APPENDIX A

BIOLOGICAL OPINION ON THE U.S. ARMY CORPS OF ENGINEERS, MOBILE DISTRICT, REVISED INTERIM OPERATIONS PLAN FOR JIM WOODRUFF DAM AND ASSOCIATED RELEASES TO THE APLACHICOLA RIVER

Biological Opinion on the U.S. Army Corps of Engineers, Mobile District, Revised Interim Operating Plan for Jim Woodruff Dam and the Associated Releases to the Apalachicola River

Prepared by:
U.S. Fish and Wildlife Service
Panama City Field Office, Florida
May 22, 2012

EXECUTIVE SUMMARY

The action evaluated in this consultation is the Corps' Revised Interim Operating Plan (RIOP) for Jim Woodruff Dam, which describes releases from the dam to the Apalachicola River. Consultation on the RIOP was completed in 2008 and reinitiated in 2010, because of new information on the distribution and mortality of fat threeridge mussels. Substantial numbers of fat threeridge mussels recolonized habitats at elevations above the minimum 5,000 cfs flow, and many were subsequently exposed and killed when flows declined in September 2010. The Corps determined that the proposed RIOP may adversely affect the fat threeridge, purple bankclimber, and Chipola slabshell, and may affect but would not likely adversely affect (NLAA) the Gulf sturgeon or designated Gulf sturgeon or mussel critical habitat. The Service concurred with the Corps' determination of NLAA for the Gulf sturgeon and its designated critical habitat. Mussel effects were addressed in this biological opinion (BO).

The current version of the RIOP is very similar to the 2008 RIOP. It does not address operational specifics at the four federal reservoirs upstream of Woodruff. The RIOP addresses two specific parameters of the daily releases from Woodruff Dam into the Apalachicola River: a minimum discharge in relation to average basin inflows (i.e., the actual amount of water flowing into all of the Corps projects during a given time period) and maximum fall rate (vertical drop in river stage per day). These two parameters vary by basin inflow, composite conservation storage level and by month. Except when basin inflow is less than 5,000 cfs and during some down-ramping periods, the minimum releases are not required to exceed basin inflow. The Corps proposed five modifications to the 2008 RIOP to minimize impacts to listed species: 1) volumetric balancing is eliminated; 2) minimum flow releases will match basin inflow between 5,000 and 10,000 cubic feet per second (cfs) from June through November (except during drought contingency operations); 3) drought contingency operations are not suspended until composite conservation storage has recovered above Zone 2 into Zone 1; 4) when releases are less than 10,000 cfs, the maximum fall rate is limited to 0.25 ft/day; and 5) river stage declines of 8 feet or more will not occur in less than 14 days when river flows are less than 40,000 cfs during the spawning season (March-May) under both normal and drought operations.

The current status of the three mussel species and their critical habitat is discussed in detail in the BO. Notable mortality of the purple bankclimber and fat threeridge has occurred during recent droughts in 2006-2008 and 2010-2012, but no Chipola slabshell mortality has been observed. The Chipola slabshell population is stable but generally occurs in relatively low abundance. The purple bankclimber is rare and occurs at low abundance in the Apalachicola River (with the exception of one location), and it appears to be experiencing poor recruitment. The fat threeridge population appears stable and may be increasing in size. They are abundant in the middle reach of the Apalachicola River and the lower Chipola River, the population is relatively large, and there is evidence of recruitment.

Fat threeridge are likely moving in response to changing water levels to maintain an optimal depth or associated habitat parameter. At the time of the 2008 BO there were no listed mussels at river stages greater than 5,000 cfs due to the drought of 2006-2008. Although we noted that take may occur when individuals occupy stages greater than 5,000 cfs, we did not anticipate take under this scenario because it was considered an anomaly related to very high flows in 2005. However, based on recent data, it appears that fat threeridge readily recolonize higher bank

elevations at flows greater than 5,000 cfs, where they could be at risk of stranding and mortality when flows decline. Mortality during these events was highest in the middle reach of the Apalachicola River where the main channel populations are the most abundant and slopes are shallow. Some mortality occurred in the Chipola River, but it appears to be limited. Mortality estimates from all of these events range from <1% to 2% depending on preceding hydrologic conditions, fall rates, habitat condition, and the size of the population in Swift Slough and unsurveyed deep-water habitats.

Relative to the Baseline period (1975-2008), the proposed RIOP provides both beneficial and adverse effects to the species and designated critical habitats we have assessed. Many of these effects derive from relatively minor differences between the RIOP and Baseline; however, we attribute these differences to changes in reservoir operations and not consumptive water use. Generally, it appears that the Corps would store water more often and augment flows less often under the RIOP than has occurred historically. The RIOP uses some of this stored water to augment basin inflow in order to maintain a minimum flow of 5,000 cfs, but the frequency and duration of flows less than 10,000 cfs is increased.

Lower flows for longer durations will negatively impact all three mussel species. We expect impacts to Chipola slabshell to be minimal because it occurs almost entirely within the Chipola River where movement is facilitated by higher bank slopes and the species' probable tendency to move. Impacts to the purple bankclimber will also likely be minimized because this species appears to occur more often in deeper portions of the stream channel, which is likely why we have observed limited mortality during recent low flows. The results of the fat threeridge population viability analysis (PVA) indicate that the population can sustain reductions of 1-2% (estimated have occurred during recent droughts) if flows are reduced to 5,000 cfs and 4,500 cfs with currently projected probabilities. However, the PVA also indicates that increasing the frequency of such events results in a greater impact to population viability. The RIOP may affect three of the five primary constituent elements (PCEs) of mussel critical habitat: 1) permanently flowing water; 2) water quality; and 3) fish hosts. It does not appear to reduce the amount of important floodplain habitat available to fish hosts. Droughts substantially change the nature of all of these PCEs, but the RIOP would not appreciably change the quantity or quality of the PCEs to the extent that it would appreciably diminish the habitat's capability to provide the intended conservation role. Therefore, it is the Service's biological opinion that the proposed action: 1) will not jeopardize the continued existence of the fat threeridge, purple bankclimber, and Chipola slabshell; and 2) will not destroy or adversely modify designated critical habitat for the fat threeridge, purple bankclimber, and Chipola slabshell.

The Incidental Take Statement issued exempts the Corps from "take" under the Endangered Species Act. During each of these events (flow reduction to 4,500 cfs, and exposure at stages > 5,000 cfs following recolonization), a maximum the following may be exposed: 30 purple bankclimbers (60 total); three Chipola slabshell (six total); and 9,150 fat threeridge (18,300 total). Three mandatory reasonable and prudent measures are also included: 1) adaptive management; 2) maintenance of the Chattahoochee gage; and 3) monitoring.

This BO is effective for five years (May 22, 2017). No further consultation is needed unless the Corps operates Woodruff Dam in a way that is different from the RIOP, new information indicates that the RIOP may affect listed species to an extent not considered in the BO, or if more mussels or Gulf sturgeon are "taken" under the Corps' operations than anticipated.

Table of Contents

LIST OF TABLES AND FIGURES

List of Acronyms

ACF	Apalachicola-Chattahoochee-Flint
Act	Endangered Species Act
BA	Biological Assessment
BO	Biological Opinion
CFR	Code of Federal Regulations
cfs	Cubic Feet Per Second
Corps	U.S. Army Corps of Engineers
CSU	Columbia State University
DO	Dissolved Oxygen
EDO	Exceptional Drought Operations
EPA	Environmental Protection Agency
FFWCC	Florida Fish and Wildlife Conservation Commission
FDEP	Florida Department of Environmental Protection
FWCA	Fish and Wildlife Coordination Act
GDNR	Georgia Department of Natural Resources
GEPD	Georgia Environmental Protection Division
HEC	Hydrologic Engineering Center
ITS	Incidental Take Statement
NPDES	National Pollutant Discharge Elimination System
NLAA	Not Likely Adversely Affect
PCE	Primary Constituent Element
PIT	Passive Integrated Transponder
PVA	Population Viability Analysis
RIOP	Revised Interim Operating Plan
RM	River Miles
RoR	Run of River
RPM	Reasonable and Prudent Measures
SEPA	Southeastern Power Administration
Service	U.S. Fish and Wildlife Service
TL	Total Length
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WCP	Water Control Plan
Wewa	Wewahitchka, FL

United States Department of the Interior

FISH AND WILDLIFE SERVICE
1601 Balboa Avenue
Panama City, FL 32405-3721

Tel: (850) 769-0552
Fax: (850) 763-2177

May 22, 2012

Mr. Curtis Flakes
Chief, Planning and Environmental Division
U.S. Army Corps of Engineers
P.O. Box 2288
Mobile, Alabama 36628-0001

Dear Mr. Flakes:

This document is the Fish and Wildlife Service's (Service) biological opinion (BO) of the Revised Interim Operating Plan (RIOP) for Jim Woodruff Dam. The RIOP addresses water management operations at Jim Woodruff Dam and the associated releases to the Apalachicola River. This opinion is provided in accordance with section 7 of the Endangered Species Act (Act) of 1973, as amended (16 U.S.C. 1531 *et seq.*) and provides considerations for provisions of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 *et seq.*).

The U.S. Army Corps of Engineers (Corps) originally requested formal consultation on this action by letter dated April 15, 2008. At that time, the Corps determined that the RIOP may adversely affect the threatened Gulf sturgeon (*Acipenser oxyrinchus desotoi*), endangered fat threeridge mussel (*Amblema neislerii*), threatened purple bankclimber mussel (*Elliptoideus sloatianus*), threatened Chipola slabshell (*Elliptio chipolaensis*), and areas designated as critical habitat for the Gulf sturgeon and these mussels. In the June 1, 2008 BO, the Service determined that the RIOP would not jeopardize the continued existence of these species nor destroy or adversely modify their designated critical habitats. An Incidental Take Statement (ITS) and Reasonable and Prudent Measures (RPMs) were issued to minimize the impacts of incidental take on these species.

Consultation was reinitiated by letter dated November 17, 2010, because of new information on the distribution and mortality of fat threeridge mussels. Substantial numbers of fat threeridge mussels recolonized habitats at elevations above the minimum 5,000 cfs flow, and many were subsequently exposed and killed when flows declined in

September 2010. Since that time, we have worked with your staff on potential modifications to the RIOP to minimize impacts to fat threeridge mussels (Corps 2011 and 2012). As described in your most recent amended biological assessment (BA), the Corps is proposing to adopt some of these modifications (Corps 2012). The Corps has determined that the proposed RIOP may adversely affect the fat threeridge, purple bankclimber, and Chipola slabshell, and may affect but would not likely adversely affect (NLAA) the Gulf sturgeon or designated Gulf sturgeon or mussel critical habitat.

Based on the information you provided in the 2012 BA and your supplementary letter on April 12, 2012, the Service concurs with the Corps' determination of NLAA for the Gulf sturgeon and its designated critical habitat. We do not expect take of Gulf sturgeon eggs and larvae to occur because the RIOP's fall rate provision prevents river stage declines of 8 feet or more in less than 14 days, which were expected to result in take in the 2008 BO. In addition, there is little, if any, change to the available amount of spawning habitat in the spring or fall or juvenile sturgeon habitat (using the surrogate measure for salinity in the bay of consecutive days with flows less than 16,000 cfs). The RIOP may benefit spawning and juvenile habitat relative to the environmental baseline period (1975-2008) by generally providing: 1) more 30 day-continuous habitat in the known spawning depth range, and 2) a slight reduction in the maximum number of consecutive days of flows less than 16,000 cfs during October through March when Gulf sturgeon are using the bay, which may be associated with lower salinities preferred by juveniles. No further impacts to Gulf sturgeon resulting from the RIOP have been identified. Therefore, we will not discuss Gulf sturgeon further in this BO.

A total of 34 federally listed species are known to occur within the Apalachicola-Chattahoochee-Flint (ACF) River Basin, but effects of the proposed action are limited to those that depend primarily on riverine habitat. Except for the temporary waiver of winter drawdown requirements during drought conditions, the Corps would implement the RIOP within the constraints of the existing water control plans for the upstream reservoir projects, i.e., the RIOP would not change the top of the flood control pools, conservation pools, or the rule curves of the upstream projects. Therefore, the proposed action will have no effect or an insignificant effect (*i.e.,* any impacts should never reach the scale where take occurs) on all but the riverine- and estuarine-dependent species. Two species of sea turtles and the West Indian manatee may sometimes occur in Apalachicola Bay or the lower Apalachicola River; however, any effects of the proposed action to these species would be insignificant also, due to their low numbers and only occasional seasonal residence in the river and bay. Three of the 34 ACF listed species are freshwater mussels that do not occur in areas downstream of the Corps' ACF projects: the shiny-rayed pocketbook, Gulf moccasinshell, and oval pigtoe. The proposed action will have no effect on these mussel species. Altogether, the proposed action will have either no effect or an insignificant effect on the species listed below; therefore, these species are not further discussed in this BO. No further consultation is necessary for these species unless the RIOP is subsequently modified in a manner that causes an effect to listed species or designated critical habitat or new information reveals the RIOP may affect listed species or designated critical habitat in a manner or to an extent not previously considered.

Frosted flatwoods salamander (*Ambystoma cingulatum*)
Reticulated flatwoods salamander (*Ambystoma bishopi*)
Loggerhead turtle (*Caretta caretta caretta*)
Eastern indigo snake (*Drymarchon corais couperi*)
Atlantic ridley (*Lepidochelys kempi*)
Piping plover (*Charadrius melodus*)
Wood stork (*Mycteria americana*)
Gray bat (*Myotis grisescens*)
Indiana bat (*Myotis sodalis*)
West Indian manatee (*Trichechus manatus*)
Shiny-rayed pocketbook (*Lampsilis subangulata*)
Gulf moccasinshell (*Medionidus penicillatus*)
Oval pigtoe (*Pleurobema pyriforme*)
Little amphianthus (*Amphianthus pusillus*)
Apalachicola rosemary (*Conradina glabra*)
Telephus spurge (*Euphorbia telephioides*)
Harper's beauty (*Harperocallis flava*)
Black-spored quillwort (*Isoetes melanospora*)
Pondberry (*Lindera melissifolia*)
White birds-in-a-nest (*Macbridea alba*)
Canby's dropwort (*Oxypolis canbyi*)
Godfrey's butterwort (*Pinguicula ionantha*)
Harperella (*Ptilimnium nodosum)*
Chapman's rhododendron (*Rhododendron chapmanii*)
Michaux's sumac (*Rhus michauxii*)
Green pitcherplant (*Sarracenia oreophila*)
American chaffseed (*Schwalbea Americana*)
Florida skullcap (*Scutellaria floridana*)
Fringed campion (*Silene polypetala*)
Gentian pinkroot (*Spigelia gentianoides*)
Cooley meadowrue (*Thalictrum cooleyi*)
Florida torreya (*Torreya taxifolia*)
Relict trillium (*Trillium reliquum*)
Gulf sturgeon (*Acipenser oxyrinchus desotoi*)

The RIOP is intended to govern the releases from Woodruff Dam until revised or replaced with a new Water Control Plan (WCP). The Corps will prepare a draft environmental impact statement for updated water control manuals for the ACF River Basin. We understand that the revision of the WCP may take up to five additional years; therefore, we have structured this opinion to evaluate the effects of the proposed action over the next five years.

This BO is based on numerous coordination meetings, clarifying letters, and conference calls between the Corps and the Service in recent months, as well as unpublished data in Service files, the experience of Service biologists, and an extensive literature search. It does not rely on the regulatory definition of destruction or adverse modification of critical habitat as set forth in the Code of Federal Regulations at 50 CFR § 402.02. Instead, we have relied upon the statutory provisions of the Act to complete the following analysis with respect to critical habitat. A complete administrative record is on file in the Panama City Field Office, Florida.

CONSULTATION HISTORY

1991-1997	Informal consultation developing information for Tri-State Comprehensive Study
1998-2003	Informal consultation on Corps operations of the reservoir system relative to ACF Compact water allocation discussions.
September 5, 2006	BO and conference report on U.S. Army Corps of Engineers, Mobile District, interim operating plan for Jim Woodruff Dam and associated releases to the Apalachicola River.
November 15, 2007	Amended BO and conference report on the U.S. Army Corps of Engineers, Mobile District, exceptional drought operations (EDO) for the interim operating plan for Jim Woodruff Dam and associated releases to the Apalachicola River.
November 21, 2007	Corps provides EDO 4,500 cfs trigger.
December 7, 2007	Corps provides revised EDO 4,500 cfs trigger.
January 10, 2008	Corps requests extension for RPM5 condition f, mussel depth distribution study plan.
January 31, 2008	Corps provides 2007 Annual Report and mussel depth distribution study plan.
March 28, 2008	Corps provides RPM5 condition h, mussel study plan.
April 15, 2008	Corps requests reinitiation of formal consultation and submits proposed project description for RIOP.
April 18, 2008	Service's letter regarding recent rapid drop in river flow.
April 24, 2008	Corps' response to Service's letter.
April 30, 2008 to May 30, 2008	Received letters from several agencies commenting on RIOP for consideration in consultation.
May 2, 2008	Corps' email summarizing status of system in Zone 4, however; decision not to implement EDO reduction in minimum releases since wet May is forecast.
May 2008	Multiple emails between Corps and Service about RIOP model input data and results.
May 26, 2008	Corps' email with RIOP model results using projected 2017 depletions.
June 1, 2008	BO on the U.S. Army Corps of Engineers, Mobile District, revised interim operating plan (RIOP) for Jim Woodruff Dam and associated releases to the Apalachicola River.
July 11, 2008	Corps' letter transmitting RPM 2008-5 Mussel Study Plans.
August 8, 2008	Corps' letter regarding August 2008 Flow.
August 29, 2008	Corps' letter transmitting RPM 2008-2 Drought Operations.

October 22, 2008	Service's letter regarding semi-annual meeting and RPM coordination.
November 2008	First formal semi-annual meeting between Corps and Service.
January 31, 2009	Corps' submission of the 2008 annual report.
February 9, 2009	Semi-annual meeting between Corps and Service.
March 27, 2009	Service's letter regarding RPM status and coordination.
May 29, 2009	Corps' response to Service's letter.
June 8, 2009	Service's letter concurring with RPM status.
September 23, 2009	Semi-annual meeting between Corps and Service.
January 31, 2009	Corps' submission of the 2009 annual report.
April 6, 2010	Semi-annual meeting between Corps and Service.
September 14, 2010	Service's letter recommending the Corps reinitiate consultation due to mussel recolonization and mortality at flows above 5,000 cfs.
September 20, 2010	Corps' response to Service's letter requesting reinitiation of consultation.
September 28, 2010 to May 21, 2012	Various teleconferences and phone calls to discuss mussel sampling, the results of analyses conducted, and progress on the BO.
October 13, 2010 to May 15, 2012	Various emails and CDs provided by Corps to Service including species and gage data and results of additional modeling and assessments.
October 14, 2010	Service's letter recommending postponing reinitiation of consultation until pending purple bankclimber surveys are complete.
November 17, 2010	Corps' response to Service letter noting purple bankclimber survey plans were suspended due to high water and requesting reinitiation.
November 23, 2010	Service's response to Corps' letter confirming reinitiation of formal consultation.
December 13, 2010	Semi-annual meeting between Corps and Service.
January 31, 2011	Corps' submission of the 2010 annual report.
February 18, 2011	FFWCC's mussel consultant EnviroScience (Greg Zimmerman) emails information about fat threeridge in Swift Slough.
February 18, 2011	Service's letter requesting extension to in order to review information from annual report and FFWCC.
March 4, 2011	Corps' letter to Service granting extension.
April 27, 2011 to February 24, 2012	Letters received from several outside parties (i.e., GEPD, FDEP, FFWCC, Andrew Miller, Steven Beissinger, Hydrologics) commenting on the status of fat threeridge and the RIOP for consideration in consultation. Requests were also made for modeling data and results. The Service responded by letter to several of these inquiries.

May 25, 2011	Corps' letter to Service requesting extension in order to conduct additional modeling simulating Run-of-River (RoR) operations.
June 14, 2011	Semi-annual meeting between Corps and Service. The status of the reinitiated consultation was also discussed.
June 22, 2011	Service's letter to Corps detailing gage calibration adjustment resulting in releases less than 5,000 cfs, resulting mussel take, and need for Corps to report the level of take that occurred and plans for preventative action.
July 8, 2011	Service's letter to Corps requesting extension in order to review the additional RIOP and RoR modeling.
July 15, 2011	Corps' letter to Service granting extension.
July 29, 2011	Corps and Service meeting to discuss modifications to RIOP to minimize take.
September 7, 2011	Corps' letter to Service requesting extension in order to complete an analysis of effects on proposed modifications to the RIOP.
September 13, 2011	Service's letter to Corps granting extension.
October 24, 2011	Corps' submission of amended Biological Assessment for the proposed modifications to the RIOP.
November 15, 2011	Service's meeting with FFWCC to discuss their concerns about the RIOP and consultation.
November 21, 2011	Service's meeting with Atlanta Regional Commission and GEPD to discuss their concerns about the RIOP and consultation.
December 14, 2011	Corps' letter to Service requesting extension in order to review the draft BO.
December 15, 2011	Service's letter to Corps granting extension.
January 13, 2012	Service and Corps meeting to discuss draft BO and potential additional modifications.
January 31, 2012	Service meeting with FDEP and FFWCC to discuss their concerns about the RIOP and consultation.
February 13, 2012	Corps' submission of a revised, amended Biological Assessment for different proposed modifications to the RIOP.
February 22, 2012	Service's letter to Corps granting extension to May 22.
April 12, 2012	Corps' letter to Service providing supplemental information on potential impacts to Gulf sturgeon possible fall spawning events.
May 2, 2012	Corps notifies Service by email that drought operations have begun.

BIOLOGICAL OPINION

This opinion supersedes the 2008 BO dated June 1, 2008, which addressed the effects of the Revised Interim Operating Plan (RIOP), because the 2008 RIOP has been amended during reinitiation of consultation. The Corps has described changes to the RIOP and its effects in the revised amended BA dated February 15, 2012. Where appropriate, we have incorporated their descriptions and analysis into this BO. This document also supersedes the 2008 ITS and associated RPMs.

1 DESCRIPTION OF PROPOSED ACTION

The action evaluated in this consultation is the Corps' RIOP for Jim Woodruff Dam, which describes releases from the dam to the Apalachicola River. The RIOP and modifications were formulated to address protection of endangered and threatened species and critical habitat in the Apalachicola River, manage reservoir storage for other project purposes, and meet drought-related contingencies. According to the Corps, the RIOP is not a new WCP for Woodruff Dam; it is a definition of ACF operations that is within the limits established by the existing ACF WCP except during defined drought conditions. It is our understanding that the RIOP is effective until it is revised or until the ACF WCP is formally updated, at which time the Corps would reinitiate consultation.

The Corps operates five dams in the ACF River Basin: (in downstream order) Buford, West Point, Walter F. George, George W. Andrews, and Jim Woodruff (Figure 1.A). All are located wholly on the Chattahoochee River arm of the basin except the downstream-most dam, Woodruff, which is located at the confluence of the Chattahoochee and Flint rivers and marks the upstream extent of the Apalachicola River. Andrews is a lock and dam without any appreciable water storage, and Lake Seminole has very limited storage capacity. Both are essentially operated as run-of-river reservoirs (i.e., what goes in comes out without being stored for any substantial amount of time). The impoundments of Buford, West Point, and Walter F. George dams, however, provide for combined conservation storage of approximately 1.6 million acre-feet, relative to the top of each reservoir's full summer pool and the bottom of the conservation pool, which is potentially available to support water management operations. For about half of its length, the Chattahoochee River forms the boundary between Georgia and Alabama. Lake Seminole straddles the boundary between Florida and the southwest corner of Georgia.

The Corps operates the ACF reservoirs as a system, and releases from Woodruff Dam reflect the downstream end-result of system-wide operations. The RIOP addresses specific parameters of the daily releases from Woodruff Dam into the Apalachicola River. The RIOP does not address operational specifics at the four federal reservoirs upstream of Woodruff or all aspects of the operations at Woodruff, other than to anticipate waivers from the winter pool rule curves at West Point and Walter F. George reservoirs during exceptional drought conditions. The RIOP specifies two parameters applicable to the daily releases from Woodruff: a minimum discharge in relation to average basin inflows (see definition below) and maximum fall rate (vertical drop in river stage [ft/day]). For purposes of this BO, we use data for both parameters that are collected by the USGS at gage number 02358000, "Apalachicola River at Chattahoochee, FL," which is located 0.6 mi downstream of Woodruff Dam. We refer to this flow measurement point throughout the BO simply as the "Chattahoochee gage".

Basin inflow is defined as the amount of water that would flow by Woodruff Dam during a given time period if all of the Corps' reservoirs maintained a constant water surface elevation during that period. The Corps estimates basin inflow daily from a combination of river and reservoir level measurements, mathematical stage/volume/discharge relationships, and operating characteristics of the various water release structures of the dams. The RIOP uses a 7-day moving average of daily basin inflow calculations for daily release decisions. Basin inflow is not the natural or "unimpaired" flow of the basin at the site of Woodruff Dam, because it reflects the influences of reservoir evaporative losses, inter-basin water transfers, and consumptive water uses, such as municipal and industrial water supply and agricultural irrigation.

The proposed action includes five modifications to the 2008 RIOP: 1) the use of volumetric balancing is eliminated; 2) minimum flow releases will match basin inflow when basin inflow is between 5,000 and 10,000 cfs during the months of June through November (this provision is suspended during drought contingency operations); 3) drought contingency operations are not suspended and normal operations reinstituted until composite conservation storage has recovered above Zone 2 into Zone 1; 4) when releases are within powerhouse capacity (which is flows less than about 16,000 cfs) and less than 10,000 cfs, the maximum fall rate is limited to 0.25 ft/day; and 5) river stage declines of 8 feet or more will not occur in less than 14 days when river flows are less than 40,000 cfs during the spawning season (March-May) under both normal and drought operations. Provisions of the proposed RIOP are described in detail below.

1.1 Action Area

Service regulations define "action area" as all areas affected directly or indirectly by the federal action and not merely the immediate area involved in the action (50 CFR §402.02). Although the RIOP specifically addresses the releases from Woodruff Dam, the downstream-most project among the Corps' ACF reservoirs, these releases are accomplished through the collective operations of all of the Corps' ACF reservoirs. Therefore, the action area includes all aquatic habitats that are downstream of the Corps' upstream-most ACF project, Lake Lanier/Buford Dam, ending with and including Apalachicola Bay (Figure 1.A). However, the only aquatic listed species that is known to occur in this action area upstream of Woodruff Dam is a single purple bankclimber found in Goat Rock Reservoir in 2000 (Stringfellow 2011 pers. comm.). The proposed action is not anticipated to result in any physical changes to the environment of this individual animal. Therefore, while the action area includes all aquatic habitats that are downstream of the Corps' upstream-most ACF project, Lake Lanier/Buford Dam, ending with and including Apalachicola Bay, the effects of the action are limited to the aquatic habitats downstream of Woodruff Dam ending with and including Apalachicola Bay. This portion of the action area, which we address in the remainder of this BO, is shown in Figure 1.1.A. Hereafter, our use of the term "action area" refers to this limited portion of the broader action area. We refer to locations in the action area by river mile (RM), which is the distance from the mouth of the river as noted on USGS 7.5-minute topographic maps.

1.2 Minimum Discharge

Like the 2008 RIOP, the proposed action varies minimum discharges from Jim Woodruff Dam by basin inflow, composite conservation storage level and by month. The releases are measured as a daily average flow in cfs at the Chattahoochee gage. Table 1.2.A illustrates minimum releases from Jim Woodruff Dam prescribed by the proposed action and shows when and how much basin inflow is available for increasing reservoir storage. Except when basin inflow is less than 5,000 cfs and during some down-ramping periods, the minimum releases are not required to exceed basin inflow. The RIOP defines basin inflow threshold levels that vary by three seasons: spawning season (March-May); non-spawning season (June-November); and winter (December-February).

The RIOP incorporates composite conservation storage thresholds that factor into minimum release decisions. Composite conservation storage is calculated by combining the conservation storage of Lake Sidney Lanier, West Point Lake, and Walter F. George Lake. Storage in each of the individual storage reservoirs is divided into four operational Zones. The composite conservation storage utilizes the four-Zone concept as well; e.g., Zone 1 of the composite conservation storage represents the combined conservation storage available in Zone 1 for each of the three storage reservoirs (Figure 1.2.A).

During the spawning season (March-May), the RIOP defines two sets of four basin inflow thresholds and corresponding releases based on composite conservation storage. When composite conservation storage is in Zones 1 and 2, a less conservative operation is in effect. When composite conservation storage is in Zone 3, a more conservative operation allows for greater retention of basin inflow in storage, and when composite conservation storage falls below the bottom of Zone 3 into Zone 4 the most conservative drought contingency operations are "triggered." Drought contingency operations are described in section 1.4 below. During the spawning season, a daily monitoring plan that tracks composite storage will be implemented in order to determine water management operations. Recent climatic and hydrological conditions experienced and meteorological forecasts will be used in addition to the composite conservation storage values when determining the appropriate basin inflow thresholds to utilize in the upcoming days.

During the non-spawning season (June-November), the RIOP defines one set of four basin inflow thresholds and corresponding releases based on composite conservation storage in Zones 1-3. The proposed action modifies the 2008 RIOP while operating in these composite conservation zones by requiring that releases match or exceed basin inflow when basin inflow is between 5,000 and 10,000 cfs (was between 5,000 and 8,000 cfs in the 2008 RIOP). This change also requires slight adjustments to the basin inflow levels and minimum release provisions at basin inflows greater than 10,000 cfs. Table 1.2.A reflects the proposed action with the modifications to the 2008 RIOP. When composite conservation storage falls below the bottom of Zone 3 into Zone 4 the drought contingency operations are “triggered”.

During the winter season (December-February), there is only one basin inflow threshold and corresponding minimum release (5,000 cfs) while in composite conservation storage Zones 1-3. There are no basin inflow storage restrictions provided this minimum flow is met. When composite conservation storage falls below the bottom of Zone 3 into Zone 4 the drought contingency operations are “triggered”.

The flow rates included in Table 1.2.A prescribe minimum, and not target, releases for Jim Woodruff Dam. During a given month and basin inflow rate, releases greater than the Table 1 minimum releases may occur consistent with the maximum fall rate schedule, described below, or as needed to achieve other project purposes, such as hydropower or flood control.

1.3 Maximum Fall Rate

The RIOP prescribes maximum fall rates for the releases from Woodruff Dam (Table 1.3.A). Fall rate, also called down-ramping rate, is the vertical drop in river stage (water surface elevation) that occurs over a given period. The fall rates are expressed in units of feet per day (ft/day), and are measured at the Chattahoochee gage as the difference between the daily average river stage of consecutive calendar days. Rise rates (i.e., today’s average river stage is higher than yesterday’s) are not addressed. The proposed action modifies the maximum fall rate schedule (Table 1.3.A) prescribed by the 2008 RIOP by limiting the maximum fall rate to 0.25 ft/day or less when releases are within powerhouse capacity and less than 10,000 cfs (was 8,000 cfs in the 2008 RIOP). Unless otherwise noted, fall rates under the drought contingency operation would be managed to match the fall rate of the 1-day basin inflow. The Corps proposes to adopt in this amended RIOP its response to RPM 2008-4 of the 2008 BO, which ensures that river stage declines of 8 feet or more will not occur in less than 14 days when river flows are less than 40,000 cfs (March-May). The proposed action eliminates the use of volumetric balancing, which was included in the 2008 RIOP.

1.4 Drought Contingency Operations

The RIOP incorporates a drought contingency operation (referred to as drought plan). The drought plan specifies a minimum release from Jim Woodruff Dam and temporarily suspends the other minimum release and maximum fall rate provisions until composite conservation storage within the basin is replenished to a level that can support them. The minimum discharge is determined in relation to composite conservation storage and not average basin inflow under the drought plan. The drought plan is “triggered” when composite conservation storage falls below the bottom of Zone 3 into Zone 4. At that time all the composite conservation storage Zone 1-3 provisions (seasonal storage limitations, maximum fall rate schedule, and minimum flow thresholds) are suspended and management decisions are based on the provisions of the drought plan. The drought plan includes a temporary waiver from the existing WCP to allow temporary storage above the winter pool rule curve at the Walter F. George and West Point projects if the opportunity presents itself and/or begin spring refill operations at an earlier date in order to provide additional conservation storage for future needs, including support of minimum releases from Jim Woodruff Dam.

The drought plan prescribes two minimum releases based on composite conservation storage in Zone 4 and an additional zone referred to as the Drought Zone (Figure 1.2.A). The Drought Zone delineates a volume of water roughly equivalent to the inactive storage in lakes Lanier, West Point and Walter F. George plus Zone 4 storage in Lake Lanier. However, the Drought Zone line has been adjusted to include a smaller volume of water at the beginning and end of the calendar year. When the composite conservation storage is within Zone 4 and above the Drought Zone, the minimum release from Jim Woodruff Dam is 5,000 cfs, and the Corps may store all available basin inflow above 5,000 cfs. Once the composite conservation storage falls below the Drought Zone, the minimum release from Jim Woodruff Dam is 4,500 cfs, and the Corps may store all available basin inflow above 4,500 cfs. When transitioning from a minimum release of 5,000 cfs to 4,500 cfs, maximum fall rates are limited to a maximum 0.25 ft/day drop. The 4,500 cfs minimum release is maintained until composite conservation storage returns to a level above the top of the Drought Zone, at which time the 5,000 cfs minimum release is re-instated.

Under the 2008 RIOP, the drought plan was in effect until composite conservation storage reached a level above the top of Zone 3 (i.e., within Zone 2). At that time, the temporary drought plan provisions were suspended, and all the other provisions were re-instated. The proposed action modifies the 2008 RIOP drought plan by increasing the composite conservation storage level “trigger” for re-instating normal operations (i.e., the Corps can store more water for a longer period than in the 2008 RIOP). Under the proposed action, the drought plan provisions remain in place until composite conservation storage reaches a level above the top of Zone 2 (i.e., within Zone 1). The proposed action also requires adherence to the spawning season fall-rate provision during drought contingency operations, which ensures fall rates less than 8 feet in 14 days when river flows are less than 40,000 cfs (March-May).

During drought contingency operations, the Corps will assess the status of water management operations relative to the triggers on the first day of each month, also considering other relevant data, recent climatic and hydrological conditions experienced, and meteorological forecasts will be used when determining the set of operations that apply to the upcoming month.

1.5 Conservation Measures

Conservation measures are actions that benefit or promote the recovery of a listed species that a Federal agency includes as an integral part of its proposed action and that are intended to minimize or compensate for potential adverse effects of the action on the listed species. The RIOP and the proposed modifications were formulated in large part to avoid and minimize impacts to listed species while achieving other authorized project purposes. Minimum flow and maximum fall rates are set based upon the current basin inflow in a way that limits most project-induced alterations of the flow regime to higher flow rates. At lower flow rates in the months of March through November and when composite storage is in Zone 3 or higher, the Corps releases a minimum of not less than basin inflow (Table 1.2.A) and limits the rate of river stage decline (Table 1.3.A). When basin inflow is less than 5,000 cfs, which did not occur in the pre-Lanier average daily flow record of the Chattahoochee gage (1929 through 1955), the Corps augments basin inflow, which offsets to some degree the impact of the evaporative losses, non-project related consumptive water uses, and drought conditions more severe than previously observed in the Basin.

1.6 Tables and Figures for Section 1

Table 1.2.A. Proposed Action RIOP Releases From Jim Woodruff Dam.

Months	**Composite Storage Zone**	**Basin Inflow (BI) (cfs)**	**Releases from JWLD (cfs)**	**Basin Inflow Available for Storage**[1]
March - May	Zones 1 and 2	>= 34,000	>= 25,000	Up to 100% BI > 25,000
		>= 16,000 and < 34,000	>= 16,000 + 50% BI > 16,000	Up to 50% BI > 16,000
		>= 5,000 and < 16,000	>= BI	
		< 5,000	>= 5,000	
	Zone 3	>= 39,000	>= 25,000	Up to 100% BI > 25,000
		>= 11,000 and < 39,000	>= 11,000 + 50% BI > 11,000	Up to 50% BI > 11,000
		>= 5,000 and < 11,000	>= BI	
		< 5,000	>= 5,000	
June - November	Zones 1,2, and 3	>= 22,000	>= 16,000	Up to 100% BI > 16,000
		>= 10,000 and < 22,000	>= 10,000 + 50% BI > 10,000	Up to 50% BI > 10,000
		>= 5,000 and < 10,000	>= BI	
		< 5,000	>= 5,000	
December - February	Zones 1,2, and 3	>= 5,000	>= 5,000	Up to 100% BI > 5,000
		< 5,000	>= 5,000	
At all times	Zone 4	NA	>= 5,000	Up to 100% BI > 5,000
At all times	Drought Zone	NA	>= 4,500[2]	Up to 100% BI > 4,500

[1] Consistent with safety requirements, flood control purposes, and equipment capabilities.
[2] Once composite storage falls below the top of the Drought Zone ramp down to 4,500 cfs will occur at a rate no greater than 0.25 ft/day drop.

Table 1.3.A. Proposed Action RIOP Maximum Fall Rate Schedule Composite Storage Zones 1,2, and 3[1].

