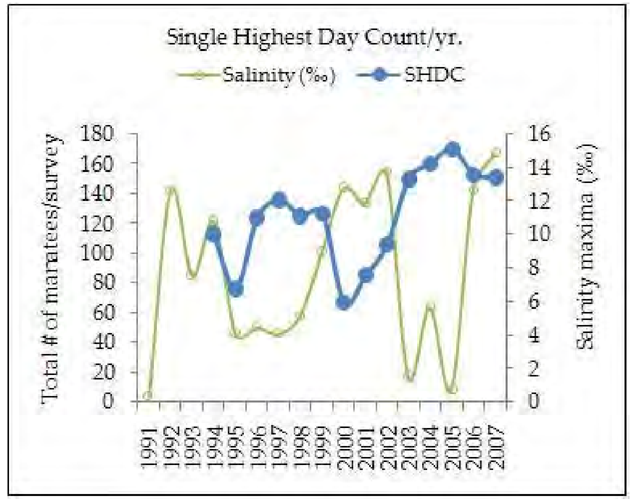


Figure 4.12 Single Highest Day Count per year of manatees in Duval Co., FL 1994-2008 (Source: Jacksonville University and City of Jacksonville) (Appendix 4.4.1.A).

<u>Ground surveys</u>: Blue Spring State Park is located about 40 miles south of the LSJRB within the St. Johns River system and, since this sub-population has increased over the years, we could potentially see more animals using the LSJRB in the future. The population of Blue Spring only numbered about 35 animals in 1982-83 (Kinnaird 1983b) and 88 animals in 1993-94 (Ackerman 1995). From 1990-1999, this population had an annual growth rate of about six percent (Runge, *et al.* 2004). It is the fastest growing sub-population and accounts for about five percent of the total Florida manatee count (FWC 2007a). Recent ground surveys indicate that the population has continued to grow at a slightly faster rate during 2000-2007 (Figure 4.13).

<u>Mortality:</u> There were a total of 406 manatee deaths between 1980 to September 2007, of which 129 were caused by watercraft, eight other human, 56 perinatal, 53 cold stress, 31 other natural and 125 undetermined. The total number of manatee mortalities (all causes) increases towards the mouth of the St. Johns River with Duval County being associated with 71%, followed by Clay (12%), Putnam (9%), St. Johns (7%), and Flagler (0%) (FWC 2007b).

<u>Manatee mortality categories defined by the Florida Wildlife Research Institute:</u>

Watercraft (Propeller, Impact, Both)
Flood Gate / Canal Lock
Human, Other
Perinatal (Natural or Undetermined)
Cold Stress
Natural, Other (Includes Red Tide)
Verified; Not Recovered
Undetermined; Too decomposed

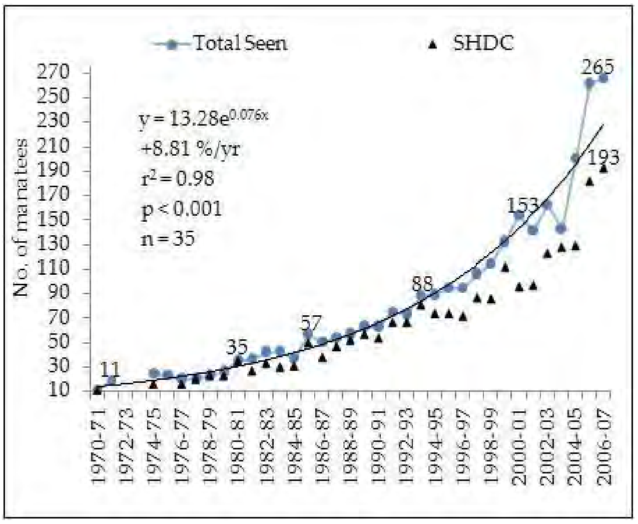


Figure 4.13 Trend (exponential regression) in counts (highest total number of animals identified during each winter) of Florida manatees at the winter aggregation site in Blue Spring State Park, Volusia Co., FL 1970-2007.Highest Single Day Counts each winter are also shown. Data provided by Wayne Hartley, Park Specialist, Blue Spring State Park, 2007.

Watercraft related mortalities as a percentage of the total mortality, on a by-county basis, was highest in Duval (34%) followed by Putnam (29%), St. Johns (25%), Clay (24%), and Flagler (0%). A comparison of two time periods (1980-93) and (1994-07) indicated a four percent decrease in watercraft mortalities for the LSJRB (Appendix 4.4.1.B). These time periods were picked because they represent 13 years either side of 1994 when the Interim Duval County Manatee Protection Plan regulations were implemented. Most of the decrease in mortality appears to have occurred in Clay and Putnam counties with St. Johns and Duval showing little or no change between the two time periods. No watercraft mortalities are reported for Flagler County. Although watercraft-caused mortality seems to have declined slightly for the LSJRB (average 32% of total mortality for 1980-2007), it is still higher than the overall watercraft mortality rate for the State of Florida which is about 23% for 2007) (FWC 2007b). The State Manatee Management Plan (FWC 2007a) requires the FWC to evaluate the effectiveness of speed zone regulations. The Plan was developed as a requirement in the process which seeks to down list manatees from endangered to threatened status. Currently, manatees are considered endangered at both the State and Federal level.

4.4.1.5. <u>Future Outlook</u>

Manatees in the LSJRB are likely to continue to increase as more manatees move north because of anthropogenic effects in south Florida that contribute to decreases in manatee habitat and its quality. Recovery from the most recent drought cycle will allow food resources to rebound and increase the carrying capacity of the environment to support more manatees (Appendix 4.4.1.A). Current information regarding the status of the Florida manatee suggests that the population is growing in most areas of the southeastern U.S. (USFWS 2007d). However, the trend in watercraft-caused deaths continues to increase over time (FWRI 2008a). Significant increases in vessel traffic in the LSJRB are projected to occur over the next decade as human population increases and commercial traffic doubles. More boats and more manatees could lead to more manatee deaths from watercraft because of an increased opportunity for encounters between the two. Dredging in order to accommodate larger ships significantly affects boat traffic patterns, noise in the aquatic environment (Gerstein, *et al.* 2006) and has ecological effects on the environment that ultimately impact manatees and their habitat. Freshwater withdrawals in addition to harbor deepening will alter salinity regimes in the LSJRB; however, it is not known yet by how much. If a sufficient change in salinity regimes occurs it is likely to cause a die-off of the grass bed food resources for the manatee. This result would decrease the environment's ability to support manatees. Some Blue Spring animals use LSJRB too, although the interchange rate is not established yet. Animals that transition through the basin are likely to be affected by the above issues. Sea level rise is another factor likely to affect the St. Johns and about which more information regarding potential impacts is needed.

"Carrying Capacity" may be defined as the maximum weight of organisms and plants an environment can support at a given time and locality. The carrying capacity of an environment is not fixed and can alter when seasons, food supply, or other factors change.

4.4.2. Bald Eagle (delisted 2007)

Photo: Dave Menke, USFWS.

4.4.2.1. Description

The Bald eagle (*Haliaeetus leucocephalus*) is a large raptor, with a wingspan of about seven feet and represents a major recovery success story. Bald Eagles were listed as Endangered in most of the U.S. from 1967-1995 as a result of DDT pesticide contamination which was determined to be responsible for causing their egg shells to be fragile and break prematurely. The use of DDT throughout the U.S. was subsequently banned. In 1995, Bald eagle status was upgraded to Threatened and numbers of nesting pairs increased from just under 500 (1960s) to over 10,000 (2007).

As a result of this tremendous recovery, Bald eagles were delisted June 28, 2007 (AEF 2008; USFWS 2007e, 2008c, 2008a). The eagles are found near large bodies of open water such as the St. Johns River, tributaries, and lakes which provide food resources like fish. Nesting and roosting occurs at the tops of the highest trees (Jacksonville Zoo and Gardens 2008; Scott 2004). Bald eagles are found in all of the United States, except Hawaii. Eagles from the northern United States and Canada migrate south to over winter while some southern bald eagles migrate slightly north for a few months to avoid excessive summer heat (AEF 2008) Wild eagles feed on fish predominantly, but also eat birds, snakes, carrion, ducks, coots, muskrats, turtles and rabbits. Bald eagles have a life span of up to 30 years in the wild and can reach 50 years in captivity (AEF 2008; Jacksonville Zoo 2008; Scott 2003c). Young birds are brown with white spots. After five years of age the adults have a brown-black body, white head, and tail feathers. Bald eagles can weigh from 10-14 lbs and females tend to be larger than males. They reach sexual maturity at five years, and then find a mate that they will stay with as long as they live (AEF 2008).

4.4.2.2. Significance

The LSJRB has in excess of 80 identified bald eagle nests located mainly along the edges of the St. Johns River, from which they derive most of their food. Most of the nests seem to be in use about 50% of the time (Figure 4.14; FWRI 2007b).

4.4.2.3. Data Sources & Limitations

Data came from a variety of sources, Audubon Society winter bird counts, Florida Fish and Wildlife Conservation Commission, Jacksonville Zoo and Gardens, United States Fish and Wildlife Service and various books and web sites. There are no significant limitations at this time with periodic surveys and a 5-Year Management Plan (FWC 2008b) (USFWS and FWC) to monitor the eagle's continued welfare (USFWS 2008a; FWC 2008).

4.4.2.4. Current Status

In Alaska, there are over 35,000 bald eagles. However, in the lower 48 states of the U.S., there are now over 5,000 nesting pairs and 20,000 total birds. About 300-400 mated pairs nest every year in Florida and constitute approximately 86% of the entire southern population (Jacksonville Zoo 2008). Statewide eagle nesting surveys have been conducted since 1973 to monitor Florida's bald eagle population and identify their population trends. Now that this species is no longer listed as Threatened, the primary law protecting it has shifted from the Endangered Species Act to the Bald and Golden Eagle Act (AEF 2008; USFWS 2008a, 2008b). According to Jacksonville winter bird counts by Audubon Society (Figure 4.15 and Appendix 4.4.2.A) numbers sighted have increased overall (1981-2006). There was a surge preceding the drought in 2000-2001 followed by a decrease in sightings after the drought, and then a rebound from about 2004-2006 (Audubon 2008) (Appendix 4.4.2.A).

4.4.2.5. Future Outlook

Although they have a good future outlook, Bald eagles are still faced with threats to their survival. Environmental protection laws, private, State, and Federal conservation efforts are in effect to keep monitoring and managing these birds. Even though Bald eagles have been delisted, it is imperative that we do our part to protect and monitor them because they are key indicators of ecosystem health. The use of DDT pesticide is now outlawed in the U.S. Threats include harassment by people that injure and kill eagles with firearms, traps, power lines, windmills, poisons, contaminants and habitat destruction (AEF 2008; FWC 2005; USFWS 2008b).

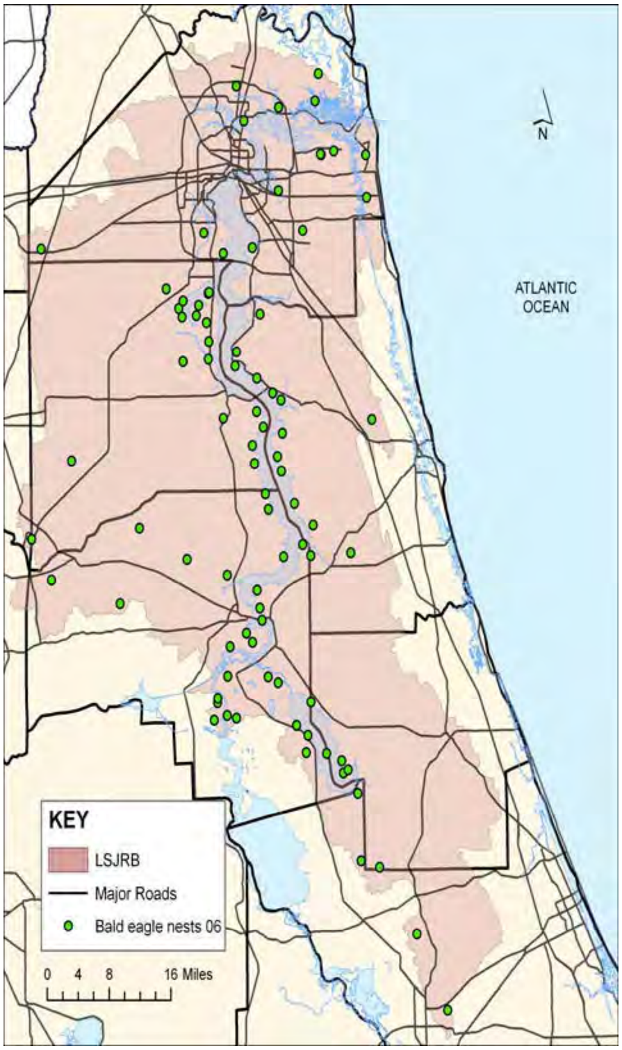


Figure 4.14 Bald eagle nesting sights in LSJRB 2006. (Source data: FWC 2007).

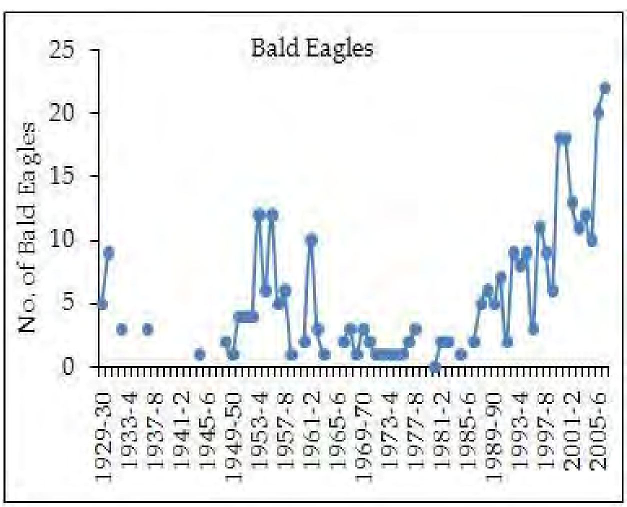


Figure 4.15 Long term trend in the number of Bald eagles counted during winter bird surveys (1929-2007) in Jacksonville, FL (Source data: Audubon 2008). (Appendix 4.4.2.A).

4.4.3. Wood Stork (Endangered)

Photo by Wayne Lasch (PBS&J)

4.4.3.1. Description

The Wood Stork *(Mycteria americana)* was listed as Endangered in 1984 and is America's only native stork. It has recently been recommended for down-listing to Threatened status (USFWS 2007a). It is a large white bird with long legs and contrasting black feathers that occur in groups. Its head and neck are naked and black in color. Adult birds weight 4-7 lbs and stand 40-47 inches tall, with a wing span in excess of 61 inches. Males and females appear identical. Their bill is long, dark and curved downwards (yellowish in juveniles). The legs are black with orange feet which turn a bright pink in breeding adults.

Wood storks nest throughout the southeastern coastal plain from South Carolina to Florida, and along the Gulf coast to central and South America. Nesting occurs in marsh areas, wet prairies, ditches and depressions which are also used for foraging. They feed on mosquito fish, sailfin mollies, flagfish, and various sunfish. They also eat frogs, aquatic salamanders, snakes, crayfish, insects, and baby alligators. They find food by tactolocation (a process of locating food organisms by touch or vibrations). Nesting occurs from February to May and is determined primarily by water levels. Pairs require up to 450 lbs of fish during nesting season. Males collect nesting material which the female then uses to construct the nest. Females lay from two to five eggs (incubation approx. 30 days). To keep eggs cool, parents shade eggs with out-stretched wings and dribble water over them. Wood storks can live up to ten years but mortality is high in the first year (Scott 2003e; USFWS 2002).

4.4.3.2. Significance

Wood stork presence and numbers can be an indication of the health of an ecosystem. The Wood stork is also

Florida's most endangered species of wading bird that requires temporary wetlands (isolated shallow pools that dry up and concentrate fish for them to feed on). Scarcity of this specific habitat type due to human alteration of the land causes nesting failures, like in the Everglades (Scott 2003e).

4.4.3.3. Data Sources & Limitations

Data came from Audubon Society winter bird counts, U.S. Fish and Wildlife Service surveys and the Jacksonville Zoo and Gardens web site. The Audubon winter bird count area consists of a circle with a radius of 10 miles surrounding Blount Island. The USFWS has conducted aerial surveys which are conservative estimates of abundance and are limited in their use for developing population estimates. However, they still remain the most cost effective method of surveying large areas. Ground surveys on individual colonies like at the zoo tend to be more accurate, but cost more on a regional basis (USFWS 2002).

4.4.3.4. Current Status

An increasing trend since the 1960s was indicated by the Audubon Society winter bird count data for Jacksonville (Figure 4.16 and Appendix 4.4.3.A). There was a fall in counts during the drought in 2000-2001 followed by a period of recovery.

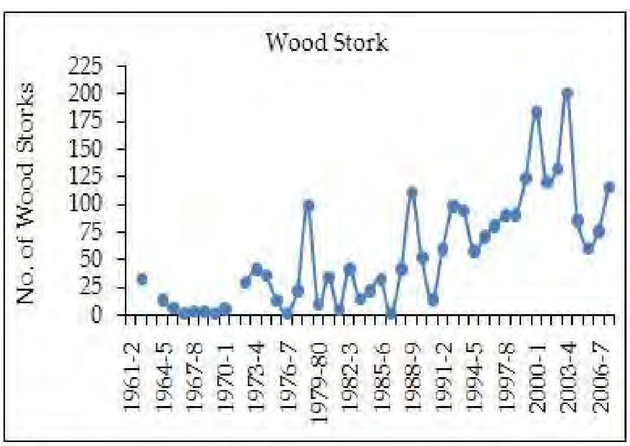


Figure 4.16 Long term trend (regression) of the number of Wood Storks counted during winter bird surveys (1961-2007) Jacksonville, Florida (Source data: Audubon 2007). (Appendix 4.4.3.A).

