Putnam County Environmental Council

Management and Restoration of the Fish Populations of Silver Springs and the Middle and Lower Ocklawaha River, Florida, USA

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MANAGEMENT AND RESTORATION OF THE FISH POPULATIONS OF SILVER SPRINGS AND THE MIDDLE AND LOWER OCKLAWAHA RIVER, FLORIDA, USA

A Special Report for
The Putnam County Environmental Council
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Cover photograph: Longnose Gar, ***Lepisosteus osseus*****,**
in Silver Springs, Underwater Photograph
by Peter Butt, KARST Environmental

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EXECUTIVE SUMMARY

Sixty-nine (69) species of native fish have been documented to have utilized Silver Springs, Silver River and the Upper, Middle and Lower Ocklawaha River for the period of record. Fifty-nine of these are freshwater fish species and ten are native migratory species using marine, estuarine and freshwater habitats during their life history. These include striped bass, American eel, American shad, hickory shad, hogchoker, striped mullet, channel and white catfish, needlefish and southern flounder. Most of these ten migratory species are currently either rare or absent from the Ocklawaha River above the Kirkpatrick Dam, where historically they were seasonally common to abundant.

The key questions to be answered from this updated review are: (1) how have fish populations changed since impoundment of the Lower Ocklawaha River in 1968, and (2) what is likely to happen to these populations after breaching of the Kirkpatrick Dam, and restoration of flows in the river, thus reestablishing both of the historical migratory routes of fish to and from the St. Johns River, and restoring more normal seasonal inundation of the floodplain habitats of these rivers?

It is obvious from the data and reports reviewed previously by Clugston (2002), and updated here, that significant changes have occurred to the fish populations of Silver Springs, Silver River and the Ocklawaha River over the last 50 years. These changes have accelerated since the construction of a portion of the Cross Florida Barge Canal and closure of the Kirkpatrick (formerly Rodman) Dam. The documented decline of 92% in the biomass of all fish species in the Silver River, and essentially the complete loss of striped mullet, channel and white catfish and shad from the Silver River, and a 60% decline in biomass of largemouth bass, are the clearest indicator of significant problems with fisheries management within this ecosystem. Other historically common species within both the Ocklawaha River and the St. Johns River ecosystems like striped bass and the American eel are now absent as self maintaining native populations due largely to blockage of essential migratory pathways and habitats.

Scientific reports are listed and discussed, and it is noted that they repeatedly recommend breaching of the Kirkpatrick Dam and restoration of flows within the Ocklawaha River to facilitate a likely increase in diversity of fish and wildlife within these north Florida river ecosystems. In addition, the breaching will most likely increase the forage fish food base for many larger fish, wading and seabirds, reptiles and mammals.

It is concluded that there is no credible scientific basis to predict any permanent decline in fish resources following restoration, nor a specific decline in sports fishing opportunities over the short or long term. The species mix may change, but fish biomass within the restored channels, wetlands and floodplains (both above and below the existing Kirkpatrick Dam) will likely remain the same or increase over time after the Rodman Pool is drained and migratory fish populations return. In specific areas such as the Silver River, the reconnected springs, and spring runs, a significant increase in fish populations can be expected.

Certain fish species now absent from these water bodies will return to former abundances, and overall ecological function will increase. Sport fishing opportunities for species like the striped bass will increase with restoration, and a viable riverine largemouth bass fishery will persist.

INTRODUCTION

Damming of the lower Ocklawaha River and the creation of Rodman Reservoir (hereafter referred to as the Pool) were completed in 1968 as part of the Cross Florida Barge Canal Project. The project was deauthorized by the U.S. Congress in 1991, and in 1993, the Florida legislature required environmental studies to assist in determining the future of the dam and Pool. The Florida Department of Environmental Regulation (now Florida Department of Environmental Protection (FDEP)) applied for a permit to breach the Kirkpatrick (formerly Rodman) Dam in 1997. This permit application was submitted to the St. Johns River Water Management District (SJRWMD). Processing of that permit is currently on hold. The future of the Pool and dam is caught up in an ongoing dispute among sport fishermen, who generally wish to preserve the Kirkpatrick Dam and the Pool, water quality experts at the SJRWMD and FDEP, wildlife and fishery scientists, the U.S. Forest Service which owns the land where breaching of the Kirkpatrick Dam would occur, and environmental advocates who support habitat restoration both above and below the existing Kirkpatrick Dam (Clugston 2002).

As previously stated by Clugston (2002) recreational fishermen cite excellent largemouth bass fishing and economic benefits with the Pool in place. Environmental activists emphasize the importance of a free-flowing river without the Pool in place for the benefit of all flora and fauna, some of which are listed by the State of Florida as endangered, threatened, and rare or species of special concern. Between these two perspectives, scientists continue to disagree about the specific science in support of one view or another. This report specifically addresses and updates the issue of fish population management and restoration in Silver Springs, Silver River and the Middle and Lower Ocklawaha River, Florida, USA, based upon the most recent scientific reports and review of data by Roy R. Lewis III, a Certified Professional Wetland Scientist (by the Society of Wetland Scientists) and a Certified Senior Ecologist (by the Ecological Society of America).

GEOGRAPHIC SETTING

The Ocklawaha River basin covers 2,769 square miles in central and north Florida. A complete description of the basin setting, history, hydrology, ecology, socioeconomic and management background is provided in FDEP (2000) (pages 29-82). Figures 1 and 2 show the overall settings of Silver Springs, the Silver River and the Upper, Middle and Lower Ocklawaha River (UOR, MOR, LOR). This report discusses issues related to management and restoration of fish populations in just the MOR and LOR. The UOR is essentially totally isolated from any hydrologic connection with the MOR and LOR by the Moss Bluff Lock and Dam (MBLD) which in recent years has been closed to any downstream flows as water is held behind the dam to maintain lake levels in the Harris Chain-of-Lakes. Only heavy storm induced rains produce any flow over the dam. Since its construction in 1925 the MBLD has also blocked upstream movements of fish. The UOR is an important ecological system and includes the Harris Chain of Lakes and Lake Apopka. The UOR deserves its own separate discussion and is not part of this report.

The classification of the segments of the Ocklawaha River in Figure 2 is a revised classification. The author was not satisfied that the previous classifications covered all portions of the examined ecosystem, and thus allowed for discussion of various elements of the ecosystem that are in fact very distinct from one another. For example, the two most recent and comprehensive documents describing the hydrology, water quality and biology of the Ocklawaha River basin are the "Basin Status Report - Ocklawaha" (Florida Department of Environmental Protection [FDEP] 2001) and the "Water Quality Assessment Report - Ocklawaha" (FDEP 2003) both contain extensive maps and descriptions of the various "hydrologic units," "water body identification units," and "planning units" for the Ocklawaha River basin. Few of these have coincidental boundaries. In addition, within each of these categories, various place names are provided. Particularly as it relates to hydrologic and ecological boundaries, there appears to be no consistent designation system, and thus we proposed this new classification.

With particular reference to more recent water quality issues, PBSJ-Atkins, a consultant to the FDEP, has provided another set of maps with further designations in several reports (PBSJ 2008, PBSJ 2010). These reports focusing on water quality issues related to potential breaching of the Kirkpatrick Dam, divide the reach of the Ocklawaha River between Eureka and the Eureka Lock and Dam (ELD) and the Kirkpatrick Dam into three sections based in part on the hydrology and vegetation: riverine, transition, and lacustrine. These designations were also previously noted and defined in CSA (1994) (Figure 3). No specific designations are given to the Ocklawaha River above (south) of Eureka that connects to the Silver River and Silver Springs, nor the Ocklawaha River below (east) the Kirkpatrick Dam that connects the Ocklawaha River basin with the St. Johns River (SJR). Both of these reaches are distinctly different from the three designated reaches, and from each other, and both play important and distinct roles in the hydrology and ecology of the Ocklawaha River. Since they have remained unnamed they are often ignored when water quality and ecological issues are discussed. The author resolves this issue by designating them in turn the "Middle Ocklawaha River – MOR" from the confluence of the Silver River with the Ocklawaha River north to the ELD, and the "Lower Ocklawaha River

Below the Kirkpatrick Dam – LORBKD." This still leaves the short reach of the Ocklawaha River between the Silver River and south (upstream) to the MBLD. This reach is designated as the "Ocklawaha Farms Reach – OFR." This produces a total of six (6) sub basins for the entire Ocklawaha River, and five for just the MOR and LOR (Table 1, Figure 2).

Table 1. Designated sub-basins of the Ocklawaha River (this review).

1. Upper Ocklawaha River (UOR)
2. Ocklawaha Farms Reach (OFR)
3. Middle Ocklawaha River (MOR)
4. Orange Creek (OC)
5. Lower Ocklawaha River (LOR)
6. Lower Ocklawaha River Below Kirkpatrick Dam (LORBKD)

Figure 1. Geopolitical map of the Ocklawaha River basin (from FDEP 2001).