Release Range (cfs)	Maximum Fall Rate (ft/day)
≥ 30,000[2]	Fall rate is not limited[3,4]
> 20,000 and ≤ 30,000[1]	1.0 to 2.0[4]
Exceeds powerhouse capacity (~16,000) and ≤ 20,000[1]	0.5 to 1.0[4]
Within powerhouse capacity and > 10,000[1]	0.25 to 0.5
Within powerhouse capacity and ≤ 10,000[1]	0.25 or less

[1] Maximum fall rate schedule is suspended in Composite Zone 4.
[2]Consistent with safety requirements, flood control purposes, and equipment capabilities.
[3]For flows greater than 30,000 cfs, it is not reasonable and prudent to attempt to control down ramping rate, and no ramping rate is required.
[4]Maximum fall rates must be less than 8 feet in a consecutive 14 day period when flows are less than 40,000 cfs in March, April, and May in order to avoid take of Gulf sturgeon eggs and larvae

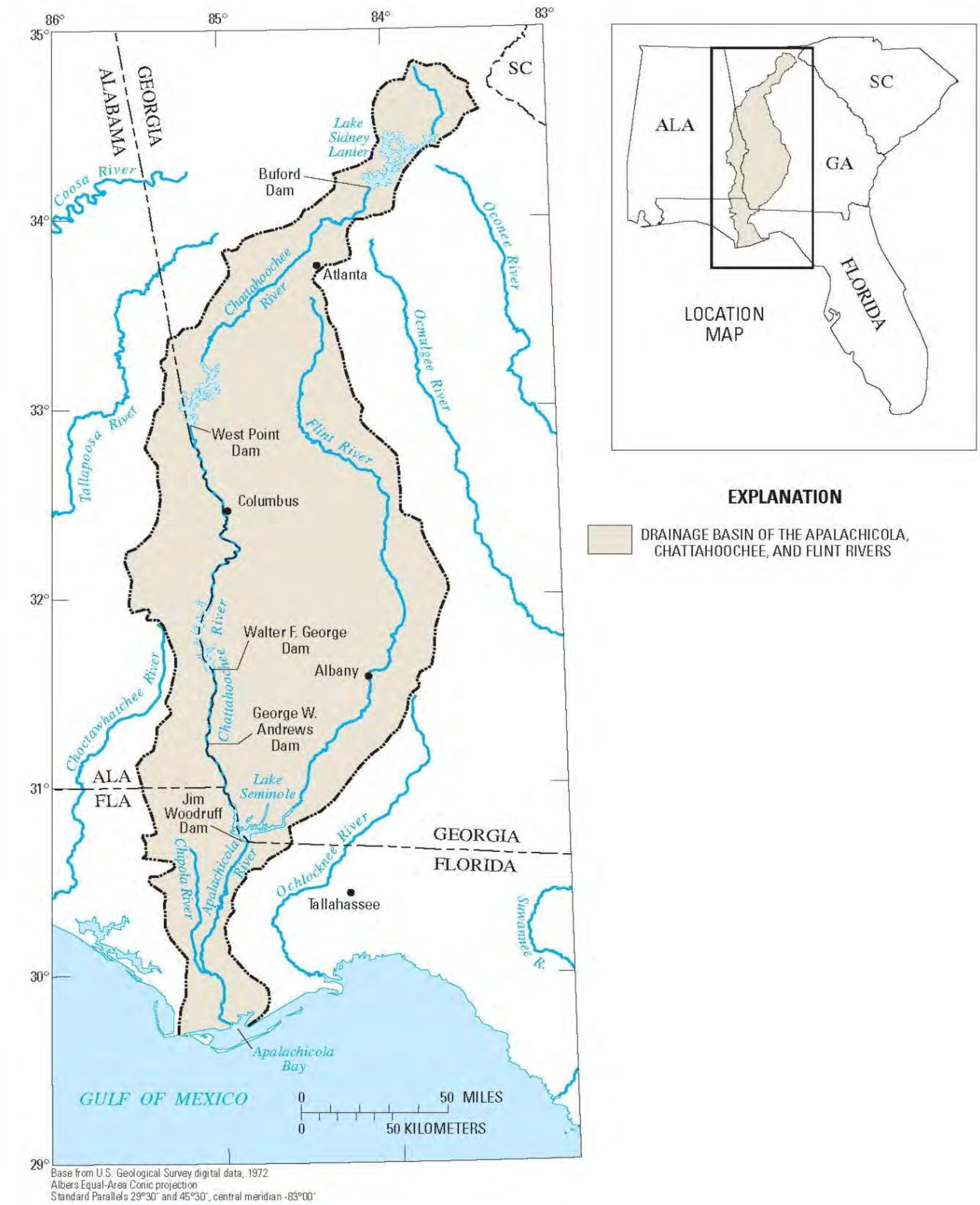

Figure 1.A. Map of the ACF Basin showing location of the Corps' dams (source: Light et al. 2006).

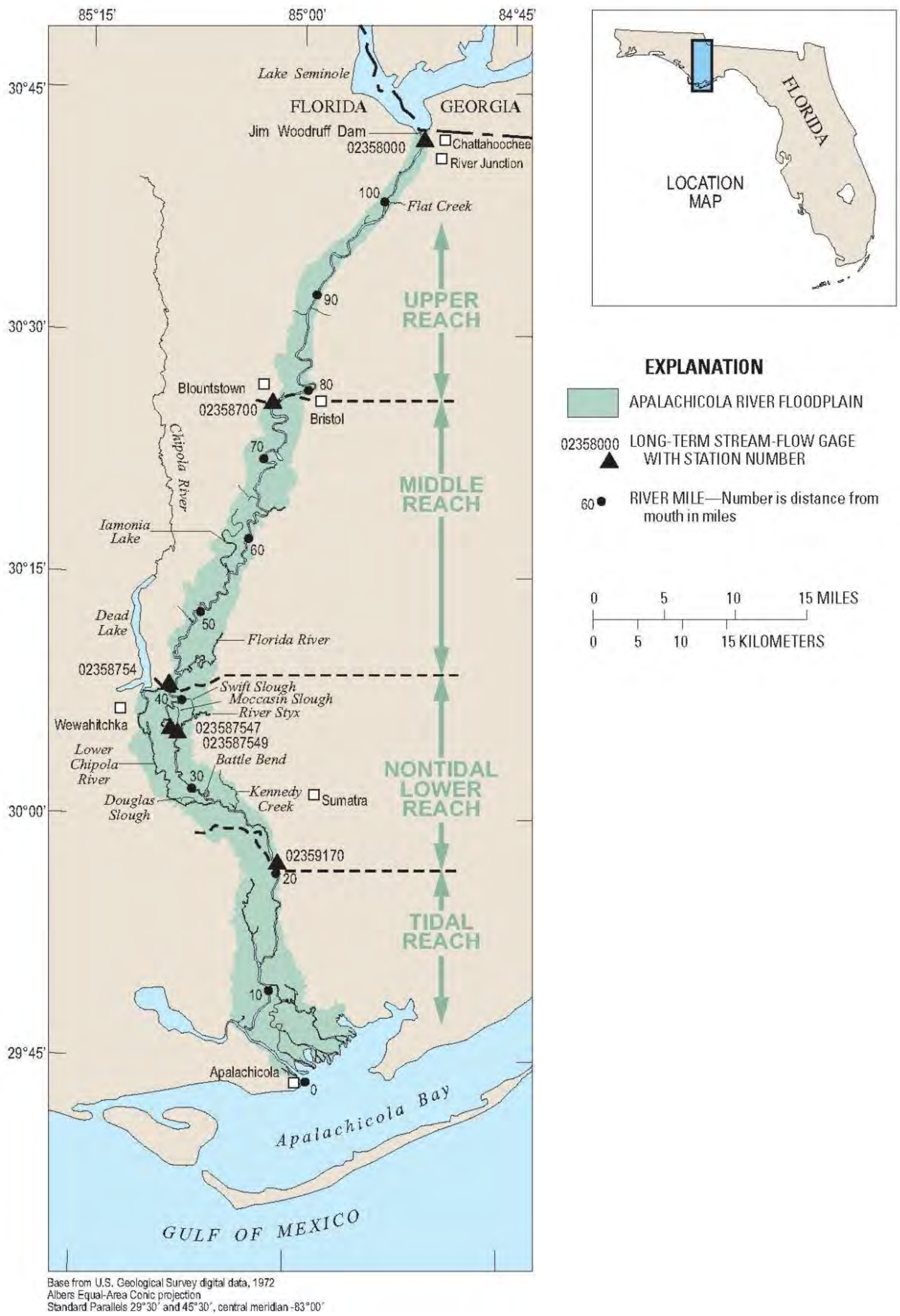

Figure 1.1.A. Map showing the Apalachicola River and Bay portion of action area (source: Light et al. 2006).

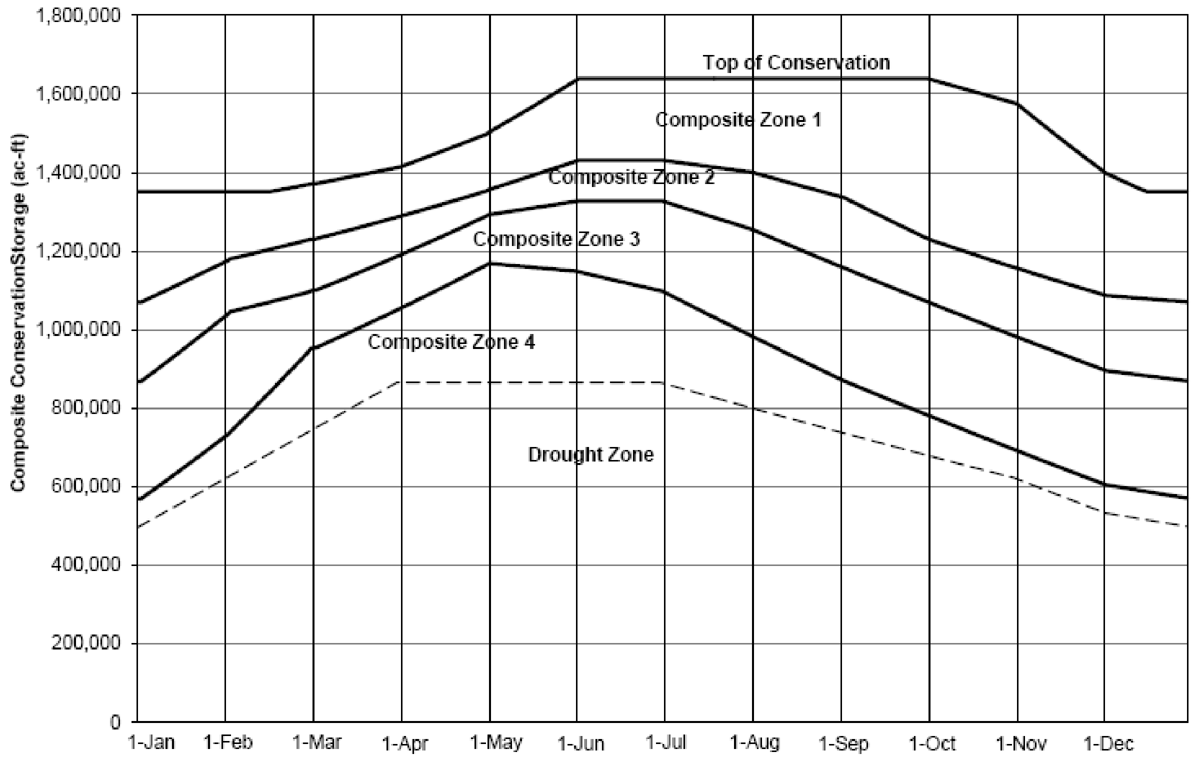

Figure 1.2.A. Composite storage zones in lakes Lanier, West Point and Walter F. George.

2 STATUS OF THE SPECIES/CRITICAL HABITAT

2.1 Species Description

Fat threeridge

The fat threeridge (*Amblema neislerii*) is a medium-sized, heavy-shelled mussel that reaches a length of about 100 millimeters (mm) (4.0 inches (in)). Large specimens are highly inflated. The dark brown to black shell is oval to quadrate and strongly sculptured with seven to nine prominent horizontal parallel plications (ridges). The umbo (the raised, rounded portion near the shell hinge) is in the anterior quarter of the shell. The inside surface of the shell (nacre) is white to bluish white. As is typical of the genus, no sexual dimorphism is displayed in shell characters (Williams and Butler 1994; Williams et al. 2008).

Purple bankclimber

The purple bankclimber (*Elliptoideus sloatianus*) is a large, heavy-shelled mussel that reaches a length of 205 mm (8.0 in). The shell is dark brown to black, quadrate to rhomboidal in shape, and sculptured by several irregular plications that vary greatly in development. A well-developed posterior ridge extends from the umbo to the posterior ventral margin of the shell. The umbos are low, extending just above the dorsal margin of the shell. Nacre color is whitish near the center of the shell becoming deep purple towards the margin and iridescent posteriorly. No sexual dimorphism is displayed in purple bankclimber shell characters (Williams and Butler 1994; Williams et al. 2008). Fuller and Bereza (1973) described aspects of its soft anatomy, and characterized *Elliptoideus* as being an "extremely primitive" genus.

Chipola slabshell

The Chipola slabshell (*Elliptio chipolaensis)* is a medium-sized mussel that reaches a length of 85 mm (3.3 in). The shell is moderately thin and moderately inflated. The shell exterior is light to dark brown in color and smooth, and typically with dark concentric circles. The umbos are prominent, well above the hinge line. Internally, the umbo cavity is wide and shallow, and the nacre color is white to bluish white, sometimes with a salmon tint. No sexual dimorphism is displayed in shell characters (Williams et al. 2008).

2.2 Critical Habitat Description

On November 15, 2007, the Service designated 11 stream segments (units) as critical habitat for the endangered fat threeridge, shinyrayed pocketbook, Gulf moccasinshell, Ochlockonee moccasinshell, and oval pigtoe, and the threatened Chipola slabshell and purple bankclimber (collectively referred to as the seven mussels) pursuant to the Act (USFWS 2007a). These units comprise portions of the Econfina Creek (Florida), ACF (Alabama, Florida, and Georgia), Ochlockonee (Florida and Georgia), and Suwannee (Florida portion only) river basins. The total length of streams designated is approximately1,909 river kilometers (km) (1,185.9 river miles (mi)). The rule became effective on December 17, 2007.

Fat threeridge

Three units are designated as fat threeridge critical habitat (Table 2.2.A). These units encompass approximately 786.6 km (488.8 mi) of river in the Lower Flint River in Georgia, Chipola River Basin in Alabama and Florida, and the Apalachicola River in Florida.

Purple bankclimber

Six units are designated as purple bankclimber critical habitat (Table 2.2.A). These units encompass approximately 1,493.5 km (928.0 mi) of river in the Flint River Basin in Georgia, Apalachicola River Basin in Florida and the Ochlockonee River Basin in Florida and Georgia.

Chipola slabshell

One unit is designated as Chipola slabshell critical habitat (Table 2.2.A). This unit encompasses approximately 228.8 km (142.2 mi) of river in the Chipola River Basin in Alabama and Florida.

Primary Constituent Elements

Each of the designated critical habitat units for these three listed mussels contains one or more of the Primary Constituent Elements (PCEs) that the Service describes as essential to the conservation of the species, and which may require special management considerations or protection. The PCEs of fat threeridge, purple bankclimber, and Chipola slabshell designated critical habitat are:

- A geomorphically stable stream channel (a channel that maintains its lateral dimensions, longitudinal profile, and spatial pattern over time without an aggrading or degrading bed elevation);
- A predominantly sand, gravel, and/or cobble stream substrate;
- Permanently flowing water;
- Water quality (including temperature, turbidity, dissolved oxygen, and chemical constituents) that meets or exceed the current aquatic life criteria established under the Clean Water Act (33 U.S.C. 1251-1387); and
- Fish hosts (such as native basses, sunfishes, minnows, darters, and sturgeon) that support the larval life stage of the mussels.

2.3 Life History

The fat threeridge, purple bankclimber and Chipola slabshell are bivalve mussels of the family Unionidae. Unionid mussels live embedded in the bottom of rivers, streams, and other bodies of freshwater. Sexes in unionid mussels are usually separate. Most unionid mussel species have a parasitic stage during which the immature mussels, called glochida, must attach to a host to transform into a juvenile. Females release glochidia either separately or in masses termed conglutinates, depending on the mussel species. Life spans vary by species, but some unionid mussels are very long-lived.

2.3.1 Feeding Habits

Adult freshwater mussels are filter-feeders, orienting themselves on or near the substrate surface to take in food and oxygen from the water column (Kraemer 1979). They siphon water into their shells and across four gills that are specialized for respiration and food collection. Food items include detritus (disintegrated organic debris), algae, diatoms, and bacteria (Strayer et al. 2004). Juvenile mussels typically burrow completely beneath the substrate surface and are pedal (foot) feeders (bringing food particles inside the shell for ingestion that adhere to the foot while it is extended outside the shell) until the structures for filter feeding are more fully developed (Yeager et al. 1994; Gatenby et al. 1996).

2.3.2 Growth and Longevity

Some freshwater mussels are long-lived and slow-growing, while others grow quickly and have short life spans. Growth in freshwater mussels tends to be relatively rapid for the first few years (Chamberlain 1931; Negus 1966), and then slows appreciably (Bruenderman and Neves 1993; Hove and Neves 1994). The abrupt slowing in growth rate occurs at sexual maturity, probably due to the diversion of energy to gamete production. Growth rates vary among species; heavy-shelled species grow slowly relative to thin-shelled species (Coon et al. 1977; Hove and Neves 1994). Also, heavy-shelled species generally tend to reach higher maximum ages (Stansbery 1961). Longevity studies conducted by Haag and Rypel (2010) on 57 freshwater mussel species, mostly from the southern US, found maximum ages ranged from 4 to 190 years. They observed a very tight relationship between longevity and growth rate, finding that slow growing species such as Margaritiferidae, Amblemini, Pleurobemini, and Quadrulini tend to reach higher maximum ages than fast growing species such as Andontini.

Fat threeridge

The Service has undertaken a long-term study to determine the age of fat threeridge using two approaches. Primarily, shells were aged by counting internal shell annuli via thin-sectioning. A growing body of evidence supports the production of annual shell rings in freshwater mussels (McCuaig and Green 1983; Neves and Moyer 1988; Haag and Commens-Carson 2008; Rypel et al. 2008). To validate this method, a second aging technique measured the amount of stable oxygen isotope variability in the shell. Some studies have found that the two methods return similar age estimates (Jones et al. 1983; Witdaard et al. 1994). For the isotope method, eight fat threeridge, varying in total length from 17 to 85 mm, were compared to ages obtained from counting annuli. For individuals in all age groups, the annuli method yielded ages greater than those generated using the isotope method (Table 2.3.2.A). The annuli age estimates for mussels ≤2 years old exceed isotope-derived ages by an average of 0.13 years. However, closer inspection of these data revealed more consistent results for younger individuals. Annulus formation likely occurs in the winter when growth slows or ceases (Haag and Commens-Carson 2008). Results of Arnold et al. (2011) confirm that fat threeridge growth slows in the winter. The time of spawning indicates that the formation of the first annulus may occur before the mussel is one year old. Table 2.3.2.A also includes a correction for this phenomenon, which indicates complete agreement in mussels ≤ 2 years old. There was acceptable agreement between the two methods in animals that were 7-8 years old (annuli estimates exceeded isotope method by an average of <2 years); however, annuli estimates exceeded isotope estimates for the oldest individuals (18-24 years), by a mean of 6.5 years (Arnold et al. 2011). The internal line method may overestimate age by counting less significant growth bands (false annuli) interspersed within larger growth increments. Conversely, Arnold et al. (2011) outline several factors that make it increasingly difficult to distinguish annual increments during the later stages of the mussel's life using the isotope method. The two methods might more closely approximate one another if growth bands were more distinct. This study cannot definitively establish which of the two methods determines the age of the mussels more accurately.

Although we acknowledge that our ages may be overestimated using the internal line method, we rely on the work of Haag and Commens-Carson (2008) and Rypel et al. (2008), which indicate that validated shell rings can provide accurate estimates of growth. Preliminary results of ongoing field validation of annual ring formation indicate that fat threeridge may form annual rings but further validation is necessary (Moyer 2011 pers. comm.). To date, the Services' Warm Springs Fish Technology Center has aged 236 individuals including the 31 individuals the Panama City Field Office aged in 2007. The majority of these shells were collected freshly dead during the droughts in 2006-2007 and 2010-2011 from the RM 40-50 reach of the main channel. Some were also collected in Swift Slough and the Chipola Cutoff. Sizes ranged from 11-86 mm total length and estimated ages ranged from 1 to 24 years old. To describe growth, we fitted a von Bertalanffy growth equation to the mean length-at-age data: $L_t = L_{inf}\,(1\text{-}e^{-K(t-t_0)})$ where L_t is the shell at a given age (t), L_{inf} is the theoretical shell length-at-age infinity, K is a fitted constant showing the rate of L_t approaching L_{inf} over time, and t_0 is the theoretical age when the shell length is 0 (Neves and Moyer 1988; Anthony et al. 2001; San Migel et al. 2004). The relationship was statistically significant [$p < 0.0001$; $L_{inf} = 86.8$ (95% confidence interval (CI) 82.41 – 91.12); k=0.13 (95% CI 0.10 – 0.15); t_0=-1.14 (95% CI -1.86 – -0.43)] (Figure 2.3.2.A). This indicates that the fat threeridge exhibits low to moderate growth and intermediate longevity relative to other mussel species (Haag and Rypel 2010). We also developed an age-length key using the individuals collected from the main channel to estimate the age of an individual from a given length (sensu Isely and Grabowski 2007). We recognize that the relationship between length and age may vary over time due to variability in growth among years; however, because many of the individuals aged were collected in 2010-2011, we do not feel this potential variability restricts the usefulness of the age-length key.

Purple bankclimber

EnviroScience provided age and growth information for the purple bankclimber. They aged 11 individuals ranging from 80-184 mm total length. Ages range from 3 years old (80 mm) to 15 years old (184 mm). In addition, a specimen that was likely dead for at least one year, but still in good shape for aging, measured 63 mm and was 4 years old. A von Bertalanffy growth curve does not fit these data. Although the sample size is very small, the relationship between age and total length appears to be exponential (Figure 2.3.2.B).

Chipola slabshell

No age or growth information is available for the Chipola slabshell.

2.3.3 Reproduction

Freshwater mussels generally have separate sexes, although hermaphroditism is known for some species (van der Schalie 1970; Downing et al. 1989). The age of sexual maturity for mussels is variable, usually requiring from 3 to 12 years (Zale and Neves 1982; McMahon and Bogan 2001). Spawning appears to be temperature dependent (Zale and Neves 1982; Bruenderman and Neves 1983), but may also be influenced by stream discharge (Hove and Neves 1994). Males release sperm into the water column, which females take in through their siphons during feeding and respiration. Fertilization takes place inside the shell. The eggs are retained in the gills of the female until they develop into mature larvae called glochidia.

Mussels may be particularly susceptible to exposure by low flows during the spawning season. Once the water warms and the days become longer, mature mussels move vertically to the substrate surface (Balfour and Smock 1995; Amyot & Downing 1998; Watters et. al 2001; Perles et al. 2003). Watters et al. (2001) studied eight freshwater mussel species and found that all of the species surfaced during the spring to spawn. Mussels also aggregate via horizontal movement to enhance recruitment (Amyot & Downing 1998). Spawning itself requires substantial energy expenditure for female mussels, and therefore, females may move less than males during the reproductive season (Amyot and Downing 1998). For this reason, females may be relatively more susceptible than males to exposure-induced mortality.

After a variable incubation period, mature glochidia, which may number in the tens of thousands to several million (Surber 1912; Coker et al. 1921; Yeager and Neves 1986), are released by the female mussel. The glochidia of most freshwater mussel species, including the fat threeridge, purple bankclimber, and Chipola slabshell, must come into contact with specific species of fish, whose gills, fins, or skin they temporarily attach to in order to transform into a juvenile mussel. Depending on the mussel species, females release glochidia either individually in net-like mucoid strands that entangles fish (Haag and Warren 1997), or as discreet packets termed conglutinates (Barnhart et al. 2008), or in one large mass known as a superconglutinate (Haag et al. 1995; O'Brien and Brim Box 1999; Roe and Hartfield 2005). Glochidia failing to contact a suitable fish host will survive for only a few days (Sylvester et al. 1984; Neves and Widlak 1988; O'Brien and Williams 2002). Host specificity appears to be common in mussels (Neves 1993), with most species utilizing only a few host fishes (Lefevre and Curtis 1912; Zale and Neves 1982; Yeager and Saylor 1995). The duration of the parasitic stage, which varies by mussel species, generally lasts a few weeks (Neves et al. 1985; O'Brien and Williams 2002), but possibly much longer (Yeager and Saylor 1995; Haag and Warren 1997), and is temperature dependent (Watters and O'Dee 2000). When the transformation is complete, the newly metamorphosed juveniles drop from their fish host and sink to the stream bottom where, given suitable conditions, they grow and mature into adults.

Glochidial parasitism serves two purposes: nutrition for larval development and dispersal. Substances within the blood serum of the host fish are necessary for the transformation of a glochidium into a juvenile mussel (Isom and Hudson 1982). Parasitism also serves as a means of dispersal for this relatively sedentary faunal group (Neves 1993). The intimate relationship between mussels and their host fish has therefore played a major role in mussel distributions on both a landscape (Watters 1992) and community (Haag and Warren 1998) scale. Haag and

Warren (1998) determined that mussel community composition was more a function of fish community pattern variability than of microhabitat variability, and that the type of strategy used by mussels for infecting host fishes was the determining factor.

Villella et al. (2004) described the general unionid life history strategy as a hybrid between an *r*-strategist (high output of glochidia, lower survival of young, no parental care) and a *K*-strategist (longevity and high adult survival). It is possible that continuous (though low) reproduction during a long adult life span can be beneficial for unionids and may be an evolutionary strategy in response to uncertain larval and juvenile survival.

Fat threeridge

O'Brien and Williams (2002) studied various aspects of the life history of the fat threeridge, determining that it is likely a short-term summer brooder of its glochidia. Females appear to be gravid in Florida when water temperatures reached 75°F, in late May and June, suggesting that the species expels glochidia in the summer. Fat threeridge glochidia are released in a white, sticky, web-like mass, which expands and wraps around a fish, thus facilitating attachment. The glochidia are viable for two days after release.

The fat threeridge lacks mantle modifications or other morphological specializations that would serve to attract host fishes and appears to be a host-fish generalist that may infect fishes of at least three different fish families. Five potential host fishes were identified: weed shiner (*Notropis texanus*), bluegill (*Lepomis macrochirus*), redear sunfish (*L. microlophus*), largemouth bass (*Micropterus salmoides*), and blackbanded darter (*Percina nigrofasciata*). Transformation of the glochidia on host fishes required 10 to 14 days at 73.4 ± 2.7°F (O'Brien and Williams 2002).

Fat threeridge age and growth data suggest females reach sexual maturity at three years of age (USFWS unpub. data 2011). These results are preliminary and research is ongoing; however, these findings agree with studies conducted on a closely related congener, *Amblema plicata*, whose age at sexual maturity was determined also to be three years (Haag and Staton 2003; Haag 2008 pers. comm.).

Purple bankclimber

Females of the purple bankclimber with viable glochidia were found in the Ochlockonee River from late February through mid-April (O'Brien and Williams 2002); in the Apalachicola River, in mid-March (Fritts 2011 pers. comm.); and in the Flint River from late-March through mid-June (Hartzog 2011). The species is presumably a short-term brooder. Females expel narrow lanceolate-shaped conglutinates (10-15 mm long) that are viable for three days after release (O'Brien and Williams 2002). The white structures, which are two glochidia thick, are generally released singly, although some are attached to each other at one end and released in pairs (O'Brien and Williams 2002).

Native fish that have effectively transformed glochidia of the purple bankclimber during laboratory infections include the eastern mosquitofish (*Gambusia holbrooki*), blackbanded darter, holiday darter (*Etheostoma brevirostrum*), lake sturgeon (*Acipenser fluvescens*), shortnose sturgeon (*Acipenser brevirostrum*), Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*), and Gulf sturgeon (*Acipenser oxyrinchus desotoi*) (O'Brien and Williams 2002; Fritts 2012 pers. comm.; Hartzog 2011). The eastern mosquitofish occupies stream margins in slower (or slack) currents, and is considered a secondary host fish since the purple bankclimber is more of a main-channel species (Williams and Butler 1994). The black banded darter was identified as a host fish in two separate laboratory studies where transformation rates ranged from 36 to 49% (Fritts 2011 pers. comm.; Hartzog 2011). The highest rate of transformation occurred in the four sturgeon species which ranged from 79 to 89% (Fritts 2012 pers. comm.). The Gulf sturgeon is the only sturgeon species that co-occurs with the purple bankclimber, and it also serves as a primary glochidial host for the species.

Chipola slabshell

Chipola slabshell females were found to be gravid in June to early July (Brim Box and Williams 2000; Priester 2008). The species is presumably a short-term brooder (Williams et al. 2008). Researchers from Columbus State University (CSU) conducted laboratory studies on Chipola slabshell reproduction and found that glochidia were expelled in conglutinates approximately 13 mm long and 3 mm wide and resemble insect larva (Priester 2008). The study documented the successful transformation of glochidia on redbreast sunfish and bluegill. Sixty percent of the bluegill and 80% of the redbreast sunfish successfully transformed *E. chipolaensis* glochidia into juvenile mussels (Priester 2008).

2.4 Habitat

Adult mussels are generally found in localized patches (beds) in streams and almost completely burrowed in the substrate with only the area around the siphons exposed (Balfour and Smock 1995). The composition and abundance of mussels are directly linked to bed sediment distributions (Neves and Widlak 1987; Leff et al. 1990). Physical qualities of the sediments (*e.g.,* texture, particle size) may be important in allowing the mussels to firmly burrow in the substrate (Lewis and Riebel 1984). These and other aspects of substrate composition, including bulk density (mass/volume), porosity (ratio of void space to volume), sediment sorting, and the percentage of fine sediments, may also influence mussel densities (Brim Box 1999; Brim Box and Mossa 1999).

Stream geomorphic and substrate stability is especially crucial for the maintenance of diverse, viable mussel beds (Vannote and Minshall 1982; Hartfield 1993; Di Maio and Corkum 1995). Where substrates are unstable, conditions are generally poor for mussel habitation. Strayer (1999) demonstrated in field trials that mussels in streams occur chiefly in flow refuges, or relatively stable areas that displayed little movement of particles during flood events. Flow refuges conceivably allow relatively immobile mussels to remain in the same general location throughout their entire lives. Strayer thought that features commonly used in the past to explain the spatial patchiness of mussels (*e.g.,* water depth, current speed, sediment grain size) were poor predictors of where mussels actually occur in streams.
Williams and Butler (1994) and Williams et al. (2008) discussed the habitat features associated with the fat threeridge, purple bankclimber, and Chipola slabshell including stream size,

substrate, and current velocity. Brim Box and Williams (2000) also provided habitat information, particularly substrate associations. Following is a summary of this information, and of other recent studies.

Fat threeridge

The fat threeridge inhabits the main channel of small to large rivers in slow to moderate current, and can be found in a variety of substrates from gravel to cobble to a mixture of sand, mud, silt, and also clay (Williams and Butler 1994; Brim Box and Williams 2000; Gangloff 2011 unpub. data). The most abundant populations are found in moderately depositional areas along bank margins at depths of around 1 meter (3.3 ft.) (Miller and Payne 2005, 2006; EnviroScience 2006a; Gangloff 2011). These sites are often the up- and downstream ends of point bars. Miller and Payne (2007) analyzed sediment samples collected at moderately depositional main channel sites between RM 40-50. The results show that at sites where fat threeridge occur, the species tends to be more abundant in substrates with relatively smaller grain sizes and with slightly higher moisture and organic content. These are characteristics of sediments in moderately depositional areas. Recently, however, fat threeridge were found in deeper habitats in depths of up to 5 meters (16.4 ft.) (Gangloff 2011 unpub. data). Most of these deep sites were classified as moderately depositional habitat, but some were considered moderately erosional.

Purple bankclimber

The purple bankclimber inhabits medium to large river channels in substrates of sand or sand mixed with mud or fine gravel, often near limestone outcrops (Brim Box and Williams 2000; Williams et al. 2008). ACF Basin collections by Brim Box and Williams (2000) were often in waters more than 3 meters (10 ft.) in depth. Recent upper Apalachicola River collections, when water levels were low, found purple bankclimbers generally in depths of 0.5 to 5.0 meters (1.6 to16 ft.) (Gangloff 2011 unpub. data).

Chipola slabshell

The Chipola slabshell inhabits sandy substrates mixed with silt, clay, and occasionally gravel in slow to moderate current, often along stream margins (Williams and Butler 1994; Williams et al. 2008). It primarily occurs in the main channel of the Chipola River.

2.5 Status and Distribution

Fat threeridge

The fat threeridge is reported from the main channels of the Apalachicola, Flint, and Chipola rivers, and a few tributaries and distributaries of the Apalachicola in Florida and southwest Georgia (Clench and Turner 1956; Williams and Butler 1994; Williams et al. 2008). There are no records of the species in the Chattahoochee Basin. Two historical records from the Escambia River (van der Schalie 1940; Heard 1979) are considered erroneous (Williams and Butler 1994; Williams et al. 2008).

Clench and Turner (1956) described fat threeridge as being a "rather rare species [but]. . . locally abundant." The fat threeridge was added to a list of regionally rare mussels compiled by Stansbery in 1971. Heard (1975) noted the decline of this species in the Apalachicola River (likely at US Highway 90) (Butler 2003 pers. comm.) from abundant to rare over a seven-year period. In two separate reports, Williams et al. (1993) assigned the fat threeridge mussel a status of endangered rangewide, while Williams and Butler (1994) assigned it a status of threatened in Florida. The Service listed the fat threeridge as an endangered species in 1998 (USFWS 1998a).

Currently, the fat threeridge is known throughout much of its historical range (Figure 2.5.A); however, it is extirpated from localized portions of the Apalachicola and Chipola rivers. The fat threeridge no longer occurs in the portion of the Apalachicola and Flint rivers that is now submerged in the reservoir created by Jim Woodruff Lock and Dam. Clench and Turner (1956) reported it common (56 specimens collected in 1954) from a now submerged Apalachicola River site. Also, the population below Woodruff dam appears to be reduced for quite some distance downstream (Brim Box and Williams 2000; USFWS unpub. data 2006-2011; Gangloff 2011). It was extirpated from the Dead Lake area in the Chipola River. Although the low-head dam was removed in 1987, Dead Lake has aggraded with sediment, which may have contributed to the localized extirpation of the fat threeridge (Brim Box and Williams 2000).

Although the species persists in the Flint River, it appears to be extremely rare. In the summer of 2006, 2007, and 2009, biologists from the Georgia Department of Natural Resources (GDNR) and USFWS found a total of 10 live adults near the highway 37 bridge, and one live individual approximately 1 river mile downstream of the bridge (Wisniewski 2007, 2009 pers. comm.). In 2011, another five individuals were collected live by the GDNR near the bridge (Wisniewski 2011 pers. comm.). The 2011 survey was part of a larger study by the GDNR which examined 110 km of the Flint River from the backwaters of Lake Seminole to the Albany dam. Thirty-nine stations were surveyed, and several rare species were found, however, fat threeridge were collected only near the Highway 37 bridge.

The fat threeridge is documented in numerous recent collections from many main channel sites on the Apalachicola River and lower Chipola River, both upstream and downstream of Dead Lake. Surveys conducted recently in these areas include studies by Miller and Payne in 2003 and 2007; EnviroScience in 2005, 2006, 2007, and 2010; Florida Fish and Wildlife Conservation Commission (FFWCC) in 2007; Gangloff in 2008, 2010 and 2011, and Service biologists in the years 2006 thru 2011. We report the findings of these studies in Sections 3.4.1.1 and 3.4.1.2. In most instances, these studies took place during drought conditions when water levels were moderately to extremely low. In general, these studies found that, in suitable habitat, the fat threeridge is common to abundant and recruitment is occurring. Results from these surveys demonstrated that the fat threeridge was more abundant than we previously believed, and recent recruitment was documented at many locations. In addition, a large quantitative study by Gangloff (2011 and 2010-2011 unpub. data) estimated the population to be around 826,000 to 1,144,000 and that 49-66% of the population occurs in the lower Chipola River.

Considerable fat threeridge mortality occurred in the Apalachicola and Chipola rivers and Swift Slough in 2006-2007 and 2010-2011 when water levels dropped as a result of drought. Most of the mortality occurred in areas where movement to deeper water was not possible or where shallow slopes prevented the mussels from tracking the receding water. We further discuss the effects of mortality on the fat threeridge population in Sections 3.4.1.

The fat threeridge is locally common, the population is seemingly large, and recruitment is occurring. Although the drought-induced mortality may be causing some localized population declines, we currently consider the species' status to be stable or improving (see Section 3.4.1 for more information).

Purple bankclimber

The purple bankclimber is endemic to the Apalachicola Basin in Alabama, Georgia, and Florida, and the Ochlockonee River drainage in Georgia and Florida (Brim Box and Williams 2000; Williams et al. 2008). The species is historically known from the main channels of the Apalachicola, Chattahoochee, Flint, Chipola, and Ochlockonee rivers, and also from two tributaries in the Flint River system. Heard (1979) erroneously reported it from the Escambia River system (Williams and Butler 1994). Based on museum records, the species was relatively common in the lower Flint, upper Apalachicola, and upper Ochlockonee Rivers (Brim Box and Williams 2000).

The purple bankclimber was recognized in lists of rare species published by Clench and Turner (1956), Athearn (1970), and Stansbery (1971). Williams et al. (1993) assigned this species a status of threatened rangewide, and Williams and Butler (1994) also assigned it a status of threatened in Florida. The Service listed the purple bankclimber as a threatened species in 1998 (USFWS 1998a).

Presently, the purple bankclimber occurs in much of it historical range (Figure 2.5.B); however, it is extirpated from localized areas, and it has likely been completely extirpated from the Chattahoochee River. We had only historical collections of purple bankclimber in the Chattahoochee River up until 2001, when a single, live and old specimen was found in the upper portion of Goat Rock Reservoir (Stringfellow 2011 pers. comm.). Within the Flint and Ochlockonee river drainages, the species is relatively common, but occurs at fewer sites than it did historically due in part to two mainstem dams on the Flint River and one on the Ochlockonee River. The purple bankclimber no longer occurs in the portion of the Apalachicola and Flint rivers that is now submerged in the reservoir created by Jim Woodruff Lock and Dam. The population numbers are reduced in the Apalachicola River compared to historical observations. Heard (1975) considered the species to be common in the Apalachicola River in the 1960s, but that population sizes by the mid-1970s, particularly below Jim Woodruff Lock and Dam, had been "drastically reduced."

The purple bankclimber has been collected recently from the Apalachicola, Flint, and Ochlockonee rivers. A survey of five sites in the main channel of the Flint River between Warwick Dam and Lake Worth found that the purple bankclimber was the most abundant among nine species collected, but very few small individuals were observed (McCann 2005). A GDNR survey of the Flint River examined 110 km of the lower river from the backwaters of Lake Seminole to the dam near Albany, GA. The purple bankclimber was found at 19 of the 39 stations surveyed, and shell length data showed good size variation and also the presence of small (23, 30, 41 mm) individuals (Wisniewski 2011 pers. comm.). Apalachicola and lower Chipola River dive surveys of deeper habitat when water levels were very low found purple bankclimbers in depths ranging from 0.5 to 5 meters (1.6 to 16.4 ft.) (Gangloff 2011 unpub. data). These collections were mostly in the Apalachicola River in the vicinity of Race Shoals (RM 105.5), though several were located in a deep bed near Apalachicola RM 47. Very few juvenile bankclimber were found, and of 113 individuals collected, only five were less than 100 mm in length. During surveys of the Ochlockonee River conducted from 2007 to 2011, the USFWS identified purple bankclimbers at 29 sites, many of which represented new locations for the species. At sites where the species was present, an average of 15 purple bankclimbers were collected. Few small and medium-sized individuals were found, although juveniles and small adults of other species were collected regularly (USFWS 2007-2011 unpub. data).