Furthermore, after four hurricanes skirted Florida in 2004, another decline occurred followed by another recovery.

Brooks and Dean 2008 describe increasing wood stork colonies as somewhat stable numbers of nesting pairs (Appendix 4.4.3.A). Hankla 2007 stated in a recent press release by the USFWS that the data indicates that the wood stork population as a whole is expanding its range and adapting to habitat changes and for the first time since the 1960s, that there had been more than 10,000 nesting pairs. USFWS 2007a shows a map of the distribution of wood stork colonies and current breeding range in the southeastern U.S. (Figure 4.17).

In the LSJRB, there are several colonies of interest - three of these for which data is available include:

(1) Jacksonville Zoo and Gardens: This colony is the most important recently established rookery in Duval County (Brooks 2008). Donna Bear-Hull from the Jacksonville Zoo reported that the 4th year colony had doubled in size again from 40 breeding pairs (111 fledged chicks) in 2002 to 82 pairs (191 fledged chicks) in 2003 (USFWS 2004). This group had the highest number and productivity of birds (Figure 4.18 and Appendix 4.4.3.B).

(2) Dee Dot Colony: The USFWS reported that there were 125-130 nests in this Cyprus swamp impounded lake in Duval County. However, the fledgling rate was poor (1.51 chicks/nest in 2003 and 1.42 in 2004). These rates represent poor nest productivity (> 2 chicks/nest is considered acceptable productivity) (USFWS 2005). Furthermore, the number of nests decreased from 118 in 2003 to 62 in 2006. Fledgling rate improved from an average of 1.75 chicks/nest/year (2003-2005) to 2.11 chicks/nest/year in 2006 (USFWS 2007a).

(3) Pumpkin Hill Creek Preserve State Park: This colony in Duval County had 42 nests in 2005 (down from 68 in 2003) and fledgling rate averaged 1.54 chicks/nest/year in those years (USFWS 2005).

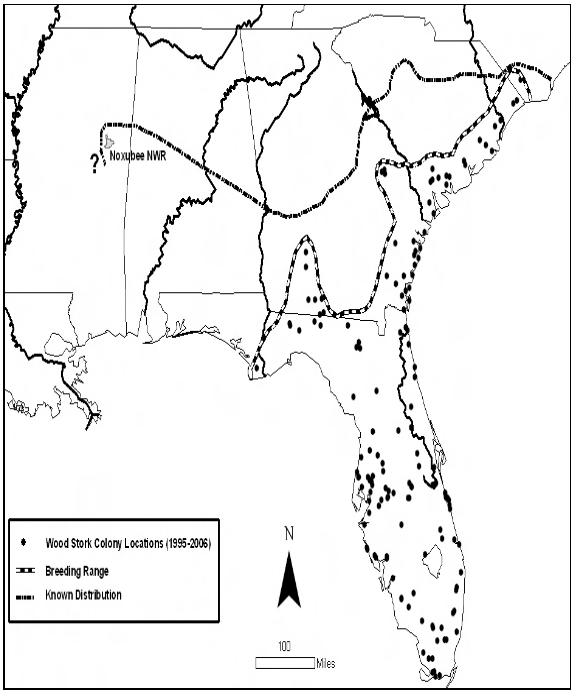


Figure 4.17 Current breeding range and distribution of wood storks in the Southeastern U.S. (USFWS 2007a).

4.4.3.5. Future Outlook

Historically the wood stork breeding populations were located in the Everglades but now their range has almost doubled in extent and moved further north. The birds continue to be protected under The Migratory Bird Treaty Act and state laws. Although they are not as dependent on the Everglades wetlands, wetlands in general continue to need protection. Threats continue to exist such as contamination by pesticides, harmful algae blooms, electrocution from power lines and human disturbance such as road kills. Adverse weather events like severe droughts, thunderstorms or hurricanes also threaten the wood storks. The USFWS Wood Stork Habitat Management Guidelines help to address these issues. Continued monitoring is essential for this expanding and changing population (USFWS 2007a).

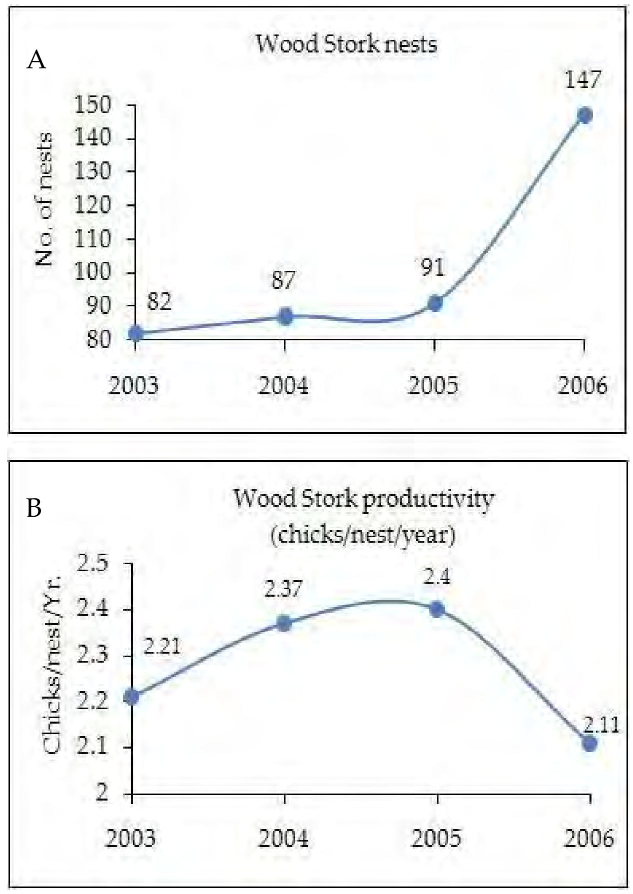


Figure 4.18 Number of wood stork nests (A) and productivity chicks/nest/yr (B) at Jacksonville Zoo (2003-2006) (USFWS 2005, 2007).

4.4.4. Shortnose Sturgeon (Endangered)

Source: USFWS

4.4.4.1. Description

The Shortnose sturgeon (*Acipenser brevirostru)* was listed as Endangered in 1967. It is a semi-anadromous fish that swims upstream to spawn in freshwater before returning to the lower estuary, but not the sea. Shortnose are found in rivers along the east coast from Canada to Florida. The species is particularly imperiled because of habitat destruction and alterations that prevent access to historical spawning grounds. The St. Johns River is dammed in the headwaters, heavily industrialized and channelized near the sea, and affected by urbanization, suburban development, agriculture, and silviculture throughout the entire basin. Initial research conducted by the National Marine Fisheries Service in the 1980s and 1990s culminated in The Shortnose sturgeon Recovery and Management Plan of 1998 (FWRI 2008b; NMFS 1998).

4.4.4.2. Significance

There are no legal fisheries or by-catch allowances for Shortnose sturgeon in U.S. waters. Principal threats to the survival of this species include blockage of migration pathways at dams, habitat loss, channel dredging, and pollution. Southern populations are particularly at risk due to water withdrawal from rivers and ground waters and from eutrophication (excessive nutrients) that directly degrades river water quality causing loss of habitat. Direct mortality is known to occur from getting stuck on cooling water intake screens, dredging, and incidental capture in other fisheries (NMFS 1998).

4.4.4.3. Data Sources & Limitations

Data was limited to a few mentions of specimen captures recorded in the literature which consisted of books, reports and web sites. Shortnose sturgeons have been encountered in the St. Johns River since 1949 - Big Lake George and Crescent Lake (Scott 2003f). Five shortnose sturgeons were collected in the St. Johns River during the late 1970's (Dadswell, *et al.* 1984) and, in 1981, three sturgeons were collected and released by the Florida Game and Freshwater Fish Commission. All these captures occurred far south of LSJRB in an area that is heavily influenced by artesian springs with high mineral content. None of the collections were recorded from the estuarine portion of the system (NMFS 1998). From 1949 - 1999, only 11 specimens had been positively identified from this system. Eight of these captures occurred between 1977 and 1981. In August 3000, a cast net captured a shortnose sturgeon near Racy Point just north of Palatka. The fish carried a tag that had been attached in March 1996 by Georgia Department of Natural Resources near St. Simons Island, Georgia. During 2002/2003 an intensive sampling effort by researchers from the Fish and Wildlife Research Institute captured one 1.5 kg specimen south of Federal Point, again near Palatka. As a result, FWRI considers it unlikely that any sizable population of shortnose sturgeon currently exists in the St. Johns River. In addition, the rock or gravel substrate required for successful reproduction is scarce in the St. Johns River and its tributaries. Absence of adults and marginal habitat indicate that shortnose sturgeons have not actively spawned in the system and that infrequent captures are transients from other river systems (FWRI 2008b).

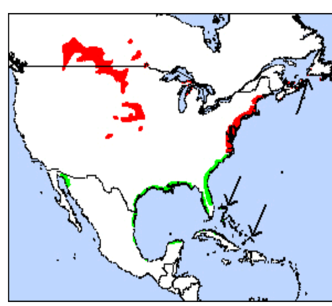
4.4.4.4. Current Status

The species is likely to be declining or almost absent in the LSJRB (FWRI 2008b). Population estimates are not available for the following river systems: Penobscot, Chesapeake Bay, Cape Fear, Winyah Bay, Santee, Cooper, ACE Basin, Savannah, Satilla, St. Marys and St. Johns River (Florida). Shortnose sturgeon stocks appear to be stable and even increasing in a few large rivers in the north but remain seriously depressed in others, particularly southern populations (Friedland and Kynard 2004).

4.4.4.5. Future Outlook

The Shortnose Sturgeon Recovery and Management Plan (NMFS 1998) identifies recovery actions to help reestablish adequate population levels for de-listing. Captive mature adults and young are being held at Federal fish hatcheries operated by the U.S. Fish and Wildlife Service for breeding and conservation stocking.

4.4.5. Piping Plover (Threatened)



Source:Birdlife International

Source:USFWS

4.4.5.1. Description

The Piping Plover (*Charadrius melodus)* has been a protected species under the Endangered Species Act since January 10, 1986 and is Threatened along the Atlantic Coast. There are three populations of the Piping Plover, The Great Plains, Great Lakes and Atlantic Coast. The piping plover breeds on coastal beaches from Newfoundland and southeastern Quebec to North Carolina. These birds winter primarily on the Atlantic Coast from North Carolina to Florida, although some migrate to the Bahamas and West Indies. Piping plovers were common along the Atlantic Coast during much of the 19th century, but nearly disappeared due to excessive hunting for the millinery trade. Following passage of the Migratory Bird Treaty Act in 1918, numbers recovered to a 20th century peak which occurred during the 1940s. The current population decline is attributed to increased development and recreational use of beaches since the end of World War II. The most recent surveys place the Atlantic population at less than 1,800 pairs (USFWS 1996). Its name *Charadrius melodus* comes from its call notes, plaintive bell-like whistles which are often heard before the bird is seen.

Piping plovers are small, stocky, sandy-colored shore birds that resemble sandpipers. Adults have yellow-orange legs, a black band across the forehead from eye to eye, and a black ring around the base of its neck. The piping plover runs in short starts and stops as it blends into the pale background of open, sandy habitat on outer beaches where it feeds and nests. In late March or early April, they return to their breeding grounds, where a pair then forms a depression in the sand somewhere on the high beach close to the dunes (USFWS 2007c). Normally, new pairs are formed each breeding season. The males will perform aerial displays to attract the attention of unpaired females during courtship (Audubon 2008). Sometimes their nests are found lined with small stones or fragments of shell (USFWS 2007c). Usually nests are found close to, but not in, areas of patchy vegetation and often close to a log rock or other prominent object (Audubon 2008). The adults, both male and female, incubate the eggs for about four weeks, after which four eggs are hatched. The eggs, like the piping plovers, are camouflaged by the surrounding sand or cobblestones and are rarely seen unless stepped on. The surviving young are flying in about 30 days. When on the forage, they look for marine worms, crustaceans, and insects that they pluck from the sand. When the young are out foraging and a predator or intruder come close, the young will squat motionless on the sand while the parents attempt to attract the attention of the intruders to themselves, often by faking a broken wing. However, if the adults spend too much time doing this, the eggs and chicks become vulnerable to predators and to overheating in the hot sun (Scott 2003d; USFWS 2007c).

4.4.5.2. Significance

The piping plover is one of many species that have suffered from drastic ecosystem changes, like river channelization, impoundment, and shoreline development (Stukel 1996). Critical wintering habitat designated by USFWS in 2001 for the bird exists from Nassau Sound to the St. Johns River (Map http://www.fws.gov/plover/finalchmaps/Plover_FL_35_to_36.jpg).

4.4.5.3. Data Sources & Limitations

Data came from Audubon winter counts for Jacksonville in addition to a variety of books, reports and web sites. The winter bird count area consists of a circle with a radius of 10 miles surrounding Blount Island.

4.4.5.4. Current Status

Current wintering populations in Florida showed decline attributed mainly to increased development and recreational use of beaches in the last sixty years. In 2005, Bird Life International estimated the entire piping plover population at 6,410, comprising of three groups- Atlantic Coast (52%), Great Planes (46%), and Great Lakes (2%). Totals in the Atlantic Coast population increased from 1,892 birds in 1991 to 3,350 birds in 2003. Totals for the Great Plains area increased from 2,744 birds in 1991 to 3,284 birds in 1996, then decreased to 2,953 birds in 2001. In the Great Lakes region, the population increased from 32 birds in 1991 to 110 birds in 2004. Overall there has been a total population increase of 9.5% (using the 1996 data) to 32.6% (using the 1991 data). However, the 1996-2001 data indicate a slight decline of the Great Plains population. The increases are the result of sustained management initiatives (Audubon 2008; BirdLife 2008). Although numbers of birds appear to have increased slightly since the mid 1980s, the Jacksonville data did not indicate that a significant trend was present (Figure 4.19).

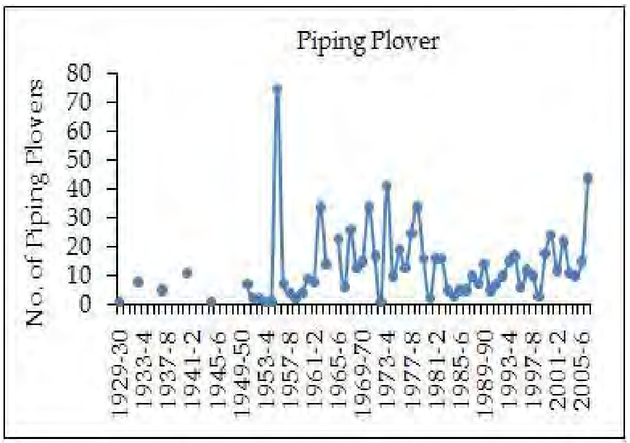
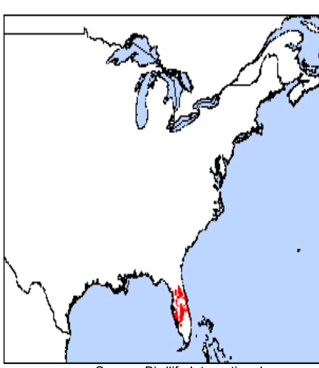


Figure 4.19 Numbers of piping plovers counted during winter bird surveys (1929-2005) in Jacksonville, Florida (Source data: Audubon 2008).

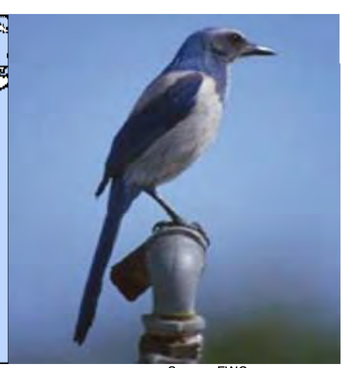
4.4.5.5. Future Outlook

The piping plover can be protected by respecting all fenced or posted for protection of wildlife areas, by not approaching or remaining near piping plovers or their nests. Pets should be kept on a leash where piping plovers are present. Trash or food scraps should not be left behind or buried at beaches because they attract predators which may prey on piping plover's eggs or chicks. Structures called exclosures are sometimes erected around a nest to protect the eggs from predators. The Endangered Species Act provides penalties for taking, harassing, or harming the piping plover and affords some protection to its habitat. By protecting the piping plover, other species such as the Federally endangered roseate tern, the threatened northeastern beach tiger beetle, the threatened seabeach amaranth, the least tern, the common tern, the black skimmer, and the Wilson's plover, may also benefit from the piping plover protection efforts (Scott 2003d; USFWS 2007c).

4.4.6. Florida Scrub-Jay (Threatened)



Source: Birdlife International



Source: FWC

4.4.6.1. Description

The Florida Scrub-jay (*Aphelocoma coerulescens)* was listed as Threatened in 1987. It is 12 inches long and weighs 2.5-3 ounces. Adults have blue feathers around the neck that separate the whiter throat from the gray under parts. They have a white line above the eye that often blends into their whitish forehead. The backs are gray and the tails are long and loose in appearance. Scrub-jays up to five months old have a dusky brown head and neck and shorter tail. In the late summer and early fall, it is almost impossible to differentiate the juveniles from the adults. During this time juveniles undergo a partial molt of body feathers. Adult males and females have identical plumage, but are set apart by a distinct "hiccup" call vocalized only by the females (Brevard County 2008). Scott 2003b describes the bird as partly resembling the Blue-jay (*Cyanocitta cristata).* The Florida scrub-jay differs from a Blue Jay in that it is duller in color, has no crest, has longer legs and tail, and lacks the bold black and white marking of the blue Jay (Brevard County 2008). As one of the few cooperative breeding birds in the United States, the fledgling scrub-jays typically remain with the breeding pair in their natal territory as "helpers" (Brevard County 2008). These family groups range from two to eight birds. Pre-breeding groups usually just have one pair of birds with no helpers or families of three or four individuals. The helpers within the groups participate by looking out for predators, predator-mobbing, helping with territorial defense against neighboring scrub-jay groups, and the feeding of both nestlings and fledglings. On average, Florida scrub-jays typically do not begin mating until they are at least 2-3 years of age. Nestlings can be observed from March 1st through June 31st and are usually found in shrubby oaks 1-2 meters in height. Each year a new nest is built, usually about 3-10 feet above ground and structured as a shallow basket of twigs lined with palmetto fibers (FWC 2008a). Most nests contain three or four eggs, which are incubated for 17-18 days. Fledging occurs 16-19 days after hatching. The fledglings are reliant on the adults for food for up to two months after leaving the nest. Once they become independent, Florida scrub-jays live out their entire lives within a short distance of where they were hatched (Brevard County 2008).