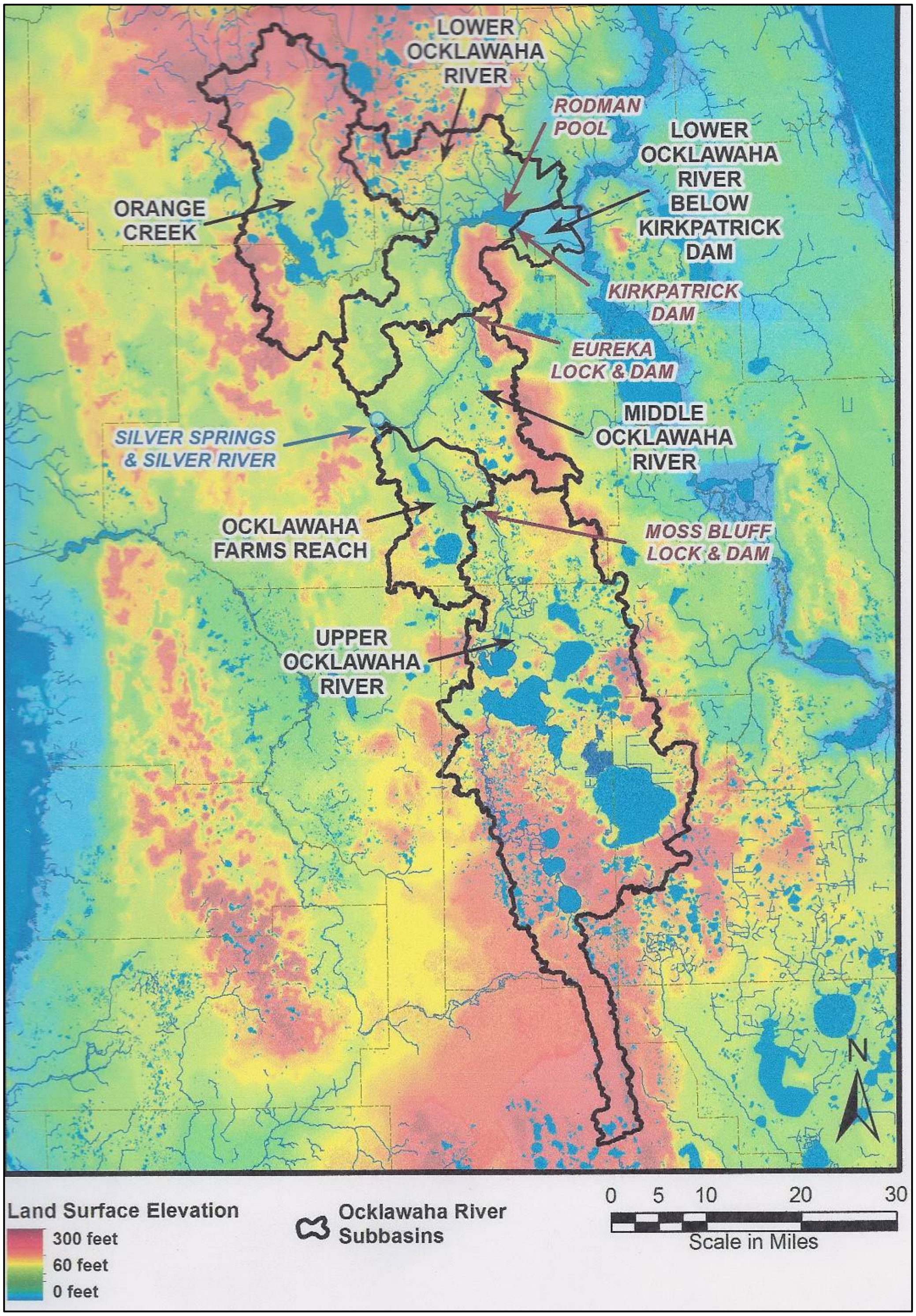

Figure 2. Revised map of the subbasins of the Ocklawaha River.

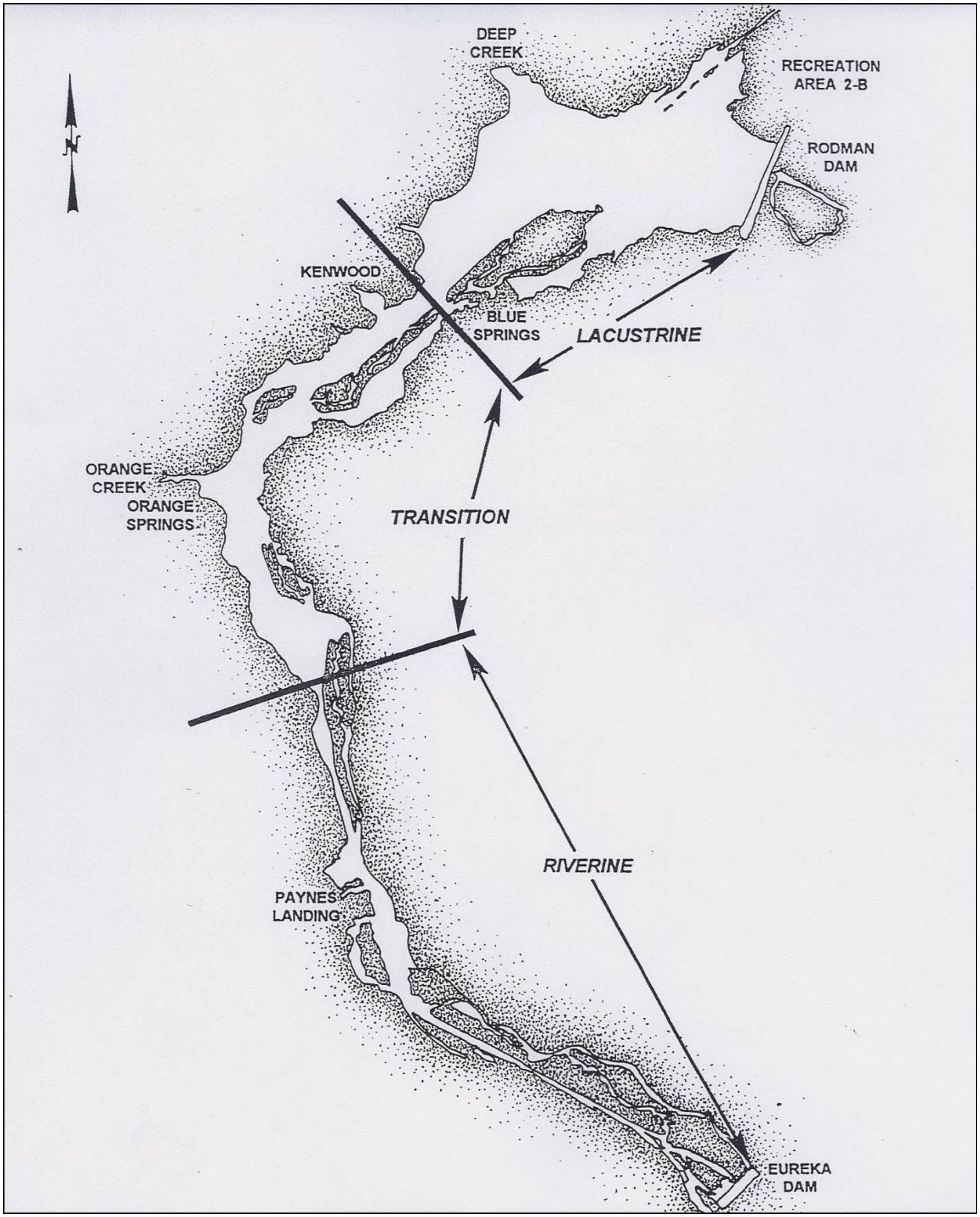

Figure 3. Lacustrine, transition and riverine zones of the Rodman Pool (from CSA 1994).

HYDROGRAPHIC SETTING

Figure 4 graphically summarizes the major sources of water flows in the entire Ocklawaha River basin. Specific flows are discussed in a number of sources including FDEP (2000, 2003) and (Hall 2005). Recent declines in flows through 2009 are discussed in SDI (2010). They concluded that "[F]or the decade since 1999, the average flow of the Ocklawaha River has declined to 1,049 cubic feet per second (cfs), which is 36.3 percent lower than the long-term average stream flow (1,647 cfs)…" These declines have a major impact on fish use and populations in the MOR, LOR and the LORBKD, as important fishery-related floodplain habitats are less frequently inundated on a seasonal basis (Rogers and Allen 2004).