Similar to fat threeridge, considerable purple bankclimber mortality also occurred in the Apalachicola River in 2006-2007 and 2011 when water levels dropped as a result of drought. Most of the mortality occurred at Race Shoals on the Apalachicola River where movement to deeper water is difficult given the complex nature of the shoal habitat. We further discuss the effects of mortality on the Apalachicola River population in Sections 3.4.2. Drought-induced mortality was also observed on the Flint and Ochlockonee rivers in 2011.

The lack of small and medium-sized individuals in the studies described above of the Apalachicola and Ochlockonee rivers, and portions of the Flint River, suggests that either recruitment is occurring at very low rates or sampling methods are not suited to detecting juveniles of this species. Studies to verify recruitment, by an age-structure analysis of the adult population and by detecting juveniles in the field, are needed to adequately assess the bankclimber's status. Although past studies have indicated that the species range and abundance are relatively unchanged, we currently consider the species' status to be declining over the short term as a result of the possible poor recruitment and recent mortality due to droughts.

Chipola slabshell

The Chipola slabshell is known only from the Chipola River system in Florida and Alabama, and from a tributary of the lower Chattahoochee River in southeastern Alabama, where it is represented by a single museum specimen from Howard's Mill Creek (Williams et al. 2008). The historical range of this ACF Basin endemic is centered throughout much of the Chipola River main stem and several of its headwater tributaries. The Chipola slabshell is one of the most narrowly distributed species in the drainages of the northeast Gulf of Mexico.

Clench and Turner (1956) considered it to be "rather rare, though it does occur throughout most of the length of the river proper and its smaller tributaries." Heard (1975) reported this species as being relatively uncommon but that it could be locally abundant. van der Schalie (1940) reported 31 specimens of this species from 6 of 25 sites. The largest museum collections with localities and dates were from Cowarts Creek, Houston County, Alabama (28 specimens collected in 1916) and Chipola River (22 specimens collected in 1954). Williams et al. (1993) assigned the Chipola slabshell a status of threatened range wide. Williams and Butler (1994), who considered it a Florida endemic, also assigned it a status of threatened. In 1998, the Service listed it as a threatened species (USFWS 1998a).

Currently, the Chipola slabshell occurs in nearly all of its historical range, with the exception of Howards Mill Creek (Figure 2.5.C). The species was re-discovered in the Alabama reaches of the Chipola drainage in 2007 where it had not been reported since 1916 (Garner et al. 2007). In addition, a single individual was recently collected by Service biologists in the Apalachicola River main channel, about 0.5 mi. downstream of the Chipola Cutoff, and is the first known occurrence of Chipola slabshell in the Apalachicola main channel. However, the species was not detected during the many surveys conducted in this reach in recent years, and we do not believe that a reproducing population occurs in the main channel.

Recent surveys (1990 to present) have documented many new sites, but found the species generally occurs in relatively low abundance, with 64% of sites sampled yielding five or fewer individuals. Only three surveys yielded more than 40 individuals and two of those were extensive dive surveys. We have no evidence that these populations are currently declining and we consider the Chipola slabshell status to be stable.

2.6 Analysis of the Species/Critical Habitat Likely to be Affected

This BO addresses effects of the Corps' water management operations under the Woodruff Dam RIOP and the associated releases to the Apalachicola River on the fat threeridge, purple bankclimber, and Chipola slabshell and their designated critical habitats. These listed species are found in the Apalachicola River and distributaries downstream of Woodruff Dam, which is the downstream-most federal reservoir within the ACF system.

The Apalachicola River is designated as critical habitat for the fat threeridge and purple bankclimber. It is included as Unit 8 of 11 critical habitat units (USFWS 2007a). Unit 8 includes the main stem of the Apalachicola River, two distributaries: the Chipola Cutoff downstream to its confluence with the Chipola River and Swift Slough downstream to its confluence with the River Styx; and one tributary: the downstream-most portion of River Styx. Kennedy Creek and Kennedy Slough do not receive flow from the Apalachicola River, but could receive backwater inundation from the river. The Chipola River is designated as critical habitat for the fat threeridge, shinyrayed pocketbook, Gulf moccasinshell, oval pigtoe, and Chipola slabshell. Unit 2 includes the Chipola River mainstem and several of its tributaries, including the portion of the Chipola River that is within the action area−the Chipola River downstream of Dead Lake and the Chipola Cutoff. Therefore, we limit our analysis of effects to the fat threeridge and purple bankclimber in Unit 8 and to the fat threeridge and Chipola slabshell in Unit 2.

2.7 Tables and Figures for Section 2

Table 1.2.A.. Critical habitat for the fat threeridge, purple bankclimber, and Chipola slabshell.

Species, Critical Habitat Unit, and State(s)	Miles
fat threeridge	
2. Chipola River, AL, FL	142.1
7. Lower Flint River, GA	246.5
8. Apalachicola River, FL	100.2
Total	488.8
purple bankclimber	
5. Upper Flint River, GA	236.4
6. Middle Flint River, GA	187.8
7. Lower Flint River, GA	246.5
8. Apalachicola River, FL	100.2
9. Upper Ochlockonee River, FL, GA	110.2
10. Lower Ochlockonee River, FL	46.9
Total	928.0
Chipola slabshell	
2. Chipola River, AL, FL	142.2
Total	142.2

Table 2.3.2.A. A comparison of the internal annuli ages and isotopic ages of fat threeridge collected from the Apalachicola River (modified from Arnold et al. 2011). The internal line age correction factor column is derived using the information that mussels may only be 6 months old when the first winter annulus is formed. If the "Collection date" was after the individual's birthday (as indicated under "Season of spawning"), then no change was applied to the "Internal line ages" estimate.

Mussel ID	Collection date	Total length (mm)	Internal line ages	Internal line age correction	$\delta^{18}O$ ages	Season of spawning
11b	8/7/2006	17	1	0.5	<1	-
12b	8/7/2006	16	1	0.5	<1	-
6	6/27/2006	33	2	1.5-2	1.5-2	indeterminate
23	7/6/2006	31	2	2	2	summer
10	5/15/2007	60	8	7.5	5.5	summer
63	10/11/2007	61	8	8	4.5-6.5	late spring
2a	6/14/2006	82	18	18	9-11	early spring
39	7/13/2006	85	24	24	16-18	late spring

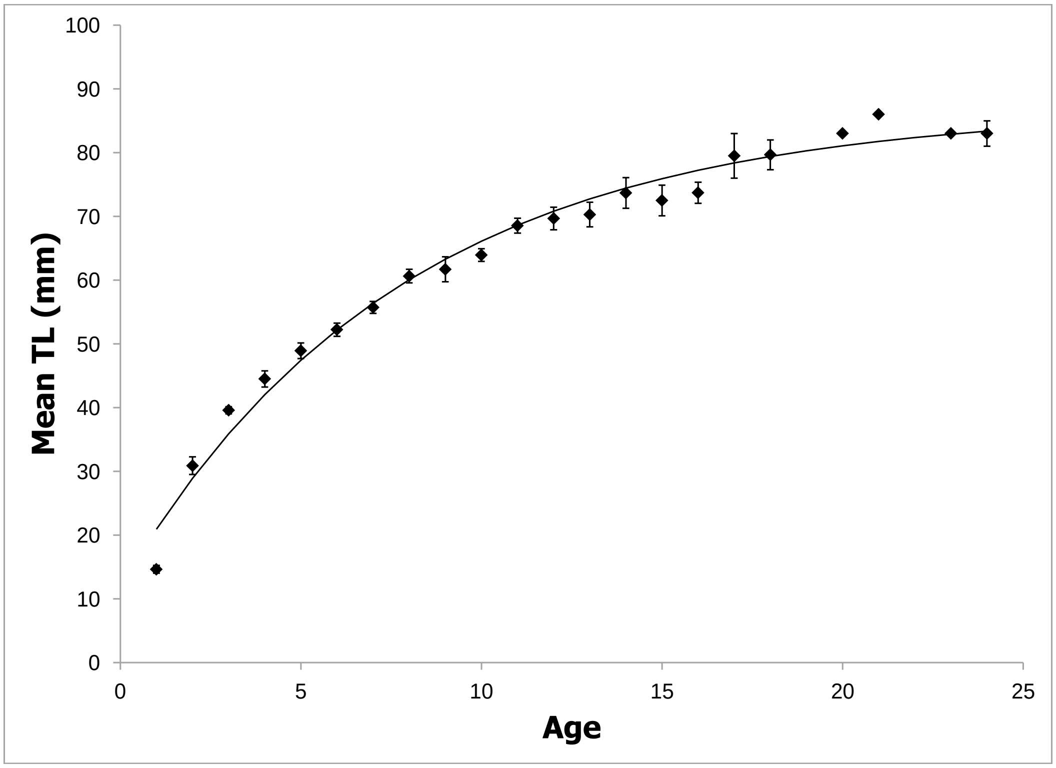

Figure 2.3.2.A. The von Bertalanffy growth relationship for the 236 fat threeridge aged from the Apalachicola River, Swift Slough, and the Chipola Cutoff.

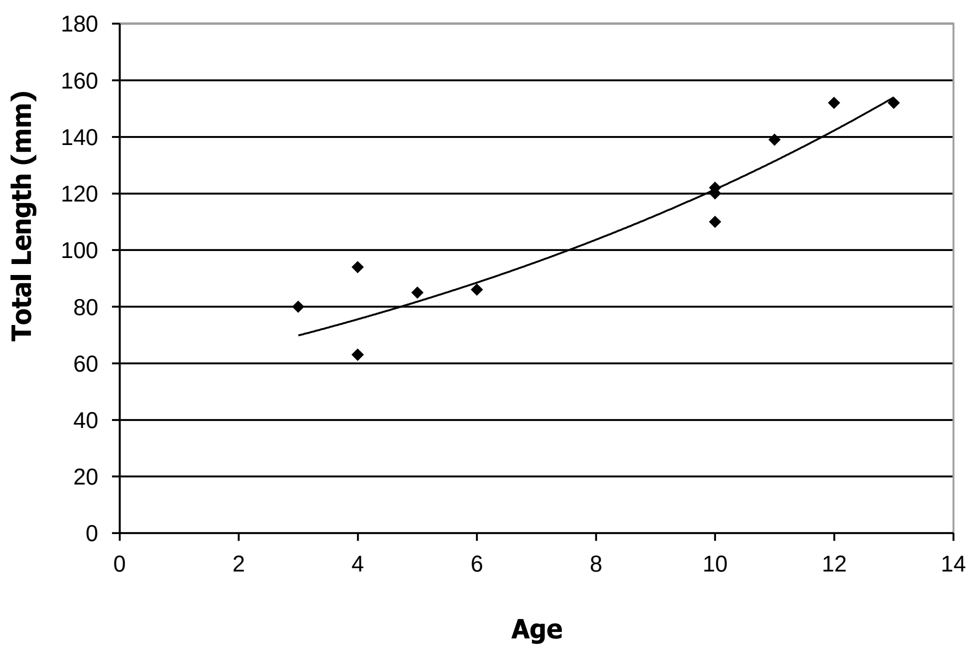

Figure 2.3.2.B. The relationship between length and age for the purple bankclimber sampled in the main channel of the Apalachicola River**.**

Figure 2.5.A. Current (1990-2011) occurrences of fat threeridge throughout its range.

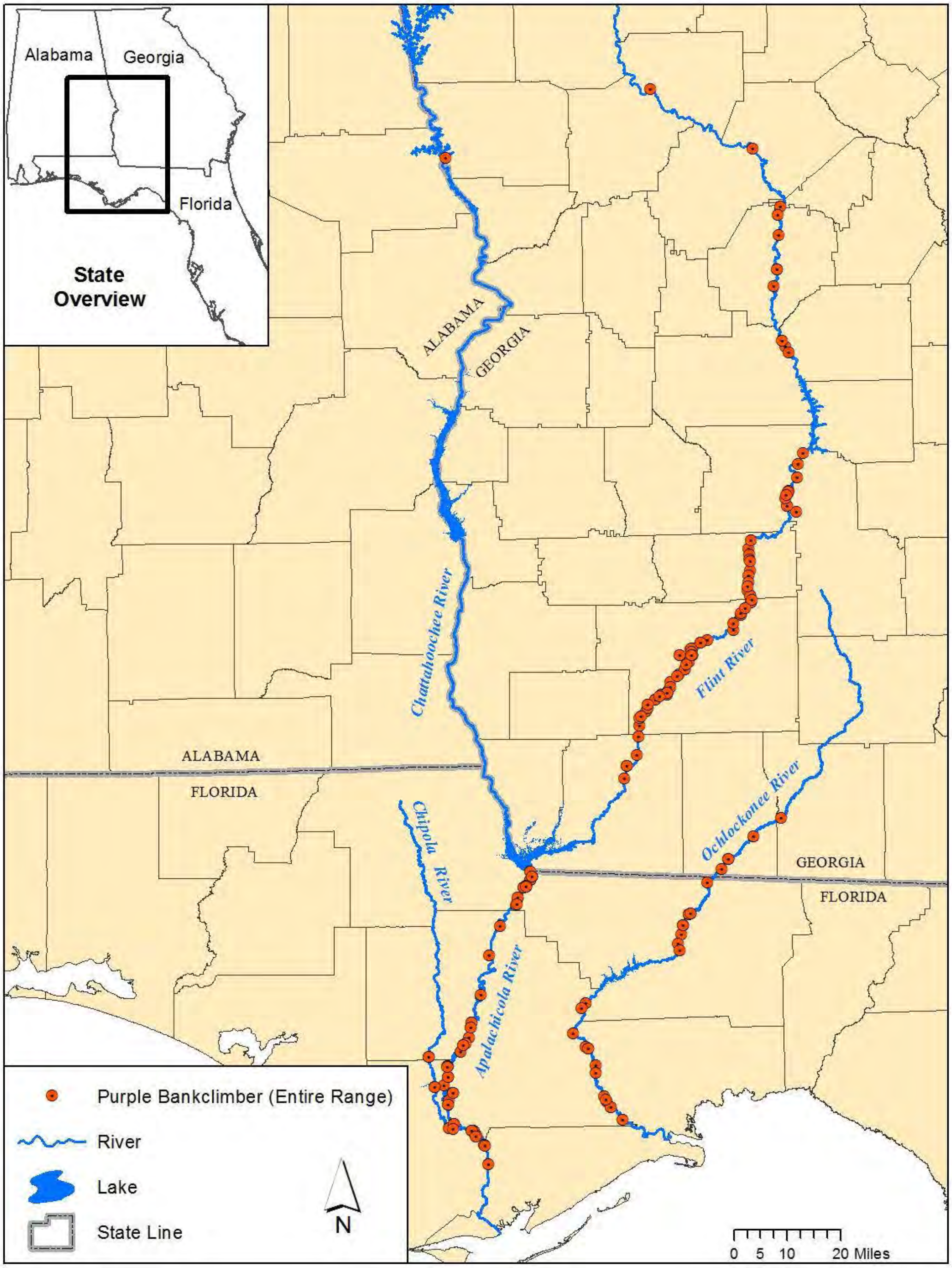

Figure 2.5.B. Current (1990-2011) occurrences of purple bankclimber throughout its range.

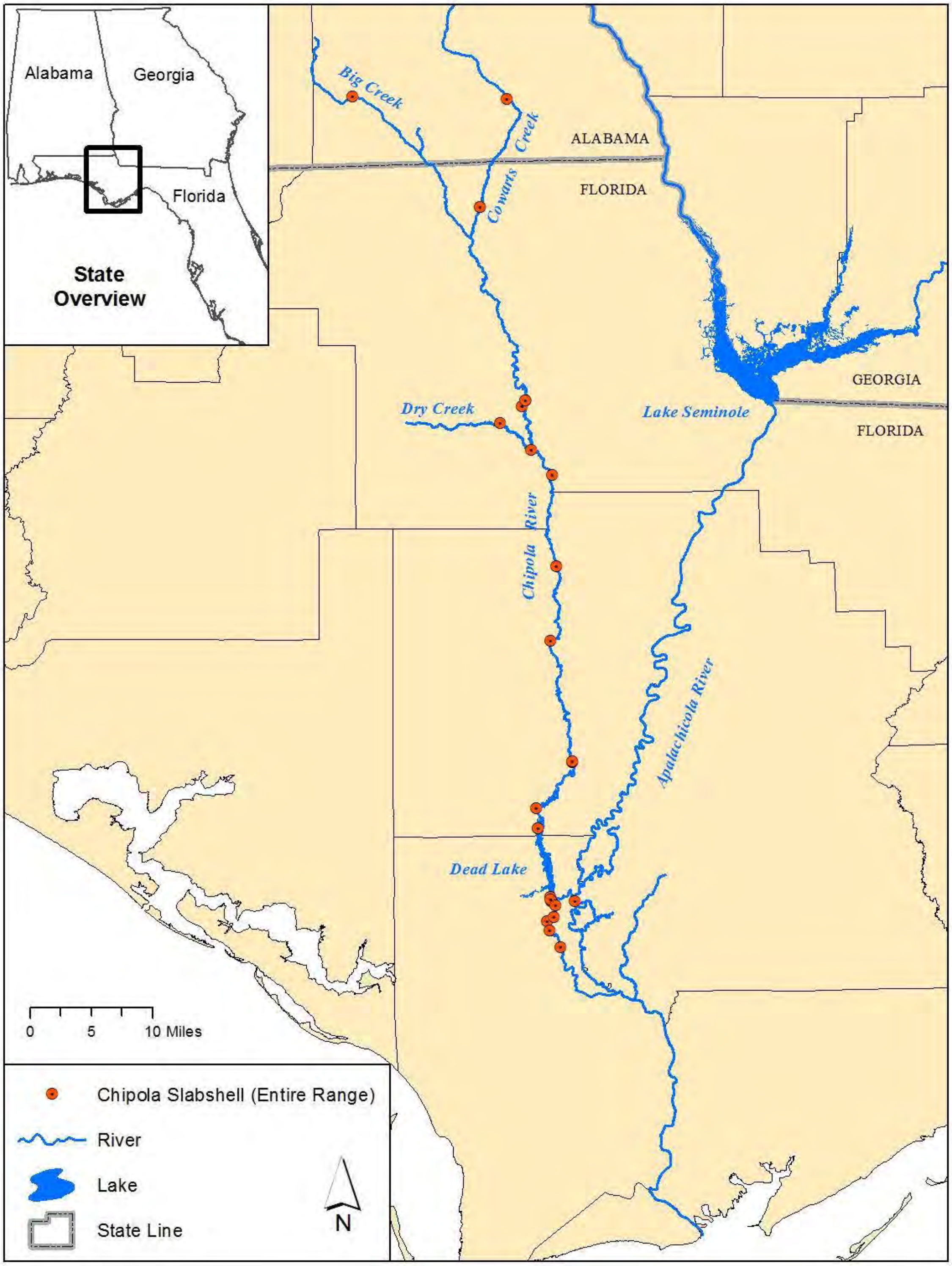

Figure 2.5.C. Current (1990-2011) occurrences of Chipola slabshell throughout its range.

3 ENVIRONMENTAL BASELINE

This section is an analysis of the effects of past and ongoing human and natural factors leading to the current status of the species, its habitat (including designated critical habitat), and ecosystem, within the action area. The environmental baseline is a "snapshot" of a species' health at a specified point in time. It does not include the effects of the action under review in the consultation. The action under review is the Corps' RIOP for the releases from Woodruff Dam. In the case of an ongoing water project, such as Woodruff Dam, the total effects of all past activities, including the effects of its construction and past operation, current non-federal activities, and federal projects with completed section 7 consultations, form the environmental baseline (USFWS 1998b).

Within the action area, various federal, state, and private actions affect the Apalachicola River ecosystem and the listed species considered in this opinion, which we discuss in this section. The construction of the Corps' dams, which preceded the Act and the listing actions for the sturgeon and mussels, continue to affect the Apalachicola River by trapping sediment in reservoirs that would otherwise move as bed load through the system. The interruption of this bed load movement is a major factor contributing to altered channel morphology, which we address in this section. Consultations regarding water supply storage contracts, hydropower contracts, and the water control master operations manual are expected in the future.

3.1 General Description of the Action Area

See section 1.1 for a definition of the action area. The Apalachicola River has the highest annual discharge of any river in Florida. It is the fifth-largest river in the continental United States, as measured by annual discharge to the sea (Leopold 1994). Together with the Chattahoochee and Flint rivers, its two largest tributaries, the Apalachicola drains an area of 19,800 square miles in parts of southeastern Alabama (15%), northwestern Florida (11%), and central and western Georgia (74%). The basin extends approximately 385 miles from the Blue Ridge Mountains to the Gulf of Mexico, and has an average width of 50 miles. The ACF Basin spans 50 counties in Georgia, 8 in Florida, and 10 in Alabama.

The Apalachicola River is entirely within the State of Florida and flows from Woodruff Dam about 107 miles to the Apalachicola Bay. Tidal influences on the river extend about 25 miles upstream from the bay. Within Florida, it receives flow from several tributaries, the largest of which is the spring-fed Chipola River. Lidstone and Anderson, Inc., (1989) described general morphological features of the Apalachicola River, which we summarize here. Almost the entire floodplain is forested and averages 1-2 miles in width in the upper river (> RM 77.5), 2-3 miles in the middle river (RM 77.5-41.8), and 2.5 to 4.5 miles in the lower river (RM 41.8-20.6). Limestone outcrops are found within the channel from river mile RM 86 to RM 105, where slope averages 0.424 ft per mile, and channel width averages 670 ft. The middle river has a slope of 0.495 ft per mile, is about 600 ft wide, and includes several abandoned river channels and oxbow lakes. In the lower river, both tidal and nontidal portions, slope is 0.334 ft per mile with an average width of 533 ft.

As a sand-bed alluvial river, the Apalachicola is a dynamic system constantly changing by ongoing processes of erosion and deposition. Historically, the river included large meanders and tree-lined banks. The river banks were dominated by cohesive sediments that include large quantities of silt and clay (Lidstone and Anderson, Inc., 1989). Winter floods deposited tons of tree limbs, trunks, and stumps in the main channel. Jeanne (2002) noted that the extensive tree growth in the subtropical environment required constant trimming to reduce hazards to steamboats that plied the river in the 1800s.

The flow of the Apalachicola is carried by a complex of channels that includes the main channel and various distributaries. The upstream-most distributary is a "loop stream" called The Bayou, which departs the main channel at RM 86 and returns to the main channel at RM 78. Loop streams like this become increasingly more common downstream, particularly downstream of the river gage near Wewahitchka, Florida (~RM 42). These loop streams carry a substantial portion of the total flow of the river at medium and high flows (Light et al. 2006). The Chipola Cutoff is a more complex loop stream because the Cutoff receives about 34% of the flow of the Apalachicola River but then enters the Chipola River, which is a large tributary of the Apalachicola River (Biedenharn 2007). Therefore, flows in the Chipola River downstream of the Chipola Cutoff are directly affected by flows in the Apalachicola River. Distributaries that do not loop back to the main channel and instead carry water directly to Apalachicola Bay begin at RM 14.

3.2 Channel Morphology Alterations

The Apalachicola River is a large, meandering, alluvial river that migrates across the floodplain (Hupp 2000). However, the Apalachicola has not followed the normal pattern of lateral migration in which erosion and deposition are balanced so that the channel maintains a relatively constant width and bed elevation (Light et al. 2006). In the past 50 years, many portions of the Apalachicola have substantially declined in elevation (incised) and/or become substantially wider. The Corps previously maintained the navigational channel by dredging; however, except for limited dredging in 2001, the Corps has not maintained the channel since 1999. Although the federal navigation project is still authorized, the State of Florida has denied project certification under its delegated authority in section 401 of the Clean Water Act. At this time, channel maintenance is deferred indefinitely. Unless otherwise noted, the source for our summary of these changes in this section is Light et al. (2006) and Price et al. (2006).

Mean bed elevation declined to some degree from 1960 to 2001 at 42 of 51 cross sections measured by the Corps throughout the nontidal portion of the Apalachicola River (Price et al. 2006). This decline is greatest in the upper river (> RM 77.5). During the period 1954 to 2004, the stage equivalent to 10,000 cfs declined 4.8 ft. During the period 1960 to 2001, in the upper 41 miles of the river, mean bed elevation declined an average of 2.2 ft at 26 cross sections measured in this reach. The probable cause of the bed degradation is sediment sequestration in Lake Seminole following construction of Woodruff Dam.

Channel width, measured as the distance between the treeline of opposite banks on aerial photography, has significantly increased since 1941. The mean increase in width of the nontidal river has been 77 ft, using 2004 aerial photography as the most recent measure. Relative increases were greater going downstream. Most of the widening occurred between 1959 and 1979, and appears to have stabilized between 1979 and 1999, with the exception of some minor widening in the middle (RM 77.5-41.8) and non-tidal lower reaches (RM 41.8-20.6) that continued between 1999 and 2004 and warrants continued monitoring. Channel widening is in part responsible for the declining elevation associated with a given discharge over time, as the same amount of water spreads over a larger area. The current widening in the middle and lower nontidal reaches may slow or even reverse itself somewhat in the future as riparian vegetation stabilizes point bars and other depositional areas on the channel margins.

Channel incising (declining mean bed elevation) and channel widening both contributed to reduced connectivity between the main channel and its distributaries and its floodplain. We examine the effects of reduced connectivity on the baseline specifically in section 3.3.2, and again when considering the effects of the proposed action in section 4.2.4.

In order to better understand active channel morphology relative to the habitats of the listed species, the Corps conducted an evaluation of the sediment dynamics and channel morphology trends on the Apalachicola River in accordance with RPM4 of the 2006 BO (USFWS 2006). Such an analysis was needed in order to improve our understanding of dynamic river conditions, to monitor the zone at which take may occur, and to identify possible alternatives to minimize effects to listed mussels in vulnerable locations. The Corps consulted with experts, jointly identified by both agencies, to identify the current status of sediment transport and channel stability in the Apalachicola River as it relates to the distribution of listed mussels and their vulnerability to low-flow conditions. The goals of the evaluation were to identify: 1) feasible water and/or habitat management actions that would minimize listed mussel mortality; 2) current patterns and trends in morphological changes; and 3) additional information needed, if any, to predict morphological changes that may affect the listed mussels. Due to time constraints, the evaluation was based on available information and tools and on best judgment.

Based on the experts' review of existing information, the reconnaissance field trip, presentations and discussions at the technical workshop, and the summary of individual findings prepared by the experts (Biedenharn 2007; Harvey 2007), the Corps determined that the river appears to be in a relatively stable dynamic equilibrium. The morphology of the river has been altered over time by land use changes, upstream impoundments, consumptive use of water, and tectonic movement, as well as channel alterations such as the construction of dike fields, meander cutoffs, and channel dredging and snagging operations. Obvious channel degradation impacts were noted below Jim Woodruff Lock and Dam immediately after construction, but this degradation has slowed over time. Data from the Blountstown and Wewahitchka gages downstream of the dam indicate that there was a small change in low-flow water surface elevations at those sites in response to Jim Woodruff construction, but the changes appear to have stabilized.

Field observations and data analysis suggest that the river was not continuing to degrade and that it may have attained a state of relative equilibrium. This is consistent with the findings of Light et al. (2006). Although a large portion of the middle river (RM 78 to RM 35) is very sinuous and actively meandering, maximum erosion rates on the outside of the bends in this reach are extremely low compared to other large alluvial rivers. Furthermore, the erosion appears to be part of the natural down-valley meander migration which is common to most alluvial streams and is not the result of continuing post-dam system-wide adjustments. It appears unlikely that erosion rates will increase over time (Beidenharn 2007; Harvey 2007).

Since the 2008 BO, we have consistently observed a more localized substantial aggradation in areas from about RM 45 to RM 35. According to the Corps, this area required regular maintenance for a navigation channel (Brian Zettle 2011 pers. comm.). Although the river may have stabilized relative to the effects of the dam, it appears that this reach may be undergoing substantial change related to the cessation of dredging. Biedenharn (2007) and Harvey (2007) both noted that there is an apparent lack of sediment being diverted into the Chipola Cutoff along with an increase in flow diverted into the Cutoff, which could explain why the reach between the Chipola Cutoff and RM 35 was the most frequently dredged section of the river. Biedenharn further noted that the effects of the cessation of dredging on the channel morphology in this reach warrants further investigation.

Dredging routinely removed or redistributed sand bars in this reach, which may have prevented this section of the river from reaching equilibrium. This removal or redistribution may also have included the sandbar in front of Swift Slough (Biedenharn 2007), an area that harbored a large fat threeridge population. We discuss the relevance of Swift Slough in section 3.4.1. Dredging may have prevented this area from reaching equilibrium relative to the water divergence into the Chipola Cutoff. Now that dredging has ceased, ongoing changes are part of an apparent natural aggradation process that may stabilize the channel and create suitable mussel habitat, perhaps benefiting mussels in the long term. However, further studies are needed to better understand post-dredging sediment and river hydrodynamics relative to the habitats of the listed species. The FFWCC is currently conducting a large-scale geomorphic study of this reach, and results are expected in 2012.

3.3 Flow Regime Alterations

Because the proposed action is an operational plan that prescribes the flow of the river, the habitat characteristic of greatest relevance to this consultation is the flow of the river, which is highly variable over time. A river's flow varies in its magnitude, seasonality, duration, frequency, and rate of change, and collectively, this variability is called its flow regime. The environmental baseline is a "snapshot" of a species health and habitat suitability within the action area (USFWS 1998b), but to capture intra- and inter-annual variability, the flow regime of the environmental baseline is necessarily a depiction of river flow that begins at an appropriate date in the past and concludes at the present. Determining effects to the species and their habitat in the baseline flow regime is an evaluation of the degree to which the natural flow regime in the action area has been altered to date by all anthropogenic factors, including past operations of the Corps' ACF projects. Determining effects of the proposed action is an evaluation of the degree to which the baseline flow regime may be further altered by operations under the RIOP.

As noted in the "Description of Proposed Action" section, USGS stream gage number 02358000 at Chattahoochee, Florida, which is located 0.6 mi downstream of Woodruff Dam, is the point at which Woodruff releases and ramping rates under the RIOP are measured. We use this gage also as the source of data for describing the historical flow regime and for estimating characteristics of the natural flow regime of the river. The continuous discharge record of this gage begins in

1928, with 1929 as the first complete calendar year of record. The flow of the Apalachicola River has been altered over time by land use changes, reservoirs, and various consumptive water uses, and in combination these alterations contribute to the environmental baseline.

The first dam/reservoir completed among the Corps' ACF projects was Buford Dam/Lake Lanier, which began operations in 1956. Although several other ACF main channel dams were built before Buford, only Bartlett's Ferry Reservoir on the Chattahoochee River has appreciable storage capacity. The capacity of Bartlett's Ferry is less than 10% of Lanier's capacity, and less than 5% of the total capacity of the Corps' ACF projects. We therefore use the 27-year pre-Lanier flow record of the Apalachicola River's Chattahoochee gage from 1929 to 1955 to characterize the pre-impoundment flow regime. The Corps' full complement of ACF projects were not completed until October 1974, when operations of West Point Reservoir began. Although we could use all 50 post-Lanier years, we use only the post-West Point years, 1975 to 2008 (34 years), as the flow regime of the environmental baseline (hereafter referred to as baseline) because this period is the full history of the present configuration of the Corps' ACF projects. We recognize that the environmental baseline also includes the years from 2009 to the present; however, the Corps' modeling (see section 4.2.1) is only available through 2008. The years from 2009-2011 were not atypical; therefore, we would not expect these years to appreciably change the flow regime. To maintain consistency with our Analysis of Effects (section 4), the baseline includes the post-West Point years from 1975 to 2008.

The Corps' operations have changed incrementally over the post-West Point period. These changes were documented in a draft water control plan in 1989. Additional incremental changes in water control operations have occurred since 1989, and are reflected in the current operations and the RIOP. Except in very general terms, it is not possible to describe a single set of reservoir operations that apply to the entire post-West Point period.

To compare the flow regimes of the pre-Lanier and the post-West Point periods, we use several of the measures identified in the Service's instream flow guidelines for the ACF Basin (USFWS and USEPA 1999), as well as other measures appropriate to this consultation. We recognize that unimpaired flow datasets can be used to compare flow regimes across different historical time periods; however, unimpaired flow is not the flow experienced by the resident biota. Differences in pre-Lanier and post-West Point periods may result from climatic and anthropogenic differences. Our objective was to describe these differences in the context of what the biota have experienced.

3.3.1 Annual Flow

To better understand the effects of climate versus operations, we begin with a general comparison of the two periods. Figure 3.3.1.A shows the distribution of annual average discharge for the Apalachicola River in the 1929-1955 pre-Lanier period and the 1975-2008 post-West Point period. Although the median annual discharge is slightly higher in the post-West Point period, the three lowest-flow years (2000, 2002, and 2007) and six of the 10 lowest-flow years belong to this period. The occurrence of these lowest-flow years in the baseline period may be due to differences in precipitation patterns.

We examined readily available historical precipitation data (NOAA 2011) in the Chattahoochee and Flint basins to determine if there is a difference in the amount of precipitation between these two periods. Figure 3.3.1.B shows annual precipitation during the two periods compiled for Alabama climate zones 5, 6, and 7, and Georgia climate zones 1, 2, 3, 4, 5, 7, and 8. The climate zone boundaries do not coincide with the ACF Basin boundaries; therefore, we computed annual precipitation data as an average of the annual inches reported for these ten climate zones weighted by the area of each zone within the ACF Basin. These data suggest that, despite the occurrence of the lowest-flow years in the post-West Point period, the amount of annual precipitation was generally similar in these two periods (post-West Point median was 52.15 inches vs. pre-Lanier median of 49.31 inches). The driest 10 years are divided equally between the pre-Lanier and post-West Point periods.

Figure 3.3.1.C shows the relationship between annual precipitation in the ACF basin upstream of Woodruff Dam, estimated as described above, and annual discharge of Apalachicola River at the Chattahoochee gage for the two periods. The addition of 3.7 million acre ft of reservoir storage (including inactive storage) during the post-West Point period does not appear to have altered the overall relationship between precipitation in the Chattahoochee and Flint Basins and discharge into the Apalachicola Basin. The trend lines (linear model best fit) for the two periods are similar. Only 56 to 65% of the variance in mean annual discharge can be explained by variation in mean annual precipitation within the basin during these time periods; therefore factors other than annual precipitation also influence annual discharge in the river.

Figure 3.3.1.D illustrates the flow frequency exceedance relationships for the two periods taken from an analysis that combines all daily discharge values in each period, sorts the data in ascending order, and computes the percentage of the period containing values that exceed each unique value in the sorted list. This kind of flow frequency analysis shows the distribution of discharge magnitude in a period of record as a whole and is useful in characterizing overall differences between two periods of record. The frequency plots of the two periods are close to each other for flows greater than about 25,000 cfs, but the curves separate by about 4 to 5% for flows less than about 15,000 cfs. Flows less than 25,000 cfs occur more often in the post-West Point Period than the pre-Lanier Period. Differences in flow frequency in the range greater than 25,000 cfs are less than 2%; therefore, Figure 3.3.1.D is truncated at 35,000 cfs to allow for greater clarity in the range less than 35,000 cfs.

These differences in flow frequency exceedance relationships may be due to climatic differences, consumptive use, differences in operations, or a combination of all three factors. Although there is not an obvious difference in the amount of annual precipitation in these two periods, it is clear that factors other than the annual amount of precipitation also influence river flow. The Corps provided flow duration curves for these two periods at four additional unregulated (i.e., not influenced by reservoir operations) locations: Flint River at Griffin, GA; Flint River at Montezuma, GA; Uchee Creek at Fort Mitchell, GA (Chattahoochee River tributary); and Choctawhatchee River at Newton, AL (nearby reference stream) (Figure 3.3.1.E.). These curves also indicate that flows were lower in the post-West Point periods at these four unregulated sites. This may indicate that these differences are climatic in nature; however, differences may also result from consumptive uses of water that were occurring in all four of these basins.

Climate change has potential negative implications for the current and future status of ESA-listed species in the Apalachicola River. The four key climate drivers in the region (Burkett 2008) – rising temperatures, changing precipitation patterns, rising relative sea levels, and increasing storm intensity – all have water management implications. Alterations to the hydrograph, water temperature increases, and habitat alterations are a few possible effects of climatic variation. The Intergovernmental Panel on Climate Change (IPCC 2007) concluded that it is very likely that heat waves, heat extremes, and heavy precipitation events over land will increase during this century. Even in mid-latitude regions where mean precipitation is expected to decrease, precipitation intensity is expected to increase (IPCC 2007).

The Climate Change Scientific Committee noted in their 2008 report on the Central Gulf Coast (Burkett 2008) that the models to predict future precipitation rates are complex, but tend to indicate a slight decrease in annual rainfall across the Gulf Coast. The Committee found that average runoff is likely to remain the same or decrease when changing seasonal precipitation is considered with increasing temperatures. However, droughts are more likely to become more severe. Climate change projections for the ACF watershed conducted by the Georgia Insitiute of Technology indicate that future droughts are likely to be more intense (Yao and Georgakakos 2011). The actual effects of changes in climate are likely to be variable across the 19,800 square miles of the Apalachicola basin, but the potential for an unprecedented duration or recurrence frequency of drought cannot be discounted.

3.3.2 High Flow

High flows perform many functions that are vital to the maintenance of riverine and estuarine ecological integrity (USFWS and USEPA 1999), including:

- the maintenance of channel and floodplain features by transporting sediment;
- the export of organic matter, nutrients, and organisms from the floodplain to the main channel and the estuary;
- removing and transporting fine sediments, clearing interstitial spaces in gravel bars used for fish spawning;
- importing woody debris into the channel, creating new high-quality habitat for fish and invertebrates;
- scouring floodplain soils, which rejuvenates habitat for early-successional plant species;
- reducing estuarine salinity, which provides nursery habitat for many marine species with early life stages that are intolerant of high salinity, and prevents the permanent intrusion of marine predators, such as oyster drills, that are intolerant of low salinity;
- connecting the main channel to the floodplain, providing access to spawning habitats, nursery areas, and food sources; and
- maintaining flood-resistant, disturbance-adapted communities.

Higher-flow events move more sediment per unit time than lower-flow events and, therefore, exert the greatest influence on channel morphology (Leopold and Wolman 1957). Although the analysis referenced in the previous section did not show appreciable differences in the overall frequency of the highest flow rates between the pre-Lanier and post West Point, this kind of analysis does not necessarily detect a change in the inter-annual recurrence of flow events, which could affect channel-forming processes. The discharge generally associated with the greatest volume of sediment movement over time is the bankfull discharge, which is typically the annual peak flow event that occurs an average of two out of three years (1.5-year recurrence interval) (Dunne and Leopold 1978). Bankfull discharge tends to occur almost annually (1.1-year recurrence interval) in the coastal plain portions of Alabama, north Florida, and Georgia (Metcalf et al. 2009). Although higher flow rates than the 1.1- to 1.5-year recurrence peaks move more sediment per unit time, these more frequent events move the greatest sediment volume over time. Using the full record of annual instantaneous peak flow data downloaded from the USGS Chattahoochee gage website, the 1.1- and 1.5-year recurrence peak flows for the Apalachicola River are 45,600 cfs and 72,000 cfs.