Florida scrub-jay populations are found in small isolated patches of sand pine scrub, xeric oak scrub, and scrubby flat woods in peninsular Florida. Scrub jays occupy territories averaging 22 acres in size, but they hunt for food mostly on or near the ground. Their diet is made up of mostly terrestrial insects, but may also include tree frogs, lizards, snakes, bird eggs and nestlings, and juvenile mice. Acorns form one of the most important foods from September to March (Brevard County 2008).

4.4.6.2. Significance

Populations occur on the southwest boundary of the LSJRB (USFWS 2007b) and add to the overall species diversity in the basin.

4.4.6.3. Data Sources & Limitations

Information was gathered from books, reports and web sites, but limited data was available for the LSJRB.

4.4.6.4. Current Status

The population of the scrub jays has declined by 90% over the last century and by 25% since 1983. In 1983 the estimated population was 8,000 birds according to the Audubon Society (Audubon 2007c). A single bird was reported in Jacksonville in 1950/51 (Audubon 2007b) and three birds were observed in winter of 2000 (Audubon 2007a). The species is now being legally protected by the United States Fish and Wildlife Service and the Florida Fish and Wildlife Conservation Commission. The Florida Scrub-jay is being studied in their natural habitats and in areas undergoing rapid development. In addition, land acquisition activities have been ongoing in Florida to purchase the remaining privately-owned oak scrub habitat in order to conserve critical habitat for the scrub-jay (FWC 2008a). The Florida scrub-jay is being studied in their undisturbed, Since the late 1980s, scrub-jays have been reported to have been extirpated (locally extinct since people settled in the area) from Broward, Dade, Duval, Gilchrist, Pinellas, St. Johns, and Taylor counties (USFWS 1990). A 1992-1993 surveys indicated that scrub-jays were also extirpated from Alachua and Clay counties. Scrub-jays are still found in Flagler, Hardee, Hendry, Hernando, Levy, Orange, and Putnam counties, but ten or less pairs remained in these counties and were considered functionally extirpated (Fitzpatrick, *et al.* 1994). Subsequent information indicated that at least one breeding pair remained in Clay County as late as 2004 and an individual bird was observed in St. Johns County in 2003 (USFWS 2007b). Fitzpatrick, *et al.* 1994 indicates that scrub-jays have been noticeably reduced along their former range all along the Atlantic coast (Figure 4.20).

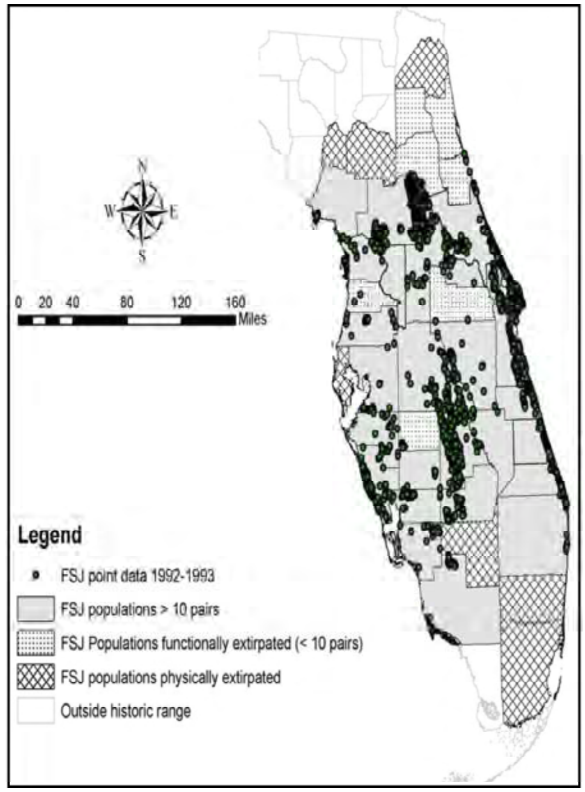


Figure 4.20 Historical vs. current scrub-jay distribution. Stripping and/or shading reflects known new sightings of scrub-jays since the 1992-1993 statewide survey (Source: USFWS 2007b).

4.4.6.5. Future Outlook

Florida Audubon has developed a Recovery Resolution Plan (http://www.audubonofflorida.org/conservation/jay.htm) for the Florida scrub-jay and has also played a big role in their protection. Florida Fish and Wildlife Conservation Commission suggest the following measures to help protect Florida scrub-jays:

1) *The best protection is to protect scrub-jay populations on managed tracts of optimal habitat.*
2) *Provide habitat by planting, protecting, and growing patches of shrubby scrub live oak, Chapman's oak, myrtle oak, and scrub oak on your property. Also, maintain landscaping at a maximum height of 10 feet if you live on or near scrub-jay habitat.*
3) *Encourage passage and strict enforcement of leash laws for cats and dogs in your community and protect areas being used by nesting scrub-jays from domestic animals, especially cats.*

4) *Limit pesticide use because pesticides may limit or contaminate food used by the jays.*
5) *Report any harassment of Scrub jays or their nests to 1-888-404-FWCC (3922).*

4.4.7. *Eastern Indigo Snake (Threatened)*

Source: USFWS.

4.4.7.1. Description

The Eastern Indigo snake (*Drymarchon corais couperi)* is the largest snake found in the US and is protected by federal (1978) and state laws (1971). Typically an adult is 5-6 feet long and 2-3 inches in girth. The range is currently restricted to Florida and southeastern Georgia with isolated populations in other parts of Georgia and in Alabama. They are most common on the Upper and Lower Florida Keys. Breeding occurs between November and April (Dodd Jr and Barichivich 2007; Scott 2003a).

4.4.7.2. Significance

Indigos are habitat generalists that require large areas of unsettled land from 25-450 acres in which to roam, depending on the season (Hyslop, *et al.* 2006; Moler 1985; Zappalorti 2008). Habitats used vary widely. Sandhill communities are preferred, but Indigo snakes can also be found in pine flatwoods, scrub, coastal strand ecosystems and orange groves (Scott 2003a). The snake is diurnal and will subdue and swallow prey whole, feeding on water snakes and a large variety of small prey along the edges of waterways and marshes. Indigo snakes are well known for using Gopher tortoise burrows for refuge (Dodd Jr and Barichivich 2007; Scott 2003a). However, Gopher tortoise populations have been severely reduced in some areas which may affect Indigoes (Scott 2003a).

4.4.7.3. Data Sources & Limitations

Information was gathered from books, reports and web sites but there was limited data available for LSJRB. Dodd Jr and Barichivich 2007 mention most information regarding habitat, use and requirements for the Indigo snake is found in unpublished, non peer reviewed, and largely inaccessible agency reports.

4.4.7.4. Current Status

The literature indicates declining populations throughout its range because of habitat destruction and fragmentation from development, vehicle collisions, gassing burrows (illegal activity 3925.002 FAC), illegal collection and mortality caused by domestic dogs and humans (Lawler 1977; Moler 1992; Scott 2003a; Stevenson, *et al.* 2003).

4.4.7.5. Future Outlook

The focus of habitat protection should be on large non-fragmented tracts of land of about 2,500 acres in size (Dodd Jr and Barichivich 2007; Moler 1992). Moler 1992 proposes that mitigation funds from developments that unavoidably eliminate habitat should be pooled to allow for such large land acquisitions. In north Florida's xeric habitats the future status of Indigos is closely linked to that of Gopher tortoises (Dodd Jr and Barichivich 2007; Moler 1992; Scott 2003a). Rebuilding the tortoise populations will benefit the Indigo snake. Furthermore, Moler 1992 asserts that laws against violations such as "gassing" of tortoise burrows should be strongly enforced.

4.5. Nonindigenous Aquatic Species

4.5.1. Description

The invasion and spread of nonindigenous species is currently one of the most potent, urgent, and far-reaching threats to the integrity of aquatic ecosystems around the world (NRC 1995, 1996, 2002; Ruckelshaus and Hays 1997). Nonindigenous species can simply be defined as "any species or other biological material that enters an ecosystem beyond its historic, native range" (Keppner 1995).

4.5.2. Significance

The transport and establishment of nonindigenous aquatic species in the St. Johns River watershed is significant due to a number of ecosystem, human health, social, and economic concerns.

4.5.2.1. Ecosystem Concerns

"Generalizations in ecology are always somewhat risky, but one must be offered at this point. The introduction of exotic (foreign) plants and animals is usually a bad thing if the exotic survives; the damage ranges from the loss of a few native competing species to the total collapse of entire communities" (Ehrenfield 1970). The alarming increase in the number of documented introductions of non-native organisms is of pressing ecological concern (Carlton and Geller 1993). This concern is supported by the evidence that nonindigenous species, within just years of introduction, are capable of breaking down the tight relationships between resident biota (Valiela 1995). Once introduced, exotic species may encounter few (if any) natural pathogens, predators, or competitors in their new environment.

The exotic plant *Hydrilla verticillata* is the #1 aquatic weed in Florida. Native to Asia, hydrilla was likely introduced to Florida in the 1950s (Simberloff, *et al.* 1997) and has spread through the Lower St. Johns River Basin since at least 1967 (USGS 2008). Even the smallest fragment of hydrilla can rapidly grow and reproduce into dense canopies which are poor habitat for fish and other wildlife. *Hydrilla* is a superb competitor with native species by monopolizing resources and shading out other native plants. Huge masses of *Hydrilla* slow water flow, obstruct waterways, reduce native biodiversity, and create stagnant areas ideal for the breeding of mosquitoes (McCann, *et al.* 1996a). The negative impacts of hydrilla have been so pervasive and intense in Florida, that U.S. scientists have experimentally released four biological control insects from Pakistan that feed on hydrilla in its native habitat and have also stocked infested Florida lakes with non-reproducing Chinese grass carp *(Ctenopharyngodon idella)*, which preferentially eat hydrilla (Richard and Moss 2005). Introducing exotics to control exotics, of course, can produce a secondary layer of ecological problems and unforeseen implications.

As voracious herbivores, a number of exotic fish are altering native ecosystems in the Lower St. Johns River. These fish are common in the aquarium trade and include the Eurasian goldfish (*Carassius auratus*; commonly becomes brown in the wild), Mozambique tilapia *(Oreochromis mossambicus)*, African blue tilapia *(Oreochromis aureus)*, South American brown hoplo *(Hoplosternum littorale)*, and a number of unidentified African cichlids *(Cichlidae spp.)* (Brodie 2008; USGS 2008). Additionally, several species of South American algae-eating catfish commonly known in the aquarium trade as "plecos," including the suckermouth catfish *(Hypostomus sp.)* and vermiculated sailfin catfish *(Pterygoplichthys disjunctivus)* appear to be established in the Lower St. Johns River (USGS 2008). As most aquarium enthusiasts know, "plecos" are extremely efficient algae eaters, and, when released into the wild, can have profound impacts on the native community of aquatic plants and animals.

4.5.2.2. Human Health Concerns

Nonindigenous aquatic species can negatively affect human health. Some nonnative microorganisms, such as blue-green algae and dinoflagellates, produce toxins that cause varying degrees of irritation and illness in people (Hallegraeff and Bolch 1991; Hallegraeff, *et al.* 1990; Stewart, *et al.* 2006). During the summer of 2005, large rafts of toxic algal scum from Lake George to the mouth of the St. Johns River in Mayport, Florida, brought headline attention to toxic bloom-forming algae. The organisms responsible for this bloom were two toxin-producing cyanobacteria (blue-green algae) species: the cosmopolitan *Microcystis aeruginosa* and the exotic *Cylindrospermopsis raciborskii* (Burns Jr 2008). *Cylindrospermopsis raciborskii* has been recorded throughout tropical waters globally, but appears to be expanding into temperate zones as well throughout the U.S. and world (Jones and Sauter 2005; Kling 2004). Although *Cylindrospermopsis* may have been present in Florida since the 1970s, its presence in the St. Johns River Basin was not noted prior to 1994, and, thus, it is considered nonindigenous and invasive in this system (Chapman and Schelske 1997; Phlips, *et al.* 2002; SJRWMD 2005). Genetic studies reveal strong genetic similarities between populations in Florida and Brazil, suggesting the two populations continually mix or came from the same source relatively recently (Dyble, *et al.* 2002).

Cylindrospermopsis now appears to bloom annually each summer in the St. Johns River with occasionally very high concentrations in excess of 30,000 cells/ml (Phlips, *et al.* 2002). During the intense bloom of 2005, the Florida Department of Health released a human health alert recommending that people avoid contact with waters of the St. Johns River, because the toxins can cause "irritation of the skin, eyes, nose and throat and inflammation in the respiratory tract" (FDOH 2005). This public health concern will likely continue to menace the Lower St. Johns River Basin in the foreseeable future, particularly when the water becomes warm, still, nutrient-rich, and favorable to toxic algal blooms.

Additionally, bacterial and viral pathogens, such as the bacterium *Vibrio cholerae,* have been transported in the ballast water of ships and caused outbreaks and deaths in the recipient port cities (Colwell 1997). *Vibrio cholerae* causes cholera—a severe diarrheal illness in humans. The illness can rapidly spread to epidemic proportions in the absence of adequate treatment of sewage and drinking water and can spread through the consumption of contaminated raw shellfish (like raw oysters) (CDC 2008b). A number of other *Vibrio* species are commonly known as the "flesh-eating bacteria" and can enter the human body through open wounds and cause crippling or lethal infections. Although attributed to the native species *Vibrio vulnificus*, one human death has resulted from contact with the waters of the St. Johns River near Jacksonville, Florida—a jet-skier contracted a lethal *Vibrio* infection through an open wound in 2005 (Burns Jr 2008). This event occurred during the severe blue-green algal bloom mentioned above and demonstrates that algal blooms are often the most obvious signal that river conditions are favorable for a number of harmful human pathogens to flourish.

4.5.2.3. Social Concerns

The invasion of an exotic organism can lead to significant social disruption to certain segments of the human population by disrupting traditional patterns of commercial, recreational, and subsistence fishing or altering navigational or industrial use patterns (GESAMP 1997; Shiganova 1998). A number of nonindigenous aquatic species, such as the zebra mussel (*Dreissena polymorpha*) and the Chinese clam (*Portamorcorbula amurensis*), are prolific reproducers that will foul most any hard surface. On a large scale, this fouling, of course, can lead to tremendous economic losses to industries. Just as importantly, yet often overlooked, exotics can be serious nuisances on a small scale. They foul people's recreational boats and personal docks. They foul sunken ships and sites of historical and cultural value. Clean-up and control of aquatic pests, such water hyacinth, can have high economic costs to citizens, not only in taxpayer dollars, but in out-of-pocket money as well. In general, many nonnative species reproduce so successfully in their environment, that they create unsightly masses that negatively impact recreation and tourism. Such unsightly masses, as those created by zebra mussels or water hyacinth, also shift the way we view and appreciate the aesthetic, intrinsic qualities of our aquatic ecosystems.

4.5.2.4. Economic Concerns

History has shown that the establishment of nonnative species can have far-reaching economic impacts on fisheries, seafood industries, aquaculture, and landside industries (GESAMP 1997). Shoreside industries are affected by a number of nonindigenous aquatic species that are prolific reproducers and will foul most any hard surface. Such exotic fouling organisms, such as the Eurasian zebra mussel (*Dreissena polymorpha*) in the Great Lakes, are literally clogging the vitality of water-dependent, landside industries by the excessive fouling of underwater structures and engineering works (Hedgpeth 1993; Johnson and Carlton 1996). The U.S. has spent billions of dollars on efforts to control such organisms (Labi 1996; Ross 1997).

Even locally, excessive fouling by successful nonnative species can lead to economic losses to industries. In 1986, the South American charrua mussel (*Mytella charruana)* caused extensive fouling at Jacksonville Electric Authority's Northside Generating Stationon Blount

Island, Jacksonville, Florida (Lee 2008a). The charrua mussel probably hitchhiked to the St. Johns River in the ballast water of a ship from South America and continues to persist in the area as evidenced by collections in Mayport, Marineland, and the Arlington area of Jacksonville as recently as 2008. Other nonindigenous fouling organisms identified in the St. Johns River include the Asian clam *(Corbicula fluminea),* Indo-Pacific green mussel *(Perna viridis),* and Indo-Pacific striped barnacle *(Balanus amphitrite).* Cleaning these fouling organisms off of docks, bridges, hulls of boats and ships, and industrial water intake/discharge pipes is time-consuming and extremely costly.

4.5.3. Data Sources

Numerous online databases containing nonindigenous species reports were queried. The most comprehensive listing of species is maintained in the Nonindigenous Aquatic Species (NAS) database of the United States Geological Service (USGS 2008). Additional records and information were obtained from agency reports, books, published port surveys, and personal communication data (complete list of data sources in Appendix 4.5.A.).

4.5.4. Limitations

We expect that many more nonindigenous species are sited, but specimens are not collected or formally recorded with any local or state governmental agency. These sightings are typically lost and are not included in this study. Additionally, it is expected that numerous exotic species are unrecognized or unrecorded, either because they are *naturalized*, *cryptogenic,* or because the taxonomic expertise to identify foreign species, subspecies, or hybrids is not available.

A naturalized species is any nonnative species that has adapted and grows or multiplies as if native (Horak 1995).

A cryptogenic species is an organism whose status as introduced or native is not known (Carlton 1987).