In addition, although not noted in Figure 4, some of the indicated blockages in the system (dams, locks and weirs) represent major impediments to the movement and normal reproduction of migratory fish species and other species such as the endangered Florida manatee (*Trichechus manatus latirostris*). Kirkpatrick Dam and the Moss Bluff Lock and Dam are major impediments. The Eureka Lock and Dam are not, as the dam itself was never completed. It is likely still an impediment to some fish and wildlife use and should be removed, but other projects will likely have higher priority, such as the breaching of the Kirkpatrick Dam.

FISH HABITATS

Available area and quality of specific habitats is an important factor in limiting fish population sizes. Fish go through a number of different forms and sizes as they mature, from eggs to larvae to juveniles to adults. Each of these stages typically requires different habitats. For example eggs may survive best if they are in pelagic (open water) or demersal habitats (associated with bottom sediments or vegetation). Some eggs such as those of the striped bass require long stretches of cool flowing water to allow enough time to hatch and seek good feeding and protective shoreline habitats with slower water velocities and cover provided by aquatic plants or woody debris.

Smaller adult and juvenile fish (forage fish) are subject to predation by larger fish, wading birds, reptiles and mammals, and thus refuge habitat in the form of shallow water with vegetation or debris like downed trees becomes important habitat (Cathey et al. undated). Larger fish may be subject to the same predation by even larger organisms such as adult alligators.

For this reason all fish thrive in a specific <u>mosaic of habitats</u> (Lewis et al. 1985), not typically just a single habitat. The habitat type that is least available relative to the amount necessary to maintain an existing population then can become a controlling point for the ultimate survival of the entire population (<u>bottleneck</u>).

For example, if shallow water forested <u>floodplain</u> stream or pond is an important nursery habitat for a species, declining water flows that keep these areas dry and not available for fish use can limit the ultimate population of adult fish of that species within that watershed.

Rogers and Allen (2004) reviewed long term FFWCC data from several Florida rivers, including the Ocklawaha River, to evaluate trends in fish abundance and fish communities and related those trends to historical river levels. They concluded "…that lower river levels negatively affect fish communities by reducing fish abundance" and recommended that regulations such as Minimum Flows and Levels (MFLs) should be set to reduce the periodicity of low flow events in order to prevent sequential years of adverse effects on fish populations.

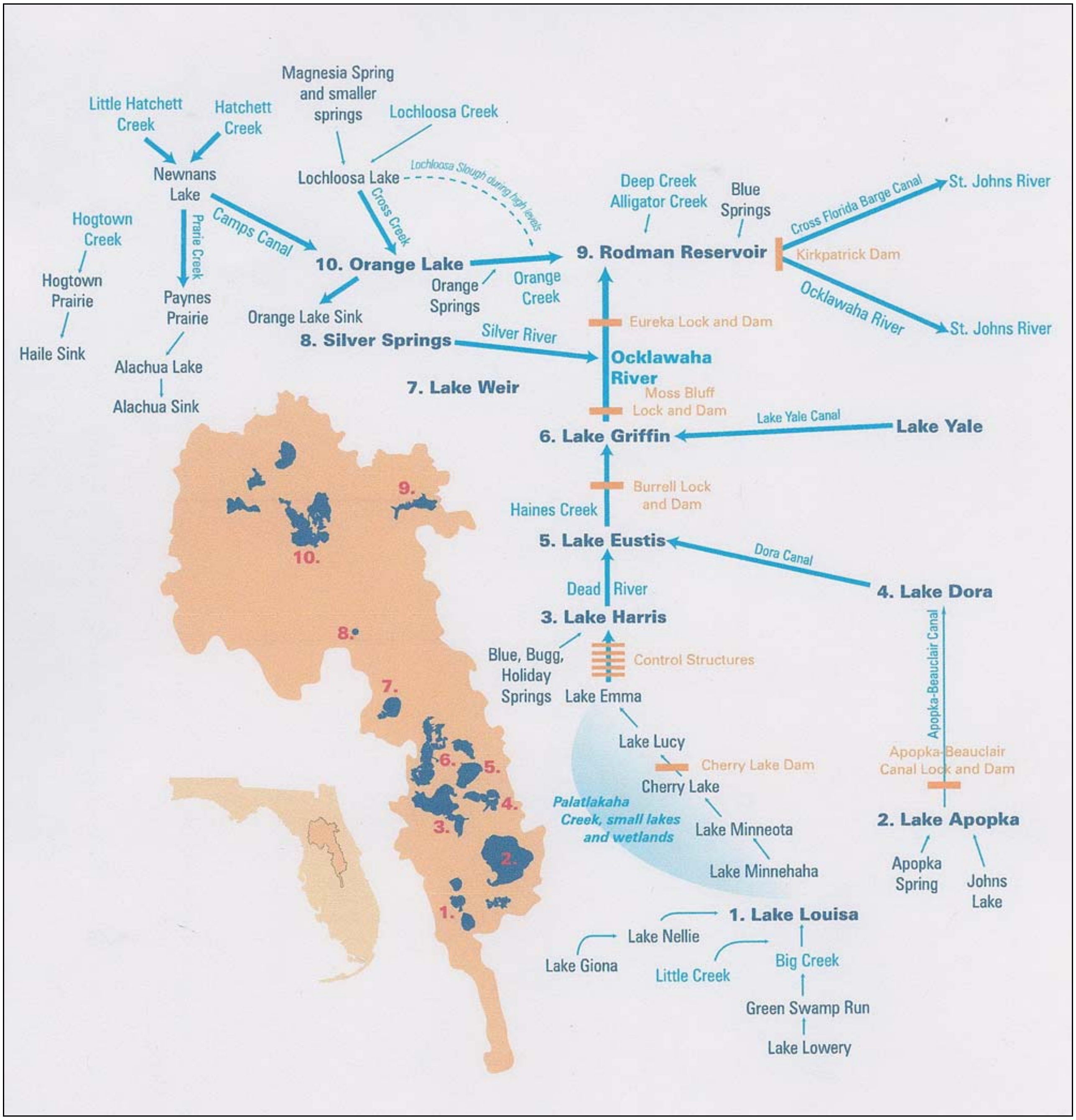

Figure 4. Schematic of water movement in the Ocklawaha River basin (from FDEP 2001).

Leitman et al (1991) documented the fish utilizing the forested floodplain of the Ochlockonee River, Florida, and noted that "[I]nundated vegetative structure, both live and dead, provides important substrate, refuge, or food for any invertebrates and fish…Stumps, logs or clumps of vegetation provide shelter for nests of several species of sunfishes and catfishes…Vegetative cover as protection against predation is an important survival factor for young bluegill…the amount of flooded vegetation and the duration that it was flooded significantly influenced survival of young largemouth bass during the first 3 months of life" (page 22).

Hill and Cichra (2002a, 2002b) have published a literature review and summary of the effects of water levels on fish populations particularly as it relates to floodplain inundation frequencies and the setting of MFLs by the SJRWMD Bureau of Water Supply. They note that "[W]ater level fluctuations have numerous management implications…For systems where flow or water level manipulations is a possibility, water management can be used for fisheries management purposes…given the past history of hydrology alteration for water management and the present and future demands for ground and surface water resources in Florida, fisheries implications can be an important consideration for water management projects and policies" (page 7).

Fish may be resident or transient in a specific habitat, and for some species that move longer distances we use the term migratory. If this migratory portion of their life history takes them between marine, estuarine and fresh waters, depending on the specific pattern, these life histories may be described as anadromous, catadromous, or simply diadromous which is catch-all term for these kinds of life history movements.

Diadromous refers to a species, fish or invertebrate, that exhibit regular migrations at defined life history stages between freshwater and the sea. It can be subdivided into:

Anadromous refers to a fish species that spawns in freshwater, but primarily spends its juvenile and adult life in salt water. Various species of salmon are the most familiar of these species, returning to their natal streams to spawn and die as part of their life cycle. In north Florida the striped bass (*Morone saxitilis*) and several species of shad (*Alosa* spp) exhibit this life history (McBride 2000).

Catadromous refers to the reverse, where adult spawning takes place in salt water, with the juveniles seeking freshwater as their nursery habitat. The American eel (*Anguilla rostrata*) is a typical species occurring in north Florida and the LOR that exhibits this life history pattern.

These life history patterns may be obligatory or facultative. If obligatory, the life stage that is moving between habitats must make a successful migration on time or it dies breaking the cycle of recruitment of the species for a certain area. The striped bass is an obligatory anadromous species in north Florida, and since its spawning habitat in the LOR was blocked in 1968 with the closure of the Kirkpatrick Dam, the native population disappeared. The current population, primarily in the St. Johns River and in the LORBKD, is a combination of a stocked population from inland South Carolina and captured stocked adults in the SJR. The SJR must be regularly restocked as it is not self maintaining through natural reproduction. The striped mullet (*Mugil cephalus*), on the other hand is a facultative catadromous species (Blaber 2009), and can survive in both salt and fresh portions of the SJR, and is occasional found in the MOR and LOR above the Kirkpatrick Dam after passing through the Buckman Lock. Its biomass within the Silver River has been reduced by 99%, (Munch et al. 2007) and the similar reductions are likely in the MOR and LOR. Thus this species is not totally absent as a self-maintaining population, just drastically reduced in population size.