Figure 3.3.2.A shows a comparison of the annual duration of high flow in the pre-Lanier and post-West Point periods using a threshold of 50,000 cfs, which is between the 1.1-to 1.5-year peak flow values. Flow did not exceed 50,000 cfs in about 18% of the years in both periods, however, the median number of days ≥ 50,000 cfs was greater in the post-West Point period (25 days vs. 15 days). This shift in the inter-annual duration of high flows suggests a relatively greater potential for sediment transport in the baseline period, which may have exacerbated the process of bed degradation and channel widening set in motion following the construction of Woodruff Dam (see section 3.2).

One effect of bed degradation and channel widening has been to reduce the amount of floodplain inundation associated with a given discharge (Figure 3.3.2.B) (pre- and post-impoundment total acres v. flow chart) (Light et al. 1998; Light et al. 2006). For example, the amount of floodplain habitat inundated by a flow of 30,000 cfs was about 46,500 acres in the pre-Lanier period and about 35,000 acres in the post-West Point period (a 25% reduction). Floodplain inundation during the growing season (generally April through October) is critical to the reproduction of many fish species, including some identified host species for the listed mussels. Figure 3.3.2.C shows the frequency and spatial extent of growing-season (April through October) floodplain inundation in the pre-Lanier and post-West Point periods, which is computed by transforming the daily flow records to daily acres inundated in each period using the applicable area versus discharge relationship shown in Figure 3.3.2.B. Despite an increase during the post-West Point period in the annual duration of flows greater than 50,000 cfs, discussed in the previous paragraph, the frequency and extent of floodplain inundation during the post-West Point period is decreased relative to the pre-Lanier period, largely due to altered channel morphology. For example, 20,000 floodplain acres were inundated for 32% of the growing-season days in the pre-Lanier period, but for only 18% of the growing-season days in the post-West Point period.

Figure 3.3.2.C is an analysis of the pre-Lanier and post-West Point periods as a whole, and does not assess the inter-annual frequency or magnitude of floodplain inundation. Inter-annual patterns are important in interpreting effects to riverine and estuarine biota, because the year-to-year variability in habitat conditions influences reproductive success and other population characteristics. In the case of fish spawning in floodplain habitats, it is further important to consider continuous days of inundation within a year, because utilization of these floodplain habitats requires time for movement from the main channel into the floodplain, courtship and spawning behaviors, egg incubation, and juvenile growth to a size capable of moving to and surviving in the main channel when water levels recede. We analyzed the growing-season floodplain inundation during the pre-Lanier and post-West Point periods using a 30-day moving

minimum to represent this aspect of habitat availability, identifying the maximum acreage inundated for at least 30 days each year in both periods. Figure 3.3.2.D shows the results of this analysis, and again, habitat availability during the post-West Point period is substantially less than the pre-Lanier period. In 50% of the pre-Lanier years, more than about 23,500 floodplain acres were inundated for at least 30 continuous growing-season days. The median for the post-West Point period is less than half this amount, about 11,000 acres.

3.3.3 Seasonality

Many riverine organisms have life history features that are adapted to seasonal patterns of river flow (Poff et al. 1997). Seasonal flow adaptations of the mussels have not been investigated, but due to their limited mobility, it is likely that any such adaptations would serve to enhance fertilization of gametes and infection of fish hosts with glochidia. The habits of many fish species, some of which may serve as hosts for the listed species, are seasonal and flow dependent (Angermeir 1987; Schlosser 1985). We briefly discussed the importance of floodplain inundation as spawning and rearing habitat for fishes in the previous section and cover it more thoroughly in section 3.5.5. A seasonally variable flow regime is for many reasons vital to the health of the riverine ecosystem. In this section, we examine the possibility of seasonal shifts in the baseline flow regime.

Figures 3.3.3.A and 3.3.3.B compare the distribution of monthly average flow in the pre-Lanier and post-West Point periods. The distributions of monthly flow for January, June, September, October, and December are similar. In February and March, the median monthly flow is appreciably higher in the post-West Point period, which is probably not the result of reservoir project operations. The ACF federal reservoirs' are generally drawn down in the fall from summer to winter pool levels, and this drawdown is completed before February. The fall drawdown is a likely explanation for a higher distribution of monthly flow for November in the post-West Point period. The Corps generally begins refilling West Point reservoir to its summer pool level sometime in February, which reduces, not increases, flow to the Apalachicola River. Higher flow during February and March, therefore, suggests possible climatic differences between the two periods, but since the average annual flow of the two periods is comparable (Figure 3.3.3.A), the post-West Point period must necessarily also contain months with lower flow than the pre-Lanier period. These months appear to be April, May, July, and August, which show a generally lower distribution of monthly flow. The Corps' project operations may explain to some degree lower flow in April and May, since the system is generally operated to fill the reservoirs to summer pool levels by the end of May, and this necessarily reduces flow to the Apalachicola. Lower flow in July and August is likely a combination of climatic differences in the two periods, higher consumptive uses, as well as reservoir operations.

3.3.4 Low Flow

Extreme low flows are likely among the most stressful natural events faced by riverine biota. Cushman (1985) and Kingsolving and Bain (1993) described some of the effects of low flows. Low flow constricts available habitat and portions of the channel become dry. Aquatic animals perish that are unable to move to remaining pools or burrow into the moisture of the streambed itself. Others become concentrated in pools, where small-bodied species are more vulnerable to aquatic predators and large-bodied species are more vulnerable to terrestrial predators, particularly birds and raccoons. During warm months, extreme low water levels are accompanied by higher-than-normal water temperatures and low dissolved oxygen levels, further stressing river biota. Given the physical and biological harshness of extreme low-flow conditions, decreasing the magnitude, increasing the duration, or increasing the inter-annual frequency of low-flow events is likely to cause detrimental effects on native riverine biota, including the listed species.

Figures 3.3.4.A and 3.3.4.B show the distribution of monthly 1-day minimum flow in the pre-Lanier and post-West Point periods. The medians of the two periods are about the same in the months of January, February, July, September, and October. The distribution of monthly 1-day minimum flow is shifted to generally higher levels in the post-West Point period in the months of November and December, and to lower levels during the months of March through August. In the month of May, for example, flows less than 10,000 cfs occur in three times the number of years in the post-West Point period. The shift in the seasonal occurrence of low-flow rates into the March through June time frame is important to the listed species and many other riverine species, as these are the months of concentrated reproductive activity and early life stage development.

Figure 3.3.4.C shows the inter-annual frequency of flow rates less than 5,000 to 10,000 cfs in the pre-Lanier and post-West Point periods. Flows less than 9,000 cfs occurred more frequently in the post-West Point period, and the inter-annual frequency of flows less than 6,000 cfs was substantially higher during that time (Figure 3.3.4.C). Since hydrologic monitoring began prior to the construction of the dams, flows were not measured below 5,000 cfs (lowest daily flow was 5,010 cfs on October 20 and 27, 1954). The increased frequency of low flow events may have resulted in increased exposure and mortality of listed mussels in the post-West Point period.

The duration of low-flow events in the two periods is shown in Figures 3.3.4.D and 3.3.4.E, which shows the maximum number of days per year and the maximum number of consecutive days per year that flow rates were less than 5,000 to 10,000 cfs. It is appropriate to focus on the maximum duration, because the mortality or reproductive failure associated with a severe episode of extended low flow may adversely affect a population for many years. For all rates between 5,000 and 10,000 cfs, the post-West Point period has a greater maximum event duration, expressed as both total days per year and consecutive days.

3.3.5 Rate of Change

Riverine rate of change is the rise and fall of river stage over time. Rapid changes in river stage may wash out or strand aquatic species (Cushman 1985; Petts 1984). By capturing high flows in storage, reservoirs typically accelerate the drop in stage compared to pre-reservoir conditions by closing spillway gates during flood recession, which may reduce germination and survival of riparian tree seedlings that colonize banks and sandbars by drying these areas out too fast (Rood et al. 1995). Successful regeneration of riparian vegetation is essential in the balance of erosion and deposition to maintain channel stability.

The RIOP prescribes daily minimum releases and daily maximum fall rates from Woodruff Dam; therefore, we address rate of change in this BO in an average daily context; *i.e.*, change in river stage from one day to the next. We further focus on fall rates, and not rise rates, in this analysis due to the possible effect of stranding listed species and host fishes for the mussels in higher portions of the stream channel or floodplain when river stages decline too rapidly. Figure 3.3.5.A shows fall rates in the pre-Lanier and post-West Point periods, using the same intervals of fall rates that define this measure under the proposed action, which range from less than 0.25 ft/day to greater than 2.00 ft/day. The most extreme fall rates, 1.00 to 2.00 ft/day and > 2.00 ft/day, are the least common in both periods, but the frequency of these events is more than doubled in the post-West Point period (9.8% vs. 4.4%). This increase represents a substantial increase in the risk of stranding aquatic organisms due primarily to how the system of reservoirs was operated in this period.

Listed mussels have been known to occur at riverbank elevations equivalent to as high as 10,000 cfs (see section 3.4.1.1). Fall rates that occur in this range may be particularly important to mussels. Figure 3.3.5.B shows the cumulative frequency of fall rates when flows are less than 10,000 cfs in the pre-Lanier and post-West Point periods. In general, fall rates between the two periods are similar, but for fall rates less than 0.40 ft/day, the river declined at a slower rate in the post-West Point period (e.g. fall rates of 0.21 ft/day occurred about 70% of the days in the pre-Lanier record vs. 0.13 ft/day with a comparable frequency in the post-West Point period). This may have benefitted mussels by decreasing the risk of stranding; however, sediment dynamics including bed degradation and channel widening may have changed the relationship between fall rates and the resulting rate of exposure of mussel habitat.

3.4 Status of the Species within the Action Area

This portion of the environmental baseline section focuses on each listed species, describing what we know about its spatial distribution, population status, and trends within the action area.

3.4.1 Fat threeridge

Our knowledge of the status and distribution of fat threeridge in the action area has greatly improved since the original IOP BO in 2006, and we have learned much since the 2008 BO on the RIOP. This new information is the cause for preparing this BO. We now consider the most current distribution and status information, much of which has been collected since the 2008 BO.

3.4.1.1 Current Distribution in the Action Area

Approximately 84% of the currently occupied range of the fat threeridge (111.2 out of 132.5 river miles) falls within the action area of this consultation. Two portions of the species' current range are outside the action area: four sites at the upstream end of Dead Lake on the Chipola River, and two sites on the lower Flint River. These sites are on the upstream fringe of the species' extant range and likely support a very small percentage of its total population. Known current locations of fat threeridge in the action area (Figure 3.4.1.1.A) result from recent surveys conducted in the Apalachicola River and its tributaries and distributaries including Miller and Payne (2005, 2006, 2007), EnviroScience (2006a, 2006b, 2011), Columbus State University

(Stringfellow 2006 unpub. data, and Priester 2008), FFWCC (2011, 2007 unpub. data), Gangloff (2008, 2011, and 2011 unpub. data), and USFWS (2011, 2006-2011 unpub. data).

The fat threeridge occurs in the main channels of the Apalachicola and Chipola rivers and near the mouths of a few tributaries and distributaries, with the exception of Swift Slough, where the upper 1.5 miles of the distributary is known to contain fat threeridge (EnviroScience 2006b). The well-documented main channel habitats typically occupied by the fat threeridge are moderately depositional hydraulic eddies of the channel usually downstream of point bars. In general, these aggrading sites have banks that are not eroding, slopes that are neither too shallow nor too steep (10-40%), firm silty-sand substrate, and are often associated with pioneering black willow (*Salix nigra*) stands.

We used these criteria to identify and map this type of fat threeridge habitat in the main channels with surveys in the Apalachicola River from Woodruff Dam to RM 24 in 2007 and in the Chipola River downstream of Dead Lake and the Chipola Cutoff in July 2008. We delineated the upstream and downstream extent of each site, and when possible, we performed a quick survey to verify the presence of fat threeridge in these habitats. A total of 175 sites[3] were identified as potential fat threeridge habitat within the entire action area. Because channel morphology varied by reach, the number and length of sites also varied by river reach. We modified the Light et al. (2006) delineation of river reaches based on differences in fat threeridge abundance (see section 3.4.1.2) and grouped the sites into four river-reach units: Upper (upstream of RM 50), Wewa (RM 50 to 40), Lower (downstream of RM 40), and Chipola (downstream of Dead Lake and the Chipola Cutoff). A total of 52 sites were identified in the Upper river, 25 in the Wewa reach, 32 in the Lower river, and 66 in the Chipola reach.

To quantify the amount of fat threeridge habitat in each reach, we used the habitat data from (Dr. Michael) Gangloff's 2010 survey work. We did not use the 2008 data because these were collected at lower flows; therefore, the full amount of habitat available was not represented. We analyzed his bathymetric data from three sites within each reach (see section 3.4.1.2) and calculated an average site width, which was then multiplied by the total length of the sites to derive an estimate of acres of habitat. This yielded estimates of 28 (Upper), 11 (Wewa), 20 (Lower), and 31 (Chipola) acres of habitat. In total, these sites represent about 90 acres of suitable fat threeridge habitat in the action area. Results of the habitat surveys are summarized in Table 3.4.1.1.A. Some limited observations during our surveys in 2007 indicated that fat threeridge may also inhabit deeper portions of the channel (USFWS 2007 unpub. data). Based on these findings, we contracted with Gangloff to examine deeper main channel habitats. This study is underway and all results are preliminary, but results indicate that some fat threeridge do occur in deeper, stable habitats in the Wewa and Chipola reaches where fat threeridge are known to be abundant (Gangloff 2011 unpub. data). We do not expect the mussels located in these deeper habitats to be exposed under the RIOP.

The best available information on the current distribution of fat threeridge populations within the action area is provided by Gangloff's 2008-2011 quantitative study (Tables 3.4.1.1.A and 3.4.1.1.B). The differences in population estimates in these two tables are explained in

[3] The number of sites (and in some cases their lengths) has changed slightly since the 2008 BO and Gangloff 2011, but is based on our current knowledge of these habitats.

section 3.4.1.2. Within the roughly 85 miles of non-tidal Apalachicola River main channel, the largest population (23-35%) occurs in the 10 mile Wewa reach, even though only 12% of the identified habitat occurs here. The largest portion of the population in the action area (49-66%) occurs in the Chipola reach (35% of the identified habitat). The upper 55 miles and lower 20 miles of the river constitute the smallest portions of the population (3-4% and 9-12%, respectively), even though a substantial amount of potential habitat occurs in these areas (31% and 22%, respectively) (Gangloff 2011 unpub. data). Despite being the longest in length, the upper river reach contains the smallest portion of the population (only 3-4%). Channel morphology changes (entrenchment, dredging, snagging and the construction of dike fields; see section 3.2) have likely contributed to a decline of the species in the upstream-most 30 miles of the river, and it is almost entirely absent upstream of RM 90 probably as a result of channel incision from the dam. Despite considerable mortality between 2006-2011, recent surveys indicate that fat threeridge persist in Swift Slough (USFWS 2010 and 2011 unpub. data; FFWCC 2011; EnviroScience 2011).

Distributions of fat threeridge populations by depth

Fat threeridge have been known to occur at bank elevations equivalent to discharges above 8,000 cfs (Miller and Payne 2005; EnviroScience 2006a; Gangloff 2011) and even as high as elevations associated with discharges of 10,000 cfs at the Chattahoochee gage (USFWS 2006 unpub. data); however, the distribution of fat threeridge is dependent on recent hydrologic conditions. In moderately depositional habitat, fat threeridge seem to prefer depths that center around 1 meter (3.3 ft.), regardless of flows. This conclusion is based on depth distribution studies over a wide range of flows since 2005. Miller and Payne (2005) found the species was most abundant at a depth of 1.2 m. This survey was conducted at discharges generally greater than 9,000 cfs; however, similar patterns of fat threeridge depth distribution have also been observed with lower flows. EnviroScience also sampled a main channel location near RM 46.8 in 2006 when flows were about 6,000 cfs and found a majority of fat threeridge were at depths of about 1 m (EnviroScience 2006 unpub. data). The Service (2007 unpub. data) sampled during low flows (around 5,130 cfs) in 2007 at depths up to 0.9 m and found that 60% of fat threeridge were between 0.3 to 0.6 m deep. The consistent observance of fat threeridge at depths of 0.5-1.5 m regardless of discharge suggests the species prefers the conditions associated with this depth range, and that animals are likely moving laterally on the river bed in response to changes in flow.

The notion that fat threeridge are generally distributed around 1 m in moderately depositional habitat regardless of flow was further supported by Gangloff during low and high flows in 2008 and 2010. Flows were at or near the 5,000 cfs minimum for much of the summer of 2008, but beginning that winter, flows increased and never dropped below a mean monthly discharge of 8,000 cfs until the fall of 2010. In 2008, a total of 791 fat threeridge were collected at a mean depth of 0.6 m with flows averaging about 5,300 cfs (range 5,050-5,590); and in 2010, a total of 1,345 were collected at a mean depth of 1.1 m around flows averaging about 7,900 cfs (range 6,750-9,840) (Gangloff 2011[4]). He estimated that 23% of the overall population occurred at depths associated with 9,000 to 5,000 cfs river levels in 2010, a zone that was devoid of mussels

[4] These flows do not match what was reported in Gangloff (2011) because he was using provisional data. These flows also incorporate the 2-day lag time between the Chattahoochee gage and Wewa where necessary.

in 2008. Similar percentages were observed in both the Apalachicola and Chipola rivers. Figure 3.4.1.1.B is a direct comparison of two sites sampled in both years when Apalachicola River flows were about 5,350 in 2008 and again in 2010 when Apalachicola River flows were around 9,700 cfs. This figure illustrates how mussels recolonize habitats greater than Apalachicola River flows of 5,000 cfs when conditions change. One of these two sites was in the Chipola, but if we remove the Chipola site from Figure 3.4.1.1.B, the pattern remains the same.

At the time of the 2008 BO, no listed mussels were known to occur at bank elevations equivalent to river stages greater than 5,000 cfs due to the drought of 2006-2008. However, the 2010 surveys indicated that substantial numbers (23% of the population) of fat threeridge mussels recolonized stages above 5,000 cfs. Therefore, the 2008 and 2010 surveys demonstrate that, as time and conditions permit, fat threeridge distribution shifts to center around 1 m. There are three hypotheses for this distribution shift:

1. Fat threeridge move in relation to flows to maintain a preferred depth. More information is needed to understand whether they are moving as a result of unfavorable flow conditions, shear stress, predation, or other factors.
2. Sediment deposition is occurring in their habitats during high flows, causing the mussels to move vertically up in elevation in order to remain at the surface of the sediment to spawn and feed.
3. Fat threeridge are mechanically displaced to higher streambank elevations and loop streams/distributaries during high flow events as river currents scour and redistribute both sediment and mussels.

As described in the 2008 BO, we attributed the presence of fat threeridge at these higher elevations in 2006 to hypothesis #3, and we believed this phenomenon was an anomaly due to two very high flow events in 2005. These events included a flood during late March through early May that exceeded 50,000 cfs for 18 days, and reached a daily average peak discharge of 158,000 cfs. In addition, a second event occurred in July 2005 at a time when mussels would be at the riverbed surface to reproduce, and potentially most susceptible to scour. Flows during this event exceeded 50,000 cfs for 15 days, and reached a daily average discharge peak of 112,000 cfs.

Since the 2008 BO, new evidence has been gathered revealing that mussel redistribution can occur in the absence of flood or extreme high flow events during susceptible periods. Between 2008 and 2010, Gangloff monitored the lateral distribution of fat threeridge at multiple sites on the Apalachicola River. During this period, two bankfull flow events occurred that were capable of transporting sediment and triggering a response consistent with our second hypothesis. These events did not occur during the reproductive period for fat threeridge. The USFWS measured sediment deposition at four locations in October 2010, and found that mussel habitat had aggraded only 0.5 ft on average since measurements in 2007 (USFWS 2010 unpub. data). While deposition of sediments may have contributed to some mussel movement to higher bank elevations (hypothesis #2), the observed level of aggradation cannot explain the substantial shifts in distribution to higher streambank elevations (>0.5 ft) revealed by Gangloff's observations (Figure 3.4.1.1.B). The recolonization of these areas in the absence of summertime high flow events and corresponding levels of sediment aggradation instead supports our first hypothesis, that the mussels respond to changing water levels by actively moving in search of preferred habitat conditions. In general, active movement appears to be much more common than previously assumed based on observations made in 2005-2008. Therefore, we now believe that the primary reason for shifts in fat threeridge distribution (in moderately depositional habitat) is that they move in response to changing water levels to maintain optimal habitat conditions, which are associated with a depth of about 1 m. Sediment deposition may also play a role, but more research is needed to assess the degree to which sediment deposition or scour may influence mussel movement.

3.4.1.2 Population Status and Trends in the Action Area

Population Estimate

Recent surveys conducted have shown that the fat threeridge is locally abundant in moderately depositional habitat. For example, in the surveys by Miller and Payne (2005, 2007), EnviroScience (2006a), and Gangloff (2011), fat threeridge was abundant, representing anywhere from 25-36% of the total.

In 2008, an extensive study was initiated to more accurately estimate the number of listed mussels present in these moderately depositional habitats. The study was conducted by Gangloff in collaboration with the Corps and Service. The resulting data were heavily utilized in this BO. Thirty-nine sites (29 in the Apalachicola River and 10 in the Chipola River) were sampled from 2008-2011 from the 175 sites we delineated as potential fat threeridge habitat (discussed in section 3.4.1.1.). Surveys occurred in the fall of 2008 during low flows (averaging about 5,300 cfs), the summer of 2010 during higher flows (averaging about 7,900 cfs), and the summer of 2011 during very low flows (4,400-5,000 cfs). In addition, two sites sampled in 2008 were re-sampled in 2010. Quantitative methods were used to determine mussel density at each site. Using a hydraulic gold dredge, quadrats (0.25 m^2) were excavated along regularly spaced transects from the wetted edge to a depth of 1.0 m when flows were low and to 2.0 m when flows were higher. A total of 2,625 fat threeridge were collected during the course of the study (Gangloff 2011, 2011 unpub. data).

Sites were grouped into river reach units: Upper (upstream of RM 50), Wewa (RM 50 to 40), Lower (downstream of RM 40), and Chipola (downstream of Dead Lake and the Chipola Cutoff). Fat threeridge estimated mean densities were highest in the Chipola River reach (7.9 m^2). The highest densities within the Apalachicola were found in the Wewa reach (3.9 m^2), followed by the Lower river (1.4 m^2), and then the Upper river (0.5 m^2). The local fat threeridge population of each site was calculated using the mean density of the site multiplied by the site length and mean site width (i.e., transect width). These numbers were summed by river reach. To extrapolate to the entire reach, we divided the total sampled length within each reach by the total identified length of habitat mapped within the reach to get a percent of sampled length. We derived an estimate of the total number of fat threeridge within each reach by dividing the percent of sampled habitat by the local population estimate within each reach. This yielded population estimates of 542,846 (Chipola), 190,530 (Wewa), 70,367 (Lower), and 22,313 (Upper), with a total population estimate of approximately 826,000 in the action area. Results of the quantitative surveys are summarized in Table 3.4.1.1.B. This current population estimate is substantially higher (3.5 times) than the population estimate of 233,500 noted in the 2008 BO.

The difference apparently results from additional sampling, particularly in the Chipola River, where data were lacking for available habitat and mussel density. Since our population estimates focus only on moderately depositional habitat where fat threeridge are known to be abundant, we still may be underestimating the population if fat threeridge occur in substantial numbers in other habitat types.

Estimates of the total amount of fat threeridge habitat in the 2008 BO were based on the amount of moderately depositional habitat below 5,000 cfs, previously 11.2 ft at the Wewa gage. More recent data (July 2010) indicate that fat threeridge will use habitat available at discharges of up to approximately 9,100 cfs at the Chattahoochee gage. Therefore, the amount of available habitat in the 2008 BO was underestimated. To update the calculation of the total amount of fat threeridge habitat available and their distribution by depth, we used Gangloff's 2010 data collected from 25 sites (9 Upper, 3 Wewa, 6 Lower, and 7 Chipola sites) using the same methods described above (Gangloff 2011). By measuring depth and distance to bank at the center of each quadrat, Gangloff recorded detailed bathymetric data for these sites. At three sites within each reach, we calculated the extent of the distribution of fat threeridge mussels relative to the nearest gage height and water surface on the date sampled. That range of depths was then used to calculate the total acres of habitat available in 0.1 ft increments relative to the nearest gage. Habitat data were extrapolated, when needed, if the full range of mussel depths were not the same in all transects. All depth distributions were then standardized to flows at Chattahoochee using stage discharge relationships provided by the Corps. Results are summarized in Table 3.4.1.1.A. This method results in a different population estimate than Gangloff's because it uses only 2010 data and is based on the relative amount of available habitat within the specific depth contours. Using this method, there are an estimated 1,144,352 fat threeridge in moderately depositional habitat, with 4% of the population occurring in the Upper river, 35% in the Wewa reach, 12% in the Lower river, and 49% in the Chipola reach.

EnviroScience (2006b) estimated the population of fat threeridge in Swift Slough based on data collected in August of 2006 (Table 3.4.1.2.A.) The population estimate of 18,101 fat threeridge excluded pool habitats, areas occupied outside of the upstream segment, and bed elevations above the stage associated with 6,300 cfs at the Chattahoochee gage; therefore, because of this exclusion it may be an underestimate. Most fat threeridge in Swift Slough perished in 2006 and 2007 because of drought-related isolation. The population has not been re-estimated since that time, however, fat threeridge persist in the slough (USFWS 2010 and 2011 unpub. data; FFWCC 2011; EnviroScience 2011). A brief survey in 2010 documented juveniles and some larger individuals (EnviroScience 2011).

<u>Effects of low flow</u>

Although droughts are a natural part of the hydrologic cycle, prolonged droughts contribute to the further decline of mussel populations already suffering from other threats. Increased demand for surface and ground water resources for irrigation and consumption exacerbate the impacts of drought (e.g., effects of drought and water use in the Flint River Basin documented by Golladay et al. 2007). Mussels are highly sensitive to the secondary effects of drought and to the direct drying of their habitat (Haag and Warren 2008). Many riverine mussels appear to be intolerant of low dissolved oxygen and emersion (aerial exposure), especially in warm temperatures

(Holland 1991; Bartsch et al. 2000), and sustain high mortality when stranded in drying pools or on stream margins (Metcalf 1983; Golladay et al. 2004). Mussels can move short distances to deeper water in response to receding water levels (Coker et al. 1921; White 1979). In large streams with permanent flow, this response probably decreases drought-associated mortality (Golladay et al. 2004). However, heavy-shelled mussels, like the fat threeridge, may be more prone to stranding than lighter-shelled species (Newton et al. 2011). Indeed, we have observed many more fat threeridge stranded than lighter-shelled species like *Lampsilis floridensis* and *Elliptio pullata*, which are also abundant at sites where we observed extensive mussel stranding in the Apalachicola River.

The ability of mussels to move with, or track, receding water levels is related to bank slope (WDNR et al. 2006; USFWS 2011). Newton et al. (2011) found this to be the case during a summer 2010 drawdown on Pool 6 of the Upper Mississippi River. The study monitored the movement and survival of two mussel species, *Amblema plicata* (a fat threeridge congener) and *Lampsilis cardium*, at each of 11 sites during the drawdown. Five of the sites were characterized as high slope (9-11.5% grade), and six sites as low slope (5-7.5% grade).). During the 1.0 ft. drawdown, water levels were dropped at a fall rate of about 0.17 ft per day. *Amblema plicata* mortality was much higher at sites with low slopes (67%) than at sites with higher slopes (21%). Mussels at sites with lower slopes appeared to be stranded in dewatered areas more often than mussels at sites with higher slopes. *A. plicata* often burrowed into the substrate, whereas *L. cardium* (a lighter-shelled species) appeared to move horizontally and follow the receding water. Mortality was approximately two times higher in *A. plicata* than in *L. cardium*.

Similar observations have been made for mussels in the Apalachicola River. We examined the relationship between bank slope and the number of stranded fat threeridge as a result of declining stage height in September 2010. The number of fat threeridge exposed was inversely correlated with bank slope (Spearman nonparametric correlation analysis, $p=0.0580$, $r=-0.6905$), meaning more mussels were stranded when slopes were lower (not as steep). In the study discussed below by USFWS (2011), overall, mussels at sites with a mean slope of $\leq$20% were at a much higher risk of experiencing stranding and mortality than mussels at sites with higher gradient.

Because little is known about the effects of atmospheric exposure on fat threeridge, we assessed movement, exposure, and mortality during a steady water level decline in May and June, 2011. Fat threeridge were observed moving 50-100 cm per day to track falling water levels. Several observations were made where mussels failed to move down-slope with the falling water level and became exposed. Although some mussels moved longer distances (as much as 290 cm in one day), these long movements were atypical. Of the mussels that did not successfully track the water level and became exposed, the majority (70%) survived between one and six days. Areas where mussels were stranded received full sun for much of the day, and ambient air temperature at one site where many mussels perished reached daily maximums of around 100º F (38º C). The amount of sun exposure likely plays a role because FFWCC monitored the same site in 2006 when the area received less direct sunlight and found that 30% of exposed individuals were able to persist for four or more weeks (FFWCC 2011). They also noted that mussels buried in shaded areas with groundwater input like Swift Slough were able to persist for months. A small percentage of exposed fat threeridge (~8%) buried completely into the substrate in our study, and survival in these mussels was higher, ranging from 7 to 27 days. Conversely, some mussels that tracked the declining water were later found dead in the water. We suspect that that these mussels died due to stress from moving, elevated water temperatures, or low dissolved oxygen (USFWS 2011).

We used our 2011 assessment to evaluate the influence of fall rates on fat threeridge movement and mortality. We calculated the linear distance of exposed bank (i.e., the distance a mussel must move to maintain its depth of position) over a range of stage declines for a suite of site gradients (5-45% slopes) (Figure 3.4.1.2.A). This model provides a convenient way to compare hypothetical risk of exposure among sites related to slope and drawdown factors. For example, site RM 44.5 had a mean slope of 28%. A decline of water surface elevation of 0.25 ft/day (i.e., the prescribed fall rate in the Corps' current operations) on a 25% slope grade exposes approximately 30 cm of bank per day, requiring mussels located in this zone to move equivalent distances to remain submerged at comparable depth. We observed that mussels can move more than 50 cm/day, which may be sufficient to avoid exposure on slope gradients of 25% at a drawdown rate of 0.25 ft/day. This relationship may explain why very little exposure and mortality was observed at RM 44.5. On the other hand, site RM 44.3 had a mean slope grade of 9%, requiring mussels to move 77 cm per day at a drawdown rate 0.25 ft/day. Although mussels demonstrated the ability to move such distances, slopes at the upper end of this site, where most stranding and mortality occurred, were actually <5%. Such drawdown on 5% slopes expose 150 linear cm of bank per day, and our data show that these distances exceeded the movement capacity of many mussels at RM 44.3. Fall rates are likely particularly important in the Wewa reach of the Apalachicola River where fat threeridge density is high, but many sites are relatively shallow-sloped, especially at the upstream-most portions as described above.

Recent Mortality Events Affecting Population Status

2006-2007

We observed a significant mortality event during the summer of 2006 at flows between 5,000-10,000 cfs in the main channel Wewa reach, Chipola Cutoff, and Swift Slough during which thousands of fat threeridge were exposed. This was the first mortality event of this scale for the fat threeridge that had been documented. Estimates of mortality varied by site and date of survey (range: 8 to 98%, EnviroScience 2007 unpub. data). Some animals survived by burrowing or by movement into local refugia. The Service conducted a limited survey during June 2006 to quantify the mortality that occurred at flows greater than 5,000 cfs (Table 3.4.1.2.B). There were six sites in the main channel of the Apalachicola River (RM 40-50) and Chipola Cutoff where mussels experienced extensive stranding and mortality. Using density estimates from our quantitative mussel survey conducted in October 2007 in RM 40-50 (Table 3.4.1.2.C), we estimated about 31,200 individuals may have been present in these locations when the mortality occurred. Based on data collected in 2010 (see 2010 discussion below), we expect that about 95% of these individuals may have moved, which would result in about 1,560 dead fat threeridge in those six sites at flows above 5,000 cfs. With the exception of Race Shoals, we measured the elevation of all mussels found relative to the current water surface elevation, and found listed mussels exposed at stages as high as about 10,000 cfs. During the summer and fall of 2007, we continued to observe additional mortality of fat threeridge at the sites in RM 40-50 at flows greater than 5,000 cfs, so it is likely this is an underestimate.

In addition to mortality at main channel sites, we know that significant mortality also occurred in Swift Slough in 2006 and 2007 at flows greater than 5,000 cfs. The total population estimate of fat threeridge in Swift Slough was about 18,100 individuals at the end of the summer 2006. However, about 5% of the total population, about 900 fat threeridge, was already dead at the time they were surveyed in August 2006 (Zimmerman 2007 pers. comm.). FFWCC reported that estimated mortality from tagged individuals in Swift Slough during 2007 was about 98% (Hoehn 2007 pers. comm.). If tagged individuals died at the same rate as the rest of the population, about 17,700 fat threeridge in Swift Slough died during 2007. Overall, we estimated that a total of about 18,600 fat threeridge died in Swift Slough at flows less than 10,000 cfs.

The Corps reduced flows to 4,750 cfs in November and December of 2007. They implemented surveys to estimate listed mussel mortality after reducing flows and determined that a total of 1,469 individual fat threeridge were taken as a result of the flow reduction to 4,750 cfs. This did not exceed the authorized incidental take of up to 5,600 fat threeridge mussels. Although Swift Slough was not monitored during this time, additional mortality may have occurred.

Most of the mussel mortality we observed in 2006 and 2007 was in the RM 40-50 reach of the river, and was either in elevated side channel swales along the main channel of the river and Chipola Cutoff, or in Swift Slough. Combined mortality estimates suggest that about 21,630 fat threeridge died in 2006 and 2007 (1,560 at six main channel sites in 2006; 18,600 in Swift Slough; 1,469 in the main channel in winter 2007). In the 2008 BO, we estimated that 19% of the population may have died during that event. Because we underestimated the population size in the 2008 BO, we revised the 2006 mortality event to be about 2% of the population. At the time of the BO, all mussels above an elevation of 5,000 cfs were assumed dead, and we assumed no mortality would occur at flows above 5,000 cfs for the foreseeable future.

In the 2008 BO, we attributed mortality at flows above 5,000 cfs to redistribution of mussels during two extended periods of very high flow in 2005. As described in section 3.4.1.1, we now believe that the primary factor responsible for fat threeridge depth distribution is horizontal movement; therefore, we no longer believe redistribution is the primary explanation for the mussel mortality that occurred. With respect to the presence of mussels in Swift Slough, the slough has received large amounts of sediment in recent years, and the sediment inputs may have included mussels. However, we have no evidence to date that fat threeridge are being redistributed into other areas of the river. We have not found populations in other distributaries or loop streams. We have encountered fat threeridge tagged in 2007 in the same relative location in 2010 and 2011 at several locations in the Wewa reach (USFWS unpub. data 2010-2011; FFWCC 2011), which indicates that fat threeridge in moderately depositional locations are not redistributed from these areas during high flows. Our theory (in part) was also based on our and EnviroScience 2006 survey data (2006b) showing that densities in the slough generally decreased downstream. This patchy distribution within the slough could also be a reflection of habitat conditions and of host fish abundance at these sites. Although it is possible that mussels were carried into the slough with the sediment, it is also possible that Swift Slough provided suitable habitat for fat threeridge mussels before the high-flow events of 2005, as recent evidence shows that recruitment continues to occur within the slough. Regardless, Swift Slough continues to harbor populations of fat threeridge in the action area, and it continues to aggrade.

2010

At the time of the 2008 BO, there were no listed mussels known to occur at river stages greater than 5,000 cfs due to the drought of 2006-2008. Although we noted that mussel mortality may occur when individuals occupy stages greater than 5,000 cfs, we did not anticipate further significant mortality at such stages because we considered it to be an anomaly related to very high flows in 2005 (see previous discussion). However, mussel surveys conducted in 2010 indicated that substantial numbers of fat threeridge mussels recolonized stages above 5,000 cfs. We observed a mortality event in September 2010 at flows between 5,000-10,000 cfs, and this constituted the second part of the new information that prompted the reinitiated consultation.

To determine the impact of low flows in 2010, we surveyed eight moderately depositional sites throughout the action area during September 10-24 (see summary in Table 3.4.1.2.D). We directly observed 393 individuals exposed and/or dead during this time and estimated that about 2,500 died in the action area based on the amount of habitat searched during this survey and the total estimated amount of moderately depositional habitat available. Based on the population estimates provided in this section, less than 1% of the population (0.2-0.4%) may have died in September 2010. Repeated site visits confound the reliable estimation of the number of exposed individuals that were dead versus exposed but still alive. Based on field observations, data confirm that at least 50% of the exposed fat threeridge that we observed were dead on our first site visit on September 10. Wewa gage data indicate that mean daily stage declined below the highest stage at which fat threeridge were known during Gangloff's 2010 surveys (14.3 ft; roughly 9,100 cfs at the Chattahoochee gage) on September 1, 2010; therefore, fat threeridge were exposed for less than 9 days before dying. In addition, most of the live exposed individuals were found very near the water surface, which indicates they had been exposed within the past 24 hours. Flows continued to decline beyond the level observed on September 10, 2010, for an additional 16 days. Ambient air temperatures were very warm (highs ranging between 92-97°F at weather stations in Carrabelle and Marianna, Florida), and all these sites received full sun for much of the day. Based on what we measured in the 2011 study (USFWS 2011), where the majority of exposed individuals died within 7 days of exposure at similar sites, it is reasonable to assume that nearly all mussels exposed in 2010 died.