4.5.5. Current Status

A total of 56 nonindigenous aquatic species are documented and believed to be established in the LSJRB (see Table 4.5.5; Appendix 4.5.B.).

The nonnative species recorded in the Lower Basin include a variety of lifeforms of organisms, including floating or submerged aquatic plants (29%), molluscs (23%), fish (21%), crustaceans (16%), amphibians (3%), jellyfish (2%), mammals (2%), reptiles (2%), and alga/seaweed (2%).

A majority (62%) of the nonindigenous species that have been introduced into the LSJRB are freshwater (Figure 4.21). The habitats that are most commonly utilized by these exotic species are lakes (36%), watercourses (36%), and marine habitats (14%). Other habitats utilized include agricultural areas, disturbed areas, estuaries, urban areas, and wetlands.

The majority (29%) of the nonindigenous aquatic species that have been introduced into the LSJRB have native ranges in South America (Figure 4.22).

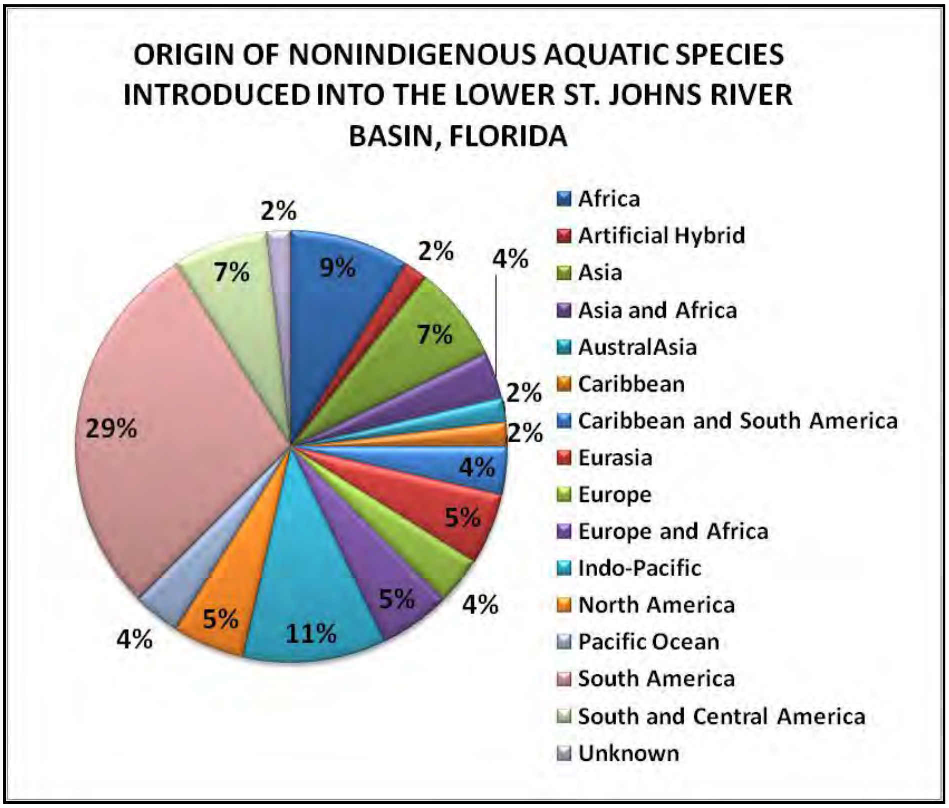


Figure 4.21 Aquatic Systems Utilized by Nonindigenous Aquatic Species Introduced into the Lower St. Johns River Basin, Florida.

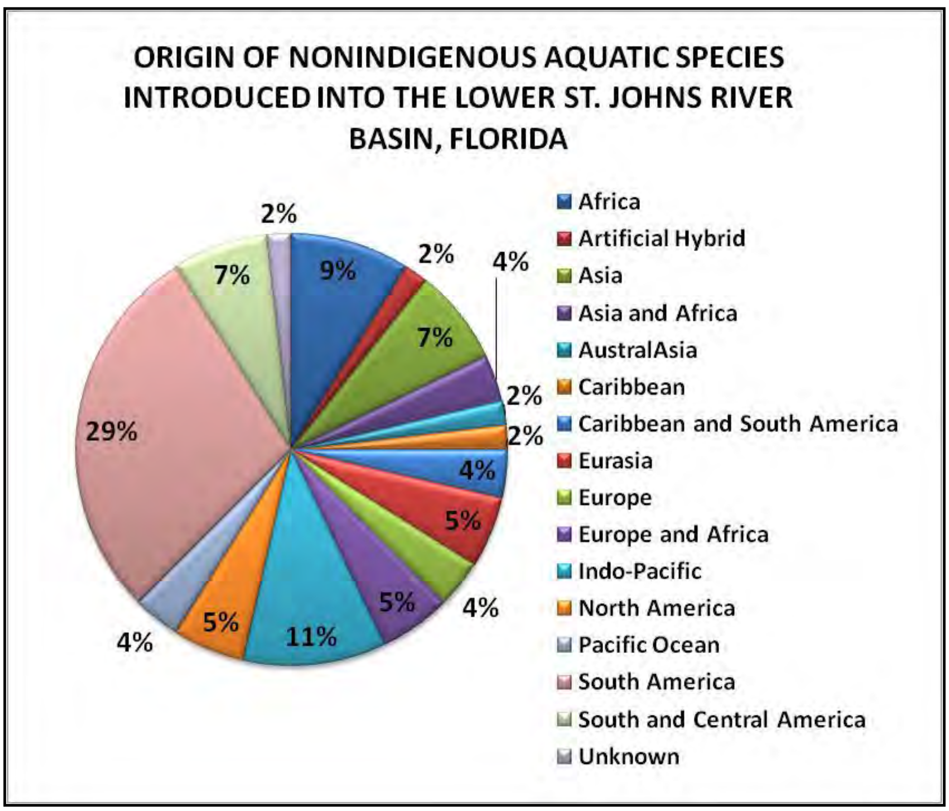
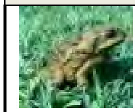
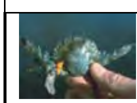
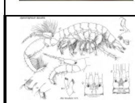
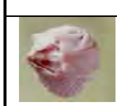
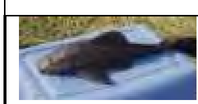
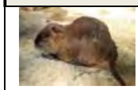
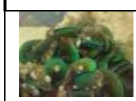


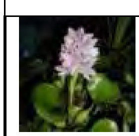
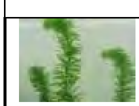
Figure 4.22 Native Habitat of Nonindigenous Aquatic Species Introduced into the Lower St. Johns River Basin, Florida.

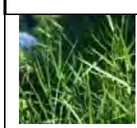
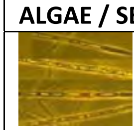
Table 4.5.5. Nonindigenous Aquatic Species Recorded in the Lower St. Johns River BasiN

LIFEFORM	COMMON NAME	SCIENTIFIC NAME	HABITAT REALM	DATE	ORIGIN	PROBABLE VECTORS	PROHIBITED STATUS?	REFERENCES
AMPHIBIANS								
	Cane toad *Photo: USGS NAS*	*Bufo marinus*	Freshwater, Brackish	Intentionally introduced to several locations in South Florida between 1936 and 1958.	South and Central America	Humans,Range expansion from South Florida populations	No	USGS 2008
	Cuban treefrog *Photo: USGS NAS*	*Osteopilus septentrionalis*	Terrestrial, Freshwater	First detected in Key West before 1928. Spread northward through Keys. Now recorded in southern half of Florida.	Caribbean	Dispersing northward from S. Florida populations, floating vegetation/debris, humans, vehicles, bulk freight/cargo, plant or parts of plants	No	USGS 2008
JELLYFISH								
	Freshwater jellyfish *Photo: USGS NAS*	*Craspedacusta sowerbyi*	Freshwater	First described in Philadelphia in 1928. Recorded throughout the US. Most common in temperate states in eastern US	Asia	Aquaculture stock, other live animal, plant or parts of plants	No	USGS 2008
CRUSTACEANS								
	Bocourt swimming crab *Photo: USGS NAS*	*Callinectes bocourti*	Marine, Brackish	First US report was Biscayne Bay, FL, 1950.	Caribbean and South America	From the Caribbean via major eddies in Gulf Stream or southern storm events	Federal Injurious Wildlife List "No such live fish, mollusks, crustacean, or any progeny or eggs thereof may be released into the wild" (without a permit from FWC) (U.S. Lacey Act; 50 CFR Ch. I Sec. 16.13)	USGS 2008
	Indo-Pacific swimming crab *Photo: J. Piraino*	*Charybdis hellerii*	Marine	First US report was South Carolina (1986), Indian River Lagoon, FL (1995)	Indo-Pacific	Ship ballast water/sediment, or drift of juveniles from Cuba	Federal Injurious Wildlife List (U.S. Lacey Act)	USGS 2008
	Green porcelain crab *Photo: D. Knott*	*Petrolisthes armatus*	Marine, Brackish	Indian River Lagoon, FL (1977), Georgia (1994), and SC (1995)	Caribbean and South America	Natural range expansion, Ship ballast water/sediment, importation of mollusk cultures	Federal Injurious Wildlife List (U.S. Lacey Act)	Power, *et al.* 2006
	Amphipod *Illustration: Bousfield 1973*	*Apocorophium lacustre*	Brackish	unknown	Europe and Africa	Ship ballast water/sediment from Europe	Federal Injurious Wildlife List (U.S. Lacey Act)	Power, *et al.* 2006
	Wharf roach *Photo: Bishop Museum*	*Ligia exotica*	Marine	unknown	Northeast Atlantic and Mediterranean Basin	Bulk freight/cargo, Ship ballast water/sediment, Shipping material from Europe	Federal Injurious Wildlife List (U.S. Lacey Act)	Power, *et al.* 2006
	Striped barnacle *Photo: R. DeFelice*	*Balanus amphitrite*	Marine	unknown	Indo-Pacific	Ship/boat hull fouling	Federal Injurious Wildlife List (U.S. Lacey Act)	Power, *et al.* 2006
	Triangular barnacle *Photo: D. Elford*	*Balanus trigonus*	Marine	unknown	Indo-Pacific	Ship/boat hull fouling	Federal Injurious Wildlife List (U.S. Lacey Act)	GSMFC 2007
	Barnacle *Illustration: Bishop Museum*	*Balanus reticulatus*	Marine	unknown	Indo-Pacific	Ship/boat hull fouling	Federal Injurious Wildlife List (U.S. Lacey Act)	GSMFC 2007
	Titan acorn barnacle	*Megabalanus coccopoma*	Marine	First recorded in Duval Co, FL - 2004; Common by 2006.	Pacific Ocean	Ship/boat hull fouling	Federal Injurious Wildlife List (U.S. Lacey Act)	Frank 2008b

LIFEFORM	COMMON NAME	SCIENTIFIC NAME	HABITAT REALM	DATE	ORIGIN	PROBABLE VECTORS	PROHIBITED STATUS?	REFERENCES
	Photo: B. Frank							
FISH								
	Goldfish *Photo: USGS NAS*	*Carassius auratus*	Freshwater	Intentional releases in the US, late 1600's.	Eurasia	Intentional release, Ornamental purposes, Stocking, Aquarium trade, Escape from confinement, Landscape/fauna "improvement"	Federal Injurious Wildlife List (U.S. Lacey Act)	USGS 2008
	Unidentified cichlids *Photo: USGS NAS*	*Cichlidae spp.*	Freshwater	Recorded in LSJRB between 2001 and 2006.	Africa	Humans	Federal Injurious Wildlife List (U.S. Lacey Act)	Brodie 2008; GSMFC 2007; USGS 2008
	Blue tilapia *Photo: USGS NAS*	*Oreochromis aureus*	Freshwater	In 1961, 3,000 fish stocked in Hillsborough Co, FL. Recorded in LSJRB between 2001 and 2006.	Europe and Africa	Humans: Intentional fish stocking	Federal Injurious Wildlife List (U.S. Lacey Act)	Brodie 2008; GSMFC 2007; USGS 2008
	Mozambique tilapia *Photo: USGS NAS*	*Oreochromis mossambicus*	Freshwater, Brackish	1960's - Introduced/established in Dade Co, FL. Recorded in LSJRB between 2001 and 2006.	Africa	Humans: Stocked, intentionally released, escapes from fish farms, aquarium releases	Federal Injurious Wildlife List (U.S. Lacey Act)	Brodie 2008; GSMFC 2007; USGS 2008
	Unidentified tilapia *Photo: USGS NAS*	*Tilapia spp.*	Freshwater	Recorded in LSJRB between 2001 and 2006.	Africa	Humans	Federal Injurious Wildlife List (U.S. Lacey Act)	Brodie 2008; GSMFC 2007
	Unidentified Pacu *Photo: USGS NAS*	*Colossoma or Piaractus sp.*	Freshwater	1984-1989	South America	Aquaculture stock (Fish farm escapes or releases), Humans (aquarium releases)	Federal Injurious Wildlife List (U.S. Lacey Act)	USGS 2008
	Brown Hoplo *Photo: USGS NAS*	*Hoplosternum littorale*	Freshwater	First recorded in Indian River Lagoon, 1995.	South America	Humans	Federal Injurious Wildlife List (U.S. Lacey Act)	USGS 2008
	Wiper (Hybrid Striped Bass) (Whiterock = *female striped bass x male white bass,* Sunshine Bass = *male striped bass x female white bass*) *Photo: T. Pettengill*	*Morone chrysops x saxatilis (Artificial hybrid between the white bass and the striped bass)*	Freshwater, Brackish, Marine	Intentionally stocked in the 1970's. Identified in 1992.	Artificial Hybrid	Humans: Intentional fish stocking	Federal Injurious Wildlife List (U.S. Lacey Act)	USGS 2008
	Unidentified armoured catfish *Photo: USGS NAS*	*Loricariidae spp.*	Freshwater	Recorded in LSJRB between 2001 and 2006.	South and Central America	Aquaculture stock (Fish farm escapes or releases), Humans (aquarium releases)	Federal Injurious Wildlife List (U.S. Lacey Act)	Brodie 2008; FWRI 2006b
	Suckermouth catfish *Photo: L. Smith*	*Hypostomus sp.*	Freshwater	1974, 2003	South and Central America	Aquaculture stock (Fish farm escapes or releases), Humans (aquarium releases)	Federal Injurious Wildlife List (U.S. Lacey Act)	USGS 2008
	Southern sailfin catfish *Photo: K.S. Cummings*	*Pterygoplichthys anisitsi*	Freshwater	2007	South America	Humans: Likely aquarium release	Federal Injurious Wildlife List (U.S. Lacey Act)	USGS 2008

LIFEFORM	COMMON NAME	SCIENTIFIC NAME	HABITAT REALM	DATE	ORIGIN	PROBABLE VECTORS	PROHIBITED STATUS?	REFERENCES
 Photo: USGS NAS	Vermiculated sailfin catfish	*Pterygoplichthys disjunctivus*	Freshwater	2003	South America	Aquaculture stock (Fish farm escapes or releases), Humans (aquarium releases)	Federal Injurious Wildlife List (U.S. Lacey Act)	USGS 2008
MAMMALS								
 Photo: USGS NAS	Nutria	*Myocaster coypus*	Freshwater, Terrestrial	1956, 1957, 1963 Introduced into Florida for fur farming.	South America	Humans: escaped or released from captivity	Possession of nutria prohibited without a license from FWC (F.S. 372.98)	USGS 2008
MOLLUSCS								
 Photo: USGS NAS	Asian clam	*Corbicula fluminea*	Freshwater	Florida in 1964; 1990- Volusia County; 1975- Lake Oklawaha; 1974-76 Black Creek	Asia and Africa	Humans, Live seafood, Bait, Aquaculture stock, Water	Federal Injurious Wildlife List (U.S. Lacey Act)	Lee 2008c, 2008b
 Photo: USGS NAS	Charrua mussel	*Mytella charruana*	Marine	1986- Jacksonville; 2004- Mosquito Lagoon; 2006- Mayport (Duval Co), 2006- Marineland (Flagler Co)	South America	Ship ballast water/sediment	Federal Injurious Wildlife List (U.S. Lacey Act)	Lee 2008b
 Photo: USGS NAS	Green mussel	*Perna viridis*	Marine, Brackish	1999- Tampa Bay; 2003- St. Augustine and Jacksonville	Indo-Pacific	Ship ballast water/sediment, Ship/boat hull fouling, Humans	Federal Injurious Wildlife List (U.S. Lacey Act)	Frank 2008b
 Photo: B. Frank	Paper pondshell	*Utterbackia imbecillis*	Freshwater	Lake Oneida, UNF (Duval Co, FL) 2005, Recorded in 1990 in Sawgrass area	North America: Native in Mississippi River and Great Lakes.	Other live animal, plant or parts of plants, ship/boat	Federal Injurious Wildlife List (U.S. Lacey Act)	Lee 2008c, 2008b
 Photo: B. Frank	Red-rim melania	*Melanoides tuberculata*	Freshwater	1976- Willowbranch Creek, Riverside, Jacksonville, FL	Asia and Africa	Other live animal, plant or parts of plants, ship/boat	Federal Injurious Wildlife List (U.S. Lacey Act)	Lee 2008c, 2008b
 Photo: B. Frank	Fawn melania	*Melanoides cf. turricula*	Freshwater	Fruit Cove (St. Johns Co, FL) 2006; Arlington area of Jacksonville (Duval Co, FL) 2006	North America: Native in western US and Canada.	Other live animal, plant or parts of plants, ship/boat	Federal Injurious Wildlife List (U.S. Lacey Act)	Lee 2008b
 Photo: B. Frank	Spiketop applesnail	*Pomacea diffusa*	Freshwater	2006	South America	Humans: probable aquarium releases	Federal Injurious Wildlife List (U.S. Lacey Act)	Frank 2008a
 Photo: Georgia DNR	Channeled applesnail	*Pomacea canaliculata*	Freshwater	unknown	South America	Humans: probable aquarium releases	Federal Injurious Wildlife List (U.S. Lacey Act)	Frank 2008a
 Photo: B. Frank	Island applesnail	*Pomacea insularum*	Freshwater	unknown	South America	Humans: probable aquarium releases	Federal Injurious Wildlife List (U.S. Lacey Act)	Frank 2008a
 Photo: B. Frank	Mouse-ear marshsnail	*Myosotella myosotis*	Marine	unknown	Europe	Bulk freight/cargo, Ship ballast water/sediment,	Federal Injurious Wildlife List (U.S. Lacey Act)	Lee 2008b
 Photo: B. Frank	Striped falselimpet	*Siphonaria pectinata*	Marine	unknown	Europe and Africa (Mediterranean Sea)	Bulk freight/cargo, Ship ballast water/sediment, Ship/boat hull fouling, Humans	Federal Injurious Wildlife List (U.S. Lacey Act)	Lee 2008b; McCarthy 2008