GENERAL FISH TERMINOLOGY

Several other terms are loosely applied to various species of fish. Some fish are "sportfish" and some are "rough" or "trash" fish. Obviously sportfish are those prized by sport fisherman, like largemouth bass, or speckled perch (black crappie), and can be eaten. "Rough" or "trash" fish are not typically the target of either sport or commercial fisherman and are derogatorily referred to with these terms. None of these terms are scientific terms, and technically all native fish species are part of the ecosystem and likely play a role in that ecosystem, and are likely a source of food for other larger organisms.

The term "forage fish" is a scientific term defined here as "small fish that feed on plants, detritus and small organisms and are in turn consumed as forage [food] by larger predators, such as larger fish species, birds, reptiles [alligators] and mammals [otters, bobcats]". A recent worldwide review of forage fish management issues has been released by the Lenfest Ocean Program and the Institute for Ocean Conservation Science (Pikitch et al. 2012).

Gizzard shad (*Dorosoma cepedianum*), for example, are generally thought of by sports fisherman as "trash fish." However, when a careful examination of the feeding habits of many of the prized species is made, interesting information is derived. For example, young gizzard shad are described by McLane (1955) (p. 49) as a "…very valuable forage fish, being eaten in considerable quantities by black bass, ten pounders, needle fish, flounders, garfishes, and the black crappie…" Gizzard shad are also likely an important food item for stocked striped bass in the St. Johns River. Juvenile, young adult and adult striped mullet are also important forage fish for a number of larger predators. Their overall population and that of the various species of other forage fish species such as shad (*Alosa*), menhaden (*Brevoortia*), various silversides, mosquitofish, sailfin mollies, true minnows and suckers are impacted by habitat loss, such as the blockage to movements by the Kirkpatrick Dam. The loss of this forage for larger organisms (bass, gar, alligators, otters, wading birds, ospreys) in turn reduces these species' populations. Thus any successful fisheries (and ecological) management program must address not just the availability of prized sport fish or commercial fish to humans, but also the food of these targeted species, the habitat requirements of important forage fish consumed by these species and other wildlife, and thus the availability and quality of all fish habitats within a given ecosystem.

Finally, we have "non-native invasive species" or exotic species of fish that compete with native species for habitat and food. Two of the most common of these in the Ocklawaha River are the suckermouth armored catfish (*Hypostomus plecostomus*) and the vermiculated sailfin catfish (*Pterygoplichthys disjunctivus*) (Nico et al. 2009). Another is the blue tilapia (*Tilapia aurea*). Little scientific study of the impact of these species on river habitats or fish populations has been done, but excavation of depressions and burrows, and loss of benthic vegetation caused by these species are common observations by those who frequent the river (Nico et al. 2009, Lewis pers. obs). They are also commonly observed as dead specimens after cold weather events reflecting their lack of resistance to normal weather conditions (Lewis pers. obs).

FISH POPULATIONS IN SILVER SPRINGS AND THE MIDDLE AND LOWER OCKLAWAHA RIVER – REVIEW AND DISCUSSION

<u>The following thirteen paragraphs repeat important literature excerpts with only minor updates from the excellent summary found in the Clugston 2002 review. Direct quotations are appropriately marked. Following these excepts is the author's discussion.</u>

"The major objective of recent studies was to examine past and present fish populations in the Ocklawaha River system, including Silver Springs, to provide some insight in the possible effects dam removal might have on fishes now present in these systems and in the St. Johns River. Background data prior to the 1993 legislative mandate for additional studies are available from Hubbs and Allen (1943), the Florida Game and Fresh Water Fish Commission (now Fish and Wildlife Conservation Commission - FFWCC) and the University of Florida (Bass and Guillory 1976; Canfield et al. 1993; Duchrow and Starling 1972; Estes et al. 1989; Haller and Shireman 1984; Holcomb 1973; McKinney et al. 1986; Owen 1998)(Clugston 2002). McLane (1955) an unpublished Ph.D. dissertation entitled "The Fishes of the St. Johns River System" is the only extensive study of the fishes in the Ocklawaha River prior to dam construction." A second series of studies concentrating on Silver Springs and Silver River are contained in Hubbs and Allen (1943), Odum (1957), Knight (1980), and Munch et al. (2007) which contains a summary of all of these documents and points to large declines in fish populations over that period of time.

"A review by Continental Shelf Associates, Inc. (1994) summarizes much of the fishery data through 1993. Despite the reports available related to the Pool and the fish communities found throughout the river system, it remains somewhat unclear specifically how the fish community in the Ocklawaha River has been altered by dam construction. Some uncertainties exist because sampling locations and techniques have changed over the past 40 years, and the data are not directly comparable. Establishing cause and effect of some long-term changes in aquatic communities is difficult unless studies are well-planned and initiated long before the environment is purposely altered." Absent such studies, the "weight of evidence" approach looking at all data available and having experts evaluate it, can be used to make "science based" judgments as to likely changes over time and further make management recommendations.

"It has been suggested that a number of fish species have been lost from the Ocklawaha River system because of the construction of the Kirkpatrick Dam. However, the numbers of species present prior to dam construction, the species believed to be lost or displaced following construction, and their identities vary among reports. In order to clarify the effects of the dam and Pool on various fish species." Clugston (2002) did an initial review based primarily on literature sources dated prior to 1994. This review reexamines many of these past studies in relation to habitats required by specific species and the actual habitat sampled, and updates that information based upon data and reports through 2012.

"McLane (1955) reports collecting 118 species representing 36 families in the St. Johns River system. His record included 62 marine species from 27 families. He said the number of marine species 'could be increased considerably if species only collected at the river mouth were included.' He further stated that all the primary freshwater species he found in the St. Johns River proper were also found in the Ocklawaha River drainage. However, he found five species in the Ocklawaha River drainage to be absent from the rest of the St. Johns River basin: dusky shiner (*Notropis cummingsae*), southern tessellated darter (*Etheostoma oimstedi*), mud sunfish (*Acantharchus pomotis*), banded pygmy sunfish (*Elassoma zonatum*), and blackbanded sunfish (*Enneacanthus chaetodon*). Three of these—blackbanded sunfish, banded pygmy sunfish, and mud sunfish—plus the pugnose minnow (*Opsopoeodus emilliae*) were found only in the headwater lakes of the Ocklawaha River (upstream of the Moss Bluff Dam – river mile 64) and from the Alexander Springs Creek and Juniper Springs Creek, both of which flow directly into the St. Johns River. McLane (1955) also stated that the bluenose shiner was extremely rare in the St. Johns River drainage system. He collected this species at two sites in the Ocklawaha River (7 and 25 miles upstream from the mouth of the Ocklawaha River) and also again from Alexander Springs Creek and Juniper Springs Creek…"

"Reid (1970) said "Approximately 110 species of fishes are known from this (Ocklawaha River) drainage system…". However, he did not identify most of these species. He did note that dusky shiner, bluenose shiner, southern tessellated darter and snail bullhead (*Ameiurus brunneus*) were rare and exist as disjunct colonies and that their habitat should be preserved to prevent their extinction."

"Continental Shelf Associates, Inc. [CSA] (1994) provides a table (See modified version as Table 2) that lists native fish species collected from the Ocklawaha River system by 14 sources. Included are those identified by McLane (1955) and those identified and preserved as official records at the Florida Museum of Natural History, Gainesville, Florida. Although the table shows 1993 as the year for museum records (source number 11, Table 2), the data represent specimens collected as far back as the 1940's. The table is subdivided into those species collected from the Pool and those from the river and watershed. Their summary shows a total of 69 species. This listing can be broken down further into 59 freshwater species, 7 brackish and/or saltwater species, and 3 species whose life requirements include some time in both fresh and salt water (anadromous and catadromous)."

"Further examination of the table provided by Continental Shelf Associates, Inc. (1994) shows that 24 species found in the river and watershed were not found in the Pool. Three species are saltwater invaders and one is an anadromous species. The southern flounder (*Paralichthys lethostigma*) and hogchoker (*Trinectes maculates*) are benthic dwellers and upstream movement was possibly stopped by the Kirkpatrick Dam. The white mullet (*Mugil* *curema*) was collected in the river in 1993 (Continental Shelf Associates, Inc. 1994)." Hubbs and Allen (1943) also note one specimen collected in Silver Springs. "The anadromous American shad (*Alosa sapidissima*) was documented only in the river by a single specimen collected by McLane (1955). A relatively recent study designed to evaluate the use of the lower Ocklawaha River by migratory fishes during spring spawning season did not collect American shad (Jordan 1994a). However, commercial fishermen were interviewed and indicated that American shad or hickory shad (*Alosa mediocris*), were seen at Silver Springs prior to construction of Kirkpatrick Dam" (J. M. Barkuloo, retired U.S. Fish and Wildlife service, personal communications to J. Clugston in Clugston 2002). Large schools of threadfin shad (*Dorosoma petenensis*) have been reported to have historically occurred in Silver Springs (Hubbs and Allen 1943). McBride (2000) notes that with reference to the Kirkpatrick Dam "…[R]emoving this dam would be the first step towards restoring a shad run to this area…" (page 10).