Fat threeridge will move to track water level declines depending on the slope and rate of water level decline. On our first visit on September 10, we observed mussels moving to track the water level decline, although not all were successful. Because Gangloff had recently sampled during the summer of 2010 when flows were higher, we repeated his surveys at four sites in the main channel (1 Upper, 2 Wewa, 1 Lower) to estimate the potential movement and mortality that may have occurred at these locations. We observed minimal stranding mortality at these four sites. Following the same methods, we sampled along evenly spaced transects to a depth of 1.0 m, using a hydraulic gold dredge to excavate 0.25 m^2 quadrats. Because transects were stationed relative to the water surface elevation during Gangloff's work when flows were higher, several quadrats were above the water line; these were hand excavated and sieved to look for mussels that may have burrowed. Comparisons of the four sites sampled in 2010 at higher flows (9,000 cfs) and again later in the year at lower flows (Wewa stage of 11.95; equivalent to Chattahoochee flows of 5,700 cfs) showed that nearly all fat threeridge moved down slope (Figure 3.4.1.1.B). Our (post-decline) average density estimate of 4.2 m^2 (± 0.6) is comparable to Gangloff's (pre-decline) estimate of 3.3 m^2 (± 0.4). In addition, none of the 123 quadrat samples excavated above the current waterline contained fat threeridge, indicating that the species did not burrow. The only area where burrowed live mussels (*Glebula rotundata*) were encountered was in a swale, where the mussels could not escape to deeper water by moving downslope.

It is important to note that during our survey, Wewa stage never went below 11.95 ft, which is equivalent to a Chattahoochee discharge of 5,700 cfs. Although Chattahoochee releases did get a low as about 5,100 cfs during this time, local inflows below the dam and drainage from the banks and floodplain kept the river higher in the Wewa reach where most of the mortality was observed. Wewa stage did decline below 11.95 ft for an additional 11 days in October and it is likely that additional mortality occurred during this time, although heat stress may have been less than observed during September mortality event. Interestingly, the Chattahoochee gage data indicate the Corps' releases during this time were 5,800 cfs. This may have resulted from a relatively large shift of 0.5 ft to the rating curve at the Chattahoochee gage on October 28, 2010. When a rating shift is made by the USGS, it is applied to all data back to the last field discharge verification measurement, which was September 29. If these rating shifts are slightly off, or if applying the shift to previous data is not appropriate, then the stage-discharge relationship using these data may be different. We discuss the implications of this and other shifts in the rating curve under the 2011 Mortality section below.

Although data were not collected during the October event, we can use the depth distribution data from Gangloff's 2010 surveys to extrapolate the potential exposure that may have resulted. Using estimates of the distribution of mussels at depth in July 2010 (see Population Estimate above for a description of how this was calculated), we estimated that about 204,000 fat threeridge were in the depth interval from about 9,100 to 5,700 cfs, which is where we estimated about 2,500 died in September 2010. Comparing the number in the interval to the estimated mortality indicates that about 95-99% of mussels located in the 9,100 to 5,700 cfs interval may have moved (Table 3.4.1.2.D; assumes complete detection of exposed individuals). This result varies by reach, with the lowest movement rate (about 95%) estimated in the Wewa reach, which has generally been the area of the river with the highest exposures because it has shallower slopes and the highest Apalachicola River mussel densities. If we assume the same rate of movement in the October 2010 event in each reach and use Gangloff's depth distribution data that indicate roughly 211,000 were distributed above 5,600 cfs elevation (Wewa 11.83 where it stayed for about six days in late October), we estimate that an additional 2,500 individuals may have been exposed. Ambient air temperatures ranged between average highs of 83-86ºF (28-30º C) at weather stations in Carrabelle and Marianna, Florida. Although temperatures were about 10ºF higher during the September 2010 event, the October temperatures were still high and mortality probably occurred in areas that received full sunlight for most of the afternoon. We assume that the additional 2,500 potentially exposed also resulted in mortality for a total estimated mortality of about 5,000 in 2010.

It is important to note that the 2010 estimate does not include Swift Slough, which was responsible in large part for the higher mortality in 2006. Most of the population in Swift Slough perished during the 2006 event, but as discussed above, we have recently documented new recruitment in Swift Slough along with limited survival from the 2006 event. We also observed mortality in September of 2010, but we do not have sufficient data to determine the relative amount.

2011

As basin inflows declined to 5,000 cfs in May, we initiated a study to document and examine factors associated with the movement, exposure, and mortality of fat threeridge mussels at select sites along the Apalachicola and Chipola rivers. We intensively monitored (almost daily visits) two sites on the main channel (one with a low slope of 0.09 and one with a relatively higher slope of 0.28), measuring daily movement of fat threeridge and documenting exposure, survival after exposure, and mortality. We also visited an additional 11 sites to collect data on mortality. Some results are reported in the "Effects of low flow" section above. Additional results are summarized in Table 3.4.1.2.E. For detailed methods, results, and discussion see USFWS (2011).

We detected a combined total of 863 dead fat threeridge at 13 sites at flows less than 7,000 cfs. A total of 468 exposures and mortalities occurred when releases were inadvertently less than 5,000 cfs at the Chattahoochee gage (more on this below). Site-specific population estimates indicate that less than 1% of the population at the site died at eight of the 13 sites, and the remaining sites experienced 1-7% mortality of the local population. The three sites in the Chipola River had limited mortality (≤ 0.2% of the population). Mussels at the low gradient site moved more often and farther than mussels at the steeper site, likely due to site gradient, a factor that influences the ability of mussels to track declining water levels, maintain position at depth, and avoid exposure. Differences in mortality between sites during the 2011 drawdown and past episodes, suggest a relationship between site gradient and the risk of exposure and mortality. To examine this relationship we plotted the percent mortality against mean site slope, drawing upon data from Gangloff (2011) (Figure 3.4.1.2.B). We derived an inverse, threshold-response relationship between mean site slope and mortality from these data. As slope decreases, risk of mortality and risk of increasing proportion of mortality markedly increases. Sites with a mean slope of <20% grade were at a much higher risk of experiencing >1% mortality than sites with higher gradient.

Of the 38 sites sampled by Gangloff, approximately one-third (13 sites) had slopes of 0.20 (i.e., 20%) or less. Chipola River sites have slopes ≥20%, which may explain why little mortality is observed in the Chipola River. Also, water levels may not drop as quickly or as far in the lower Chipola River as flow declines are attenuated by discharges from the Chipola main channel. Because site slopes are generally >0.20 in the Chipola River, we estimate that about one-third of the Apalachicola River fat threeridge population might be at risk of experiencing more than 1% mortality (range 1-7%, mean 3%, excludes Chipola sites) during this event and comparable drawdown episodes. We used this relationship to estimate how many individuals may have died in 2011. As previously described, population estimates for moderately depositional habitat in the Apalachicola River only range from about 283,200-587,900. Mortality during the 2011 event may have ranged from about 2,830-5,880 individuals (using the mean 3% mortality at sites with slopes ≤0.20). This is also consistent with what we predicted for mortality in 2010. We estimate that total fat threeridge mortality in 2010 and 2011 was around 10,880 individuals, about 1% of the total population.

Impacts from river draw-downs may depend on preceding hydrologic conditions. In this study we documented the ability of fat threeridge to move 50+ cm per day as water levels receded. As discussed earlier, fat threeridge are likely moving to maintain position at depths of around 1.0 m, a depth (or associated factor like flow) apparently preferred by the species. Indeed, the ability to track changes in water depth by moving provides a mechanistic explanation for the location of mussels at bank elevations greater than the new Fall 2010 "ceiling" (i.e., the bank elevation of the previous lowest flow) level at the start of this study. For example, we observed about 116 individuals exposed at bank elevations above 11.83 ft at the Wewa gage, which would have been the Fall 2010 ceiling. Assuming that all surviving mussels retreated to, or were already located at depths associated with the Fall 2010 ceiling, these mussels likely moved there within the intervening 6-month time period. Therefore, although observed mortality was relatively low in May and June 2011, hydrologic conditions in the fall of 2010 may have set the stage for lower mortality by causing fat threeridge to move to lower elevations. Although mortality observed in 2011 was undoubtedly elevated by the unintentional reduction of flows below 5,000 cfs, impacts associated with a drawdown to 5,000 cfs might have been considerably higher in 2011 if preceding hydrologic conditions represented higher flows.

<u>2011 Corps' Incidental Take</u>

On June 20, 2011, the Service was notified that flows were below the minimum 5,000 cfs for a prolonged period (24 days) as a result of an adjustment (i.e., shift) to the rating curve (relationship between stage and discharge) for the USGS Chattahoochee gage. River levels dropped below the 5,000 cfs minimum flow from May 23-29 and again from June 4-20. Daily flows varied but were as low as 4,340 cfs. Discharge was measured at the gage on June 16 and the data were used to recalibrate the rating curve for accurate release of 5,000 cfs. Take occurred during this event, and we requested the Corps provide an estimate of the amount of take. The take estimate number is part of (not in addition to) the 2,830-5,880 we estimated died in 2011.

Using data from the May and June 2011 surveys, we calculated the relationship between the mean site slope and the percent mortality of the total number of individuals at the site that occurred when releases were less than 5,000 cfs (Figure 3.4.1.2.C). The Corps used this relationship to estimate the amount of take that may have occurred throughout the whole river. Current estimates from the Corps indicate that about 1,091 fat threeridge were killed when flows were below 5,000 cfs for 7 days in May and 17 days in June.

As a result of this observation, we completed an analysis of the rating table and field verification discharge measurements, and rating curve shifts have been occurring relatively frequently since 2009. Since 2000 when this rating curve was adopted, the average gage height associated with 5,010 cfs was 39.08 ft, which almost matches the rating table value of 39.07 ft. However, several recent shifts have resulted in lower gage heights associated with 5,010 cfs, and exposure and take of listed mussels has occurred as described. As previously mentioned, the October 2010 adjustment was relatively large (0.5 ft), and this may have resulted in under-releases from the dam. It is also possible that changes within the channel occurred in the reach that changed the stage-discharge relationship.

At these low flows, mussel movement and exposure is probably influenced more by the water level (i.e., gage height) than a specific discharge, especially if that discharge varies at a specific gage height depending on shifts to the rating table. Because rating curve shifts have the potential to expose listed mussels, we need to assure that the relationship between stage and discharge will be measured and verified on a regular basis. Together with the Corps, we have discussed this issue with the USGS, and they believe monthly discharge measurements would be sufficient to assure that the current rating curve accurately reflects the relationship between stage and discharge.

Population Demography

Recent surveys have all reported evidence of fat threeridge recruitment in the Apalachicola River. In the 2008 BO, we noted that poor fat threeridge recruitment may have been occurring from 1998 to 2005 because these year classes were under-represented in the October 2007 quantitative samples collected by the Service. The collection method included sieving the substrate to target younger individuals, and recruitment was noted in all of these years, but the number of individuals in these year classes was less than expected in a population with stable recruitment. Gangloff's sampling from 2008-2011 used similar methods of excavating and sieving quadrats; however, quadrats were excavated using a hydraulic gold dredge, which is believed to better target younger individuals. We have not yet had the opportunity to examine the number of individuals in each year class in his data, so we rely on his recent report to assess the status of recruitment in the Apalachicola and Chipola rivers (Gangloff 2011). It appears that populations in the Wewa and Lower reaches are actively recruiting juveniles. Recruitment in the Upper river may be limited as evidenced by a lack of individuals <20 mm TL and a higher overall mean total length. Relatively few individuals <20mm were collected in the Chipola River, and recruitment may also be lower in the Chipola River relative to the lower and middle Apalachicola River (Gangloff 2011).

We received an analysis of fat threeridge shell length data collected by Gangloff from Andrew Miller (Miller 2011a). He noted that Gangloff's data indicated that recruitment (defined as the percent composition of ages ≤ 3 years old) varied by site, year, and river reaches during 2008 and 2010. We recreated Mr. Miller's analysis using the percent composition of juveniles (individuals <35 mm, now considered to be 3 years old). As expected, juvenile recruitment appears to vary by river reach, but comparisons between years are confounded by the nature of Gangloff's sampling in that the reaches were sampled with different intensities between the two years. Results of both years combined indicate that the percent composition of juveniles was similarly higher in the lower and Chipola reaches (27% for both) compared to the upper and Wewa reaches (8% and 12%, respectively). Based on this analysis, recruitment may not be limited in the Chipola River, but more information is needed to adequately assess the status of fat threeridge recruitment.

For the Population Viability Analyses (PVA) (Miller 2008 and 2011b) and 2008 BO, we estimated annual adult survival of fat threeridge using catch curve regression analysis. Catch curves are computed by regressing the natural log of the number of individuals at each age against age or year class. This method is appropriate for populations with relatively stable age-structure, as illustrated by an exponential decline between year classes (van den Ayvle and

Hayward 1999; Slipke and Maceina 2001). We acknowledged that there was uncertainty around these estimates given the assumptions of catch curve analysis, some uncertainty in the age data, and the fact that catch curves provide a "snapshot" estimate of the mortality for a population. At the time of all three of these reports, this was the best option for estimating adult survival (a parameter essential to population modeling) because multi-year mark recapture data were not available. However, during this reinitiated consultation, we completed our first year of a small mark-recapture study at one site in the Wewa reach (RM 44.3).

On October 27, 2010, we tagged 96 fat threeridge of various sizes with Passive Integrated Transponder (PIT) tags. Tagged individuals were returned to the substrate at depths of about 1 m when flows were about 5,800 cfs at the Chattahoochee gage. We returned to the site on September 19, 2011 (327 days later) and recaptured 93 individuals, two of which were dead. We calculated 327-day survival to be 0.978 (91 divided by 93), and estimated the annual survival rate as 0.976 using the instantaneous mortality rate. It should be noted that the PIT tagged individuals were not susceptible to exposure mortality that occurred in 2010 because they were placed in 1 m deep water at low flows and did not appear to move. Although there is less uncertainty associated with the mark recapture estimate of adult survival than with the estimate provided by catch curve analysis, this estimate only represents survival over one year of observation at one site, and should be interpreted cautiously in light of these limitations.

Population Viability Analysis

For the 2008 BO, we contracted Dr. Phillip Miller to develop a PVA to evaluate the current status of the population using best-available estimates of key population parameters, and explore the impacts of various flow-related mortality episodes on model population trajectory. Given the new information about fat threeridge mortality at flows above 5,000 cfs, we again contracted with Miller to update the PVA. The information that follows is a summary from the report; refer to Miller (2011b) for a more detailed description of the methods and results. It is important to note that PVAs are sensitive to various assumptions made during model development, all of which can affect the accuracy of the output and conclusions. Rather than place importance on the exact quantitative values, we used these models to provide a qualitative assessment of the species status within the action area, and provide insight on model population trajectory relative to management scenarios.

The female-only stage-structured population matrix model of fat threeridge was updated with more recent data on population size, age/size relationships, time in stage, and stage-specific fecundity and survival rates. The description of the five stages used is given in Table 3.4.1.2.F. Stage classes and associated survival and fecundity estimates were derived either from available fat threeridge data or by using a closely related congener, *Amblema plicata*, and details on these parameters can be found in Miller (2011b). Stage-specific fecundity rates were calculated using sex ratios, gravidity, and length-maternity relationships derived by Haag and Staton (2003) for *A. plicata* in the Sipsey and Little Tallahatchie rivers (Alabama and Mississippi). Survival of glochidia to year 1 was estimated using fat threeridge data available from Gangloff's quantitative sampling in 2008 and 2010. As described above, the new mark-recapture based survival estimate was not available at the time of the PVA update. Similar to Miller (2008), we bounded the adult survival estimate to capture the uncertainty of the estimate. The lower bound was estimated from catch curve analysis of quantitative fat threeridge data collected in 2007, 2008, and 2010. These data were pooled over the three years to account for the influence of variable recruitment (Guy and Brown 2007). The upper bound was an estimate of adult survival of *A. plicata* reported by Hart et al. (2004). The model also included annual environmental variation in demographic rates and demographic stochasticity, and density dependence was included in the form of a carrying capacity. All stochastic population projections were simulated 1,000 times. Each projection extended 50 years, and demographic information was obtained at annual intervals. Confidence intervals on population growth and quasi-extinction rates were not calculated. Instead, uncertainty was evaluated using what we considered to be the best available estimates of the upper and lower bounds of the adult survival rate.

The 50-year trajectory of population size for each of the three adult survival values is shown in Figure 3.4.1.2.D. along with the estimated stochastic population growth rate, λ. λ values less than 1 indicate a population decline, and values greater than 1 indicate an increasing population. The models suggest that that a population with high adult survival (pAD = 0.98, *A. plicata* from Hart et al 2004) may grow by more than 6% per year; whereas, a population with low adult survival (pAD=0.81, *A. neislerii* from catch curve analysis) may decline at a rate approaching 10% per year. Population dynamics were also evaluated from the perspective of risk (i.e., how likely is it that a given population will grow or decline to a certain size). Terminal quasi-extinction gives a probability that a population will be at or below a given threshold at the end of a simulation (50 years) (Figure 3.4.1.2.E.). As expected, under conditions of lower adult survival, there was a 100% probability that the final population size will be below the initial size. The probability of the population declining to zero was negligible within the 50-year timeframe of the simulation; however, the population would not be viable over the long-term if such a low mean adult survival rate persisted. Under conditions of higher adult survival, there was no measurable risk of population decline below the initial abundance.

The ability to generate accurate predictions of population dynamics is limited because model parameters were estimated with varying levels of uncertainty. However, an analysis of the sensitivity of the models to this measurement uncertainty can be used to decide which parameters are most important to the model output. The elasticity of the population growth rate (i.e., the proportional change in λ that results from a proportional change in one or another matrix element) was calculated to directly compare the sensitivity of population growth to changes in any one parameter estimate. The results from this approach to sensitivity analysis indicate the dominance of survival within adult stages (P_i) in determining the final value of population growth rate, with increasing elasticity in larger (i.e., older) adults Figure 3.4.1.2.F. In other words, the results of this modeling exercise suggest that female adult survival has the greatest impact on long-term population dynamics in this species. The relative importance of female adult survival to population growth is consistent with results presented in Haag and Staton (2003) and Hart et al. (2004). These findings highlight the importance of pursuing an accurate and representative estimate of this key population parameter through future research and monitoring. Given that fecundity rates may exhibit very high inter-annual variability, the elasticity analysis may not have effectively assessed the importance of this parameter to population growth rates. Future research should be devoted to the development of an accurate estimate of the fecundity parameter and its expected range of variability.

We suspect the lower bound to the adult survival rate (pAD=0.81) is low because it likely incorporates the low-flow mortality from the extended 2006-2008 drought. Moreover, it is unclear at this time whether the fat threeridge population meets a critical assumption of catch curve analysis, i.e., whether the population exhibits a stable age distribution resulting from constant recruitment and mortality across all age classes. The results from our preliminary mark-recapture study of fat threeridge provides some evidence that adult survival in the Apalachicola River is similar to the estimates of adult *A. plicata* survival in the Upper Mississippi River. Our survival estimate of 0.976 may be somewhat inflated since it does not account for mortality at flows above 5,000 cfs, which we now believe occurs with some frequency. However, we do not expect at this time that such mortality considerably reduces the annual survival rate applicable to the entire population in the action area because about half of the population occurs in the Chipola River, where mortality resulting from low flows does not appear substantial. If the other parameter estimates in the PVA are accurate, and an accurate population survival rate is ~0.98, then the PVA indicates that the population of fat threeridge in the Apalachicola River is stable and probably increasing.

Summary

At the time of the 2008 BO, no fat threeridge were known to occur at bank elevations equivalent to river stages greater than 5,000 cfs due to the drought of 2006-2008. Surveys during 2010 indicated that substantial numbers (23% of the population) recolonized stages above 5,000 cfs. Fat threeridge located in moderately depositional habitat are likely moving in response to changing water levels to maintain an optimal depth or associated habitat parameter. Sediment deposition also likely plays a role in fat threeridge depth distribution. Because fat threeridge readily recolonize elevations above 5,000 cfs, it also now appears that mortality events that occur at flows above 5,000 cfs as a result of water level declines are not anomalies, as we surmised in the 2008 BO. This is the new information that resulted in reinitiating the RIOP consultation. Mortality during these events was highest in the Wewa reach of the Apalachicola River where the main channel populations are the most abundant and bank slopes are shallow. Some mortality occurred in the Chipola River, but it appears to be limited. We estimated this mortality to be about 2% of the known population in 2006-2008, and about 1% of the known population in 2010-2011. Recent evidence suggests that a deep-water component of the fat threeridge population exists; these mussels are largely unsampled; therefore, their proportional contribution to the population is unknown. It stands to reason that this segment of the population is likely at low risk for low-flow induced mortality. Given that our estimates of total population size do not account for this unsampled component, we may have overestimated the percentage of the population in the action area that died during the 2006-2008 and 2010-2011 mortality episodes.

Considering all of the information assembled in this section, the fat threeridge population in the action area appears stable and may be increasing in size. Fat threeridge are abundant in moderately depositional habitat in the Wewa reach and the Chipola River and the population is relatively large. In addition, there is evidence of recruitment in the Wewa and Lower reaches, yet more information is needed to determine the status of recruitment in the Chipola River. Given the uncertaintly associated with PVA model parameters and the trajectory of the population, more research is necessary to support the development of accurate parameter estimates for population modeling. Long term, mark-recapture studies that reveal actual changes in abundance over time could be used to support the development of parameter estimates and validate results of model predictions with empirical observations.

3.4.2 Purple bankclimber

3.4.2.1 Current Distribution in the Action Area

About 23% of the currently occupied range of the purple bankclimber (104.6 river miles) falls within the action area of this consultation, where it is currently known from about 35 locations (Figure 3.4.2.1.A). Purple bankclimber occur primarily in the main channel of the Apalachicola River from the Woodruff Dam (RM 106) downstream to RM 17.7. The species has also been collected in the Chipola River (below Dead Lake), the Chipola Cutoff, Swift Slough, River Styx, and a distributary that flows into Brushy Creek.

Information about current distribution is based on recent collections by Miller, EnviroScience, the FFWCC, the Service, and Gangloff. In these surveys, as in previous surveys of the action area (Brim Box and Williams 2000), bankclimbers were found to be locally abundant at Race Shoals, a long limestone outcropping in the upper Apalachicola River near RM 105, but somewhat rare and sporadic from RM 22 to 103. By far, the majority of individuals collected in the action area are from the upper river. Very few individuals have been collected in the lower Chipola River (below Dead Lake), the Chipola Cutoff, Swift Slough, or the River Styx.

The purple bankclimber is characterized as preferring the deeper portions of main channels, often at depths greater than 3 m (10 ft), in larger rivers (Brim Box and Williams 2000). One exception is a flat area at the north end of Race Shoals, which becomes quite shallow in low flow, where bankclimbers are often found in depths of less than 0.5 m. Because deep-water habitats have not been adequately sampled for listed mussels, we contracted Gangloff to conduct dive surveys in the deeper portions of the Apalachicola and Chipola main channels. This study, which is underway, has found purple bankclimbers in depths ranging from 0.5 to 5 meters (1.6 to16 ft) relative to the water surface (Gangloff 2011 unpub. data). FFWCC surveys near Race Shoals similarly found purple bankclimbers at depth ranges of 0 to 4 m (0 to 13 ft), and most were at depths of 0.6 m (2 ft) or less (FFWCC 2007 unpub. data). Both surveys were conducted when water levels were very low (4,400 and 5,140 cfs, respectively). Gangloff's surveys were conducted during the inadvertent release of less than 5,000 cfs in May and June of 2011.

3.4.2.2 Population Status and Trends in the Action Area

We do not have complete population estimates for the purple bankclimber in the entire action area or sufficient length-at-age data from which to infer population structure, annual survival rates, or year class strength. This is mainly because purple bankclimber occur sporadically and in relatively low numbers, in deeper habitats. For example, no purple bankclimber were collected in the recent quantitative surveys by Gangloff (2011) of near shore habitats at depths less than 2 m, despite collecting over 8,400 mussels. Therefore, much of the available data has typically been qualitative and only catch-per-unit-effort data is available. This qualitative data suggests that the purple bankclimber may be one of the rarest members of the Apalachicola River mussel fauna, as it comprised less than 2% of the total mussels sampled between the years

1996 to 2007 (Miller and Payne 2005; EnviroScience 2006a; USFWS 2006 and 2007 unpub. data).

Surveys by Gangloff in June 2011 provide some quantitative data for the Race Shoals area, the expected location of the majority of the population in the action area. The study sampled near-shore and deep-water habitats along the long limestone outcropping on the left descending bank. Flows were very low (4,400 cfs) at the time of the surveys and a few purple bankclimbers had become exposed just prior to the survey. The study site is approximately 580 m in length and the width of the habitat averaged 141 m, resulting in a total habitat area of about 81,780 m^2. The deep-water habitat comprised about 63% of the total area. Right-bank habitats were not sampled and this habitat is included in the shallow-water habitat estimate. Initially, a dredge was used to sample 0.25 m^2 quadrats in shoreline transects, but proved too time consuming, and a timed search of a discrete area was used instead. For near-shore habitats (<1.5 m deep) 2-m wide linear transects placed perpendicular to the bank were searched, and in deeper water habitats, radial transects (area = 19.5 m^2) were searched. The mean density of purple bankclimbers in near-shore transects was 0.17 m^2 and the mean density in deep-water transects was 0.48 m^2. Extrapolating from these densities across the total area of the shoals produces an estimate of 24,984 bankclimbers in deep water habitats and 5,127 bankclimbers at depths <1.5 m on the left bank, and an estimated 30,111 purple bankclimbers within the survey reach, 95% of which, were in deeper (>1.5 m) portions of the channel. This estimate may vary depending on the density of purple bankclimbers in the unsampled right-bank habitats.

No population estimates are available for other areas of the Apalachicola main channel. Very few individuals have been collected in the lower Chipola (below Dead Lake, the Chipola Cutoff, Swift Slough, or the River Styx. In total, 13 purple bankclimbers were recently collected from these areas altogether.

Recruitment in the species appears to be occurring at very low levels. Only eight relatively small (<100 mm) purple bankclimbers have been collected in the action area recently. Five of these were found during the June 2011 surveys by Gangloff (3 RM 47, 1 Chipola, 1 Race Shoals). Sizes ranged from 29 to 93 mm (Gangloff 2011 unpub. data), and based on known-age individuals (discussed in section 2.3.2), all are probably at least three years old. The lack of young individuals suggests either poor reproductive success or sampling methods that are not suited to detecting juveniles of this species.

Mortality

We have no evidence that purple bankclimber move to avoid exposure. We conducted a purple bankclimber movement study at Race Shoals while flows were less than 5,000 cfs in November and December of 2007. A total of 46 bankclimbers were collected and tagged in the flat upstream portion of the shoal. FFWCC also separately collected and tagged 93 additional bankclimbers in approximately the same location. We and FFWCC returned to this location separately to assess movement of tagged individuals and found no evidence of movement for almost all of the recaptured tagged bankclimbers. A few individuals were relocated less than a foot from their original tagging location, but we later learned that FFWCC may have inadvertently moved these during their sampling. Substrate in these areas consists of a shallow and unconsolidated layer on top of limestone. This firm substrate may explain why many shoal bankclimbers are found lying on their side; once in this position these large mussels are unable to upright or move

Purple bankclimber mortality occurred at several sites in the Apalachicola River and Swift Slough during the low flows of 2006-2007, although the extent of the mortality in 2006 was not adequately quantified. In 2007, when releases were less than 5,000 cfs at the Chattahoochee gage, the Corps implemented surveys to estimate listed mussel mortality associated with the flow reductions. No purple bankclimber were observed to be fully exposed in habitat areas surveyed during the monitoring effort; therefore, the Corps estimated that no purple bankclimber take resulted from the reduction in flow. After the Corps' surveys, the FFWCC found that at least three had died at the shoal in December of 2007 (Hoehn 2007 pers. comm.).

In 2008, we observed a large die-off of Asian clams (*Corbicula fluminea*) at Race Shoals which resulted in dead Asian clams floating into shallow areas where purple bankclimbers were present. This area of the Apalachicola has an extremely high abundance of Asian clams, a species which is intolerant of low DO and high temperatures. As explained in the Water Quality section (3.5.5), the decay of tissue may further reduce DO concentrations during droughts. There may have been some effects associated with poor water quality that resulted in purple bankclimber mortality, however, these effects are difficult to assess. Also, in the summer of 2008, we relocated some of the 46 bankclimbers tagged for the movement study in 2007. Eight had died during this time, although the cause is unknown.

No mortality due to low flows was observed in 2010. A single site visit to the Race Shoals area, when flows were around 5,500 cfs, revealed numerous purple bankclimbers in shallow water, but no exposed or dead individuals were observed. On this visit, as in others, the limestone outcropping was littered with the shells of several species. During the September 2010 visit, we observed dozens of bankclimber and washboard shells that were smashed open. When water levels are low, anglers harvest purple bankclimbers and other species for use as bait.

Purple bankclimber exposures and mortalities occurred in 2011 when releases were inadvertently reduced below 5,000 cfs at the Chattahoochee gage. We made three visits to the Race Shoals area during the period of June 6-16 and found 5 freshly dead purple bankclimbers. Three of these were as a direct result of exposure, and were found very near the water margin. The other two were harvested for bait, either that day or the day before. The Corps provided an estimate of purple bankclimber take based on Gangloff's quantitative study. They estimate that 39 bankclimbers were killed during the June 2011 low-water event. However, this take estimate is based on only one dead individual. Combined, the amount of observed take was six individuals. Since all dead individuals were within the reach of Gangloff's study, we used his population estimate to examine mortality, and estimate that much less than 1% of the population within the reach perished, regardless of which mortality count is used. No other purple bankclimber mortality was observed in the action area in 2011. We did not quantify take on the right descending bank so it is unknown if bankclimbers were exposed on this bank. We observed only two harvested purple bankclimbers during our visits; however, this number may be much higher. Gangloff noted that anglers were very active (10-20 observed every day) during his surveys at the shoals and were using exposed mussels for bait. Although anglers appeared to primarily use *Corbicula*, fractured shells indicated that some native mussels were also used for bait.

Although the population of purple bankclimbers at the shoal is relatively large, the species is apparently rare in the rest of the river and may be experiencing poor recruitment. However, more surveys are necessary in stable, deep water habitats throughout the river to more fully understand the population's status in the river.

3.4.3 Chipola slabshell

3.4.3.1 Current Distribution in the Action Area

About 14% of the currently occupied range of the Chipola slabshell area (13.8 river miles) falls within the action area of this consultation, where it is currently known from about eight locations on the lower Chipola River (downstream of Dead Lake) and from one location on the Apalachicola main channel (Figure 3.4.3.1.A). As described in section 2.5, a single individual was recently collected by Service biologists in the Apalachicola River main channel, about 0.5 mi. downstream of the Chipola Cutoff, and is the first known occurrence of Chipola slabshell in the Apalachicola main channel. However, the species was not detected during the many surveys conducted in this reach in recent years, and we do not believe that a reproducing population occurs in the main channel.

3.4.3.2 Population Status and Trends in the Action Area

We do not yet have enough data to make an accurate population estimate for the Chipola slabshell in the action area. The recent survey conducted by Gangloff (see section 3.4.1.2. for methods) provided a population estimate of 2,645 slabshell in bank margin habitats <2 m deep. This estimate, however, is based on only 10 individuals collected at two sites. Individuals were collected from depths >0.5 m in 2008 when flows were low and at depths > 1 m in 2010 when flows were higher.

Another recent survey discovered a relatively large Chipola slabshell population at a new location. Prior to a dredging project at Land's Landing boat ramp on the Chipola River main channel, we conducted a brief, qualitative survey for listed mussels. A total of 21 Chipola slabshell were detected in the small basin. These are relatively high numbers, and noteworthy considering there is an active boat ramp nearby. It is possible that this species utilizes slow-flowing habitats more than previously understood.

Both studies found a good variation in sizes. In the quantitative survey by Gangloff, lengths ranged from 22.1 to 56.4 mm; and individuals from the Land's Landing location ranged from 31.0 to 60.5 mm. We do not have length-at-age data for Chipola slabshell from which to infer the age of these mussels, however, presence of small individuals and a variety of sizes likely indicates that Chipola slabshell are reproducing.

We found no evidence of Chipola slabshell mortality at flows above 5,000 cfs during surveys of the Cutoff during 2006, and no mortality was reported in the Chipola River in 2006 or 2007. In addition, none were found exposed or dead in any of the recent low water events occurring in 2010 or 2011, even when flows were less than 5,000 cfs in 2011. The Corps estimated that no Chipola slabshell take resulted from the reduction in flows below 5,000 cfs in 2011.

The lack of mortality may be attributed to its selected depth and ability to move. Members of the genus Elliptio have smooth and relatively thin shells, shell characteristics associated with an ability to move more easily (Watters 1994). Another factor that may explain the lack of mortality is that bank slopes are generally >20% grade in the Chipola River. As explained in section 3.4.1.2, we believe these higher slopes also explain why little fat threeridge mortality has been observed in the Chipola River. Finally, water levels may not drop as quickly or as far in the lower Chipola River as flow declines are attenuated by discharges from the Chipola main channel.

3.5 Status of the Critical Habitat within the Action Area

This portion of the environmental baseline section focuses on the designated critical habitats for the listed species, describing what we know about the physical and biological features that are essential to the species' conservation within the action area.

The entire length of the Apalachicola unit designated as critical habitat for the fat threeridge and purple bankclimber is within the action area. The downstream-most 13.8 miles of the Chipola unit designated as critical habitat for the fat threeridge, purple bankclimber, and Chipola slabshell is within the action area. The action area contains all of the PCEs that we described as features of occupied critical habitat that are essential to these species' conservation. The following is a summary of what is known about the status of these PCEs in the action area.

3.5.1 Channel Stability

> *A geomorphically stable stream channel (a channel that maintains its lateral dimensions, longitudinal profile, and spatial pattern over time without an aggrading or degrading bed elevation);*

Studies of freshwater mussels have found that mussel distributional patterns are influenced by river bed stability (e.g. Vannote and Minshall 1982; Strayer and Ralley 1993; di Maio and Corkum 1995). Generally, mussels can withstand some changes in the river bed due to floods by burrowing deeper into the bed (di Maio and Corkum 1995). On the River Kerry in Scotland, Hastie et al. (2001) found that a large number of mussels were moved and killed following a flood. However, upon further inspection of previously surveyed sites, they found that most of the mussel population had survived, and that mortality was highest in geomorphically unstable portions of the river.

In section 3.2 we summarized observed channel morphology changes in the Apalachicola River. Entrenchment following dam construction and various activities associated with the federal navigation channel, such as dredging, snagging and the construction of dike fields, changed channel stability, and likely reduced habitat availability for the fat threeridge, as it is now rare in the upstream-most 30 miles of the river. In the RM 35-50 reach channel instability related to water diversion into the Chipola Cutoff and recovery from maintenance dredging may be affecting mussel habitat and contributing to stranding, especially in Swift Slough, which occurs in an area that required regular maintenance. We believe this reach remains unstable and susceptible to substantial changes as the river reaches equilibrium relative to the Chipola Cutoff. However, most of the river does not likely share this characterization. The Corps' dredging records show that since 1992, 84.1 miles of the 105.4 miles between Woodruff Dam and RM 1.0 received no dredging, suggesting that these portions of the river transport the sediment they receive without substantial aggradation.

The overall amount of stable riverine habitat available for the listed mussels varies from year to year due to the dynamic nature of the river. Our observations in the RM 40-50 reach in 2010 and 2011 indicate that the moderately depositional habitat downstream of large point bars has shifted downstream since 2007, which is consistent with actively meandering rivers. As a meander bend of the channel migrates downstream, the point bar upstream of the bend moves with it. The upstream end of the bar aggrades while new moderately depositional habitat is created at the downstream end of the bar. It appears that the loss and creation of new habitat is happening at relatively the same rate, but geomorphic monitoring would be necessary to address this question.

Many changes in the channel affect individual mussels, but conservation of the species depends on sufficient stable instream habitat. Strayer (1999) suggested that mussels might generally be found in areas with stable habitat at flows with 3 to 30 year recurrence intervals. Morales et al. (2006) developed a model to predict substrate stability that coincided with reported mussel locations. They noted that large areas that seemed stable under low flow conditions have active sediment motion at high and medium flows that would render the locations unsuitable for mussels. They hypothesized that annual peak flows most often limit the spatial distribution of freshwater mussel communities. The concepts developed by Morales et al. suggest to us that the moderately depositional areas that support fat threeridge mussels remain stable during high flows. Recent survey data documenting fat threeridge and purple bankclimber mussels in stable deep-water habitat (Gangloff unpub. data 2011) suggests that some unknown proportion of deep-water habitat also remains stable under high flows. It is possible that the observed changes in annual peak flows have reduced the available stable habitat, but the relative amount is unknown. Additional channel morphology and sediment transport studies of the Apalachicola are needed to estimate the amount of stable mussel habitat and how it changes with time and with changes in flow regime.

The river channel in Unit 8 (Apalachicola River) appears to be continuing to change (Light et al. 2006; Price et al. 2006) as meander bends migrate down-valley. At this time, we are unable to quantify the amount of stable habitat or the rate of change that might alter the status of the mussel beds found in the the river. Based on the species persistence in the river during past periods of instability affecting the entire river, we believe that sufficient stable instream habitat exists in the main channel of Unit 8 for the conservation of the species. There is no specific information available for Unit 2 (Chipola River); however, we are unaware of any factors that may change channel stability and limit the ability of the critical habitat to function for the conservation of the species.

3.5.2 Substrate

A predominantly sand, gravel, and/or cobble stream substrate.

We describe the substrate and habitat preference for all three mussel species in section 2.4. As described above, mussels need stable substrates. Because substrate stability and channel stability are inter-related, the substrate in the critical habitat units is affected in the same manner as described in the section 3.5.1. More information is needed to quantify the amount of stable substrate and the rate of change that might affect the quality of mussel habitat. Based on the current distribution of mussels and the new data collected about stable substrate in deep-water (Gangloff unpub. data 2011), we believe that substrate condition and stability in units 2 and 8 are sufficient for the conservation of the species. We are unaware of specific substrate alterations that may limit the ability of the critical habitat to function for the conservation of the species.

3.5.3 Permanently flowing water

Permanently flowing water.

The main channel of the Apalachicola River has consistently contained permanently flowing water, but loop streams, backwaters, tributaries, and distributaries require specific discharges to retain connectivity to the main channel. Flowing water is important because it transports food items to the sedentary juvenile and adult life stages, provides oxygen for mussel respiration, and with enough depth, it provides protection from terrestrial predators. Flowing water is also likely essential for reproduction through suspension of glochidia or conglutinates (O'Brien and Williams 2000). Above normal flows can affect overall recruitment and where juvenile mussels settle (Hardison and Layzer 2001). The magnitude and duration of flows can have a long-term effect on population dynamics (Vannote and Minshall 1982; di Maio and Corkum 1995).

This constituent element is also necessary for host fishes that spawn in the floodplain. According to Light et al. (1998; 2006) and analyses presented in this BO (see section 3.3 Flow Regime Alterations), the frequency and duration of main channel-floodplain disconnections has increased over time, and these disconnections are exacerbated by low flows associated with droughts (Walsh et al. 2006). There has been about a 25% reduction in floodplain habitat available to spawning fish during April and May. See section 3.5.5 for additional analysis regarding abundance of host fish.