LIFEFORM	COMMON NAME	SCIENTIFIC NAME	HABITAT REALM	DATE	ORIGIN	PROBABLE VECTORS	PROHIBITED STATUS?	REFERENCES
	Fimbriate shipworm	*Bankia fimbriatula*	Marine	unknown	Pacific?	Ship/boat hull fouling, Humans	Federal Injurious Wildlife List (U.S. Lacey Act)	Lee 2008b
 Photo: ShellMuseum.org	Striate Piddock shipworm	*Martesia striata*	Marine	unknown	Indo-Pacific?	Ship/boat hull fouling, Humans	Federal Injurious Wildlife List (U.S. Lacey Act)	Lee 2008b
REPTILES								
 Photo: USGS NAS	Red-eared slider	*Trachemys scripta elegans*	Freshwater, Brackish	unknown	North America: US midwestern states to northeastern Mexico	Humans - pet releases and escapes	Illegal in Florida: Red-eared sliders less than 4 inches carapace length may not be bought, sold, or bred after July 1, 2008 without a permit from FWC. (F.A.C. 68-5.001 and 68-5.002; F.S. 372.26).	USGS 2008
AQUATIC PLANTS								
 Photo: USGS NAS	Alligator-weed	*Alternanthera philoxeroides*	Freshwater	1887-1894 in Florida, 1982-1992 specimens collected	South America	Ship ballast water/sediment	Class I Prohibited Aquatic Plant (F.A.C. 62C-52) -- "Under no circumstances will these species be permitted for possession, collection, transportation, cultivation, and importation.")	McCann, *et al.* 1996a; USGS 2008
 Photo: F. & K. Starr	Para grass	*Urochloa (Brachiaria) mutica*	Freshwater	1982-1992	Africa	Humans: intentional release for agriculture	No	McCann, *et al.* 1996a; USGS 2008
 Photo: IFAS Univ. of Florida	Water spangles	*Salvinia minima*	Freshwater	1928 - First report for North America in and along St. Johns River; 2003 - expanding range	South and Central America	Ship ballast water/sediment, Humans, Aquarium trade	Class I Prohibited Aquatic Plant (F.A.C. 62C-52)	McCann, *et al.* 1996a; USGS 2008
 Photo: USGS NAS	Hydrilla	*Hydrilla verticillata*	Freshwater	1967-1994 (USGS), early 1950s (Simberloff et al.)	Asia	Debris associated with human activities, Ship/boat, Aquarium trade, Garden waste disposal	Federal Noxious Weed List (Public Law 108-412; 7 C.F.R. Ch. III Part 360); Regulated Plant Pest List (U.S.D.A. Animal & Plant Health Inspection Service); Class I Prohibited Aquatic Plant	McCann, *et al.* 1996a; USGS 2008
 Photo: USGS NAS	Water-hyacinth	*Eichhornia crassipes*	Freshwater	First released 1880's, 1990-1994	South America	Humans, Aquarium trade, Garden escape	Class I Prohibited Aquatic Plant (F.A.C. 62C-52)	McCann, *et al.* 1996a; USGS 2008
 Photo: USGS NAS	Water-lettuce	*Pistia stratiotes*	Freshwater	Described in Florida in 1765 (Bartram 1942)	South America	Ship ballast water/sediment	Class II Prohibited Aquatic Plant (F.A.C. 62C-52) -- May be cultured in nursuries for export out of the State; "Shall not be imported or collected from the wild"	McCann, *et al.* 1996a; USGS 2008
 Photo: USGS NAS	Brazilian waterweed	*Egeria densa*	Freshwater	1969-1995, First record at St. Johns River at Cross Florida Barge Canal (1969)	South America	Humans: accidental aquarium releases, intentional release for control of mosquito larvae	No	McCann, *et al.* 1996a; USGS 2008

LIFEFORM	COMMON NAME	SCIENTIFIC NAME	HABITAT REALM	DATE	ORIGIN	PROBABLE VECTORS	PROHIBITED STATUS?	REFERENCES
 *Photo: A. Murray*	Water sprite	*Ceratopteris thalictroides*	Freshwater	1984-1992 specimens collected	AustralAsia	Humans	No	McCann, *et al.* 1996a; USGS 2008
 *Photo: K. Dressler*	Wild taro	*Colocasia esculenta*	Freshwater	Introduced to FL by Dept of Agriculture in 1910, 1971-1992 specimens collected	Africa	Humans	No	USGS 2008
 *Photo: Washington State Noxious Weed Control Board*	Uruguay seedbox	*Ludwigia hexapetala*	Freshwater	1998 specimen collected	South America	Humans	No	USGS 2008
 *Photo: L. Lee*	Marsh dewflower	*Murdannia keisak*	Freshwater	1960 specimen collected	Asia	Humans	No	USGS 2008
 *Photo: USGS NAS*	Parrot-feather	*Myriophyllum aquaticum*	Freshwater	1940-1995 specimens collected	South America	Humans	No	McCann, *et al.* 1996a; USGS 2008
 *Photo: USGS NAS*	Brittle naiad	*Najas minor*	Freshwater	1983-1984 specimens collected, in US since 1930's	Eurasia	Humans	No	McCann, *et al.* 1996a; USGS 2008
 *Photo: C. Jacono*	Crested floating-heart	*Nymphoides cristata*	Freshwater	2003 specimen collected	Asia	Humans	No	USGS 2008
 *Photo: WI DNR*	Water-cress	*Nasturtium officinale*	Freshwater	1995 specimens collected	Eurasia	Humans	No	McCann, *et al.* 1996a; USGS 2008
 *Photo: V. Ramey*	Torpedo grass	*Panicum repens*	Freshwater	1982-1992 specimens collected, Lower Kississimee Valley 1920s	Europe	Humans	No	McCann, *et al.* 1996a; USGS 2008
ALGAE / SEAWEED / PHYTOPLANKTON								
 *Photo: Umwelt Bundes Amt*	Blue-green alga	*Cylindrospermopsis raciborskii*	Freshwater	1950's first ID in the US; 1995 first ID in Florida	South America (High degree of genetic similarity with specimens from Brazil)	Humans, Other live animal (digestion/excretion), aquarium trade, Ship ballast water/sediment, Ship/boat, Water (interconnected waterways)	No	Dyble, *et al.* 2002

4.5.6. *Trend*

The cumulative number of nonindigenous aquatic species introduced into the LSJRB has been increasing since records were kept prior to 1900 (Figure 4.23). This trend is the reason that the category is assigned a "CONDITIONS WORSENING" status – indicating that exotic species are contributing to a declining status in the health of the St. Johns River Lower Basin.

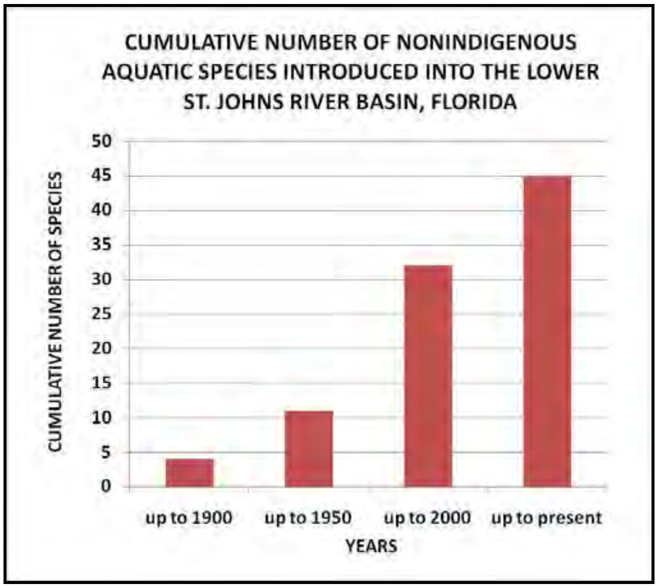


Figure 4.23 Increasing Number of Nonindigenous Aquatic Species Introduced into the Lower St. Johns River Basin, Florida since the turn of the 20th century.

Nonindigenous plants and animals arrive in the St. Johns River watershed by various means. The most common vector of transport has been humans themselves (39%), followed by ship ballast consisting of water and/or sediment (14%), aquaculture stock (11%), and ship/boat hull fouling (10%) (Figure 4.24). One of the most widespread ways that nonnative species arrive in Florida is when people accidentally or intentionally release exotic aquarium plants or pets into the wild. Such releases not only violate State and Federal laws, but can have devastating impacts on native ecosystems and native biodiversity.

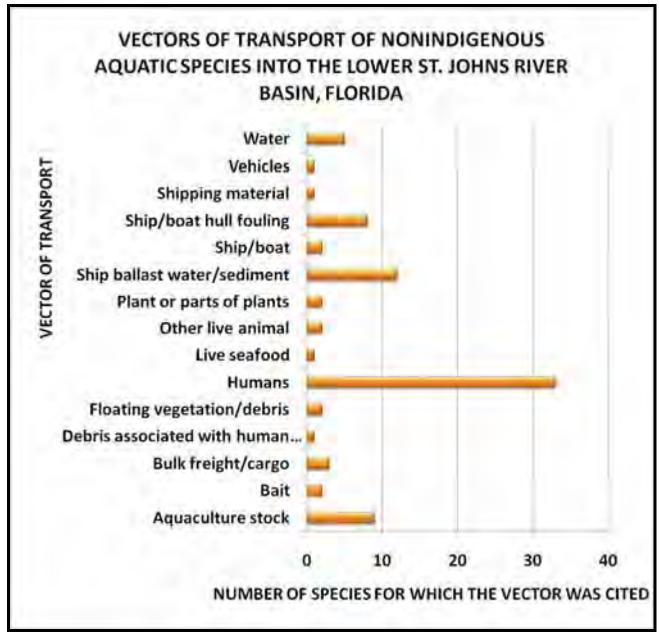


Figure 4.24 Vectors of Transport Cited for Bringing Nonindigenous Aquatic Species into the Lower St. Johns River Basin, Florida.

Nonindigenous aquatic species have been introduced into the Lower Basin by the aquarium trade (25%), as hitchhikers on ships, boats, or vehicles (19%), intentional releases by people (15%), or through the intentional stocking of the St. Johns River, its tributaries, or interconnected lakes (8%) (Figure 4.25).

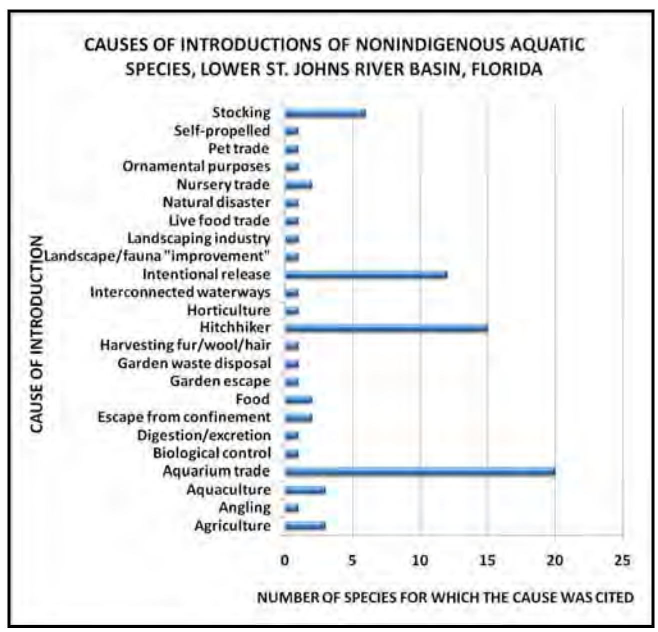


Figure 4.25 Sources for the Introduction of Nonindigenous Aquatic Species into the Lower St. Johns River Basin, Florida.

4.5.7. *Future Outlook*

IRREVERSIBLE IMPACTS. Once an exotic species becomes naturalized in a new ecosystem, the environmental and economic costs of eradication are usually prohibitive (Elton 1958). Thus, once an invasive species gets here, it is here to stay, and the associated management costs will be passed on to future generations. Since the early 1900s, taxpayer dollars have been paying for ongoing efforts to control the spread of invasive nonindigenous aquatic species in the St. Johns River.

Case Study: Water Hyacinth. One of the most, *if not the most*, notorious and devastating introductions of a nonindigenous species into the St. Johns River is the lovely South American aquatic plant known as the water hyacinth. Water hyacinth was introduced into the river in 1884 near Palatka. By 1896, it had spread throughout most of the Lower St. Johns River Basin and was already hindering steamboat navigation. Water hyacinth causes changes in water quality and biotic communities by severely curtailing oxygen and light diffusion and reducing water movement by 40 to 95% (McCann, *et al.* 1996a). If growth remains unchecked, these exotic aquatic plants form dense mats that obstruct waterways, disrupt transportation, and modify natural hydrology patterns and native communities and biodiversity.

The U.S. Army Corps of Engineers (USACE) periodically sprays herbicides on the St. Johns River to control the growth of this weedy invader. From 2001 to 2006, the USACE sprayed an average of 3,042 gallons of herbicide annually on about 5,102 acres of the St. Johns River and its tributaries (Figure 4.26). This represents an average of 608 acres in the Lower Basin that were treated with herbicides during this time period (USACE 2007b). It is likely that the use of herbicides to control invasive aquatic plants will continue into the future with negative impacts on the health of the St. Johns River watershed. The financial and ecological impacts will be multiplied, if additional invasive species become a public nuisance requiring periodic control.

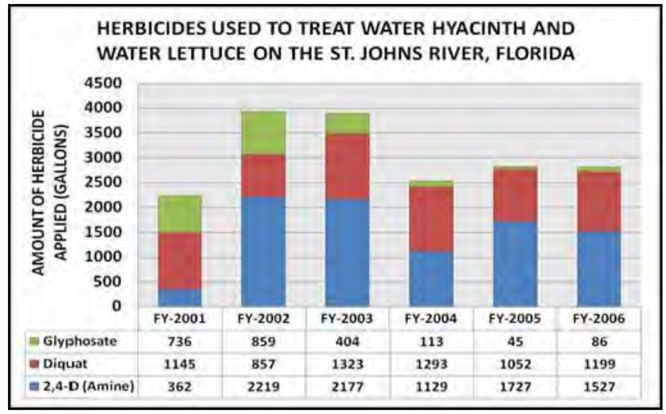


Figure 4.26 Gallons of Herbicide Applied on the St. Johns River, Florida to Control the Growth of Water Hyacinth (Eichhornia crassipes) and Water Lettuce (Pistia stratiotes) from Fiscal Year 2001 to 2006 (USACE 2007).

HIGH RISK. There is a high probability that future invasions of nonindigenous aquatic species will occur in the Lower St. Johns River Basin. This study found that the two most significant vectors for transporting exotic organisms were humans and ship ballast (Figure 4.29), and that both of these vectors are expected to increase in coming years, thereby increasing the likelihood for additional and potentially more frequent introductions. Human population growth in Northeast Florida is projected to more than double by 2060 (Zwick and Carr 2006). Additionally, the number of ships visiting the Port of Jacksonville has increased since 2002 (Figure 4.27) and is expected to increase further due to the addition of a new cargo terminal and an increasing number of cruise ship visits (JAXPORT 2008a).

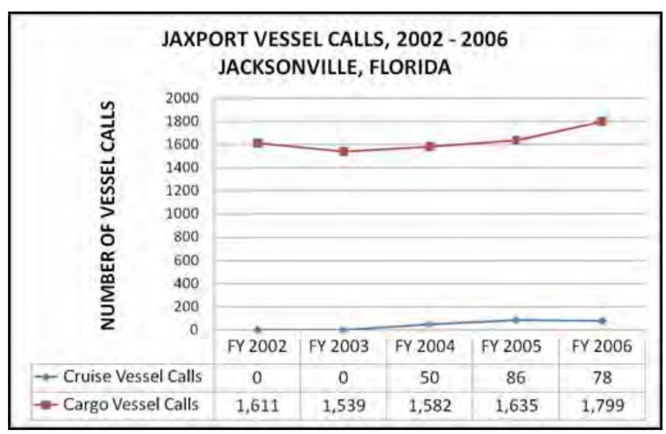


Figure 4.27 Number of Cruise Ships and Cargo Ships Calling on Port of Jacksonville, Florida (JaxPort) Terminals between Fiscal Year 2002 and 2006.

Additional invasions into the Lower St. Johns River Basin are expected from adjacent or interconnected water bodies. For example, an additional 16 nonindigenous aquatic species have been recorded in the Upper St. Johns River Drainage Basin, and an additional 21 species have been recorded in the Ocklawaha Drainage Basin (USGS 2008). It is likely that these species will disperse into the Lower St. Johns River Basin in the future. Moreover, rising global temperatures may also contribute to a northward expansion in the range of nonnative species from Central and South Florida.