"The table of native fishes in the Ocklawaha River system provided by Continental Shelf Associates, Inc. (1994) indicates that striped bass were rarely caught in the river and Pool after dam construction. However, there is little doubt that they were seasonally common in the unaltered river system." The junction of Silver River and the Ocklawaha River was a popular fishing location for striped bass prior to dam closure (see website link below). More recently, however, Jordan (1994a) failed to collect striped bass between January and June, 1994, in the Pool and river, but he did collect them from the barge canal downstream of the Buckman lock. He states based upon interviews and his knowledge that "…the striped bass was historically common to abundant in the Ocklawaha River up to Moss Bluff Dam, and "the Ocklawaha River was probably an important spawning area." Clugston (2002) notes that "every spring to date since the completion of the dam, local newspapers have reported excellent striped bass fishing in the Ocklawaha River at the base of Kirkpatrick Dam" (in the LORBKD)(see similar accounts at the website http://sites.google.com/site/ocklawahaman/striped-bass-of-the-ocklawaha-river). "The presence of striped bass carcasses in the reservoir during two fish kills in the late 1980's indicate that some passed into the Pool via the Buckman Lock (Florida Department of Environmental Protection 1997). None were seen in a September 2000 fish kill (R. W. Hujik, FL Fish and Wildlife Conservation Commission, personal communication to J. Clugston). There is no doubt that the Kirkpatrick Dam stops upstream migration of striped bass in the Ocklawaha River and likely prevents reproduction" and establishment of a self-maintaining population.

"Two saltwater species, Atlantic needlefish (*Strongylura marina*) and striped mullet, were reported both in the river and the Pool by most sources (CSA 1994). These two species commonly migrate well upstream in the St. Johns River. Two other saltwater species, ladyfish (*Elops saurus*) and menhaden (*Brevoortia* sp.) were reported only from the Pool. However, Continental Shelf Associates, Inc. (1994) indicates specimens of these fishes were not available for confirmation of identification. Jordan (1994a) collected one ladyfish in the Cross Florida barge canal leading to the Buckman Lock in 1994."

"Adult American eel, a catadromous species, was found in the Pool and river by many sources (Continental Shelf Associates, Inc. 1994). Hubbs and Allen (1943) also report it from Silver Springs. Jordan (1994a) did not collect any adult eels during the six-month study in 1994, but did collect one elver (larval eel) below the spillway of Rodman Dam. The Kirkpatrick Dam spillway has served as an elver collecting point for an eel aquaculturist for many years (Dugan

Whiteside, comments at Public Hearing on Interstate Fishery Management Plan for American Eel, Palatka, FL, 1999" in Clugston 2002). Bonvechio and Johnson (2007) report routine collections of eels below the Kirkpatrick Dam. Therefore there is no doubt that the dam is blocking movement of juvenile eels upstream and likely impacting populations in the SJR.

Clugston (2002) notes that "the absence of the 20 freshwater fish species that were collected from the Ocklawaha River and watershed from the Pool does not necessarily indicate that those species were lost from the system because of the Pool construction. The watershed includes many headwater lakes, small tributaries to these lakes, ponds, swamps and springs that were not affected by the construction of the Pool. Fourteen of these freshwater species were collected only from the upstream habitats and probably were not present in the area now inundated by the Pool. To our knowledge, no one recently has sampled the upstream habitats using appropriate collecting methods to determine if these species are present or absent."

"Jordan (1994b) recently collected the pugnose minnow and southern tessellated darter from Orange Creek, a tributary to Rodman Pool. McLane (1955) found the pugnose minnow to be '[V]ery rarely found in the Ocklawaha' and that it was 'a sluggish river and large lake dweller…' In 1992-94 it was also electrofished downstream of the Kirkpatrick Dam (in the LORBKD) by the Florida Game and Fresh Water Fish Commission (Continental Shelf Associates, Inc. 1994). McLane (1955) found the southern tessellated darter in the same vicinity prior to dam construction. Based on early and recent collection sites and knowledge of preferred habitat, these two species were probably present in the area of the Pool but are now restricted to its tributaries and the river."

"The remaining four freshwater species were collected by McLane (1955) prior to Pool construction in the main body of the Ocklawaha River and its tributaries. The most recent collections of bluenose shiner and dusky shiner appear to be 1948 and 1949 respectively (Museum records, University of Florida) from an area about seven miles upstream from the Ocklawaha River mouth" (in the LORBKD). "Jordan (1994b) made an unsuccessful effort to find bluenose shiner in 1994. The sailfin shiner and brown darter appear to have been most recently collected from tributaries of the Ocklawaha River well upstream of the Pool in 1976 (Museum records, University of Florida). The absence of these four species from the recent collections in areas near the Pool or areas now inundated suggests that they are very rare or have been eliminated from the Ocklawaha River proper and its tributaries."

"An additional species, the snail bullhead, was collected in the Pool in 1971" and more recently above the Kirkpatrick Dam at two locations (Evert and Gilbert 2006). "During the mid-1970's, the snail bullhead was collected both well upstream of the Pool and below the Kirkpatrick Dam (Museum records, University of Florida reported in Clugston 2002; Bass and Guillory 1976). Six other species of the catfish family have been collected by researchers from the river and the Pool during the 1990's." <u>This concludes the major repeated sections from Clugston (2002).</u>

Author Discussion

Largemouth bass (*Micropterus salmoides*) is an iconic sport fishing species common in lakes and rivers in Florida. Much of the argument about whether to restore the Ocklawaha River revolves around the populations of this species in the artificial impoundment which is the Rodman Pool, versus what might be the population and fishing opportunities in the Middle and Lower Ocklawaha River, and the St. Johns River, once the dam were breached. It is important to note that largemouth bass are also a common species found in the Middle Ocklawaha River outside the Pool (https://sites.google.com/site/ocklawahaman/largemouth-bass-of-the-ocklawaha-river) and while population biomass is documented to have declined by 60% in Silver Springs (Munch et al. 2007) they are still routinely caught outside of the Pool (see Figure 5). One of the largest largemouth bass ever caught in Florida was in fact caught in the Ocklawaha River. The above referenced web site at page 26 of 43 (accessed on April 11, 2012) describes with a newspaper picture a 21 pound 3 ounce bass reportedly caught in the Ocklawaha River near Moss Bluff in 1975.

There is also data and reports that seriously question the claims of some that the Pool supports many more bass, and larger bass, than adjacent lakes and the SJR. As early as 1993 Canfield et al. stated, based upon their examination of catch data and their own sampling that "…largemouth bass fishing is declining in Rodman Reservoir" (p. 25), and that "fishing is substantially better in the Ocklawaha River" [outside the Pool] (p. 24).

Livingston(2004)[http://www.fladefenders.org/publications/FishingTournamentStudy.pdf] reviewed fishing tournament results published in the Palatka Daily News between February 2001 and August 2004, notably looking at two of the area's major fishing tournaments, the Wolfson Children's Hospital benefit (which begins on the St. John's River) and the Save Rodman Reservoir benefit. Livingston (2004) examined the total weight of catches on the SJR and the Pool. Both tournaments have a seven-fish limit. He repots that "the average winning creel weight of river fish caught at the Wolfson was 31.16 pounds while the Save Rodman Reservoir tournament average winning creel is only 23.51 pounds of reservoir fish (25% less weight). The average big fish for the four years studied was two pounds heavier in the Wolfson tournament than in the Save Rodman Reservoir tournament."

The presence of large amounts of large woody debris in the Pool left over from the partially cleared floodplain forest that was created from the construction of the Cross Florida Barge Canal no doubt contributes to optimum habitat for lake dwelling bass. However this habitat is disappearing over time and will not be replaced because there is no extensive live forest growing in the Pool to replace the decaying large woody debris. Floating and submerged aquatic vegetation in the Pool also contribute to bass habitat and habitat for forage fish and invertebrates. These areas will decline in some areas of the drained Rodman Pool after restoration, but other areas will open up for these types of vegetation. In particular, the 20 drowned natural springs under the Pool (Abbott 1971, see also http://sites.google.com/site/ocklawahaman/the-springs-of-the-ocklawaha-river-florida-from rodman-dam-upstream-to-eureka-dam) will resume clear water flows and will naturally support very diverse submerged aquatic vegetation communities. Although it is reasonable to anticipate a decline in largemouth bass catches in former Pool areas with restoration, other sport fish species such as stocked and naturally reproducing striped bass will increase. Nursery habitat for largemouth bass below the existing dam within the now largely dry floodplain of the LORBKD should increase with more frequent inundation, and lead to increased bass populations in that reach of the river. Overall, there is no scientific support for the projection of any permanent major loss of sport fishing opportunities within the Middle or Lower Ocklawaha River ecosystem after restoration. Once the system stabilizes after the dam is breached, and floodplain ecosystems both above and below the dam are in the process of revegetation and rehydration (expected time frame 3-5 years), any temporary decline in fish populations should show a significant rebound. Expected increases in forage fish populations will soon offset any temporary decline in food for larger predators, not just including largemouth bass and striped bass, but wading birds, reptiles and mammals are expected to benefit from restoration.