Mussels will best survive and reproduce in specific areas that consistently provide all of the PCEs, but do not necessarily persist permanently in any one area given the dynamic nature of the riverine environment. Interrupted flow due to the accumulation of sediment in the bed of Swift Slough recently led to substantial mortality of listed mussels during periods of low-flow in the Apalachicola River (see section 3.4.1.2). Stream bed aggradation in Swift Slough signals the need for special management of the channel stability PCE in at least the Swift Slough portion of the Apalachicola River. Because the area at the inlet of Swift Slough continues to aggrade, we do not know the exact current flow necessary to keep Swift Slough connected to the main channel. A recent site visit indicates that it was still connected at a Wewa gage height of 11.65, which corresponds to a Chattahoochee flow of around 5,460 (Light 2012 pers. comm).

Because mussels inhabit the banks and are often found in shallower areas, permanently flowing water is also an issue in the main channel, especially when flows decline and there is an obstacle to movement such as in a shallow sand bar or low site slope. As described in section 3.4.1.2, the elevations where mussels are found in any particular year are likely dependent upon hydrological conditions prior to the survey. Therefore, we expect that continued mortality resulting from low flows will occur at flows above 5,000 cfs when hydrologic conditions allow for movement of mussels into higher bank elevations. We also continue to expect mortality at flows less than 5,000 cfs if composite storage reaches the drought zone and the minimum flow is 4,500 cfs.

Although the low flows in 2006-2008 and 2010-2011 have resulted in areas without permanently flowing water that exhibited mussel mortality, we do not believe that the low flows have permanently limited the ability of the designated critical habitat to function for the conservation of the species in Unit 8 or Unit 2. Our data illustrate that mussels recolonize these areas (including Swift Slough), and the habitat is not permanently lost.

3.5.4 Water quality

> *Water quality (including temperature, turbidity, dissolved oxygen, and chemical constituents) that meets or exceed the current aquatic life criteria established under the Clean Water Act (33 U.S.C. 1251-1387).*

A wealth of evidence supports the dependency of the mussels on good water quality. As animals with limited mobility, mussels must tolerate the full range of water quality parameters to persist in a stream. Most mussels are considered sensitive to low dissolved oxygen (DO) levels, high temperatures, and unionized ammonia (Fuller 1974; Johnson 2001; Sparks and Strayer 1998; Augspurger et al. 2003). The recent Florida Department of Environmental Protection (FDEP) Water Quality Assessment Report for the Apalachicola River system described the river's water quality (FDEP 2005). Although based on a limited number of water quality sampling stations, the basin has relatively good water quality. This has been attributed to a low urban and industrial growth rate, the large floodplain, and large areas of forested public lands (FDEP 2005).

Although the basin generally has good water quality, the 2005 Water Quality Assessment identified potential impairments in the action area for biology, coliforms, DO, turbidity and potentially unionized ammonia and other nutrients (FDEP 2005). As a result, several segments of the Apalachicola River area are included on the Verified List of Impaired Waters that failed to fully meet their designated uses. The sources of the nutrient loadings may be related to the violations of the water quality standards observed for coliforms, DO, and unionized ammonia (FDEP 2002). Elevated coliform bacteria counts are not known to harm freshwater mussels; however, elevated unionized ammonia and low DO are associated with adverse effects to fish and mussels (Secor and Niklitschek 2001; Fuller 1974; Sparks and Strayer 1998; Johnson 2001; Augspurger et al. 2003). Mercury-based fish consumption advisories have been issued for portions of the river, and organochlorine pesticides have previously been found at levels that have exceeded chronic exposure criteria for the protection of aquatic life (FDEP 2002; Frick et al. 1998), but these have not been linked to impacts on these species in the Apalachicola River to date. Both point and non-point sources of pollution have reportedly contributed to these water quality impairments in the Apalachicola River (FDEP 2005).

State water quality assessments are based on Florida's water quality standards. Generally, State standards, adopted to be consistent with or more stringent than the U.S. Environmental Protection Agency (EPA) water quality criteria, generally represent levels that are safe for mussels. The currently available data indicate that most numeric standards for pollutants and water quality parameters (for example, dissolved oxygen, turbidity and pH) represent levels that are essential to the conservation of these species; however, current EPA criteria for copper and ammonia are not protective of mussels (USFWS 2007b). The Service is currently in consultation with the EPA to evaluate the protectiveness of some criteria for threatened and endangered species and their critical habitats as described in the Memorandum of Agreement that our agencies signed in 2001 (66 FR 11201, February 22, 2011).

Other factors that can episodically influence the attainment of water quality standards include droughts, heavy rains and resulting nonpoint-source runoff from adjacent land surfaces (e.g., excessive amounts of sediments, nutrients, or pesticides), errant point-source discharges from municipal and industrial wastewater treatment facilities (e.g., excessive amounts of ammonia, chlorine, and metals), accidental spills, or unregulated discharge events. For this reason, the State's water quality monitoring program includes measures for monitoring and enforcement to achieve attainment of designated uses (meeting water quality standards) in State waters. Of particular relevance for this BO is the influence of drought conditions when flows are depressed and pollutants are more concentrated.

Most mussels are considered sensitive to low DO levels and high temperatures (Fuller 1974; Johnson 2001; Sparks and Strayer 1998). Higher water temperatures also result in lower dissolved oxygen potential. Walsh et al. (2006) reported that the middle reach of the main channel of the Apalachicola River had relatively low DO, and the lowest yearly DO values occurred during mid- to late summer (July to September) when temperatures were highest and flows were lowest (Walsh et al. 2006). The authors also reported a negative relationship between DO and decreased flow and connectivity in distributaries to the main river.

Sensitivity to low DO and high temperature may be particularly pronounced during drought. A study conducted in the Flint River basin during the 1999-2002 drought found there was accelerated mussel mortality as DO levels dropped below 5 mg/L, and DO levels between 0 and 3 mg/L resulted in variable mortality up to 76% (Johnson et al. 2001; Golladay et. al 2004). We have limited water temperature and DO data from recent droughts in 2006-2008 and 2010-2011, and it varies by location. Water quality data from Swift Slough indicate that DO and water temperature varied in isolated, stagnant pools from 0.9-6.7 mg/L and from 20.9-31.1°C (70-88°F), respectively (FFWCC 2007 unpub. data). Swift Slough is relatively shaded and receives ground water input. In shallow back-water areas on the main channel, DO was relatively high when measured in the middle of the day (7.7 mg/L to 7.9 mg/L); however, water temperature was very high (33-41°C (92-106°F) (FFWCC 2007 unpub. data; USFWS 2007 unpub. data). Mid-day DO was also high (7.4-11.0 mg/L) in isolated pools containing purple bankclimbers on Race Shoals at RM 105, but water temperatures were cooler ranging from 21-28°C (70-83°F) resulting from observed ground water seepage. Our temperature records from the summer of 2011 showed a substantial difference between water and air temperatures experienced by mussels during the 2011 exposure event. Water temperatures were between 27-32ºC (81-90°F) during the study, but air temperatures (experienced by mussels exposed on river banks) reached daily maximums of approximately 38ºC. Mussel mortality that may have resulted from low DO and/or high temperatures was observed in the water at all of these locations.

Low DO concentrations during droughts may also be further reduced in response to the decay of soft organs of dead mussels. For instance, the invasive Asian clam (*Corbicula fluminea*) is intolerant to drought conditions and further exacerbates hypoxic conditions (McMahon 1979; Johnson et al. 2001). In the presence of the Asian clam, DO levels are lowered at an accelerated rate, and may contribute to increased competition amongst unionids for limited supplies of DO (Johnson et al. 2001). Many study sites along the Apalachicola have extremely high abundance of Asian clams, and low DO levels during drought conditions are likely to be exacerbated by mortality of Asian clams. We observed this phenomenon at Race Shoals where a summer die-off resulted in massive numbers of dead, floating Asian clams being washed into shallow areas where purple bankclimbers were present (USFWS 2008 unpub. data). FFWCC (2011) noted a personal observation from Greg Zimmerman (EnviroScience) where an Asian clam die-off appeared to be associated with suspected poor water quality that may have resulted in purple bankclimber mortality at Race Shoals.

Spawning may also be affected by high water temperatures, as seen in 2006 when fat threeridge were observed expelling glochidia in the absence of fish hosts at high water temperatures. The fat threeridge spawning period begins when water temperatures are 23°C ± 1.5°C (Brim Box and Williams 2000). USGS has recorded water temperature intermittently at the Chattahoochee gage. Records were available from 1974-1978 and 1996-1997, which range from average to high flow years. Using these data, the mean date by which water temperature rises to 21.5°C was May 1 (range: April 5 to May 14) and to 24.5°C was May 22 (range: April 14 to June 30). Some spawning in 2006 and 2007 was probably still underway when water temperatures in the very shallow areas exceeded 30°C, which may have resulted in reproductive failure in some individuals.

Although low DO and high temperatures do occur in the action area during periods of low flows, we do not believe that these temporary changes in water quality have permanently limited the ability of the designated critical habitat to function for the conservation of the species in Unit 8 or Unit 2.

3.5.5 Fish hosts

> *Fish hosts* (*such as native basses, sunfishes, minnows, darters, and sturgeon*) *that support larval life stages of the mussels.*

The distribution and diversity of unionids is strongly related to the distribution and diversity of fish species (Watters 1992; Haag and Warren 1998). Bogan (1993) identified the dependency of mussels on fish hosts as one of several contributing causes in the extinction of several unionid species worldwide. Host fish availability and density are significant factors influencing where certain mussel populations can persist (Haag and Warren 1998), and simulations of fish-mussel interactions indicate that mussel populations are extirpated if a threshold host fish density is not exceeded (Watters 1997). Challenging this threshold density, riverine fish populations in the Southeast have been adversely affected by the same habitat alterations that have contributed to the decline of the mussel fauna (Etnier 1997; Neves et al. 1997; Warren et al. 1997). As described by Dutterer (2011), the structure of biotic communities in lotic (flowing) environments is strongly influenced by streamflow (Poff and Ward 1989; Poff et al. 1997), including species distribution (Stanford and Ward 1983, Rogers et al.2005), growth (Sammons and Maceina 2009), reproduction (Smith et al. 2005), and mortality (Tramer 1978). A growing body of research has described aquatic ecosystem responses to modified streamflows (Murchie et al. 2008).

Successful host fish trials have been conducted for all three mussels (see section 2.3.3). Potential host fishes for these three mussel species that occur in the action area include the weed shiner, bluegill, redear sunfish, redbreast sunfish, largemouth bass, eastern mosquitofish, blackbanded darter, and Gulf sturgeon. With the exception of the fat threeridge, it is not known whether these species are host generalists or specialist. The fat threeridge is considered a host-fish generalist. Watters (1997) found that generalists attained higher population sizes than specialists when host fish density was high, but declined when host fish density declined. However, Haag and Warren (1998) found that densities of host-generalist and host-specialist mussels with elaborate host-attracting mechanisms were independent of host-fish densities.

The FFWCC monitored the fish assemblage in the main channel of the Apalachicola River at four fixed stations from 1984-1993 and 2000-2003. Data from these boat electrofishing surveys were taken from the summary provided by Walsh et al. (2006). One of the four monitoring stations was in the middle reach of the Apalachicola River (RM 37.5 to 40.9). Because this general area of the Apalachicola River has the highest main channel abundance of the fat threeridge, we focused on data from this station. All five known fat threeridge host fish species were collected here from 1984-1993 and 2000-2003. When data from all years are combined, all fat threeridge host fish were considered dominant species. The weed shiner was the most abundant species collected (28.2% of the total catch), and bluegill was the third most abundant species collected (10.4%). The blackbanded darter was rarely encountered (0.7% composition), but that is not surprising given the collection method, as small benthic fishes are difficult to capture via electrofishing in a large river. These data indicate that known fat threeridge host fish are present in the main channel in areas where the mussels occur, and, with the possible exception of the blackbanded darter, they comprise relatively large proportions of the fish assemblage (particularly weed shiners and bluegills).

Gulf sturgeon are also known to occur in the main channel of the Apalachicola River. Although the population is relatively small, it is currently believed to be slowly increasing relative to levels observed in the 1980s and early 1990s (Pine and Allen 2005). Their primary spawning site at Race Shoals (RM 105) also has the largest known purple bankclimber population of about 30,000 individuals (see section 3.4.2.2), potentially resulting from frequent contact with host fish.

Although mussels are not generally found in floodplain habitats, their host fish species are likely to use floodplain habitats, and as previously mentioned, mussel population viability is likely dependent on fish host population density. Reproduction of many fishes is intricately tied to the floodplain, and alteration of flow regimes can affect reproductive success, year-class strength, growth, condition, and other life-history attributes (Guillory 1979; Welcomme 1979; Kilgore and Baker 1996; Raibley et al. 1997; Gutreuter et al. 1999; Ribeiro et al. 2004). For example, the largemouth bass is known to use seasonally inundated floodplain habitats for spawning and rearing (Kilgore and Baker 1996). Walsh et al. (2006) documented 64 species of fishes (including all five known fat threeridge host species) using floodplain habitats in the middle reaches of the Apalachicola River and demonstrated the importance of these habitats for spawning adults and young-of-the-year fishes.

The FFWCC and USGS (Walsh et al. 2006) monitored the fish assemblage in floodplain habitats (*i.e.,* loop streams, backwaters, tributaries, and distributaries) in the middle reach of the Apalachicola River using backpack and boat electrofishing from 1983-1985 (FFWCC) and 2001-2004 (USGS). Results of sampling indicate that bluegill, largemouth bass, and redear sunfish were common in Poloway Cutoff, Iamonia Lake, Florida River, and River Styx. Weed shiner and blackbanded darter were not detected at these locations by the FFWCC in 1983-1984. From 2001 to 2004, bluegill, weed shiner, and largemouth bass were common. Redear sunfish and blackbanded darter were not as common, but they were collected.

Results from Walsh et al. (2006) confirm that three components of the hydrologic cycle are especially important for Apalachicola River fishery resources: the timing, extent, and duration of floodplain inundation immediately preceding, during, and following the spawning, early growth, and survival phases. For instance, young-of-year bluegill and weed shiners were collected in the floodplain over an extended period of time (March to September), indicating prolonged spawning periods. These species are characterized as floodplain exploitative species, which often have breeding seasons that extend well beyond the time of spring flooding (Ross and Baker 1983; Walsh et al. 2006). Therefore, flow connectivity for some portion of the floodplain or adjacent shallow-water, main-channel habitat may be beneficial to fish reproduction in the summer months, beyond the typical spring spawning months. Results of analyses presented in section 3.3.2 indicate that floodplain connectivity is substantially lower since the construction of dams in the ACF Basin, due primarily to channel morphology changes.

A subsequent Apalachicola River assessment by Dutterer et al. (2011), further established that better reproductive years for host fish species were related to higher flows for river influenced habitats, as previously was reported for rivers (Bonvechio and Allen 2004; Smith et al. 2005) and large river floodplain systems (Raibley et al. 1997; Janac et al. 2011). In their report they compared multiple years of fall electrofishing for largemouth bass (sampled 2003-2010), redear sunfish (2005-2010), and spotted sucker (2005-2010) to spring and summer river flow data. Results showed a positive, significant relationship between fish recruitment (measured by age-0 catch in fall) and spring-summer discharge measures, but were less conclusive for back-calculated age-0 catch rates or total length comparisons. The conclusions further supported the findings of Walsh et al. (2009) showing the interconnection of fish recruitment, streamflow, and floodplain inundation with fish community health in the Apalachicola River. In the Walsh et al. (2009) report, extensive use of floodplain habitat by larval stream fish during spring and summer was shown, and Pine et al. (2006) reported high use of inundated floodplain habitat by adult stream fish that was coincident with appearance of larval fishes in the floodplain. Combined, these results provide evidence that floodplain connectivity provided by higher river flows is important for stream fish communities in the Apalachicola River (Dutterer et al. 2011).

Additional decreases in floodplain connectivity may further contribute to decreases in productivity of several species of fish (Kilgore and Baker 1996; Raibley et al. 1997; Walsh et al. 2006), including some that serve as hosts for the listed mussels. However, the effect to the critical habitat and listed mussels is unknown, as the relationship of fish host densities to mussel densities is unknown at this time.

3.6 Factors Affecting Species Environment within the Action Area

This section describes factors affecting the environment of the species or critical habitat in the action area. The environmental baseline includes state, tribal, local, and private actions already affecting the species or that will occur contemporaneously with the consultation in progress. Related and unrelated federal actions affecting the same species and critical habitat that have completed formal or informal consultation are also part of the environmental baseline, as are federal and other actions within the action area that may benefit listed species or critical habitat. The following actions have influenced over time to some degree the environment of the listed species in the action area, and these influences are reflected in the flow regime, the channel morphology, and other physical and biological features discussed previously as the baseline for this consultation.

3.6.1 Related Federal Actions

3.6.1.1 Navigation Channel Maintenance

The ACF navigation project consists of a 9- by 100-ft navigation channel along 107 miles of the Apalachicola River between the Gulf Intracoastal Waterway and Jim Woodruff Lock and Dam. From there the navigation channel extends 155 miles up the Chattahoochee River to Columbus, Georgia, and Phenix City, Alabama, and 28 miles up the Flint River to Bainbridge, Georgia. Jeanne (2002) summarized the Corps' history of activity associated with navigation on the Apalachicola River, which began with clearing obstructions to navigation in the river in 1832. The first navigation improvement project was authorized in 1873. At that time, work began on jetties and wing dams to control sand and gravel bars, snag removal, and rock blasting to widen and deepen shoals. Snags were cleared annually on the Apalachicola River to provide for a channel 100 ft wide by 6 ft deep at low water. In 1874, the Corps bypassed six miles of the main channel by widening and straightening an alternate channel through the River Styx and Moccasin Slough.

By 1881, the Corps recognized that these various attempted improvements to navigability in the basin were temporary fixes in the highly dynamic alluvial river system (Jeanne 2002). Dredged areas filled in more rapidly than anticipated, especially in channels near the mouth of the river. This "excessive silting" eliminated the town of Apalachicola from consideration as the area's deepwater port (Jeanne 2002). Despite these difficulties, a federal navigation project on the Apalachicola has continued for over 100 years, during which several major federal reservoir projects were authorized and constructed, all of them linked in some way to the navigation project.

According to the Corps' Information Paper on Navigation on the Apalachicola River (see Mobile district website) the controlling depth for navigation has often been less than the authorized 9 ft channel during a large portion of the normal low-flow period of summer and fall. The original design of the project estimated that a discharge from Jim Woodruff Dam of 9,300 cubic ft per second (cfs) together with dredging would provide a 9-ft channel; however, this discharge has increased over time due to channel degradation and a lack of adequate dredged material disposal capacity. In the late 1980s, the Corps developed a technique to provide for a planned period of navigation called a Navigation Window. Water was temporarily stored in West Point Lake, Walter F. George, and Lake Seminole and released over a 10-day to two week period at a rate to provide for economically navigable depths (at least a 7.5-ft channel) in the Apalachicola River. This technique was employed beginning in 1990 and continued throughout the decade with increasing frequency and discharge over time, depending upon the condition of the dredged channel. With increased water supply and recreational demands in the upstream reservoirs, fluctuations of reservoir levels necessary to support navigation window releases have become increasingly controversial.

The navigation channel on the Apalachicola River was last dredged in 2001, but the dredge ran aground due to low flow, and the job was not completed. The last complete cycle of dredging a 100-ft by 9-ft channel occurred in 1998 (in 1999, dredging was discontinued in the middle of the dredging season due to lack of dredged material disposal capacity). In 2005, the State of Florida denied the Corps' application to renew its certification under section 401 of the Clean Water Act for maintaining the navigation channel. In July of 2006, the Corps concurred with the decision to defer dredging of the subject project in light of the permit denial. Although navigation remains an authorized purpose for the ACF system, the ability to provide a navigational channel is limited to releases from storage to provide a 7- or 9-ft channel. In the past, releases to support navigation were a principal motivation for augmenting river flow; however, the Corps maintains that there is not enough water to consistently provide these releases. Unless operations for other purposes are adjusted to compensate or substitute for the role of navigation, its absence will most likely result in generally higher or more stable reservoir elevations, and in lower river flows than have occurred historically (see section 4.2.2 "General Effects on the Flow Regime").

3.6.1.2 Other Authorized Reservoir Purposes

In addition to navigation, the ACF federal dams and reservoirs are authorized for several other purposes, including flood control, hydropower, water supply, water quality, recreation, and fish and wildlife conservation. Hydropower generated at the ACF projects is marketed through the Southeastern Power Administration (SEPA), which has contracts with power customers. All project purposes must share the water resources within the conservation pool of the reservoirs. Under the Water Supply Act of 1958, the Corps may enter into contracts for storage with municipal and industrial water users. There are several water supply contracts in the ACF that were intended to compensate the municipalities for the inundation of their existing intakes on the river. Other than these contracts, there are currently no water supply contracts in the ACF basin – previous contracts were allowed to expire in 1989-1990 and have not been renewed due to ongoing litigation. The municipalities are currently withdrawing under the terms of the expired contracts under water withdrawal permits issued by the State of Georgia. No allocation of storage in the upstream reservoirs has been made in support of water supply, and no contracts from the Corps authorize water withdrawals or provide for storage in support of water supply. However, the Corps is currently under court order to determine the extent of its authority to support water supply at Lake Lanier. Any authority the Corps possesses to support water supply would require NEPA compliance and require section 7 consultation before it could be implemented. Water storage contracts do not authorize use of the water, *per se*, only use of the reservoir storage that could provide a source of water supply.

Each of these authorized purposes receives operational consideration, and the operational decisions stemming from such consideration affect how basin inflow is stored and released from the dams. The releases from Woodruff Dam are the downstream end result of all of these decisions, for which the action evaluated in this consultation provides the sideboards of a minimum flow and a maximum fall rate schedule relative to basin inflow and composite storage. The Corps' actions associated with the specific purposes listed above have not undergone the consultation for effects to listed species in the Apalachicola River. Significant changes in any operating procedures that would appreciably alter the effects analysis of this BO would require reinitiation of this consultation.

3.6.2 Unrelated Federal Actions

The Corps administers section 10 of the Rivers and Harbors Act and section 404 of the Clean Water Act. These permit programs regulate dredge, fill, and construction activities in waters of the United States. Construction activities regulated by the permit programs include: agricultural, municipal, rural, and industrial water intakes; residential, marina, and recreational developments; storm-water and waste-water outlet works; cable, pipeline, and transmission line crossings; bridges; piers; docks; navigational aids; platforms; sand and gravel operations; small dams for recreation and/or water supply; and bank stabilization projects. From 1992 to 2007, four new reservoirs have been constructed in the ACF under these permit programs, including Lake McIntosh (Fayette County, GA), Griffin Reservoir (Pike County, GA), Yahoola Creek Reservoir (Lumpkin County, GA), and Shoal Creek Reservoir (Clayton County, GA).

The National Pollutant Discharge Elimination System (NPDES) permit program authorized by the Clean Water Act regulates point-source discharges of pollutants into waters of the United States. Point sources are discrete conveyances such as pipes or man-made ditches. The USEPA oversees the NPDES program, but the States of Alabama, Florida, and Georgia, have each been authorized to administer the permitting process.

All these unrelated Federal actions will be assessed by the Federal agencies to determine if consultation under the Act is required. At this point, the collective effects of these actions are relatively minor as compared to the Corps operations of the reservoirs of the ACF. Nevertheless, they are part of the body of activities that affect listed species in the action area.

3.6.3 Contemporaneous Non-Federal Actions

Water use in the basin is regulated independently by each of the three states within their boundaries. Water use in Alabama and Georgia affects basin inflow to Woodruff Dam, which affects the Corps' operations of the federal reservoir projects. Water use in Florida, with the possible exception of water use in Jackson County along the west side of Lake Seminole, does not affect the Corps' operations, but may influence flow downstream of Woodruff Dam. As is addressed later in this document, historical and ongoing water use, including that for agriculture, industrial and municipal uses, has a substantial impact on the availability of water for use by the Corps in their reservoir operations.

3.7 Tables and Figures for Section 3

Table 3.4.1.1.A. Results of the fat threeridge habitat and quantitative depth distribution surveys conducted in moderately depositional habitat by Dr. Michael Gangloff in the summer of 2010.

River Reach	Number of Sites Surveyed	Number of Habitat Sites Quantified	Total Number of Habitat Sites	Total Habitat Length (ft)	Mean Site Width (ft)	Available Habitat (acres)	Population Estimate	% of Population per Reach	% of the Habitat per Reach
Upper (>RM 50)	9	3	52	35,805	34	28	43,949	4%	31%
Middle (RM 50-40)	3	3	25	11,133	41	11	405,685	35%	12%
Lower (<RM 40)	6	3	32	25,149	34	20	138,282	12%	22%
Chipola*	7	3	66	37,774	36	31	556,436	49%	35%
Totals	25	12	175	109,861	145	90	1,144,352		

*Only includes the Chipola River downstream of Dead Lake and the Chipola Cutoff

Table 2.4.1.1.B. Results of all of Dr. Michael Gangloff's quantitative depth distribution surveys conducted in moderately depositional habitat from 2008-2011.

River Reach	Number of Sites Sampled	Average Fat Threeridge Density (m^2)	Total Number of Habitat Sites	Total Habitat Length (km)	Sampled Habitat Length (km)	% of Habitat Sampled	Population Estimate of Sampled Habitat	Projected Number of Fat Threeridge	Percent of Population in Each Reach
Upper (> RM 50)	10	0.530	52	10.91	2.82	26%	5,767	22,313	3%
Middle (RM 50-40)	12	3.928	25	3.55	2.16	61%	115,928	190,530	23%
Lower (< RM 40)	7	1.417	32	7.67	1.55	20%	14,220	70,367	9%
Chipola*	10	7.874	66	11.51	1.27	11%	59,897	542,846	66%
Totals	39	3.396	175	33.64	7.80		195,813	826,056	

*Only includes the Chipola River downstream of Dead Lake and the Chipola Cutoff

Table 3.4.1.2.A. Results from quantitative sampling of fat threeridge for a population estimate in Swift Slough from 3 August 2006 to 7 August 2006.

Reach	Start (m from inflow)	End (m from inflow)	Est. Density (m2)	Est. Abundance	90% CL
4	200	250	4.407	1983	1332-2952
8	400	450	0.957	431	221-840
15	750	800	1.431	644	206-2009
27	1350	1400	0.20*	90	-

*No fat threeridge were detected in these quadrats. 0.20 is a conservative estimate of density at 90% confidence based on non-detection of species using 45 quadrats (EnviroScience 2006b).

Table 3.4.1.2.B. Summary of USFWS survey results from all locations sampled between 14 June 2006 and 28 July 2006. Equivalent discharge (cfs) at the Chattahoochee gage was calculated using USGS stage-discharge relationships (Light et al. 2006) and represents the discharge occurring during mussel sampling at the site. "ND" indicates that no data is available. We did not collect information on the number of dead and exposed listed species at site Z142 because this was the relocation site.

Site	Z142	Z141	C155	C152	Z203	Z213	Z218	C157	C156
Stream	Apalachicola	Apalachicola	Apalachicola	Apalachicola	Swift Slough	Swift Slough	Swift Slough	Chipola Cut	Chipola Cut
Navigation Mile	43.7	44.3	46.8	48.3	40.3	40.3	40.3	0.92	0.47
Mean Daily Stage at Wewahitchka Gage	12.55	12.55	12.55	12.55	12.6	12.6	12.6	12.47	12.47
Equivalent Site Discharge at Chattahoochee	6400-6500	7100-7200	6400-6500	6400-6500	6500-6600	6500-6600	6500-6600	6300-6400	6300-6400
Effort (min)	50	45	30	45	45	45	45	45	99
Number of Listed Species	841	91	84	12	110	14	10	63	62
Number of *Amblema neislerii*	841	91	84	12	108	14	10	63	61
Number of *Elliptoideus sloatianus*	0	0	0	0	2	0	0	0	1
Number of Dead Listed Species	ND	75	7	2	21	3	3	12	13
Number of Exposed Listed Species	ND	83	2	0	19	7	4	15	13
CPUE (hr) Listed	1009.2	121.3	168.0	16.0	146.7	18.7	13.3	84.0	37.6
CPUE (hr) *A. neislerii*	1009.2	121.3	168.0	16.0	144.0	18.7	13.3	84.0	37.0
CPUE (hr) *E. sloatianus*	0.0	0.0	0.0	0.0	2.7	0.0	0.0	0.0	0.6
CPUE (hr) Dead Listed Species	ND	100.0	14.0	2.7	28.0	4.0	4.0	16.0	7.9
CPUE (hr) Exposed Listed Species	ND	110.7	4.0	0.0	25.3	9.3	5.3	20.0	7.9
% Listed Species Dead	ND	82.4%	8.3%	16.7%	19.1%	21.4%	30.0%	19.0%	21.0%
% Listed Species Exposed	ND	91.2%	2.4%	0.0%	17.3%	50.0%	40.0%	23.8%	21.0%
Mean Length (mm) of Dead *A. neislerii*	ND	64	53	55	52	50	52	69	47
Mean Length (mm) of Exposed *A. neislerii*	ND	64	51	None	53	47	53	70	50

Table 3.4.1.2.C. Results of fat threeridge density found during the quantitative mussel survey conducted by the USFWS from 24-31 October 2007 in RM range 40-50.

Site	River Mile	# Quadrats	Mean Density (ft^2)	SD Density (ft^2)	Mean Density (m^2)	SD Density (m^2)
81	40.5	23	0.02	0.08	0.17	0.83
82	40.6	20	0.07	0.19	0.80	2.09
75	42.8	91	0.15	0.31	1.63	3.37
74	43.0	28	0.05	0.13	0.57	1.43
72	43.4	30	0.12	0.55	1.33	5.88
71	43.9	34	0.98	1.45	10.59	15.57
70	44.3	76	0.32	0.81	3.42	8.68
69	44.5	25	0.03	0.10	0.32	1.11
67	46.0	49	0.06	0.14	0.65	1.49
65	46.8	117	0.64	1.05	6.91	11.31
62	48.3	27	0.00	0.00	0.00	0.00
Grand Total		520	0.30	0.77	3.25	8.32

Table 3.4.1.2.D. Summary of results from September 2010 study conducted by the U.S. Fish and Wildlife Service to determine the impact of low flows in 2010.

Fat Threeridge Exposure Mortality	Upper River (> RM 50)	Wewa (RM 40-50)	Lower River (RM 40-20)	Chipola River and Cut[1]	Grand Total
Number of Sites Examined for Exposure and Mortality	1	5	1	1	8
Total Length of Habitat Examined (m)	134	642	136	203	1,115
Number of Observed Exposed and Dead above 5,700 cfs elevation[2,3]	2	385	1	5	393
Average of Number Exposed and Dead per meter	0.01	0.58	0.01	0.02	0.37
Total Number of Known Habitat Sites	52	25	32	66	175
Total Length of Habitat Available (m)	10,913	3,393	7,666	11,513	33,485
Total Observed Mortality from Decline to 5,700 cfs	163	1,976	56	284	2,479
Total Population Estimate	43,949	405,685	138,282	556,436	1,144,352
% of Observed Mortality from Decline to 5,700 cfs	0.4%	0.5%	0.0%	0.1%	0.2%
% of Population Vulnerable to decline to 5,700 cfs[4]	25%	9%	31%	20%	18%
Total Number Vulnerable to decline to 5,700 cfs	10,976	38,169	42,520	112,588	204,253
% of Vulnerable Population that Were Observed Dead	1.5%	5.2%	0.1%	0.3%	1.2%
% of Vulnerable Population Assumed to Move[3]	98.5%	94.8%	99.9%	99.7%	98.8%
% of Population Vulnerable to decline to 5,600 cfs[2,4]	27.4%	9.9%	32.8%	20.9%	18.5%
Total Number Vulnerable to decline to 5,600 cfs	11,879	38,187	45,300	116,012	211,377
Additional Mortality at 5,600 cfs assuming movement[5]	176	1,977	60	292	2,506
Total Potential 2010 Mortality	339	3,953	116	576	4,985
% of Total Potential 2010 Mortality[2]	0.8%	1.0%	0.1%	0.1%	0.4%

[1]Chipola River and Cut only applies to the Chipola River downstream of its confluence with the Chipola Cut

[2]Wewa Stage was 11.95 during the September mortality event, which is equivalent to about 5,700 cfs at the Chattahoochee gage. We recognize that flows at Chattahoochee were lower during this time. Local inflows were probably contributing to the higher Wewa flows.

[3]Assumes complete detection of exposed dead animals, which is not likely the case. Also does not include delayed mortality of animals that did move.

[4]data from Depth Distribution Tables of Mike Gangloff's 2010 sample data not provided here

[5]used the same estimated percent that may have moved in the September event

Table 3.4.1.2.E. Data compiled for Apalachicola and Chipola River sites visited during assessment of mortality of fat threeridge. Population estimates and slope data obtained from Gangloff (2011) and sampling we conducted (sites RM 44.5, 44.3, and 46.8). Percent mortality of population was estimated as total mortality divided by population estimate (from USFWS 2011).

River	River mile/ID	Site #	Date(s) inspected 2011	Total mortality detected	# dead on land	# dead in water	Population estimate *A.neislerii*	Year of estimate	% mortality of pop.	Mean site slope
Apalachicola	RM 44.5	A69	5/16-6/27	3			640	2011	0.5	0.28
Apalachicola	RM 44.3	A70	5/16-6/27	361			9752	2011	3.7	0.09
Apalachicola	RM 46.8	A65	5/16-6/27	222			22990	2011	1.0	0.15
Apalachicola	RM 42.1	A77	5/16-6/28	26			4015	2008	0.6	0.25
Apalachicola	RM 47.5	A64	6/27	34	24	10	32374	2010	0.1	0.45
Chipola	Site C16	C16	5/17-6/29	14	10	4	7326	2010	0.2	0.23
Chipola	Site C53	C53	6/29	1	1	0	7235	2010	<0.1	0.19
Chipola	Site C59	C59	6/29	1	0	1	17683	2010	<0.1	0.39
Apalachicola	RM 33.8	A96	6/29	0	0	0	2715	2010	0.0	0.25
Apalachicola	RM 35.4	A92	6/29	0	0	0	6694	2008	0.0	0.38
Apalachicola	RM 38.8	A87	6/29	25	9	16	692	2008	3.6	0.11
Apalachicola	RM 40.8	A83	6/29	99	97	2	1485	2008	6.7	0.13
Apalachicola	RM 45.5	A68	6/29	50	37	13	5468	2010	0.9	0.17

Table 3.4.1.2.F. Stage-based life history for fat threeridge mussels occupying the Apalachicola River (from Miller 2011b).

Stage Number	Stage Class	Size (mm)	Approximate Age (Years)	Duration in Stage (Years)
1	Juveniles	11 – 35	1 – 3	2
2	Small Adults	36 - 55	3 – 8	5
3	Medium Adults	56 - 67	8 – 15	7
4	Large Adults	67+	15+	

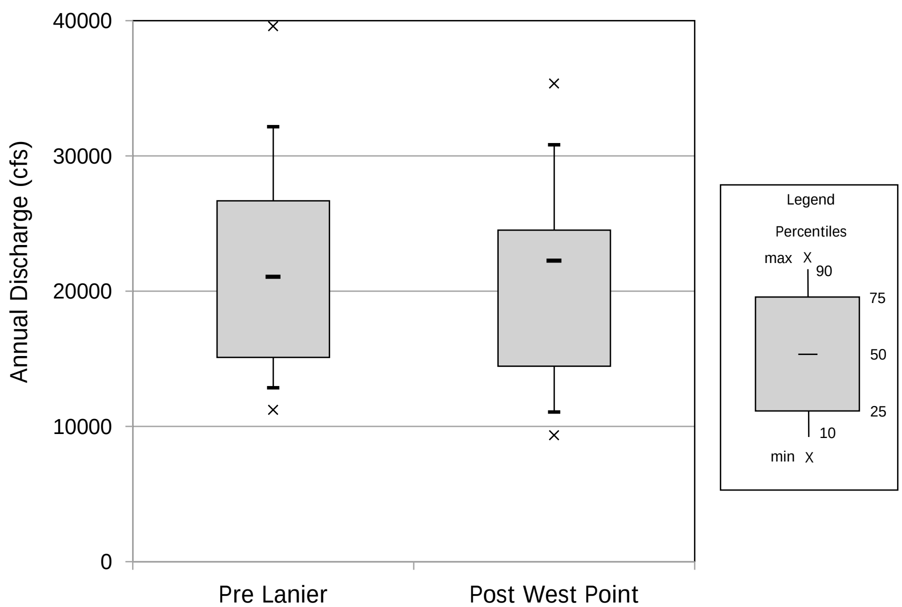

Figure 3.3.1.A. Average annual discharge (cfs) of the Apalachicola River at Chattahoochee, FL, for the pre-Lanier (1929-1955) and post-West Point (1975-2008) periods.

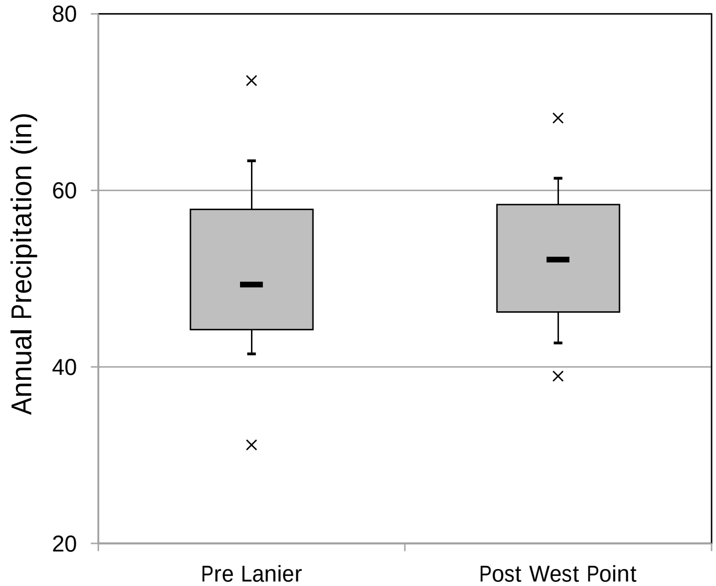

Figure 3.3.1.B. Total annual precipitation (inches) for the pre-Lanier (1929-1955) and post-West Point (1975-2008) periods computed as the average of Alabama climate zones 5, 6, and 7, and Georgia climate zones 1, 2, 3, 4, 5, 7, and 8, weighted by the area of each zone within the ACF Basin.