5. CONTAMINANTS

5.1. Background

5.1.1. Chemicals in the Environment

Contaminants are chemicals that are found at unnatural concentrations in any given environment. Some are produced solely by human activity, but many are also produced naturally in small quantities. These naturally occurring compounds become contaminants when they are introduced into organisms or ecosystems in much higher quantities than normal, often as a result of human activity (examples are polyaromatic hydrocarbons, or PAHs, and metals). Furthermore, the natural concentrations of these compounds often vary with geology and environment. Thus, it is much more difficult to detect human input and harmful concentrations for naturally occurring compounds than for those that are produced solely by human activity.

A chemical becomes environmentally significant when it is prevalent, persistent, and toxic. The prevalence of a chemical in any system depends on how much of it goes in and how quickly it goes out, either by flowing out or by degrading. A compound that is persistent breaks down slowly and is removed slowly. The probability for long-term toxic effects increases with persistence. Some types of chemicals are taken up and stored in fat tissues of plants and animals with little or no degradation, i.e, they ***bioaccumulate***. Bioaccumulated chemicals are stored in tissues of prey organisms so when prey are eaten, the chemicals can be transferred to predators and travel up the food chain in increasingly higher levels, i.e., they ***biomagnify***. Thus, organisms containing the bioaccumulated chemicals act as a reservoir or "sink," which is only slowly depleted. Chemicals in four environmentally significant categories are evaluated here. The categories include 1) metals, 2) polyaromatic hydrocarbons (PAHs), 3) polychlorinated biphenyls (PCBs), and 4) pesticides. These chemicals vary in their chemical structure, their sources, and their specific fates and effects, but they all have a high potential for prevalence, persistence, toxicity and bioaccumulation.

Information about chemical contamination is often held in the sediments of rivers. Many of the environmentally important compounds are attracted to the organic matter in sediments and end up there, regardless of how they enter the water body. Plants and animals that live in sediments, benthic organisms, are directly exposed to contaminated sediments, so their toxic responses to contaminants are particularly important. Sediment concentrations of the four classes of contaminants are reviewed here.

Figure 5.1 Sediment at Talleyrand, LSJR

5.1.2. Impact Assessment

Environmental toxicology examines the effects of contaminants on ecosystem inhabitants, from individual species to whole communities. While toxicity is often viewed in terms of human health risk, human risk is one of the most difficult toxicity "endpoints," or measures, to accurately quantify. It is environmental toxicity, or effects on ecosystems and aquatic organisms, that is the focus of our assessment of contaminants in the LSJR.

The environmental impact of a toxic compound can be evaluated several ways. One way is by comparing the concentrations in the LSJR to various toxicity measures. When the concentration of a contaminant in sediment is greater than the toxicity measure, it is an ***exceedance***. Most sediment quality guidelines for contaminants are based on the impact of contaminants on sediment-dwelling benthic macroinvertebrates, assessing both the individual species' health and the community structure. Since these organisms are at the beginning of the fisheries food chain, their health is a good indicator of general river health. One toxicity measure that is quite protective of the health of aquatic organisms is a ***Threshold Effects Level*** (**TEL**). This is the concentration at which a contaminant begins to affect some sensitive species. When the number of sites that have concentrations greater than the TEL is high, there is a higher possibility that some organisms are affected. A second, less protective guideline is the ***Probable Effects Level*** (**PEL**). This is the concentration above which many aquatic species are likely to be affected. The TEL and PEL sediment quality guidelines for marine systems are used in this assessment, with emphasis on the latter. These were the guidelines that were most widely available for the compounds of interest, plus much of the heavily impacted areas are in the marine section of the LSJR. Some alternative guidelines are used and identified for some compounds for which there were no marine TEL or PEL guidelines (MacDonald 1994; NOAA 1999). Specific values are listed in Appendix 5.1.1a.

In an approach similar to Long, *et al.* 1995 and Hyland, *et al.* 1999, we estimated the toxic pressure of nearly 40 chemicals on the river, by calculating a PEL quotient. The quotient is the concentration of a contaminant in the sediment divided by the PEL value. If the quotient, or toxicity pressure, is greater than one, toxic effects on benthic organisms are probable. As the quotient increases, we can assume that toxic effects increase. The averages of these ratios are used to compare the effects of different chemicals, and to understand their relative importance in the impairment of the river health. The PEL quotient is also useful in estimating the cumulative effect of different classes of contaminants with different toxic effects.

5.1.3. Limitations of Toxicity Assessments

While sediment quality guidelines are useful tools, it is important to appreciate the limitations of simple comparisons in the extremely complex LSJR. A major difficulty in assessing toxic impacts is that the accessibility, or bioavailability, of a contaminant to organisms may vary with sediment type. Two sediments with similar contaminant concentrations but different physical and chemical features can produce very different environmental impacts, and we know that LSJR sediments are highly variable. Furthermore, each sediment quality guideline can be specific to certain organisms and endpoints (e.g., death of fish, reproductive effects of sea urchin, sea worm community structure, etc.) and cannot easily be extrapolated to other organisms or endpoints. As a consequence, guidelines from different organizations sometimes differ. Finally, separate guidelines are often established for marine and freshwater environments, though few estuarine guidelines exist that apply to the LSJR. These challenges limit our assessment to one that is general and relative in scope.

5.2. Data Sources and Limitations

The data used in this report came from several major studies carried out on the Lower St. Johns River from 1983 to 2003. They were conducted by the SJRWMD, Department of Environmental Protection, Mote Marine Laboratories, Savannah Laboratories, and NOAA's National Status and Trends programs. A major portion of the more recent data came from a set of studies conducted by the SJRWMD from 1996-2003 in a long-term sediment quality assessment (*Durell, *et al.* 1997; Durell, *et al.* 2004; Higman, *et al.* 2008). The studies and data sets used in our data analysis are indicated in the reference section. The database that was generated represents a substantial portion of existing data for LSJR contaminants. It is not exhaustive however, and should be considered a starting point from which omitted past and future studies can be added. In particular, modern pesticides, other important priority pollutants and emerging pollutants, such as endocrine disruptors, should also be included. Future additions of data on concentrations of contaminants in water and organisms will also add to the quality of the assessment.

5.3. Data Analysis

The specific contaminants were selected for evaluation when there was an abundance of data for several years, the analytical methods were uniform in the different studies, and there was adequate site information. Advances in analytical technology during the last twenty years can skew interpretations of temporal trends if not taken into account, which we attempted to do qualitatively. Sometimes we omitted potentially important contaminants because of analytical differences between studies.

The data were first compiled from each source for approximately 200 analytes at nearly 500 sites, over a span of 20 years, and these were culled for location and analytical comparability. We omitted data from some years when the number of samples were too few, or when extreme values distorted the analysis. An example is Deer Creek samples in 1991 that consisted of nearly pure creosote (*Delfino, *et al.* 1991b). The average concentrations, percent exceedances of sediment quality guidelines, and average toxicity quotients were used for comparison between years and regions of the river. Median concentrations were used in discussions of the entire river because this approach minimizes the effect of isolated cases of very high concentrations.

The basin was divided into four areas whose boundaries are shown in Figure 5.2; additional information about the different regions is given in Appendix 5.3a. Area 1, Western Tributaries, is composed of the Trout River (including Moncrief Creek and Ribault River tributaries), Long Branch Creek, the Cedar-Ortega system, and Rice Creek. Despite their distance from one another, they were combined because they share the unfortunate characteristic of having such high levels of contamination that they mathematically obscure trends in the rest of the lower basin. Area 2, North Arm, is the northern, east-west, marine portion from Mayport to Talleyrand and where the maritime industry is prevalent. Area 3, North Main stem, includes urban Jacksonville south to Julington Creek. The southernmost Area 4, South Main stem, stretches past Palatka to the Ocklawaha and to fresher water.

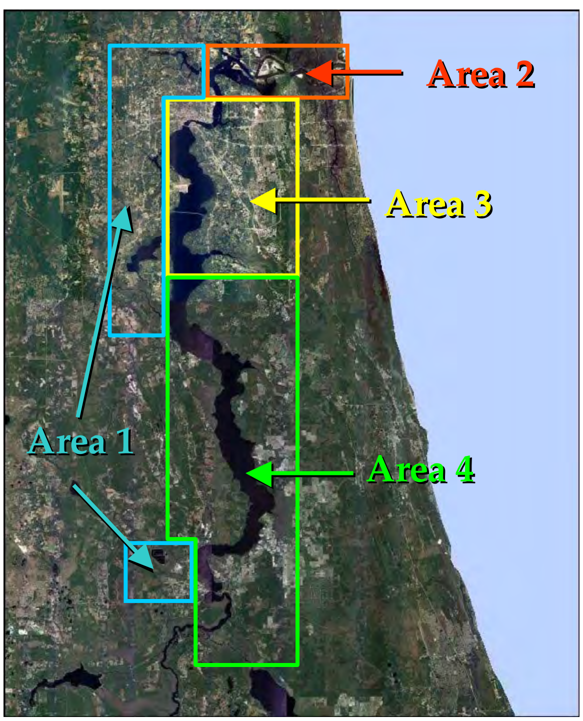


Figure 5.2 Areas of the LSJR Studied for Sediment Contamination: Area 1 – Western Tributaries (Including Trout River, Moncrief Creek, Ribault River, Long Branch Creek, Cedar-Ortega Basin, and Rice Creek); Area 2 – Northern Arm; Area 3 – North Main stem; Area 4 – South Main stem

The status of the LSJR sediments with respect to four classes of persistent, toxic, and bioaccumulative contaminants in the LSJR sediments is reviewed below. They include 1) metals, 2) polyaromatic hydrocarbons, 3) polychlorinated biphenyls, and 4) pesticides. Mercury and DDT are discussed in detail.

Trends in concentrations with time were assessed by plotting average annual concentrations and statistically determining the significance of an upward or downward slope of any line. Differences between regions were examined qualitatively because variable numbers of samples in different years prevented rigorous statistical testing. Toxicity effects were evaluated through percent exceedances of guidelines and toxicity pressure (based on PELs), as described previously.

The numbers of samples for each contaminant, year, and area are given in Appendix 5.3b. Regression statistics for the trend analysis are given in Appendix 5.3c. Where figures and tables provide average and median concentrations, data variability are given in the Appendix.

5.4. Metals

5.4.1. Background: Metals

Metals are naturally occurring components of the mineral part of a sediment particle. Major metals in sediments are aluminum, iron, and manganese and these are often used to differentiate types of sediment (more like terrestrial soil or more like limestone bedrock). Sediment composition varies naturally with geography and environment, and so the concentrations of metals in sediments also vary naturally. Sediments in the main stem LSJR have widely different geologic sources. By contrast, the Cedar-Ortega system sediments suggest common geologic sources (Durell, *et al.* 2004; Scarlatos 1993). As a result of this natural variability, it is difficult to always determine if metal levels are elevated because of human activities or simply because of the nature of the sediments. Concentrations of metals of high concern, like lead or chromium, are often compared to aluminum concentrations to try to determine what amount is the result of human input. Although aluminum "normalized" metal values are not reported here, the contamination trends from "raw" metal values have been reviewed for consistency with normalized data, where that information is available.

One of the major human sources of most metals in the environment is from coal and oil combustion. Metals are present in these fuels in small quantities, but since massive amounts of fuel are combusted, large quantities of these elements are released into the atmosphere, often fated for future deposition into water bodies. Ore smelting and refining, mining, and various manufacturing processes also introduce metals into the environment, usually as point sources. Some metals have been, or are currently used in pesticides. An example is copper, which is used to control algae. Metallic contamination also occurs with various metal-working enterprises where metal fabrications are produced and processed. Another avenue for metals to enter into aquatic environments is leaching from hazardous waste sites (Baird 1995; CDC 2008a). The metals that we evaluated include mercury, lead, cadmium, copper, silver, zinc, and chromium.

5.4.2. *Status and Trends: Metals*

Metals in general have been elevated over natural background levels in sediments all throughout the LSJR for at least two decades and continue to do so today. Nearly all (73-91%) of all of the sediments that were analyzed since 1983 have had concentrations of chromium, zinc, and mercury that are greater than natural background levels (NOAA 1999), sometimes by very large factors. Sediments in Rice Creek that were analyzed in 2002 had mercury levels that were about 100 times greater than natural background levels. While most of the highly contaminated sediments were found in the Cedar-Ortega system, notably high levels were also found elsewhere in the year 2000, including Moncrief Creek off the Trout River, Goodbys Creek and Julington Creek. However, high metals levels aren't confined to isolated sites in the river, and the data from 2003 show continued elevation over background levels for nearly all the metals examined (Table 5.1).

Table 5.1 Natural Background Levels of Metals in Sediments and Percent of LSJR Sediments that Exceed Background Levels

	BG[1]	*1983*	*1987*	*1988*	*1996*	*1997*	*1998*	*2000*	*2002*	*2003*
Copper	25	13	7	43	8	36	42	55	50	44
Chromium	13	55	100	67	72	76	97	97	92	82
Zinc	38	33	58	69	54	88	88	82	92	79
Lead	17	47	57	61	47	80	70	87	81	56
Silver	0.5	36	17	7	12	36	43	47	38	41
Cadmium	0.3	47	44	48	48	72	76	74	92	71
Mercury	0.05	100	61	66	81	80	97	97	92	74

1 BG= Natural background levels of metals in sediments in mg/L (NOAA, 1999)

Different metals exhibit slightly different trends with time, but none appear to be significantly declining in any area. There was an increase in the concentrations of many metals in the North Main stem, Area 3, until 1996 when the concentrations leveled off (Figure 5.3; Appendix 5.4.2a). Although we did not see an expected significant decrease in lead concentrations from the ban of lead products from gasoline, other researchers have analyzed cores of sediments that give a more accurate picture of the historical record of contamination, and these studies do show recovery from lead contamination (*Durell, *et al.* 2005).

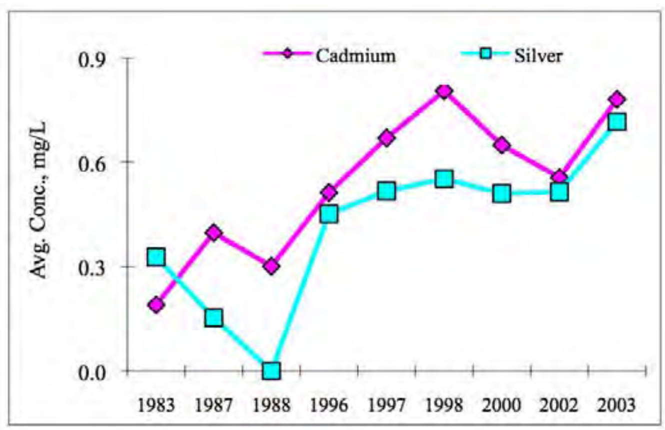


Figure 5.3 Concentrations of Cadmium and Silver in Sediments in North Main stem, Area 3

Mercury has been most often present at levels that are likely to cause environmental effects, based on the percent of samples with concentrations greater than the PEL, but lead and zinc also contribute to the toxic metal load (Figure 5.4). The number of samples that exceed the very protective guideline, the TEL, is high for all the metals (average range of exceedances from 12-63%), which indicates a high possibility of environmental impact on sensitive organisms. With the exception of the

Cedar-Ortega area and Rice Creek, both of which have had very elevated levels repeatedly over the years, metals concentrations generally hover between the two sediment guidelines. In Cedar-Ortega area and Rice Creek, metals occur at high enough concentrations that impairment of the health of organisms is likely.

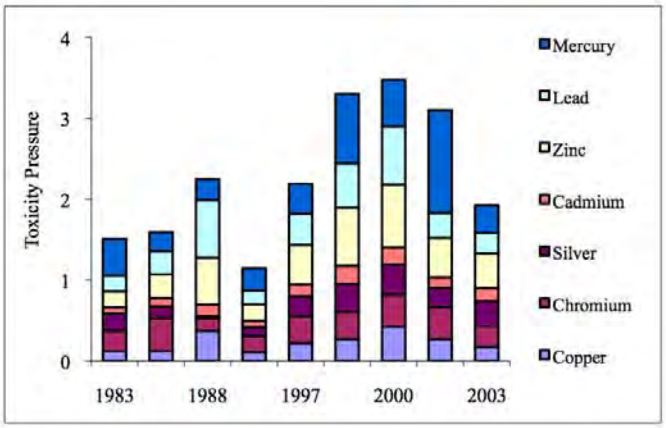


Figure 5.4 Toxicity Pressure from Metals in the LSJR

Because of its environmental significance and prevalence in the LSJR, mercury is discussed in more detail below.

5.4.3. *Mercury in the LSJR Sediments*

Mercury is typical of many of the metals that we examined in some respects. It may become elevated in the environment from coal combustion, ore mining, cement manufacture, or other industrial activities. It is associated with neural damage in humans, especially young children. Mercury is a particularly problematic contaminant because one form, methyl mercury, is highly toxic and bioaccumulates extensively in the tissues of fish and shellfish over time, making the organisms unsuitable to consume. When mercury contamination is found in fish or shellfish, health agencies may prohibit their consumption when the contamination is extensive, or they may recommend limited consumption, particularly for pregnant women and children (CDC 2008a). There is no advisory to completely restrict consumption of freshwater fish in the LSJR based on mercury, but the Florida Department of Health eating guidelines recommend limiting intake from one to four meals per week (depending on the fish and whether the consumer is a pregnant woman or child) from Volusia County to Green Cove Springs. Several marine species are recommended for limited consumption in coastal areas or, in the case of shark and mackerel, recommended to not eat at all (FDOH 2007).

Places where mercury has been analyzed in sediments over the years are shown in Figure 5.5, and the results of those analyses are given in Table 5.2 (Appendix 5.4.3a). The distribution of mercury, the TEL, PEL, and hot spots in various years are shown in Figure 5.6.

Mercury levels that exceed natural background levels and the most protective environmental guidelines are found throughout the main stem. There are isolated locations in the LSJR, particularly in the Western Tributaries (Area 1) where mercury occurs at concentrations high enough to impair the health of organisms. It is possible that mercury will bioaccumulate in fish, crabs, and shellfish at these highly contaminated sites.