Endangered shortnose sturgeon (*Acipenser brevirostrum*) and Atlantic sturgeon (*Acipenser oxyrinchus*) were once present in the St. Johns River. McLane (1955) mentions single collections of each over eight years ('46-'54) in the SJR. Both species were also collected from the St. Johns River by the State of Florida in 1981 (Fred Cross, Fish and Wildlife Conservation Commission to K. J. Sulak, USGS, personal communication to J. Clugston in Clugston 2002). No mention of possible use by these species of the Ocklawaha River is made by McLane (1955). McLane (1955) considered the one collection of a shortnose sturgeon in Lake George to be a stray.

Both species are mentioned as possibly using the Ocklawaha River historically, but no collections have ever been reported (Gilbert 1992). For these reasons they are not included in Table 2. Gilbert (1992) lists the shortnose sturgeon as endangered, and the Atlantic sturgeon as threatened. The status of the Atlantic sturgeon has recently (February 2012) been changed to endangered. Removal of the Kirkpatrick Dam is mentioned in both species descriptions in the 1992 book as a potential restoration method for them, as well as by the National Marine fisheries Service (1998).

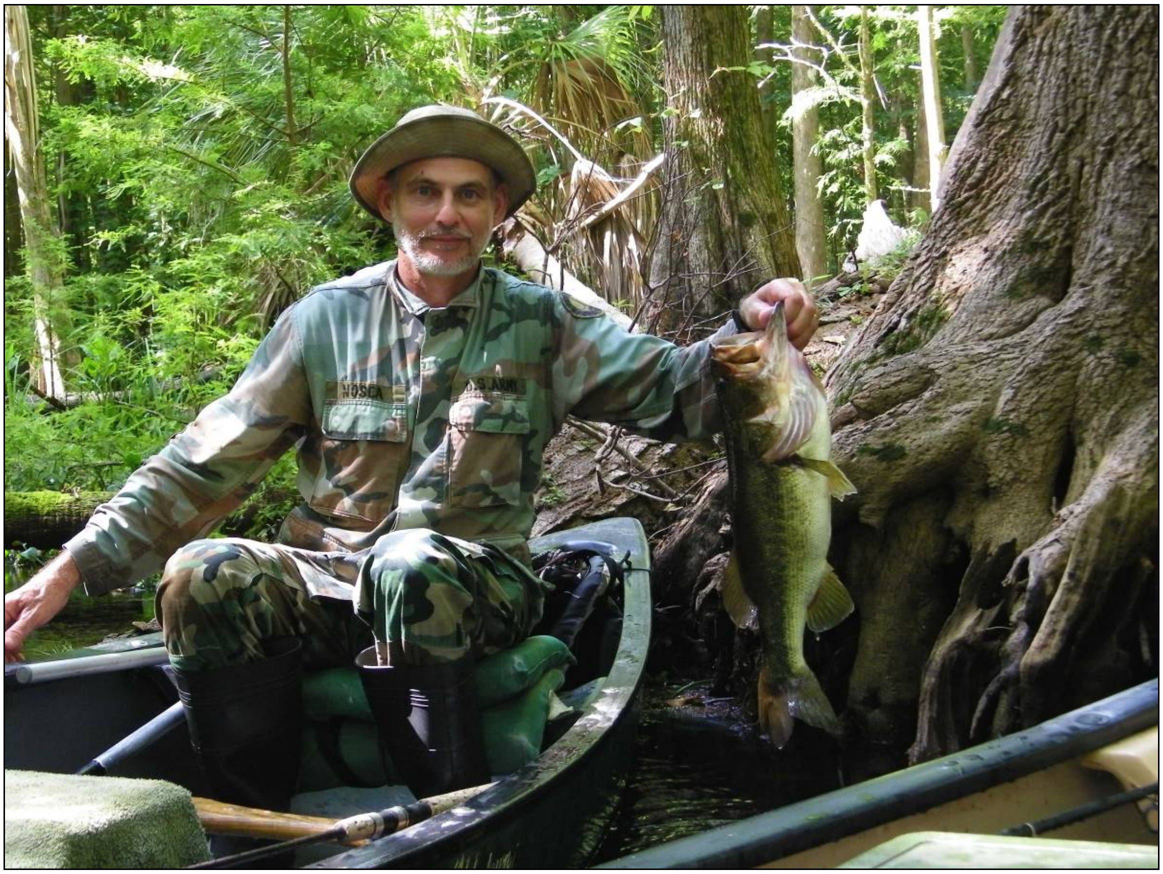

Figure 5. Largemouth bass caught by Paul Nosca on July 24, 2009 in the Middle Ocklawaha River near Gore's Landing. Photograph by K. Alwine.

Munch et al. (2007) conducted visual censuses in Silver Springs using the same techniques used in two previous studies by Odum (1957) and Knight (1980). A table summarizing their results is attached as Appendix A. Overall, 24 species were reported to have been observed historically, although the striped bass is not included in that list. Twenty-two species remain, but overall biomass has declined from 526.7 kg/ha to 41.9 kg/ha, a decline of 92% (Figure 6). As previously noted, striped mullet biomass has declined by 99%. In addition, gizzard shad biomass has declined by 96%, all catfish species biomass by 100% (total absence during sampling), and largemouth bass by 60%. The blocking of seasonal migrations of many of these species and declines in foraging biomass for species like largemouth bass are the likely cause of these major declines as noted by Knight (1980).

Finally, regarding what conditions might result from restoration; we would note that CSA (1994) concluded from their studies that "…the beneficial consequence of restoring a natural Ocklawaha River would be an increase in, and maintenance of biodiversity. The increase in biodiversity would be accompanied by a decrease in overall biomass of fishes. Conversely, retention of Rodman Reservoir [Pool] or partial restoration would provide high fish biomass production at the expense of biodiversity. The retention scenarios are obviously artificial systems that will require intensive management programs to operate properly." This conclusion, of course, came before the data of Munch (2007) clearly demonstrated a 92% decline in fish biomass in the Silver River (Figure 6). A decline the author would expect to be reversed with restoration. The author would also expect a substantial increase in nursery habitat availability for largemouth bass and sunfish in the LORBKD, and thus increased and better fishing opportunities for these species both in the LORBKD and the adjacent SJR with restoration, and an expected increase in the inundation of now relatively dry creeks and wetlands in the LORBKD.

As an example of this, Burdick and Hightower (2006) document the results of the removal of a low head dam in North Carolina (Quaker Neck Dam) and report that breaching resulted in an increase in spawning habitat for American shad, hickory shad and striped bass. Also, the recently reported restoration work at the 16,000 acre Mollicy Farms project site on the Ouachita River in Louisiana (Weber et al. 2012) notes that "fish productivity was an order of magnitude higher, and twice as many fish taxa were found during sampling of the undisturbed forested floodplain adjacent to Mollicy Farms than within the Mollicy Farms site [proposed restoration site]." This author would expect similar fish productivity restoration results after breaching of the Kirkpatrick Dam.

Miller et al (2012) describe the current degraded conditions of fish populations in the St. Johns River as follows:

"Since the 1850s, the St. Johns River has supported valuable commercial fisheries (Cary 1885; McLane 1955; Moody 1961). From 1948 to 1953, more than 4.5 million kg (10 million lbs) of fish were commercially harvested by haul seines from Lake George alone (Moody 1961). Other commercial gear types used in the river included trap nets, eel pots, gill nets, otter trawls, wire traps, and trotlines. Dominant species harvested included gizzard shad (Dorosoma cepedianum), black crappie (Pomoxis nigromaculatus), white catfish (Ameiurus catus), channel catfish (Ictalurus punctatus), American shad (Alosa sapidissima), and American eel (Anguilla rostrata)…"

"Recreational sport fishing is also extremely popular in the St. Johns River. The most sought-after freshwater species include largemouth bass (Micropterus salmoides), black crappie, bluegill (Lepomis macrochirus), redear sunfish (Lepomis microlophus), and redbreast sunfish (Lepomis auritus)…Angler survey data…indicate that annual angler sport fishing on the entire St. Johns River in 1975 to 1976 exceeded 2,300 man-hours per river km with yields exceeding 2,200 fish per river km. Compared to other Florida rivers, only the Blackwater River in the panhandle yielded more fish per river km."