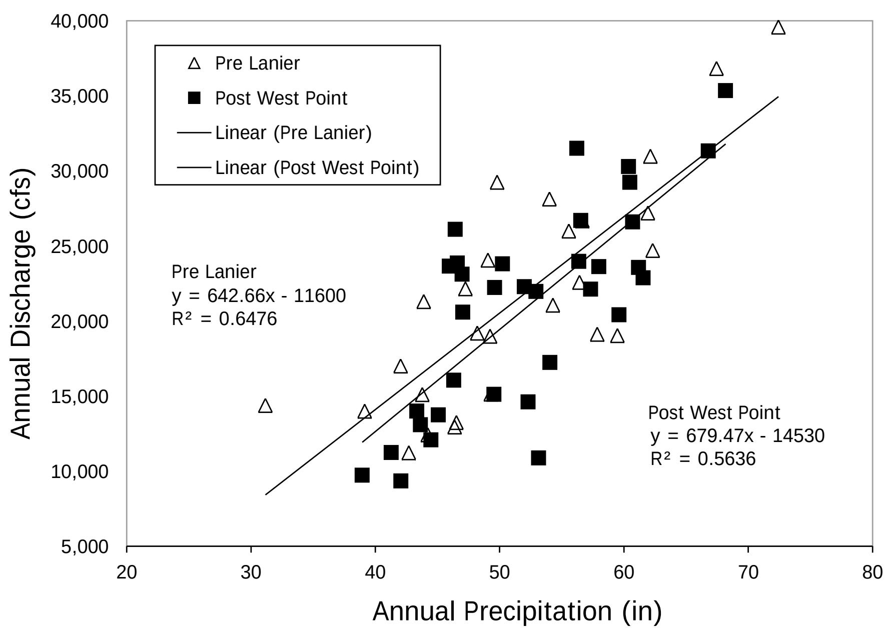

Figure 3.3.1.C. Relationship between average annual precipitation (inches) in the ACF basin upstream of Woodruff Dam and average annual discharge (cfs) at the Chattahoochee gage for the pre-Lanier (1929-1955) and post-West Point (1975-2008) periods.

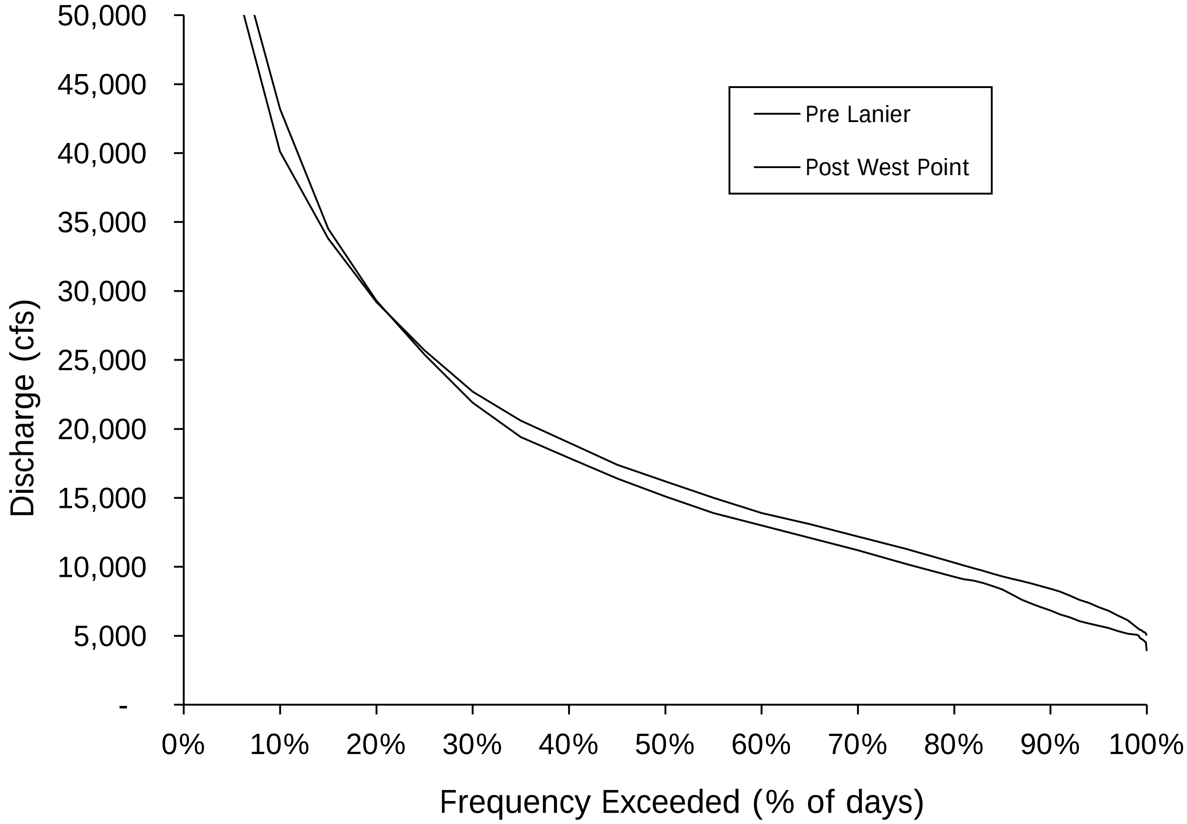

Figure 3.3.1.D. Flow frequency of the Apalachicola River at Chattahoochee, FL, for the pre-Lanier (1929-1955) and post-West Point (1975-2008) periods (discharge rates greater than 50,000 cfs are not shown**).**

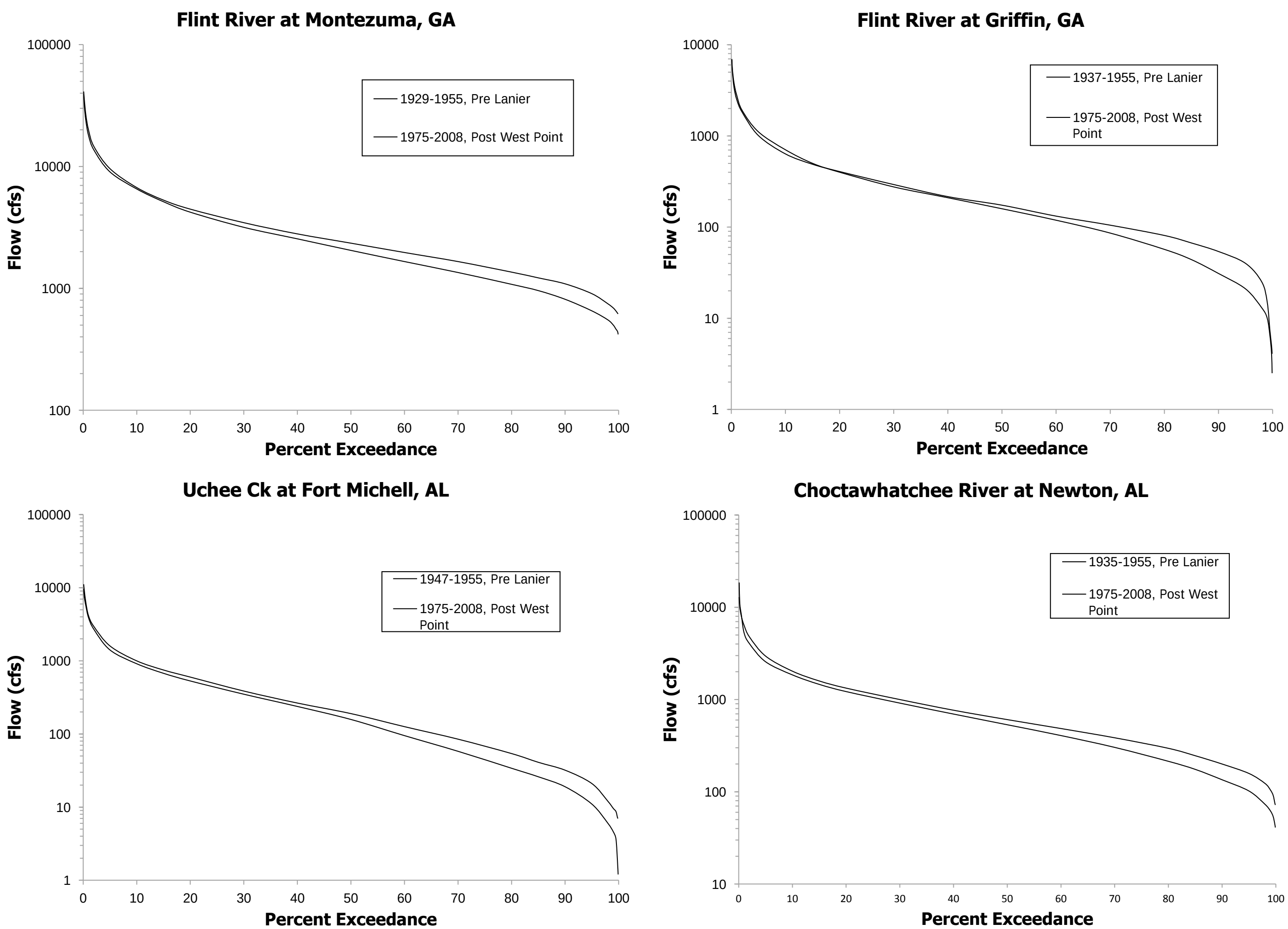

Figure 3.3.1.E. Flow frequency of four locations in Georgia and Alabama for which data is available from the pre-Lanier (1929-1955) and post-West Point (1975-2008) periods. Locations include the following USGS gages: Flint River at Montezuma, GA (02349500); Flint River at Griffin, GA (02344500); Uchee Creek at Fort Michell, GA (02342500); Choctawhatchee River at Newton, AL (02361000).

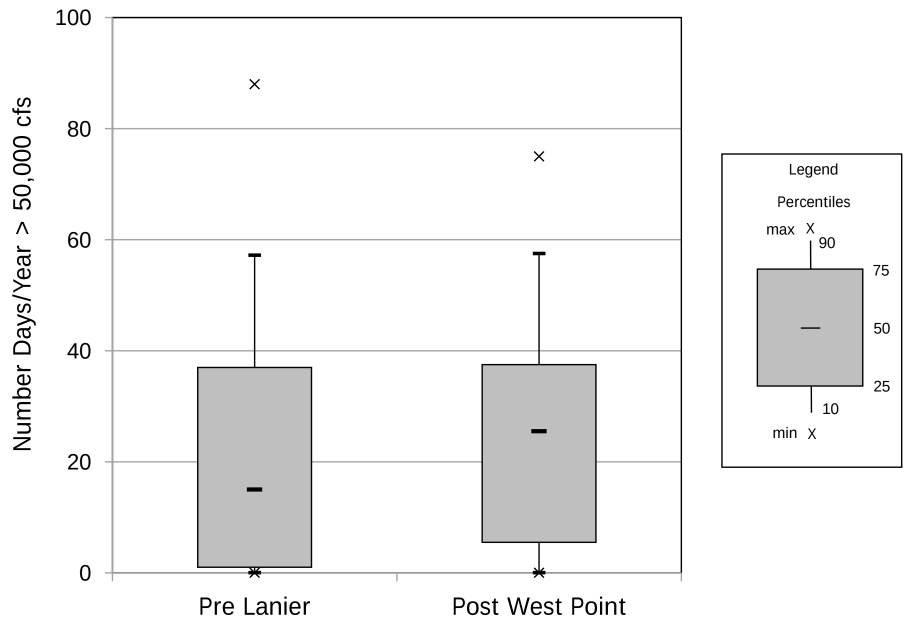

Figure 3.3.2.A. Annual duration of discharge > 50,000 cfs for the Apalachicola River at Chattahoochee, FL, calendar years 1929-1955 (Pre Lanier) and 1975-2008 (Post West Point [Baseline]).

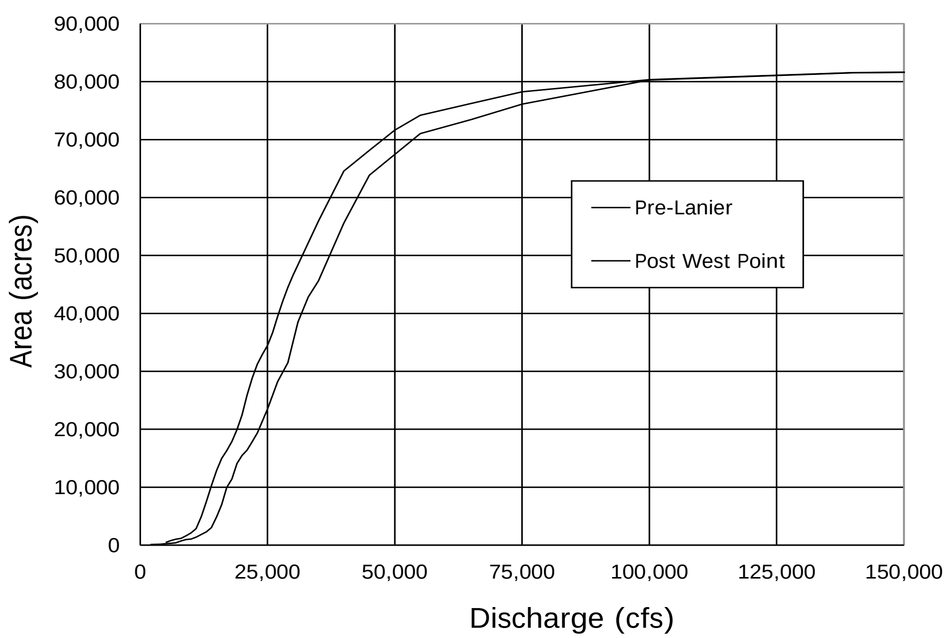

Figure 3.3.2.B. Area (acres) of aquatic habitat connected to the main channel of the non-tidal Apalachicola River at discharges of 5,000 to 150,000 cfs (taken from Light et al. 1998) for the pre-Lanier (1929-1955) and post-West Point (1975-2007) periods, accounting for changes in stage versus discharge relationships between these periods (Light et al. 2006).

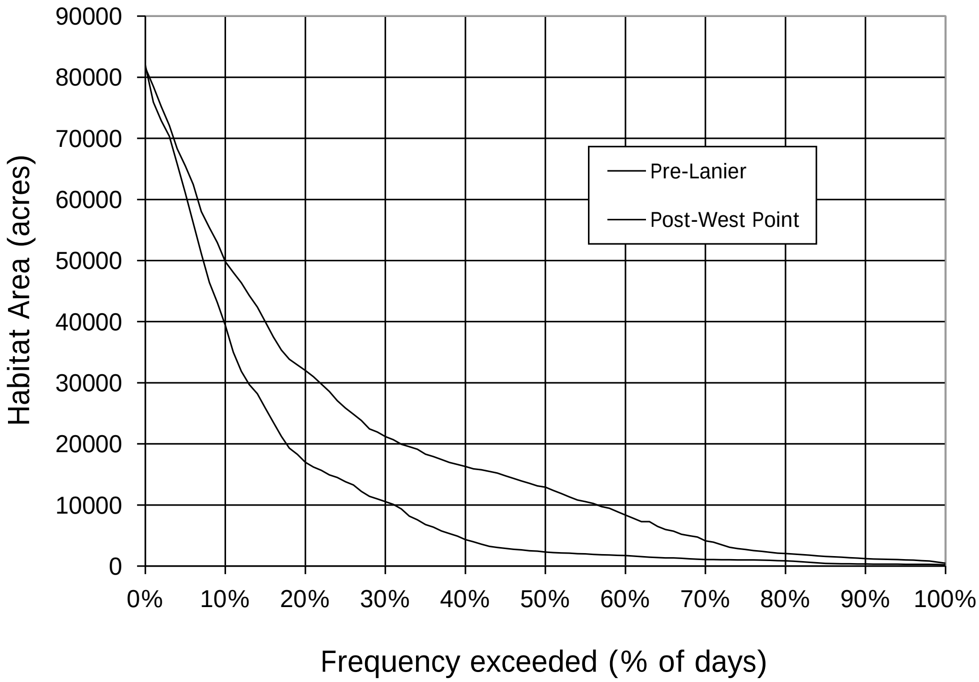

Figure 3.3.2.C. Frequency (% of days) of growing-season (April-October) floodplain connectivity (acres) to the main channel during the pre-Lanier (1929-1955) and post-West Point (1975-2008) periods.

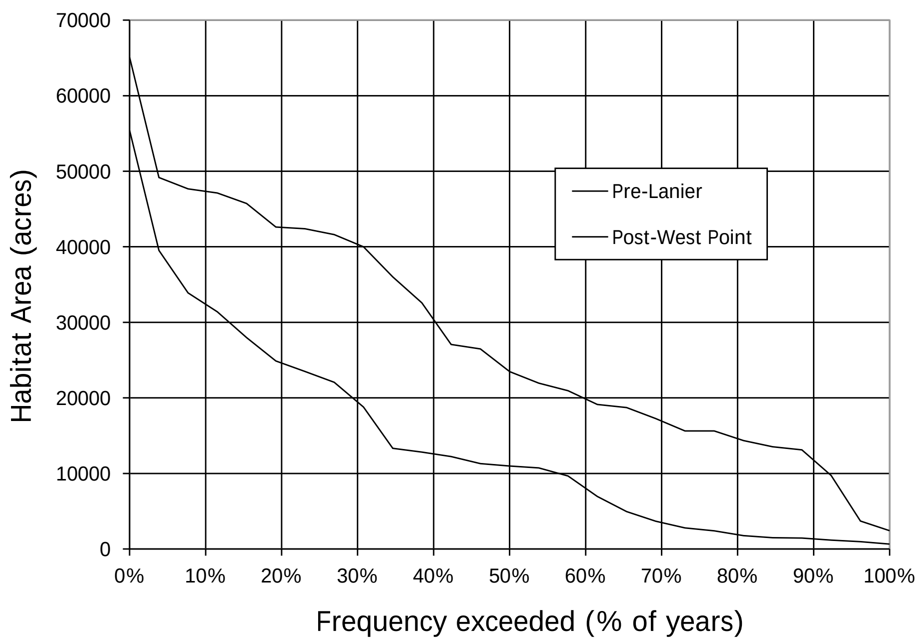

Figure 3.3.2.D. Frequency (% of years) of growing-season (April-October) floodplain connectivity (maximum acreage 30-day continuous connectivity, per year) to the main channel during the pre-Lanier (1929-1955) and post-West Point (1975-2008) periods.

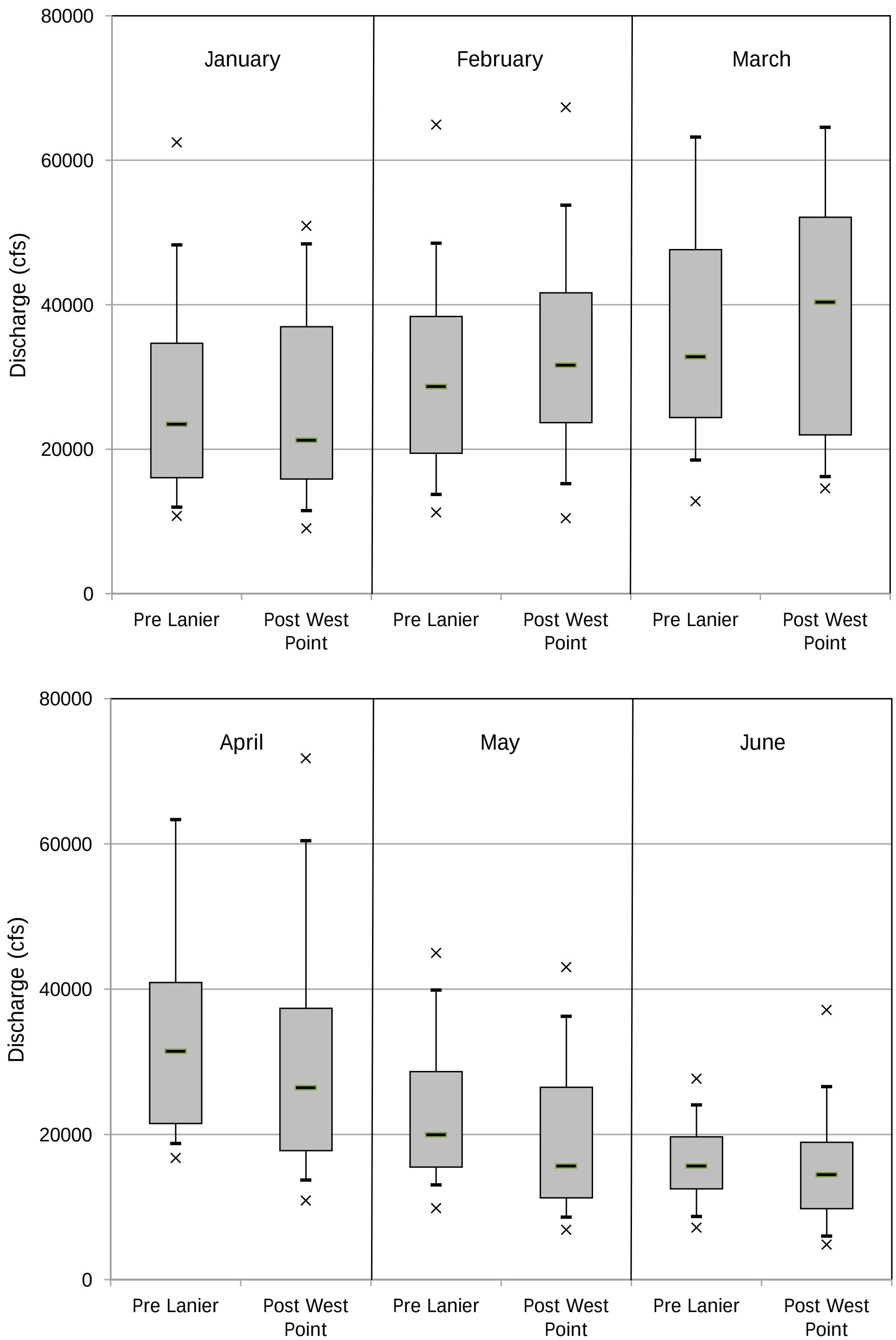

Figure 3.3.3.A. Distribution of January through June average monthly discharge (cfs) during the pre-Lanier (1929-1955) and post-West Point (1975-2008) periods.

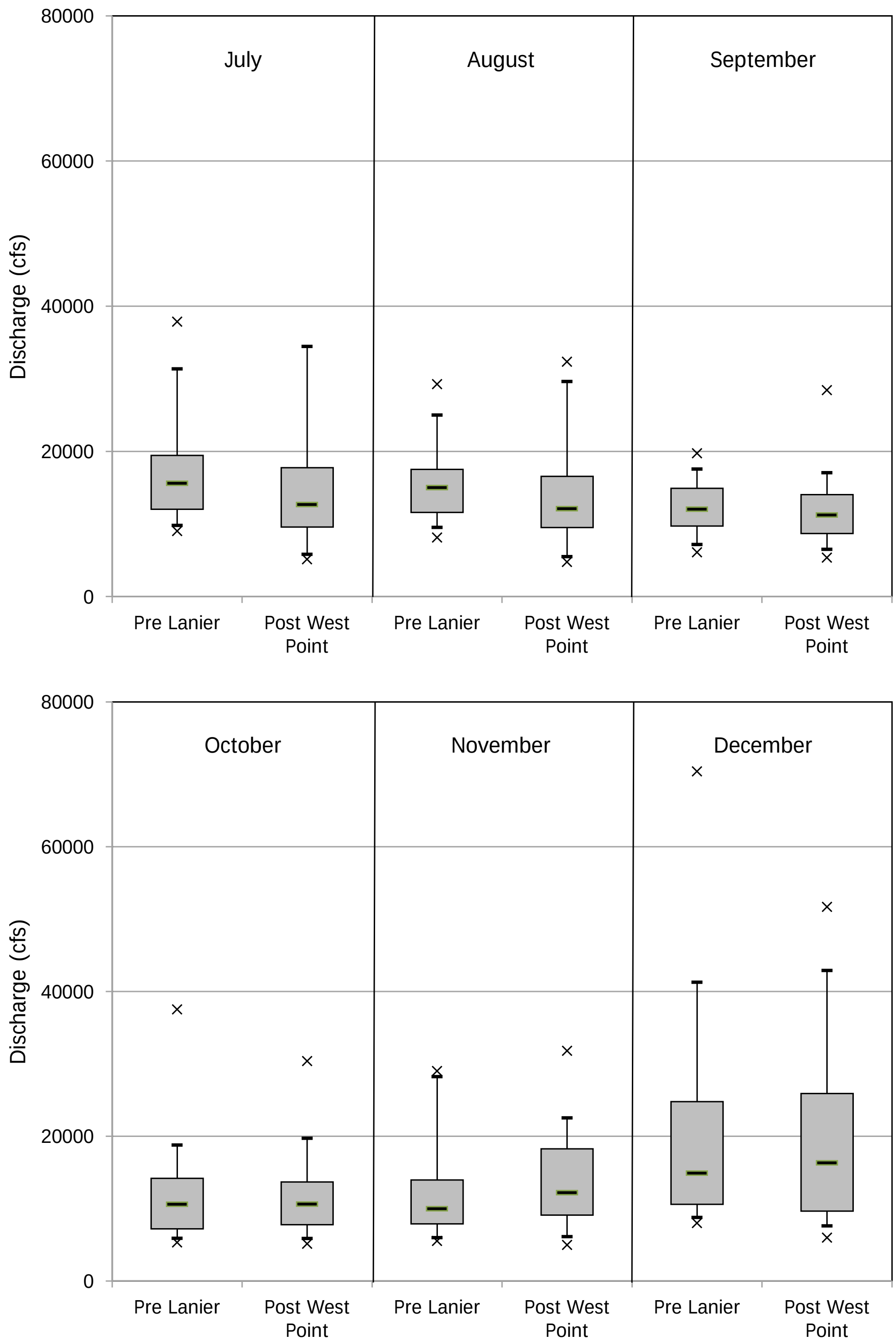

Figure 3.3.3.B. Distribution of July through December average monthly discharge (cfs) during the pre-Lanier (1929-1955) and post-West Point (1975-2008) periods.

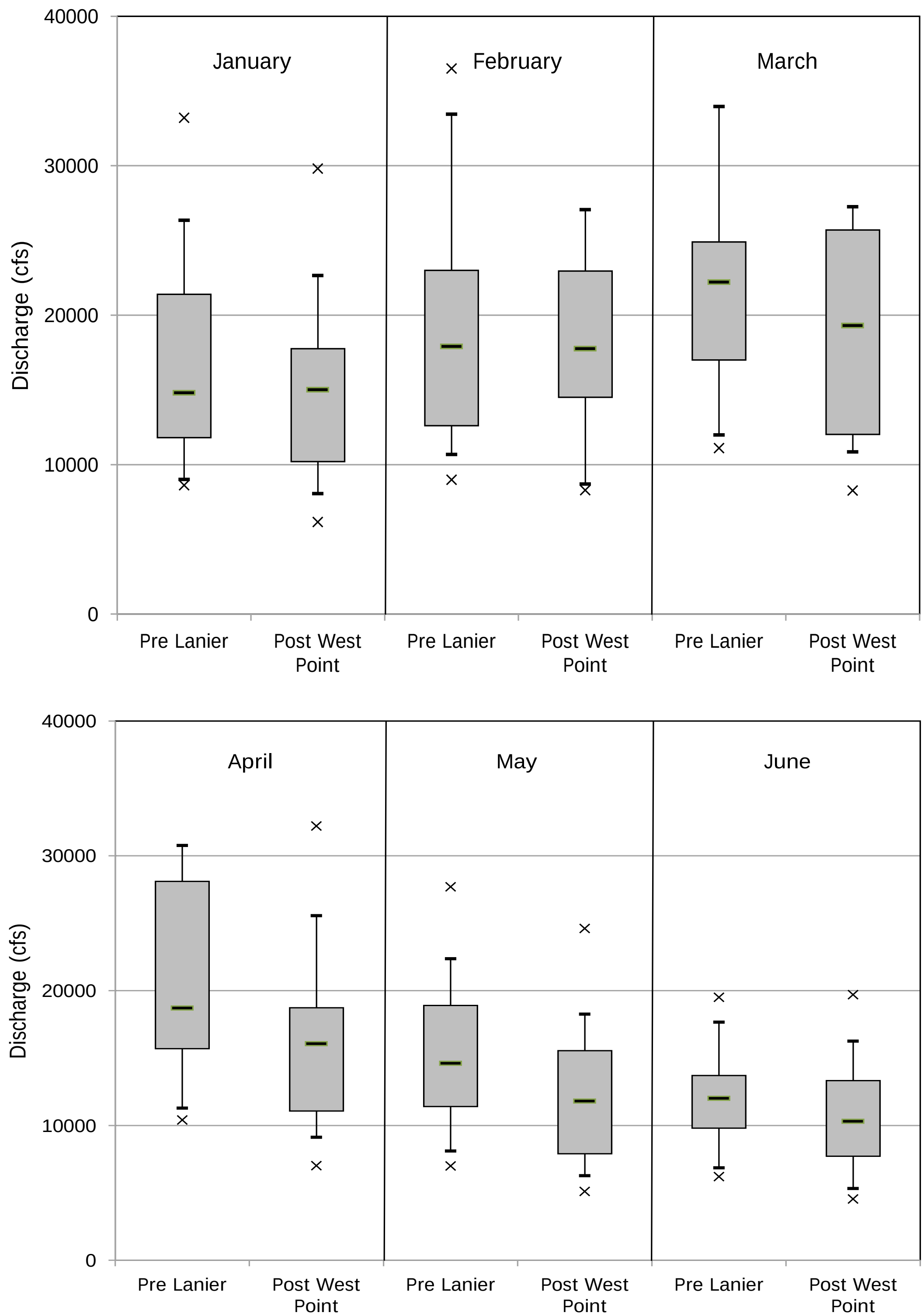

Figure 3.3.4.A. Distribution of January through June monthly 1-day minimum discharge (cfs) during the pre-Lanier (1929-1955) and post-West Point (1975-2008) periods.

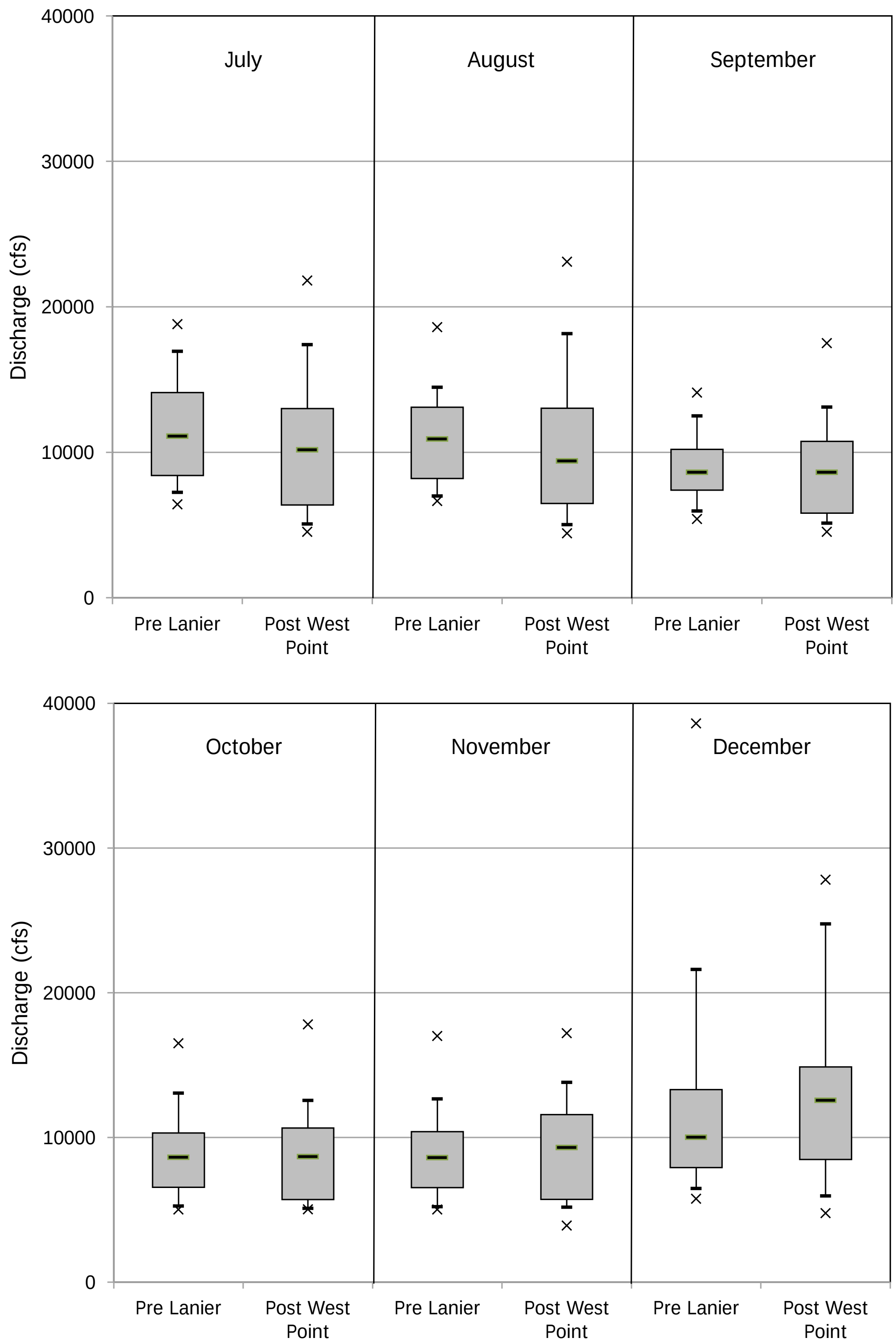

Figure 3.3.4.B. Distribution of July through December monthly 1-day minimum discharge (cfs) during the pre-Lanier (1929-1955) and post-West Point (1975-2008) periods.

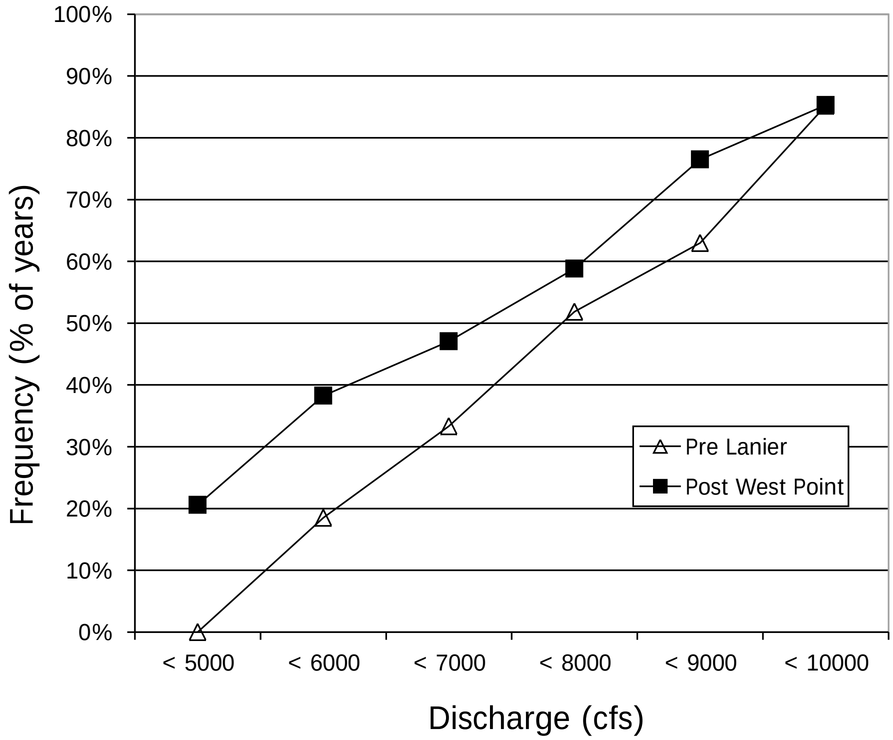

Figure 3.3.4.C. Inter-annual frequency (% of years) of discharge events less than 5,000 to 10,000 cfs during the pre-Lanier (1929-1955) and post-West Point (1975-2008) periods.

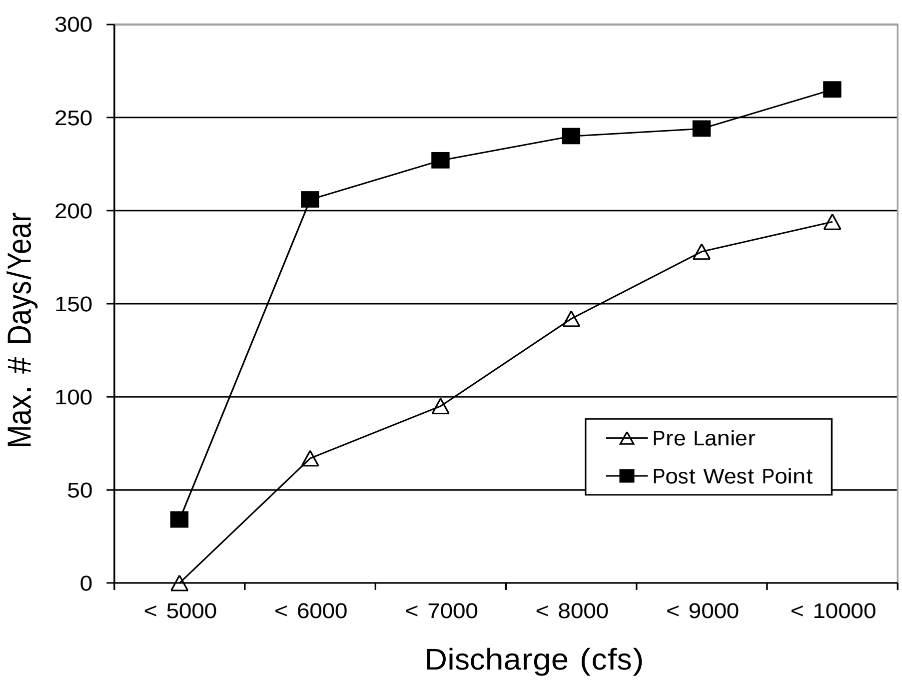

Figure 3.3.4.D. Maximum number of days per year of discharge less than 5,000 to 10,000 cfs during the pre-Lanier (1929-1955) and post-West Point (1975-2008) periods.