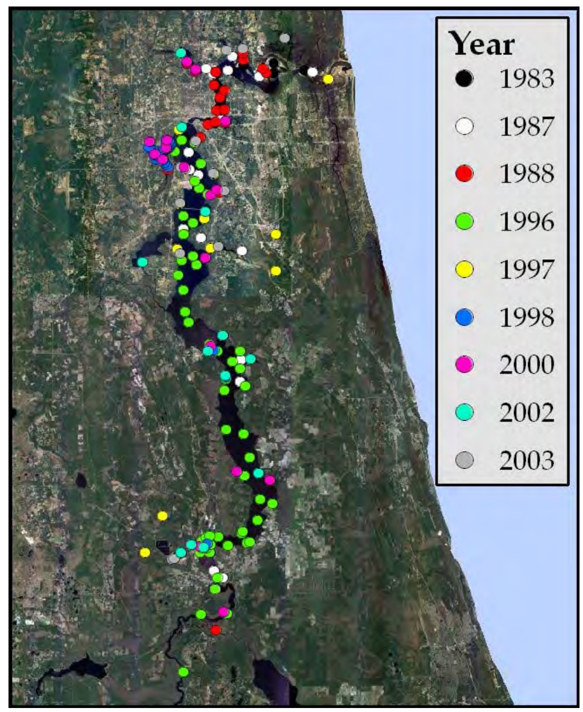


Figure 5.5 Mercury Sample Sites

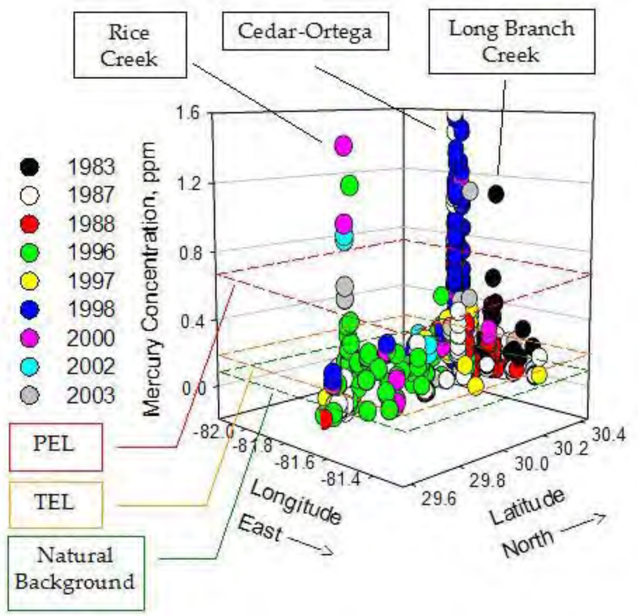


Figure 5.6 Mercury Sediment Quality Guidelines and LSJR Sediment Hot Spots (scale of mercury concentrations does not show maxima)

Table 5.2 Mercury in LSJR Sediments

	1983	1987	1988	1996	1997	1998	2000	2002	2003
No. Samples	15	99	62	118	25	154	38	26	34
Median Conc. mg/L	0.22	0.07	0.10	0.18	0.26	0.51	0.29	0.25	0.22
Percent Samples Greater than:									
PEL (0.696 mg/L)	7	6	3	1	0	34	21	19	3
TEL (0.130 mg/L)	80	36	42	61	76	71	87	92	65

1 TEL = Threshold Effects Level; PEL = Probable Effects Level

5.5. Polyaromatic Hydrocarbons (PAHs)

5.5.1. Background: PAHs

Polyaromatic hydrocarbons are a class of over a 100 different chemicals, some of which are carcinogenic. They are often found in the environment in complex mixtures. The occurrence of mixtures makes it difficult to isolate the sources and effects of individual chemicals, but sometimes the patterns of distribution of the different types of PAHs can give clues to their sources and fates. They are often subdivided into classes of small, Low Molecular Weight (LMW) compounds, and larger High Molecular Weight (HMW) compounds. The two subclasses of PAHs tend to have different sources, environmental fates, and toxic effects, although there is considerable overlap.

PAHs arise from two major pathways. Pyrogenic ("fire"-generated) PAHs are formed during the combustion of organic matter, including fossil fuels. The PAHs formed by combustion tend to be the HMW type. Petrogenic ("petroleum"-generated) PAHs are also formed naturally and are precursors and components of complex organic matter including oil, coal, and tar. Petrogenic PAH mixtures tend to have more of the LMW type of PAH.

Although PAHs are naturally occurring, large quantities are introduced into the environment in potentially toxic quantities by human activities, particularly through fossil fuel handling and combustion. About 80% of PAH emissions are from stationary sources and 20% come from mobile sources such as automobiles and trucks, but the distribution can change with locale. Urban environments have more vehicular-related PAHs than rural or agricultural areas (CDC 2008a). They may also be introduced into the aquatic environment from creosote in preserved wood, which may be a significant historic source of PAHs in the North Main stem, Area 3, of the LSJR.

PAHs are mainly introduced into water bodies by the settling of PAH-laden particles into the water, and by the discharge of PAH-bearing wastewaters. Spills of petroleum products and the leaching of hazardous waste sites into water bodies are other ways that PAHs enter the aquatic environment. Once they are in the water, the PAHs tend to settle into the sediments, especially the HMW PAHs. The LMW PAHs also associate with particles, but to a lesser extent. As a result, the LMW PAHs can be transported farther by the river's tides and currents.

PAHs can be degraded by microbes and broken down by sunlight. Biodegradation accounts for the majority of removal in slow-moving, turbid water that is typical of the LSJR. Many aquatic organisms can metabolize and excrete PAHs, particularly the LMW types, so the chemicals are not extensively passed up the food chain. However, HMW PAHs can accumulate in fish, amphipods, shrimp, and clams since they are only slowly degraded and reside in fats in organisms (ATSDR 2008, Baird 1995).

EPA has focused on 17 different PAHs primarily because they are the most harmful, have the highest risk for human exposure, are found in highest concentrations in nationally listed hazardous waste sites, and because there is information available about them (CDC 2008a). In our analysis of the LSJR sediment data, 13 of the 17 EPA compounds were examined in detail as well as two that are not on the EPA list. These PAHs were selected for study because of the extensiveness of the data, the uniformity of the study methods that were used to obtain the data, and their presence in the LSJR.

5.5.2. *Trends: PAHs*

There was extreme contamination of Deer Creek from the Pepper Industries' creosote tanks near Talleyrand that was documented in 1991 (*Delfino, *et al.* 1991a). Creosote is a product of coal tar that is used for wood preservation. While Deer Creek was the worst contaminated site, there were several other hot spots reported over the years for various PAHs. In the late 1980s, there were several sites all along the LSJR that had extremely elevated levels of PAHs, including acenaphthene in the North Main stem, Area 3, at NAS Jax (278 μg/L), fluoranthene in Dunn Creek in the Northern Arm, Area 2, (10,900 μg/L), and pyrene in Goodby's Creek (8470 μg/L). Most recently, the 2002 maxima of naphthalene and anthracene (LMW PAHs) occurred in Rice Creek, supporting the contention of Durell, *et al.* 2004 that fuel sources of PAHs, as opposed to combustion sources, are more important in that area compared to the rest of the system.

There are encouraging signs that some PAH levels have gone down since the late 1980s. In particular, several PAHs in the North Main stem (Area 3) are declining, including anthracene, acenaphthene, fluoranthene, and others (Appendix 5.3c). The contaminated tributaries have also shown some statistically significant reduction since the 1980s. Typically, the levels of these compounds appear to have declined from 1987 and leveled off since 1996. However, there are exceptions to the downward trends. Some HMW PAHs, including benzo(b+k)fluoranthene, indeno(1,2,3-c,d)perylene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene, may be increasing in the South Main stem, Area 4 (Figure 5.7; Appendix 5.3c). There are fewer data points in this area compared to the others, so conclusions need to be drawn with caution. Despite that uncertainty, it is important to continue monitoring locales such as Clay and St. Johns Counties, which are rapidly becoming more urbanized, and can be expected to generate the PAHs that are usually produced from those land uses.

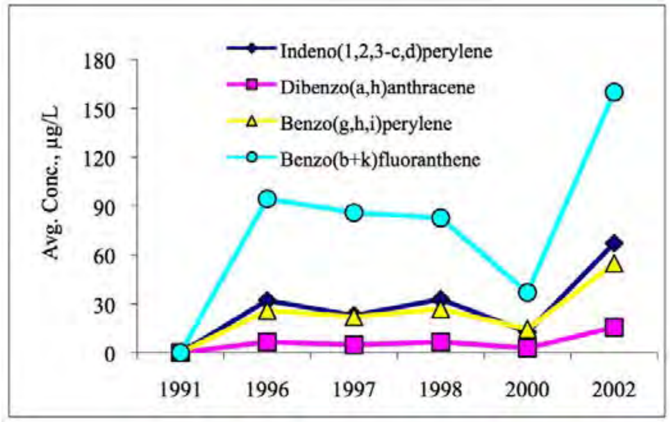


Figure 5.7 Selected PAHs in South Main stem, Area 4

The rate at which samples have exceeded probable effects levels are not as high in the last decade, compared to the 1980s. In Figure 5.8, it is apparent that toxicity pressure due to PAHs has declined, even in the Western Tributaries, Area 1. However, the data also indicate that some PAHs, such as anthracene, are still likely to be having benthic impacts (Table 5.3), and there are cumulative toxic effects when all of these compounds are taken together.

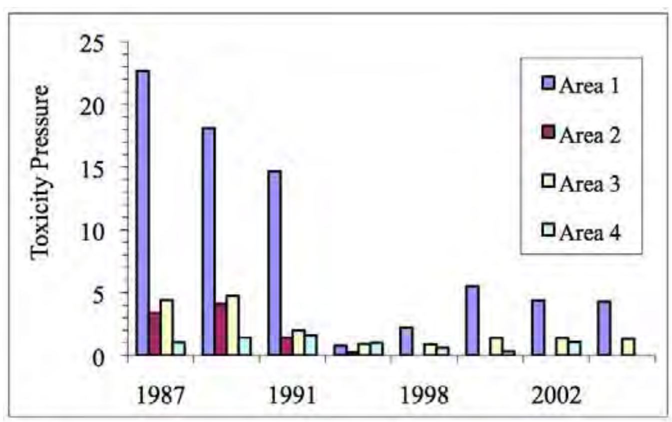


Figure 5.8 Toxicity Pressure from PAHs in Different Areas of LSJR

Table 5.3 Percent of LSJR Sediments that Exceeded Probable Effects Level (PEL) Guidelines for PAHs

	1987	*1988*	*1991*	*1996*	*1997*	*1998*	*2000*	*2002*	*2003*
Anthracene	17	33	38	1	0	0	5	8	24
Acenaphthene	11	11	10	0	12	0	0	0	3
Naphthalene	0	0	3	0	0	0	0	0	0
Fluoranthene	17	26	18	0	0	2	3	0	0
Benzo(a) anthracene	14	37	3	0	0	1	3	0	0
Pyrene	17	31	13	0	0	1	3	0	0
Chrysene	11	19	5	0	0	3	5	0	0
Indeno(1,2,3-c,d) pyrene	0	0	0	0	0	5	11	0	0
Dibenzo(a,h) anthracene	6	14	0	0	0	4	11	0	0
Benzo(g,h,i) perylene	0	0	0	0	0	3	8	0	0
Benzo(a) pyrene	20	21	10	0	0	3	5	0	0
2-Methyl naphthalene	6	0	-	0	0	0	0	8	0
Benzo(b+k) fluoranthene	20	0	0	0	0	3	5	0	0

5.5.3. PAHs in Oysters

In the Mussel Watch Project of NOAA's National Status and Trends Program, oysters in Chicopit Bay in the Northern Arm, Area 2, of the LSJR were analyzed for PAHs from 1989-2003 (Figure 5.9). These data show that there is a broad spectrum of PAH contaminants in Chicopit Bay oysters, but the PAHs with the most consistently high levels are phenanthrene, pyrene, and fluoranthene. There is no apparent decrease in the total PAH values, despite decreasing trends of other contaminants such as PCBs, some pesticides, and some metals (O'Connor and Lauenstein 2006). As with other PAHs, they have many possible sources, including gas and diesel emissions and creosote-based wood preservation in aquatic environments, but these PAHs are often associated with petroleum contamination, a possible result of Chicopit's proximity to a shipping channel and high boat traffic. This appears especially true in 2003 when the concentrations in oysters approached the levels of the 1980s. The 2003 oysters also had more of the methylated LMW PAHs that suggest petrogenic origins of the compounds. Standards for consumption are sparse for PAHs (USEPA 2007), but for the compounds where there are standards (anthracene, acenaphthene, fluoranthene, fluorene, and pyrene), the levels found in these oysters would not be harmful. However, as noted, there is little direct data about consumption of food containing other PAHs, including the notoriously carcinogenic benzo(a)pyrene or other PAH carcinogens.

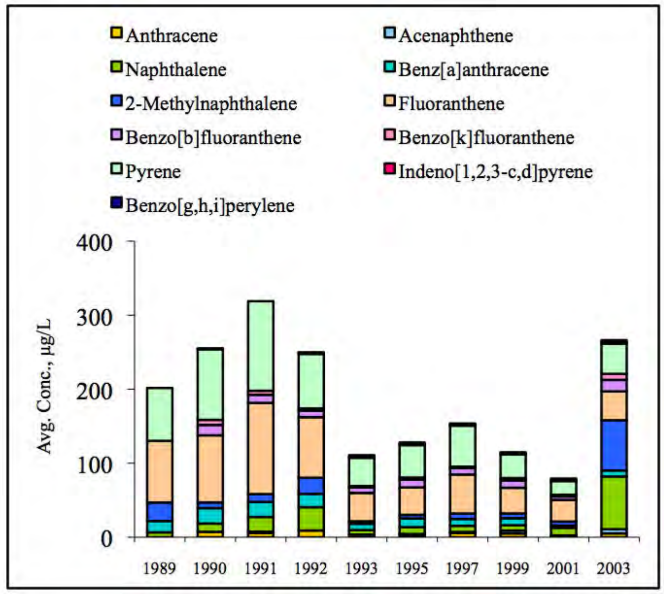


Figure 5.9 Concentration of Select PAHs in Oysters in Chicopit Bay, LSJR (North Arm, Area 2)

5.5.4. Status: PAHs

Portions of the LSJR appear to still be recovering from severe creosote contamination from the 1980s, but there are other likely petroleum and combustion sources. The compounds occur at levels that may be problematic in some areas, and there continues to be widespread contamination. Of particular concern is the southern main stem portion of the river, which appears to be beginning to suffer the same stress from urban impact that the North Main stem, Area 3, experiences. There is direct evidence that these compounds reside in consumable organisms in the river. Thus, PAHs in the LSJR are likely to be a significant source of stress to sediment-dwelling organisms, despite their overall, slow decline.

5.6. Polychlorinated Biphenyls (PCBs)

5.6.1. Background: PCBs

Polychlorinated biphenyls, PCBs, are synthetic chemical mixtures that were used for their nonflammable and insulating properties until they were restricted in the U.S. in the 1970s. They provided temperature control in transformers and capacitors, and were also used for lubrication and other heat transfer applications. They were sold primarily under the name of Arochlors in the U.S. They are still found in old fluorescent lighting fixtures, appliances containing pre-1977 PCB capacitors, and old hydraulic oil. The characteristics of the fluids were changed by changing the mixture components, so each of the major Arochlor formulations is composed of different concentrations and combinations of the 209 PCB chemicals. Until the mid 1970s, PCBs were also used in manufacturing processes for a wide range of different substances, from plastics to paint additives. The manufacture of PCBs in the U.S. was prohibited, and their import, use, and disposal, were regulated by EPA by 1979 (44 CFR 31514). One of the most visible PCB legacies is the Hudson River, where capacitor plants discharged wastewaters into the river resulting in contaminated sediments in rivers and estuaries for decades to come.

PCBs are inert, which makes them industrially valuable but environmentally harmful. They don't react readily, whether by microbes, sunlight, or by other typical degradation pathways. They are not very soluble in water, so the lighter ones tend to evaporate and the heavier ones tend to associate with particles, whether in the air, soil or sediments. Another important consequence of PCBs' chemical properties is that they are particularly compatible with fatty tissue, allowing extensive uptake and bioaccumulation in the fats of plants and animals. Because they are not easily metabolized and excreted, they are readily biomagnified.

PCBs are introduced directly into the environment today primarily from hazardous waste sites and improper disposal of old appliances and oils. However, they also may be transported long distances in the atmosphere, either in gas form or attached to particles, and become deposited into water bodies. Sometimes sources of PCB contamination can be elucidated by examining different patterns of contamination of the different PCB constituents, but several processes obscure those patterns. Weathering, currents and tides, multiple sources in a large drainage basin, and repeated cycles of evaporation, sorption and deposition all tend to mix everything up so individual sources are not usually identifiable unless there is a specific, current source.

Because of methodological developments over the years and variable definitions of "total PCBs", it is not feasible to compare total PCB or mixture concentrations (like Arochlors), so several individual PCBs were evaluated here and total PCBs were estimated from those values. The specific eight PCBs we decided to evaluate were selected on the basis of their presence in the LSJR and the availability of comparable data. We estimated that the PCBs we examined here represent approximately 20% of the total PCBs actually present. More information about the calculations we used to estimate total PCBs is given in Appendix 5.6.1a.

5.6.2. Trends: PCBs

The majority of the sediments sampled in most years contained some PCBs (79-100% of sediment samples collected from 1996 to 2003 contained PCBs). Since these compounds are produced only by human activity, their simple presence denotes human impact.