"Even though it continues to support valuable commercial and recreational fisheries, the fish community of the St. Johns River today is impaired compared to the community present 50 years ago. Native striped bass (Morone saxatilis) were extirpated, and populations are now maintained by stocking northern and hybrid strains... Spawning runs of anadromous shad and herring, that for decades supported extensive commercial and recreational fisheries, have dramatically declined ... The abundance of other commercially exploited species such as American eel and river catfish have also declined. In the 1960s, fisheries biologists began documenting shifts in the freshwater species composition in the river away from communities dominated by desirable sport fishes (e.g., largemouth bass and other sunfishes) toward communities dominated by undesirable species, such as gizzard shad and gar (Lepisosteus spp.)... By the 1980s, abundance of sport fishes had declined... Factors considered responsible for changes in the river fish community include overexploitation, persistent declines in water quality associated with urban and agricultural development, fish kills, channelization, over drainage and loss of basin wetlands, aquatic weed treatments, loss of habitat, introduction of exotics, and increased concentrations of herbicides, pesticides, and heavy metals…**Although some community changes (e.g., the extirpation of native striped bass, extensive habitat loss to development) are irreversible, others are not [emphasis added].** For example, water quality improvements or habitat restoration could result in increased abundance of sport fishes and shift communities toward more economically or socially desirable species. On the other hand, future anthropogenic impacts that further exacerbate community stressors could cause additional declines in the St. Johns River fishery resources."

Unfortunately, Miller et al. (2012) make the mistake of using unscientific descriptions of specific fish species, labeling gizzard shad and gar as “undesirable species” and further make no mention of the reason for the extirpation (local extinction) of the native St. Johns River striped bass (Kirkpatrick Dam construction), and apparently lump it along with other anthropogenic impacts into the “irreversible” category. <u>It is obviously not irreversible, and the likely benefits from dam breaching to both the Lower Ocklawaha River ecosystem, and the St. Johns River fish and wildlife resources are well documented.</u>

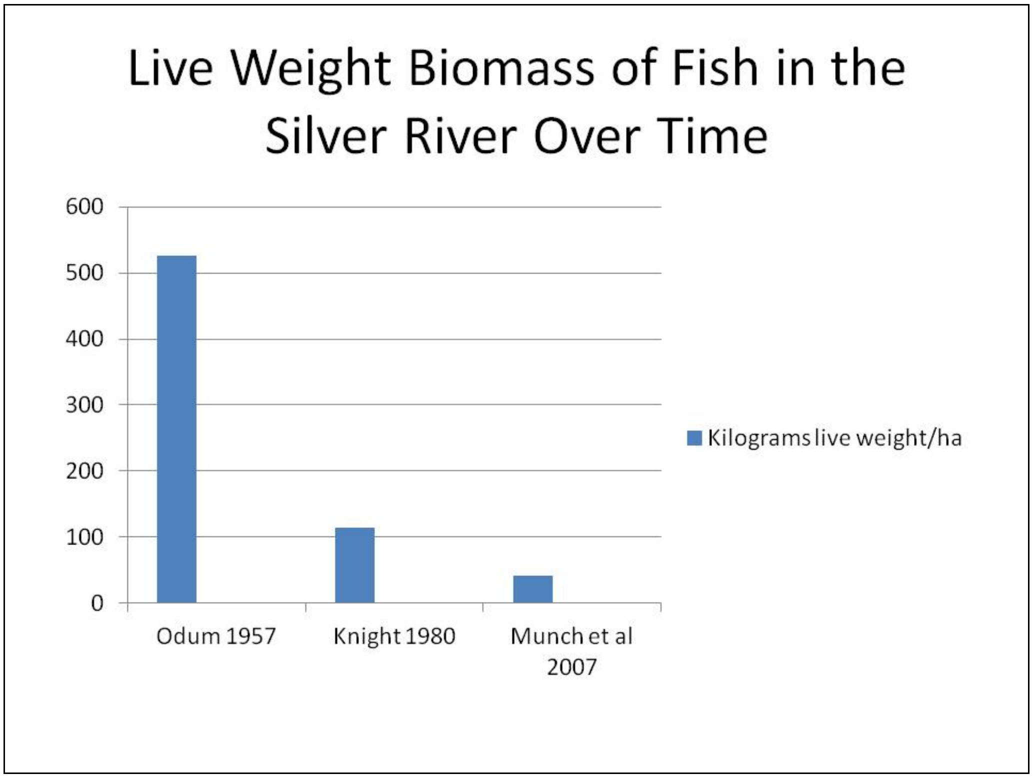

Figure 6. Graph showing the decrease in live weight biomass of fish over time in the Silver River.

CONCLUSIONS

With all of above information available, this author would conclude that there is no credible scientific basis to predict any permanent decline in fish resources following restoration, given enough time for migratory fish species to return (estimate 3-5 years), nor similarly to predict a specific permanent decline in sports fishing opportunities. The species mix may change, but fish biomass within the restored channels and wetlands (both above and below the existing Kirkpatrick Dam) will likely remain the same or increase over time after the initial breaching of the dam takes place, and migratory species including forage fish such as American shad, mullet and channel and white catfish populations are naturally restored.

Nursery habitat for largemouth bass should increase below the breached dam once normal flows are restored. A viable riverine bass and sunfish fishery will remain throughout the Ocklawaha River, and will likely increase in that portion of the Lower Ocklawaha River between the Kirkpatrick Dam and the St. Johns River. Given the 92% decline in fish biomass in the Silver River over the last 50 years, it is very likely fish populations would increase significantly in that specific habitat, and other springs and spring run habitats newly available after restoration. Sport fishing opportunities for species like the striped bass will increase with restoration, and the restoration of a self maintaining breeding population of striped bass is possible.

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Table 2. Native Fishes Recorded from the Ocklawaha River System. (Modified from: Continental Shelf Associates, Inc., 1994 and Clugston 2002).

	Rodman Pool										Ocklawaha River and Watershed							
Source:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(1)	(11)	(2)	(7)	(12)	(13)	(14)	(15)
Family Species / Sampling Year(s):	1986 - 94	1992	1987 - 88	1987	1985 - 88	1979 - 83	1975	1973	1971 - 72	1971	1986 - 94	1993	1992	1975	1946 -55	1945	1943	1899
Lepisosteidae																		
1 *Lepisosteus osseus,* longnose gar	●	●	●			●	●	●	●	●	●	●	●	●	●		●	●
2. *Lepisosteus platyrhincus,* Florida gar	●		●			●	●	●	●	●	●	●	●	●	●		●	
Amildae																		
3. *Amia calva*, bowfin	●		●	●		●	●	●	●	●	●	●	●	●	●		●	●
Elopidae																		
4. *Elops saurus*, ladyfish					●													
Anguillidae																		
5. *Anguilla rostrata*, American eel	●					●		●	●	●	●	●	●	●	●		●	
Clupeidae																		
6. *Alosa sapidissima*, American shad															●			
7. *Brevoortia sp.*, menhaden					●													
8. *Dorosoma cepedianum*, gizzard shad	●	●	●		●	●	●	●	●	●	●	●		●	●		●	●
9. *Dorosoma petenense*, threadfin shad	●	●				●		●	●	●	●	●			●	●	●	
Cyprinidae																		
10. *Notemigonus crysoleucas*, golden shiner	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●
11. *Notropis chalybaeus*, ironcolor shiner												●			●			
12. *Notropis cummingsae*, dusky shiner												●			●			
13. *Notropis harperi*, redeye chub												●			●		●	
14. *Notropis maculatus,* taillight shiner	●		●	●		●	●	●	●		●	●		●	●			
15. *Notropis petersoni,* coastal shiner	●		●	●		●					●	●	●	●	●		●	●
16. *Opsopoeodus emilliae*, pugnose minnow											●	●			●			●
17. *Pteronotropis hypselopterus,* sailfin shiner												●		●	●			●
18. *Pteronotropis welaka,* bluenose shiner												●			●			●
Catostomidae																		

	Rodman Pool										Ocklawaha River and Watershed							
Source:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(1)	(11)	(2)	(7)	(12)	(13)	(14)	(15)
Family Sampling Species Year(s):	1986 - 94	1992	1987 - 88	1987	1985 - 88	1979 - 83	1975	1973	1971 - 72	1971	1986 - 94	1993	1992	1975	1946 -55	1945	1943	1899
19. *Erimyzon sucetta*, lake chubsucker	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●
Ictaluridae																		
20. *Ameiurus brunneus,* snail bullhead										●		●		●	●			
21. *Ameiurus catus,* white catfish	●				●	●	●	●	●	●	●	●	●		●		●	●
22. *Ameiurus natalis,* yellow bullhead	●		●	●		●	●	●	●	●	●	●	●	●	●		●	
23. *Ameiurus nebulosus,* brown bullhead	●	●	●	●		●	●	●	●	●	●	●			●			●
24. *Ictalurus punctatus,* channel catfish					●	●	●	●	●	●	●	●		●	●		●	●
25. *Noturus gyrinus,* tadpole madtom	●	●				●	●	●	●	●	●	●			●			
26. *Noturus leptacanthus,* speckled madtom	●		●								●	●			●			
Esocidae																		
27. *Esox americanus,* redfin pickerel	●	●	●			●					●	●			●		●	
28. *Esox niger,* chain pickerel	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●
Umbridae																		
29. *Umbra pygmaea,* eastern mudminnow												●						
Aphredoderidae																		
30. *Aphredoderus sayanus,*pirate perch	●	●	●	●		●	●	●	●	●	●	●			●		●	
Atherinidae																		
31. *Labidesthea sicculus*, brook silverside	●	●	●			●	●	●	●	●	●	●	●	●	●		●	●
32. *Menidia beryllina,* inland silverside											●	●			●			
Cyprinodontidae																		
33. *Cyprinodon variegatus,* Lake Eustis pupfish												●			●	●		
34. *Fundulus chrysotus,* golden topminnow	●	●	●			●	●					●			●		●	●
35. *Fundulus lineolatus,* lined topminnow												●			●		●	
36. *Fundulus rubrifrons,*redface topminnow												●			●			
37. *Fundulus seminolis,* Seminole killifish	●	●	●	●		●	●	●	●	●	●	●	●		●	●		
38. *Jordanella floridae,* flagfish	●	●				●	●	●				●			●	●	●	
39. *Leptolucania ommata,* pygmy killifish												●			●		●	

	Rodman Pool										Ocklawaha River and Watershed							
Source:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(1)	(11)	(2)	(7)	(12)	(13)	(14)	(15)
Family Species — Sampling Year(s):	1986 - 94	1992	1987 - 88	1987	1985 - 88	1979 - 83	1975	1973	1971 - 72	1971	1986 - 94	1993	1992	1975	1946 -55	1945	1943	1899
40. *Lucania goodei,* bluefin killifish	●	●	●	●		●	●	●	●	●	●	●			●	●	●	●
41. *Lucania parva*, rainwater killifish												●			●		●	
Poeciliidae																		
42. *Gambusia holbrooki,* eastern mosquitofish	●	●	●	●		●	●	●	●	●	●	●		●	●		●	●
43. *Heterandria formosa,* least killifish	●	●	●	●		●	●	●				●			●		●	●
44. *Poecilia latipinna,* sailfin molly	●	●	●			●	●				●	●		●	●		●	●
Belonidae																		
45. *Strongylura marina,* Atlantic needlefish	●	●	●	●		●	●	●	●	●	●	●			●		●	
Percichthyidae																		
46. *Morone saxatilis,* striped bass					●							●			●			
Centrarchidae																		
47. *Acantharchus pomotis,* mud sunfish												●			●			
48. *Centrarchus macropterus,* flier												●			●			
49. *Enneacanthus chaetodon,* blackbanded sunfish												●			●			
50. *Enneacanthus gloriosus,* bluespotted sunfish	●	●	●	●	●	●	●	●	●	●	●	●			●			
51. *Enneacanthus obesus,* banded sunfish												●			●			
52. *Lepomis auritus,* redbreast sunfish	●		●	●	●	●	●	●	●	●	●	●	●	●	●		●	●
53. *Lepomis gulosus,* warmouth	●	●	●	●	●	●	●	●	●	●	●		●	●	●		●	●
54. *Lepomis macrochirus,* bluegill	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
55. *Lepomis marginatus,* dollar sunfish	●	●	●	●	●	●	●	●	●		●	●	●		●			
56. *Lepomis microlophus,* redear sunfish	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●
57. *Lepomis punctatus,* spotted sunfish	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●
58. *Micropterus salmoides,* largemouth bass	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●
59. *Pomoxis nigromaculatus,* black crappie	●	●	●	●	●	●	●	●	●	●	●	●		●	●		●	●

	Rodman Pool										Ocklawaha River and Watershed							
Source:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(1)	(11)	(2)	(7)	(12)	(13)	(14)	(15)
Family Species / Sampling Year(s):	1986 - 94	1992	1987 - 88	1987	1985 - 88	1979 - 83	1975	1973	1971 - 72	1971	1986 - 94	1993	1992	1975	1946 -55	1945	1943	1899
Elassomatidae																		
60. *Elassoma evergladei,* Everglades pygmy sunfish	●	●	●			●	●				●	●			●		●	●
61. *Elassoma zonatum,* banded pygmy sunfish												●			●			
Percidae																		
62. *Etheostoma edwini*, brown darter												●		●	●			
63. *Etheostoma fusiforme,* swamp darter	●	●	●	●		●	●	●	●	●	●	●			●			●
64. *Etheostoma oimstedi,* southern tessellated darter												●			●			
65. *Percina nigrofasciata,* blackbanded darter	●		●								●	●		●	●		●	
Mugilidae																		
66. *Mugil cephalus,* striped mullet	●		●		●	●		●	●	●	●	●		●	●		●	
67. *Mugil curema,* white mullet																	●	
Paralichthyidae																		
68. *Paralichthys lethostigma,* southern flounder												●			●			
Soleidae																		
69. *Trinectes maculates,* hogchoker											●	●	●	●	●		●	

Sources:

(1) Estes (1994, unpublished data).
(2) Canfield et al. (1993).
(3) Estes et al. (1989).
(4) Owen (1988).
(5) McKinney et al. (1985).
(6) Haller and Shireman (1984).
(7) Bass and Guillory (1976).
(8) Holcomb (1973).
(9) Duchrow and Starling (1972).
(10) Duchrow (1971).
(11) Museum Records (Florida Museum of Natural History).
(12) McLane (1955).
(13) Fowler (1945).
(14) Hubbs and Allen (1943).
(15) Evermann and Kendall (1899).

Appendix A

Table ES-5 Comparison of biomass estimates (kg live weight/ha) of fishes in the Silver River, Florida based on results of visual surveys from Odum (1957), Knight (1980), and this study. Methods used for visual surveys were different among studies. *Anguilla rostrata* was listed as *A. bostoniensis* in Odum (1957). Biomass was derived from grams dry weight per meter ² estimates in in Odum (1957) and in Knight (1980) using standard wet weight/dry weight conversion factors.

Family	Common Name	Scientific Name	Biomass (kg/ha)		
			Odum	Knight	This Study
Amiidae	Bowfin	*Amia calva*		0.58	2.79
Anguillidae	American eel	*Anguilla rostrata*			0.01
Belonidae	Atlantic needlefish	*Strongylura marina*		0.01	
Catostomidae	Lake chubsucker	*Erimyzon sucetta*		1.97	1.10
Centrarchidae	Redbreast sunfish	*Lepomis auritus*			0.26
Centrarchidae	Bluegill	*Lepomis macrochirus*			10.99
Centrarchidae	Redear sunfish	*Lepomis microlophus*			2.42
Centrarchidae	Spotted sunfish	*Lepomis punctatus*			0.04
Centrarchidae	Sunfish sp.	*Lepomis sp.*	47.62	15.56	
Centrarchidae	Largemouth bass	*Micropterus salmoides*	27.14	18.65	11.10
Centrarchidae	Black crappie	*Pomoxis nigromaculatus*		0.02	0.01
Cichlidae	Blue tilapia	*Tilapia aurea*			0.23
Clupeidae	Gizzard shad	*Dorosoma cepedianum*		66.28	2.57
Cyprinidae	Golden shiner	*Notemigonus crysoleucas*		6.32	0.59
Cyprinodontidae	Golden topminnow	*Fundulus chrysotus*			0.00007
Cyprinodontidae	Bluefin killifish	*Lucania goodei*	18.57		0.002
Esocidae	Chain pickerel	*Esox niger*		1.34	2.61
Ictaluridae	Channel catfish	*Ictalurus punctatus*			0.03
Lepisosteidae	Longnose gar	*Lepisosteus osseus*	1.43		2.06
Lepisosteidae	Florida gar	*Lepisosteus platyrhincus*	44.29	1.33	3.52
Mugilidae	Striped mullet	*Mugil cephalus*	266.67	2.57	1.55
Percidae	Swamp darter	*Etheostoma fusiforme*			0.00007
Poeciliidae	Gambusia sp	*Gambusia sp.*	21.43		0.00003
Poeciliidae	Least killifish	*Heterandria formosa*	3.33		0.00003
	Catfish		95.24		
	Shiners		0.95		0.01
TOTAL FISH BIOMASS			526.7	114.6	41.90

Table ES-5, page ES-xii, from Munch et al. 2007