The PCB levels were often found at levels typical for urban, industrialized environments (Durell, *et al.* 2004), and were reasonably constant along the river and over the years. An unsurprising exception is the Cedar-Ortega area, where the average PCB concentration exceeded the concentrations that are considered “high” (80 μg/L) by comparison to other coastal sediments in the nation (Daskalakis and O'Connor 1995). Particularly high levels were found in the Cedar-Ortega in the late 1990s. For 2000-2003, Rice Creek was a hot spot for PCBs 105, 118, 128, 180 and 206, the first two of which are among the most toxic (CDC 2008a). Average total concentrations in other areas were well below the 80 μg/L that characterizes a “high” level compared to the rest of the coastal areas in the country. The distributions of the PCBs we examined have stayed reasonably constant along the river and across the years, an outcome of the persistence of the long-banned substances (Figure 5.10; Appendix 5.6.2a). The elevated levels seen in 1998 reflect the fact that a large proportion of those samples were from the beleaguered Cedar-Ortega in that year.

For most years, the estimated total PCB median concentrations for the entire basin exceeded the protective TEL of 22 μg/L, but were far below the probable effects level of 189 μg/L. The picture changes slightly when we partition the river (Figure 5.11) and examine the PEL pressure based on average concentrations. It becomes apparent that the main stem areas, Areas 2-4, have far less toxicity pressure from PCBs than Area 1.

5.6.3. *Status: PCBs*

PCBs persist in the LSJR long after regulatory and environmental controls have been put into place. They are weathering but continue to exert their influence, with little discernable changes in concentration over time. Outside of the highly contaminated Western Tributaries, Area 1, these compounds by themselves are not likely to be major stressors of benthic organisms, but they exert a low-level toxicity pressure.

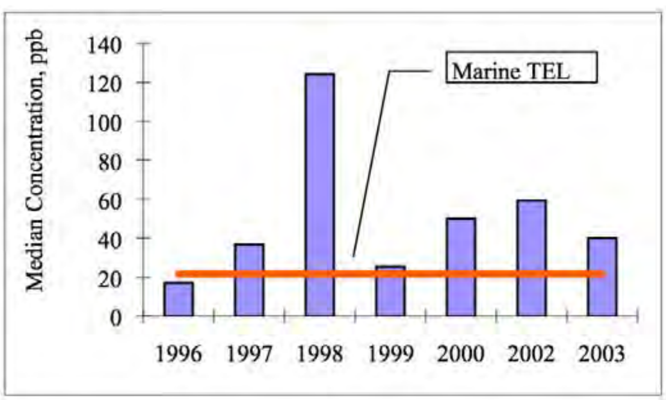


Figure 5.10 Estimated Median Concentration of Total PCBs in LSJR and Marine Threshold Effects Level

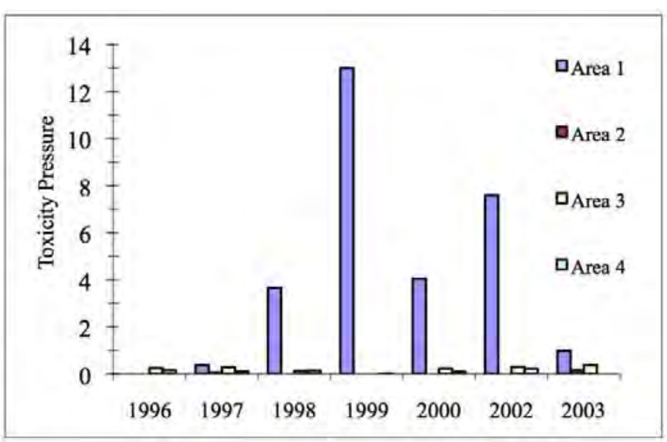


Figure 5.11 Toxicity Pressure from Total PCBs in Different Areas of the LSJR (note extreme PCB toxicity in Area 1 from the Cedar-Ortega Basin and Rice Creek

5.7. Pesticides

5.7.1. *Background: Pesticides*

Pesticides enter water bodies from a number of different pathways. They are applied directly to control aquatic nuisances like water hyacinth. They are components of runoff from residential, agricultural, and other commercial applications. They also come from the atmosphere, usually attached to particles. Pesticides are widespread in residential, urban, and agricultural areas, and they are very diverse in their chemistry and environmental fate. This largely comes about because pests are diverse as well, encompassing mold, bacteria, rats, spiders, barnacles, mosquitoes and more, each with a metabolisms that is vulnerable to different chemicals.

Pesticide manufacture and use has evolved significantly towards protecting the environment since the times when lead and arsenic compounds were dusted in homes to control insects (Baird 1995). Efforts have been made to create pesticides that can specifically target the pest and that can degrade after their function has been performed. However, pesticides used historically continue to be environmentally important because of their persistence. Organochlorine compounds (molecules containing carbon and chlorine) were introduced in the 1930s and bear some similarity to PCBs in their characteristics and environmental fate. They were effective for long periods of time against insects in homes, institutions, crops, and livestock, largely because they were nearly nondegradable. Because of their longevity, these compounds remain in the environment today despite being regulated and removed from manufacture up to forty years ago. Because of their broad-based toxicity, they have widespread effects on nontarget organisms. Because of the toxicity of their primary degradation products, their environmental impacts are very long term. Their affinity for fats and organic matter make them reside in sediments and fats of organisms and allow them to move up the food chain. Several organochlorine compounds and their degradation products are the focus of this review because of their environmental significance and the availability of historic data.

It is important in the future to also evaluate pesticides currently used, which tend to be less persistent but more toxic. The varied land use in the LSJR basin and its extensive recreational and commercial maritime activity causes a broad spectrum of pesticides to be loaded into the river. The U.S. Army Corps of Engineers directly applies herbicides 2,4-D, diquat, and glyphosate in the southern parts of the river for the control of water hyacinths and water lettuce (USACE 2008a). The city of Jacksonville sprays malathion, organophosphates, and pyrethroids for mosquito control (COJ 2008). Agriculture in southern LSJR contributes to the pesticide load. While estimates of current total pesticide loading rates into the LSJR are elusive, it is reasonable to suppose that some of the most commonly detected pesticides in agricultural, residential, and urban U.S. streams (Gilliom, *et al.* 2006) will be important. These include the herbicides atrazine, metolachlor, simazine, and prometon, as well as the insecticides diazinon, chlorpyrifos, carbaryl, and malathion. Finally, the tributyl tins used by the maritime industry should be reviewed. These common pesticides represent 11 different classes of chemical structures that will have very different fates and impacts on the environment.

Four organochlorine pesticides and their primary degradation products were assessed. These compounds were primarily used as insecticides and removed from market in the 1970s. Aldrin was used against termites and other insects in urban areas. Dieldrin is a degradation product of Aldrin, and was also used directly against termites. Endrin targeted insects and rodents, usually in agriculture, and endrin aldehyde is its degradation product. Heptachlor and its degradation product, heptachlor epoxide, are used here as markers for chlordane contamination since the complex chlordane mixtures are difficult to compare across years and analytical methods. Chlordanes were used in agriculture and in households, especially for termite control. Finally, the notorious insecticide DDT and its degradation products, DDE and DDD are reviewed in detail.

5.7.2. *Status and Trends: Pesticides*

It is unsurprising that organochlorine pesticides have been found all throughout the LSJR sediments for years, given their history of use and persistence. More than half of all of the sediments that were analyzed since 1987 have contained DDT or its degradation products, although heptachlor and dieldrin have also been frequently detected. In 1987 there were high concentrations for many organochlorine pesticides reported by Mote Marine Laboratories, but most notable that year was heptachlor, a chlordane marker, in Green Cove Springs.

After 1987, the reported levels of organochlorine compounds have been stable, with no discernible changes with time. A possible exception is heptachlor epoxide, which may be declining in Area 1, a small, positive sign for the impacted tributaries. However, when each area is examined for probable environmental impact (Figure 5.12), the comparatively high pesticide toxicity pressure on the Western Tributaries, Area 1, again is apparent. The specific compounds that are most responsible for toxicity pressure tend to be similar in each area, and it is DDT and its degradation products, DDD and DDE, that are generally the most important (Figure 5.13).

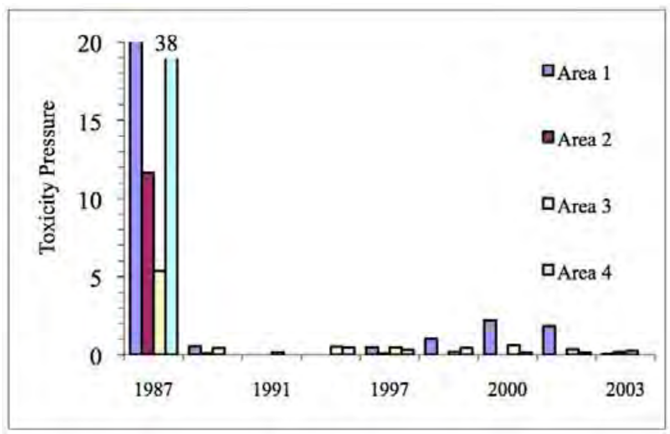


Figure 5.12 Toxicity Pressure from Total Organochlorine Pesticides in Different Areas of the LSJR

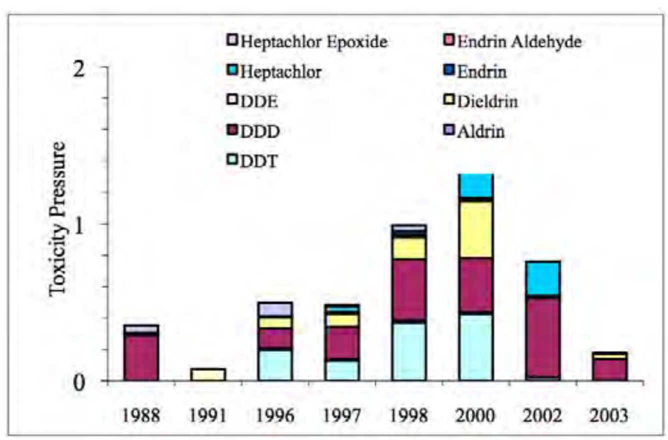


Figure 5.13 Toxicity Pressure from Different Organochlorine Pesticides and their Degradation Products

Organochlorine pesticides are present in the LSJR sediments, mostly at levels that might not cause significant adverse impacts on the benthic ecosystems, but that certainly add to the overall toxic burden on the sediments. As with other contaminants, the Cedar-Ortega system is the most contaminated area. The DDT compounds were found most frequently and at the highest levels, compared to the other organochlorine pesticides. They exerted the most toxic pressure, though dieldrin and heptachlor were also significant in recent years. DDT in the LSJR sediments is reviewed in more detail below.

5.7.3. DDTs in LSJR Sediments

As with the other organochlorine pesticides, there is little evidence of consistent decline. Contamination was greatest for several years throughout the Cedar-Ortega system, including sites far upstream. Like the PCBs, the apparent high levels in 1998 through 2002 reflect the fact that a high proportion of those samples came from the Cedar-Ortega area. Isolated instances of elevated levels of DDT have also occurred at Trout River, near Exchange Island, and in Julington Creek (Figs. 5.14 and 5.15). Even when DDT degrades, the products still exert toxicity. Indeed, it is the DDD, a DDT degradation product, which often exerts the most toxicity on the system, as illustrated in Figure 5.13. DDE is prevalent in the LSJR, but it is much less toxic than the other two compounds.

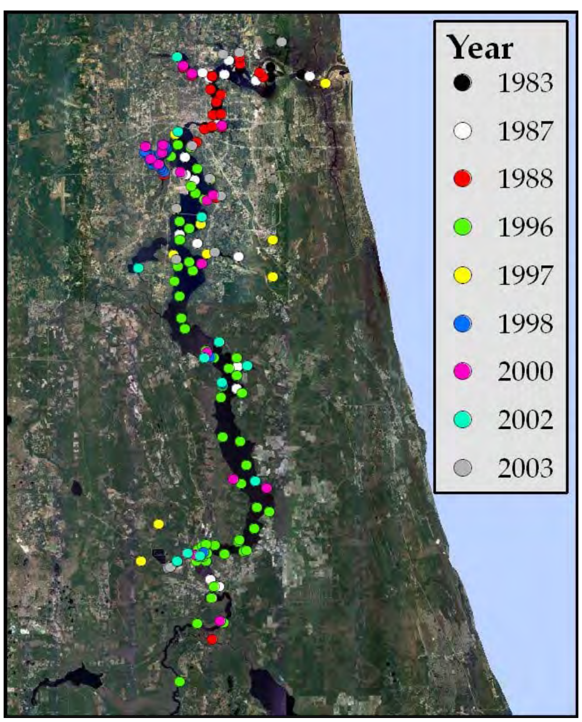


Figure 5.14 DDT Sample Sites

Excluding hot spots, background levels of DDT in the LSJR are about 10 µg/L or less, which is between the protective TEL guideline and less stringent PEL (Table 5.4; Appendix 5.7.3a). The two related chemicals, DDD and DDE, also tend to occur at concentrations between their respective guidelines. Generally, DDTs are probably not a major stressor on the LSJR benthos, with the exception being the Cedar-Ortega area where concentrations in 1998 ranged up to 4 times the PEL guideline.

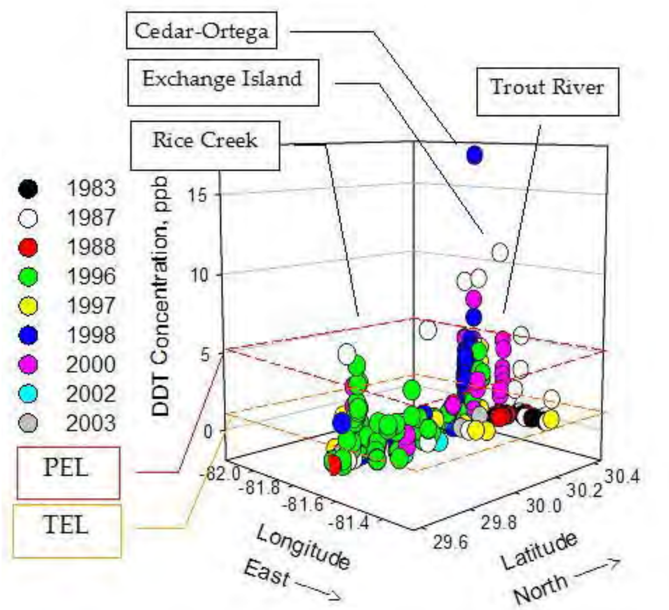


Figure 5.15 DDT Sediment Quality Guidelines and LSJR Sediment Hot Spots

Table 5.4 DDT in LSJR Sediments

	1983	*1987*	*1988*	*1996*	*1997*	*1998*	*2000*	*2002*	*2003*
No. Samples	13	36	17	118	25	118	38	26	34
% Samples with DDT	0	28	0	92	32	80	89	8	6
Median Conc. µg/L	0.0	0.0	0.0	0.7	0.0	1.2	1.8	0.0	0.0
Percent Samples Greater Than :									
PEL (4.77 µg/L)	0	17	0	1	0	4	11	0	0
TEL (1.19 µg/L)	0	25	0	26	12	50	66	4	0

1 TEL = Threshold Effects Level; PEL = Probable Effects Level

5.8. Conclusions

The history of compromised sediment quality in the LSJR from industrial and urban activities continues today (Figure 5.16). Some contaminants, such as organochlorine pesticides and PCBs, are legacies of past misjudgments, but continue to plague the river by their persistence. Other contaminants, such as PAHs, are common byproducts of modern urban life, though the LSJR also suffers from PAH contamination from past mishandling of creosote. Metals are pervasive throughout the basin at levels substantially above what is considered natural background levels. For example, in the last ten years, 3-35% of the samples that were analyzed had mercury levels that are likely to be harmful to the organisms in the sediment, and there is no sign that concentrations are diminishing. Overall, the status of the LSJR basin with respect to the contaminants we examined is similar to other large, industrialized, urban rivers. But many of the lower basin sediments have high levels of contaminants compared to nationwide surveys of coastal sediments.

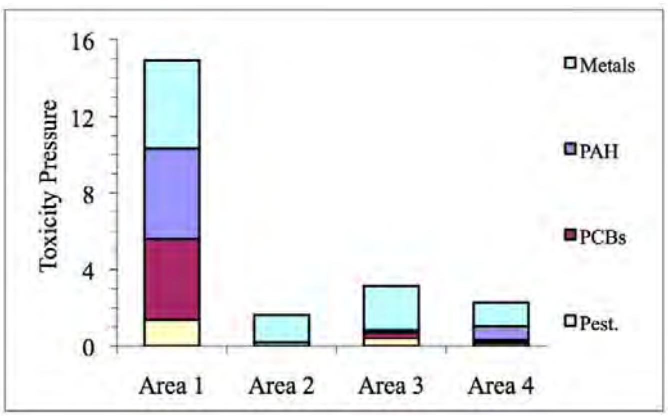


Figure 5.16 Average Toxicity Pressures of Contaminants in Sediments in Different Areas of the LSJR from 2000 – 2003 Average Toxicity Pressures of Contaminants in Sediments in Different Areas of the LSJR from 2000 – 2003

Several of the tributaries have shown severe contamination over the years, but none like the Cedar-Ortega system, which has repeatedly exhibited the highest levels and frequencies of contamination. It has been recognized at least since 1983 that the complex network of tributaries is burdened by years of discharges by wastewaters and runoff from small, poorly managed industries, and from identified and unidentified hazardous waste sites. This is particularly true of Cedar River. The Cedar-Ortega basin also suffers from its location in the middle of the LSJR, where the transition between riverine and oceanic inputs promotes sedimentation and reduces flushing. These factors produce a highly stressed system that is may be a source of contaminants to the entire LSJR main stem. Rice Creek is another western tributary of the LSJR that has exhibited long-term pressure from a variety of contaminants, including some pulp industry-related compounds that are not reviewed here but most certainly impact the area (Sonnenberg, *et al.* 2006). The Talleyrand area of the river is another section that is heavily impacted by contaminants.

Outside of the areas of highest concern, contaminants act as underlying stressors all throughout the basin. Their individual effects may be minor, but their cumulative effects become important. There are small variations in the specific compounds that are most important from site to site and year to year, but most areas were contaminated by more than one chemical at levels that are likely to be harmful to the river's benthic inhabitants.

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