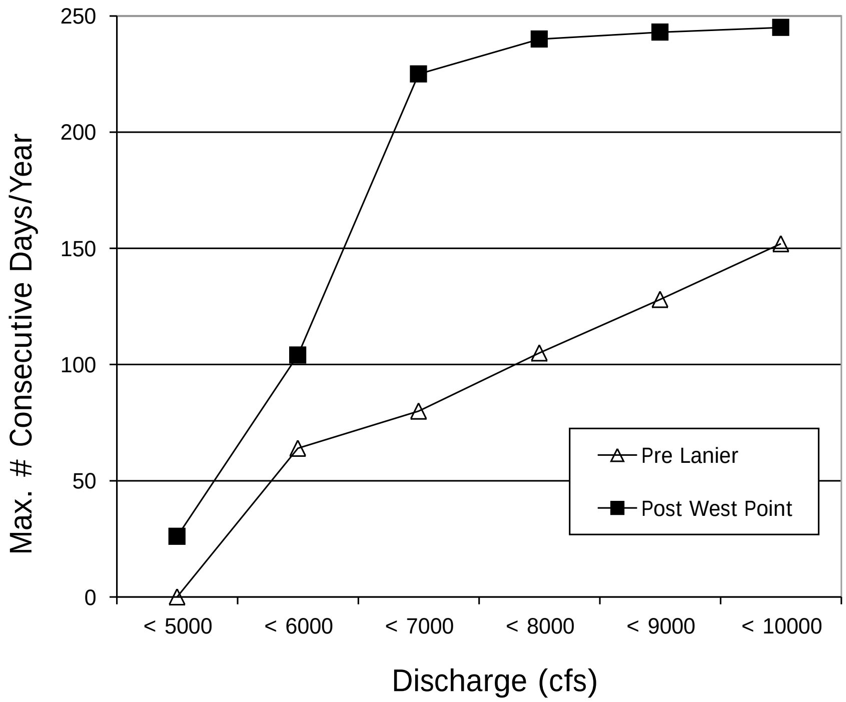

Figure 3.3.4.E. Maximum number of consecutive days per year of discharge less than 5,000 to 10,000 cfs during the pre-Lanier (1929-1955) and post-West Point (1975-2008) periods.

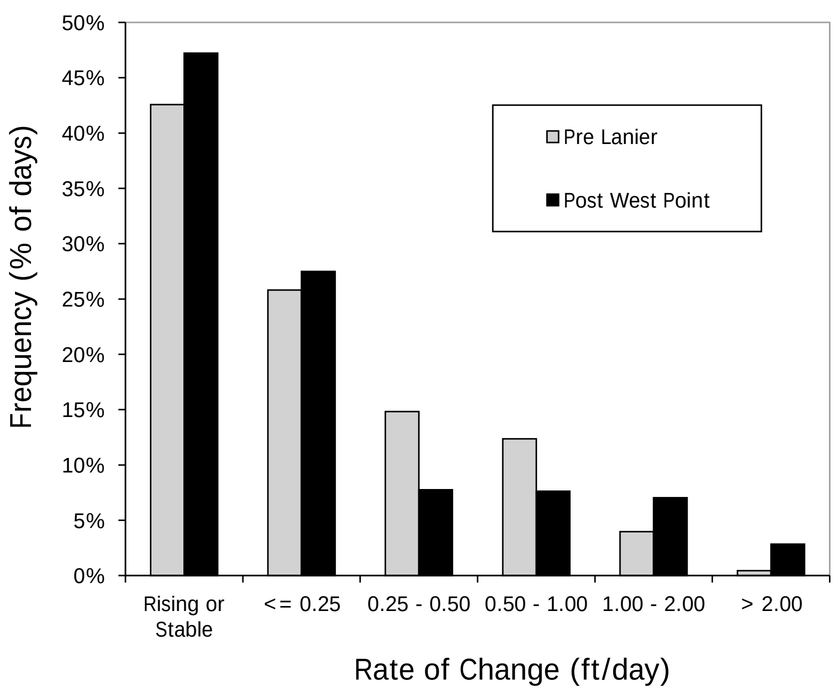

Figure 3.3.5.A. Frequency (% of days) of daily stage changes (ft/day) during the pre-Lanier (1929-1955) and post-West Point (1975-2008) periods.

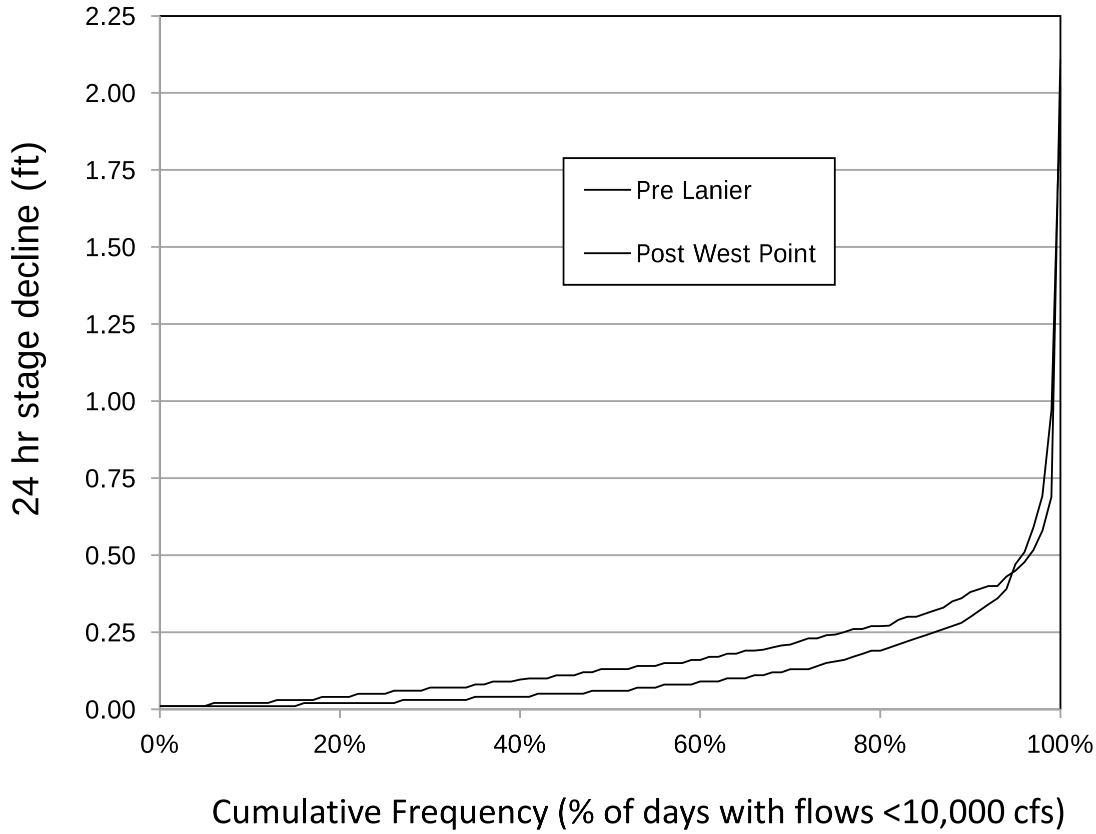

Figure 3.3.5.B. Cumulative frequency (% of days) of 24-hr stage declines (ft/day) during the pre-Lanier (1929-1955) and post-West Point (1975-2008) periods when flows were less than 10,000 cfs.

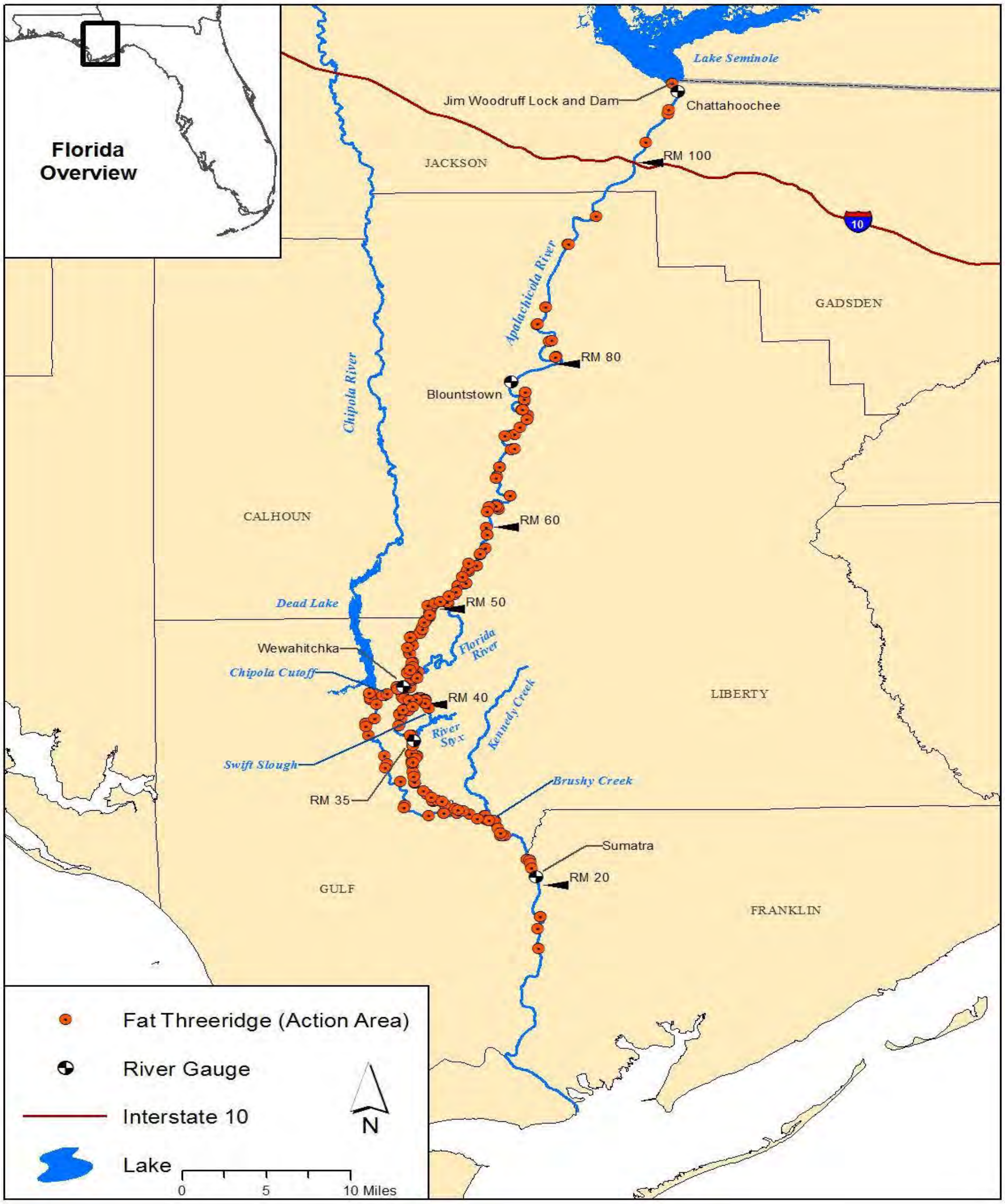

Figure 3.4.1.1.A. Current (1990-2011) occurrences of fat threeridge in the action area.

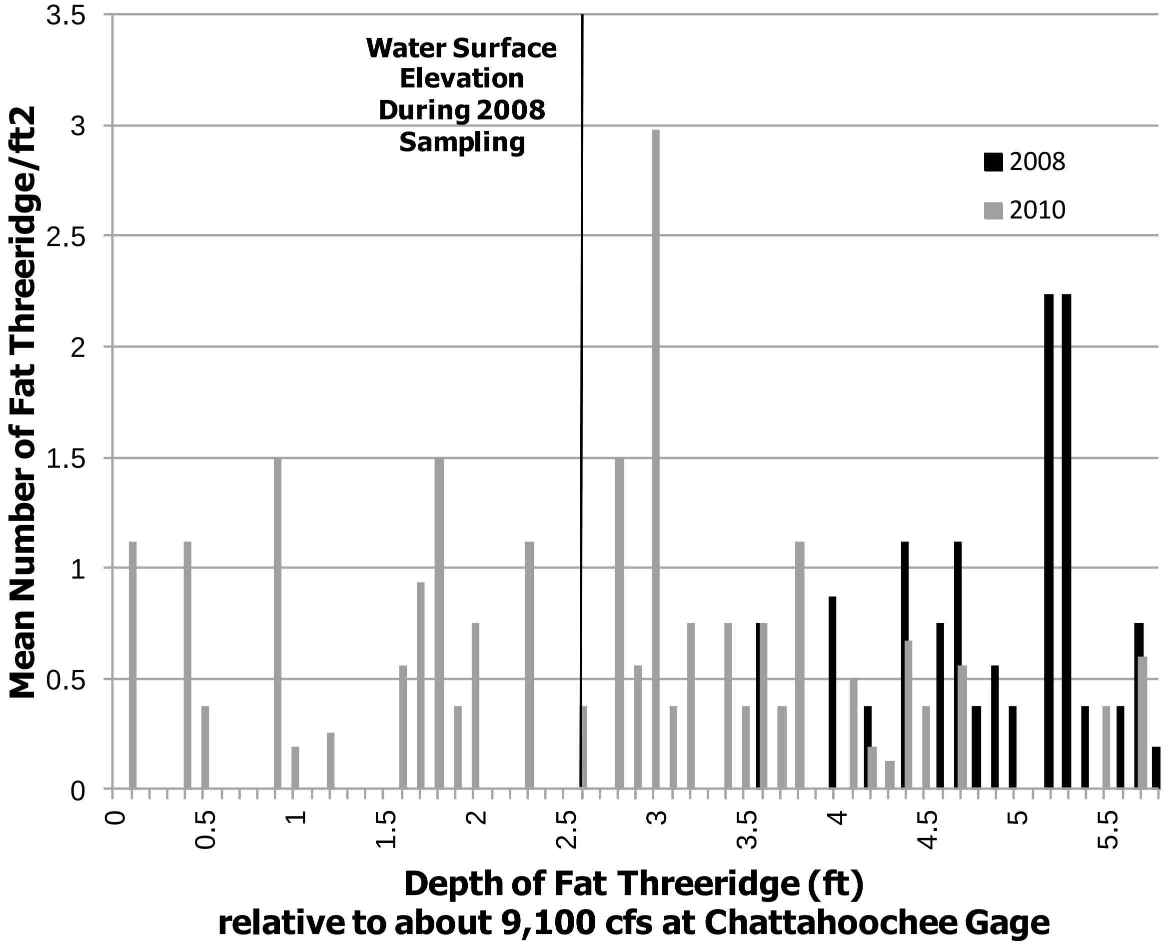

Figure 3.4.1.1.B. Comparison of the distribution of fat threeridge at two sites Gangloff sampled in the Apalachicola and Chipola rivers in 2008 and 2010 relative to a flow of about 9,100 cfs at the Chattahoochee gage. Apalachicola River flows were about 5,400 cfs when these two sites were sampled in 2008 and about 9,700 cfs during 2010 sampling (assumes the 2-day lag in flows between Chattahoochee and Wewa).

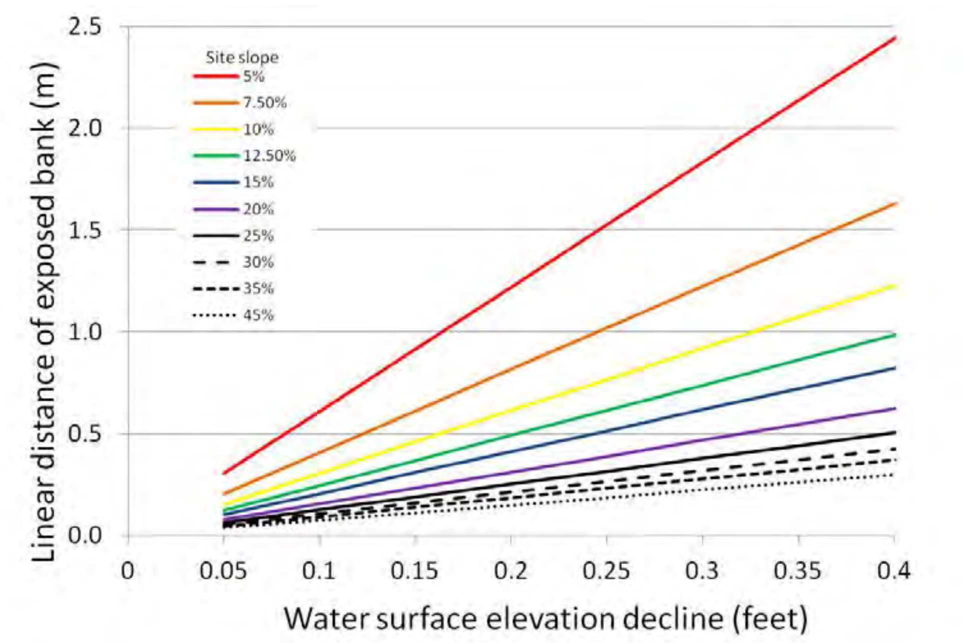

Figure 3.4.1.2.A. Model depicting the linear distance of exposed bank (m) associated with a range of water surface elevation declines (feet) for a suite of sites of different gradients (5% - 45% slopes) (Figure from USFWS 2011).

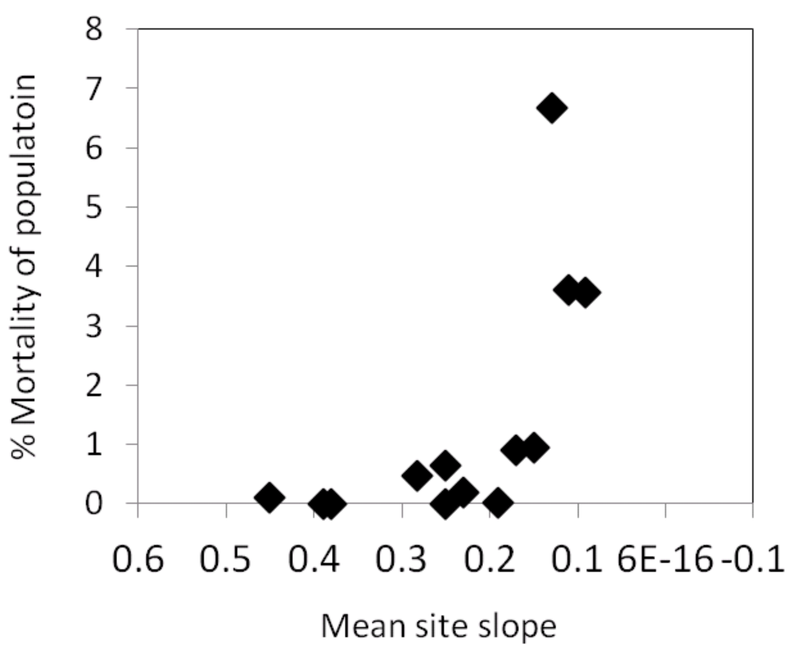

Figure 3.4.1.2.B. The relationship between % mortality of the resident fat threeridge population and mean slope among the 13 sites examined during the 2011 study period. Slope values are arranged in descending fashion along x-axis. (Figure from USFWS 2011).

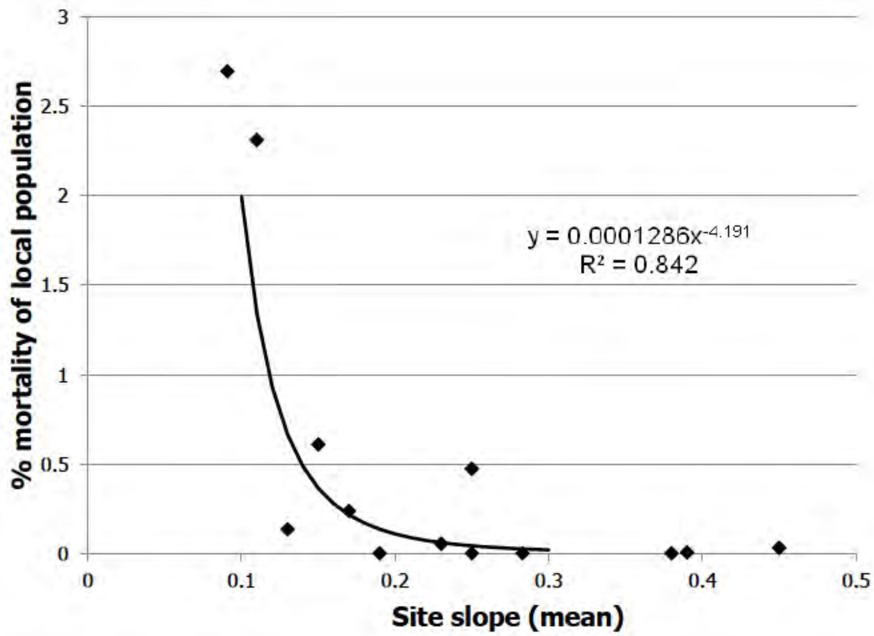

Figure 3.4.1.2.C. Relationship between percent mortality of the local fat threeridge population and mean site slope from mortality that occurred when releases were less than 5,000 cfs at Chattahoochee in May and June 2011.

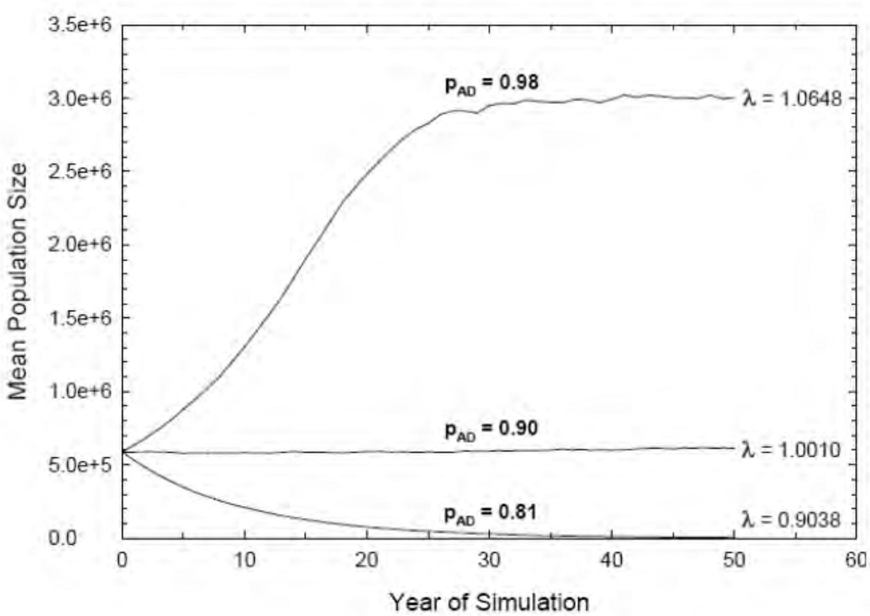

Figure 3.4.1.2.D. Mean 50-year trajectories and long-term mean growth rates (λ) across stochastic simulations of fat threeridge mussel populations for alternative values of mean adult annual survival rate, p_{AD} (from Miller 2011).

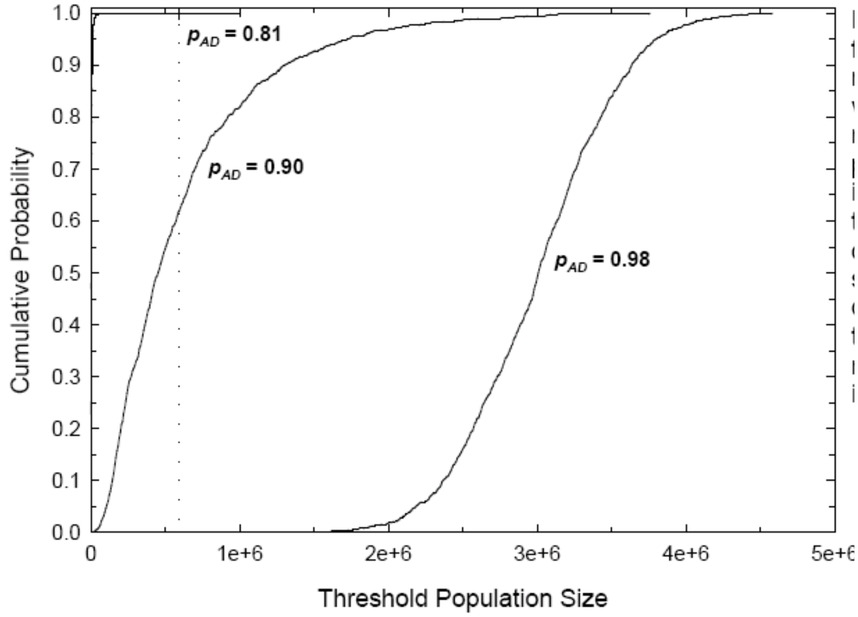

Figure 3.4.1.2.E. Quasi-extinction curves for simulated fat threeridge mussel populations for alternative values of annual adult survival rate (p_{AD}). The curves give the probability that the population of interest will fall below the range of threshold abundances at the end of the simulation. Initial population size is indicated by the vertical dotted line (from Miller 2011b).

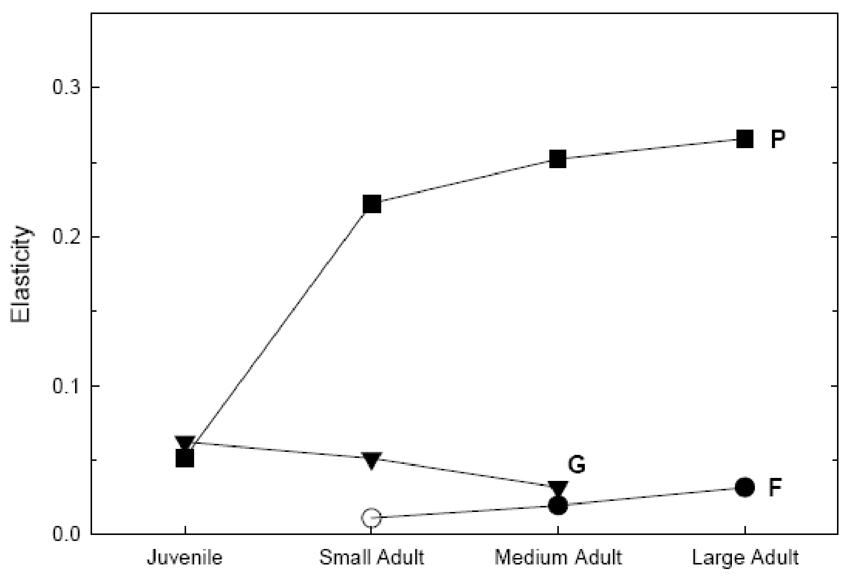

Figure 3.4.1.2.F. Elasticity of population growth rate (λ) to changes in stage-specific fecundity (F), survival with growth into the next stage (G), and survival within the same stage (P) for matrix models of fat threeridge population dynamics (from Miller 2011).

Figure 3.4.2.1.A. Current (1990-2011) occurrences of purple bankclimber in the action area.

Figure 3.4.3.1.A. Current (1990-2011) occurrences of Chipola slabshell in the action area.

4 EFFECTS OF THE ACTION

This section is an analysis of the effects of the RIOP on the species and critical habitat. In most consultations, the Service typically evaluates a project that has not been constructed or implemented. In this consultation, the Service is evaluating the effects of a project that is ongoing. The previous "Environmental Baseline" section described the effects of all past activities, including the effects of past construction and operation of the Corps ACF projects, current non-federal activities, and federal projects with completed section 7 consultations. This section addresses the future direct and indirect effects of the RIOP, including the effects of any interrelated and interdependent activities. Cumulative effects are addressed in section 5. Our determination of total effects to the species and critical habitat in the "Conclusion" (section 6) is the sum of the effects evident in the baseline plus effects of the action and cumulative effects.

4.1 Factors Considered

In the "Environmental Baseline" section, we outlined two principal components of the species' environment in the action area: channel morphology and flow regime. The RIOP defines releases into the Apalachicola River via operations of the Jim Woodruff Dam; therefore, the primary focus of our analysis is the flow regime of the Apalachicola River under the Baseline compared to the flow regime expected under the RIOP. Physical habitat conditions for the listed species in the action area are largely determined by flow regime, and channel morphology partially sets the context for the flow regime. Channel morphology has changed relative to the pre-dam period in the Apalachicola River, but the rate of change has slowed and may have entered a somewhat dynamic equilibrium condition (see section 3.2). We have no ability at this time to predict specific effects on channel morphology that may result from the influence of the RIOP. We considered water quality parameters but do not have enough information to determine whether RIOP implementation will itself alter the baseline water quality of the action area; however, we recognize a potential for localized dissolved oxygen changes through flow stagnation or more temperature extremes resulting from shallower waters. Our analysis of flow regime alteration relative to the listed species and critical habitats considers the following factors.

<u>Proximity of the action:</u> The proposed action will affect habitat occupied by the purple bankclimber, Chipola slabshell, and fat threeridge mussels. These mussels spend their entire lives within the action area, most of which is designated as critical habitat for the mussels. The proposed action is implemented through releases from Woodruff Dam, which affect species and habitat features from immediately below the dam and extending as far as 100 miles downstream.

<u>Distribution:</u> The proposed action could alter flows in the Apalachicola River and its distributaries downstream of Woodruff Dam. The action area includes most of the known range of the fat threeridge, about one third of the range of the purple bankclimber, and a small fraction of the range of the Chipola slabshell. We examine how the RIOP may variously affect different portions of the action area according to the distribution of the species and important habitat features in the action areas.

Timing: The proposed action could alter flows in the Apalachicola River at all times of the year. It will reduce flows when increasing composite storage in the ACF reservoirs and increase flows when decreasing composite reservoir storage. All three mussels occur in the action area year-round and during all life phases. The fat threeridge, a species that tends to occupy shallower waters, may be more susceptible to effects of low flows during low flows in the late spring through fall. We examine how the RIOP may alter the seasonal timing of biologically relevant flow regime features in our analysis.

Nature of the effect: The proposed action will reduce flows in the Apalachicola River when increasing composite storage in the ACF reservoirs and increase flows when decreasing composite reservoir storage. Three of the five PCEs of designated mussel critical habitat may be affected by the actions: permanently flowing water, water quality, and host fish. We examine how the RIOP may affect the listed species and critical habitat elements through specific analyses focused on relevant habitat features, such as vulnerability to exposure by low flows and floodplain inundation.

Duration: This proposed action is a Revised Interim Operating Plan applicable until revised or until a new Water Control Plan is adopted. Although the duration of the RIOP is indefinite, the nature of its effects is such that none are permanent. The Corps may conceivably alter its reservoir operations at any time; therefore, flow alterations that may result from the proposed action will not result in permanent impacts to the habitat of any of the listed species. However, we examine how the proposed RIOP may alter, while it is implemented, the duration of high flows and low flows that are relevant to the listed species and critical habitats.

Disturbance frequency: The proposed RIOP is applicable year round; therefore, changes to the flow regime and water quality parameters may occur at any time and/or continuously until such time as the RIOP is revised or a new Water Control Plan is adopted. However, we examine how the proposed RIOP may alter, while it is implemented, the frequency of high flows and low flows that are relevant to the listed species and critical habitats.

Disturbance intensity and severity: As proposed, the RIOP may variously affect the flow regime depending on time of year, basin inflow, and composite storage levels as defined in Table 1.2.A, but maintains a minimum flow of 5,000 cfs during most times and 4,500 cfs at all times. We examine how the RIOP affects the magnitude of flow events relative to the baseline.

4.2 Analyses for Effects of the Action

To determine the future effect of continued project operations as prescribed by the RIOP, we must compare the environmental conditions expected under the RIOP to the environmental baseline. The principal factor we examine is the flow regime of the Apalachicola River and how the flow regime affects habitat conditions for the listed species. For analysis purposes, we consider the flow regime of the environmental baseline (a.k.a. baseline) as the observed flows of the river since the full complement of the Corps' reservoirs were completed (calendar years 1975 to 2008 – see section 3.3).

The level of consumptive water uses supported in the basin upstream of Woodruff Dam, which affects basin inflow to the Corps' projects, increased throughout the baseline post-West Point period. For the 2008 BO, the Corps simulated the RIOP using basin inflow available under the highest level of consumptive water uses (year 2000) for all years. This means that conditions predicted under the 2008 RIOP were due in part to the RIOP and in part to an increase in consumptive uses. We attempted to isolate the effects of consumptive water use from the effects of implementing the RIOP in the 2008 BO by examining environmental conditions that would result if reservoir operations that alter the flow regime of the river were not continued, also known as "run-of-river" operations (RoR). RoR is defined as the expected flow regime if the Corps maintained a constant water surface elevation on all of the ACF federal reservoirs, never diminishing basin inflow by raising reservoir levels and never augmenting basin inflow by lowering reservoir levels (i.e., the constant release of basin inflow). By comparing all three flow regimes, Baseline (1975-2007 observed flow), RIOP, and RoR, we identified effects relative to the baseline attributable to the RIOP apart from effects attributable to an increase in consumptive use in the basin since 1975.

Since the 2008 RIOP BO, however, we have realized this method did not isolate effects of consumptive use from the RIOP as intended. The 2008 RIOP and RoR flow regimes were simulated using the highest demands data (year 2000) to represent all years simulated, whereas the Baseline is observed data with actual demands that varied annually. In the new simulations of the RIOP and RoR for this consultation, which initially used demands data for year 2007 (the driest year on record), we noticed that the total volume of water released from Woodruff Dam in the simulations for the years 1975-2008 actually exceeded that of the Baseline, which was counterintuitive, because the simulations presumably imposed higher consumptive water demands on the observed hydrology and should have resulted in a lesser volume.

At our request, the Corps investigated this observation and reported to us that the demands data used to synthesize the models' unimpaired flow data are apparently underestimated during wet years after 1994, primarily in the Flint Basin and lower Chattahoochee Basin. We agreed to remove this complicating discrepancy from our analyses by simulating the RIOP with the historically reported/estimated consumptive demands (the same data used to synthesize the unimpaired flows) so that differences with the Baseline would result from operational changes in the RIOP relative to historical operations. Further, we agreed that the 2008 RoR daily time series was not an accurate approximation of an actual run-of-river operation, because it was a calculation of 1-day basin inflow, which is the sum of basin inflow at each of the Corps' reservoirs on a given day and does not account for travel time through the basin or flow attenuation. Therefore, the Corps agreed to create a model simulating RoR operations (instead of using 1-day basin inflow), also using reported historical consumptive demands.

For this BO, the consumptive water demands used in the models are the actual reported municipal and industrial (M&I) depletions for the period of 1980-2008, estimated agricultural water use, and estimated evaporative losses from the basin's largest reservoirs (Table 4.2.A). Consumptive water-use values prior to 1980 were hindcast based on census population data. The method for estimating agricultural water use varied by month and by year (wet, normal, dry) and was consistent with the method used in developing the 2008 RIOP and the effects analysis in the

2008 BO. If these reported values and estimates of consumptive use differ substantially from the actual historical values, then the simulated flows would be influenced accordingly.

The Service and Corps agreed that this updated method for simulating the RIOP and RoR provides a more useful comparison to the baseline (observed) condition, as these simulations more accurately reflect the influences of reservoir evaporative losses, inter-basin water transfers, and consumptive water uses that also influenced the observed Apalachicola River flows during the baseline period of record (1975-2008). Therefore, difference between the Baseline and RIOP flow regimes now reflect the net effect of operational changes in the RIOP relative to historical operations, as all other influences that are unrelated to project operations (hydrology, evaporation, consumptive water use, land use, and climate change) are the same in both. We recognize that the differences in the observed and simulated flows are influenced by the consumptive water use assumptions included in ResSim. At this time we cannot differentiate between flow differences attributable to Corps' discretionary operations and those attributable to potential inaccuracies in the model assumptions; thus, we conservatively attribute all the differences to the RIOP operations. By taking this approach, the RoR flow regime is no longer necessary to differentiate whether an effect (either beneficial or adverse) is attributable to the Corps' discretionary operations. The RoR simulation includes the same assumptions regarding reservoir evaporative losses, inter-basin water transfers, and consumptive water uses as the Baseline and RIOP; therefore, we use it in section 4.2.2 to quantify the degree to which reservoir operations augment and deplete flows in the Apalachicola River but do not discuss the RoR flow regime further in this BO.

As discussed, the principal factor examined in determining effects of the proposed action is the flow regime of the Apalachicola River and how the flow regime affects habitat conditions for the listed species. Consistent with the 2008 BO, if the RIOP does not alter the Baseline, its effect on the species/habitat is a continuation of the Baseline effect, if any. If the RIOP condition represents a beneficial or adverse alteration of the Baseline condition, the effect is accordingly beneficial or adverse. We attribute any differences between the Baseline and RIOP simulated flow regime to the Corps' discretionary operations[5].

4.2.1 Model Description

The HEC-ResSim model (version 3.1 "Release Candidate 3, Build 42") was used to simulate flow operations in the ACF Basin. HEC-ResSim is a tool for simulating flow operations in managed systems developed by the Corps' Hydrologic Engineering Center (HEC) to predict the behavior of reservoirs and to help reservoir operators plan releases in real time during day-to-day and emergency operations. ResSim provides a realistic view of the physical river/reservoir system using a map-based schematic and represents a system of reservoirs as a network composed of four types of physical elements: junctions, routing reaches, diversions, and reservoirs. By combining these elements, a network was built to represent the ACF Basin. A reservoir is the most complex element of the reservoir network and is composed of a pool and a dam. ResSim assumes that the pool is level (i.e., it has no routing behavior), and its hydraulic behavior is completely defined by an elevation-storage-area table. It also uses an original rule-based description of the operational goals and constraints that reservoir operators must consider when making release decisions.

To provide a potential range of flows that might be experienced while the proposed action scenarios are in effect, the ResSim model simulates river flow and reservoir levels using a daily time series of unimpaired flow data as input for a certain period of record. Whereas basin inflow is computed to remove the effects of reservoir operations from observed flow, unimpaired flow is developed to remove the effects of both reservoir operations and consumptive demands from observed flow. The ResSim model imposes reservoir operations and consumptive demands onto the unimpaired flow time series to simulate flows and levels under those operations and demands. The unimpaired flow data set is the product of the Tri-State Comprehensive Study, in which the States of Alabama, Florida, and Georgia, participated.

The current unimpaired flow data set represents the years 1939 to 2008. The Corps has not yet computed unimpaired flow for 2009 to current day. Unimpaired flow computations require actual water use data from the three States, and 2008 is the most recent year of this data provided to the Corps. As described above, the consumptive demands used in the models are summarized in Table 4.2.A. A 70-year unimpaired flow hydrologic period of record (1939 through 2008) was used to run the simulations; however, for the purposes of this effects analysis, we focus on the data from the Baseline Post-West Point period (1975-2008; see sections 3.3 and 4.2).

The Corps has simulated the 1975-2008 ACF project operations under the RIOP using the HEC-ResSim hydrologic simulation software. To ensure comparisons that are most likely to reveal anthropogenic differences between the sets of environmental conditions (RIOP and Baseline) and not hydrologic differences between years, we use the output from the ResSim models for the period that is also represented in the baseline, which is 1975 to 2008 (34 years). Using only the latter 34 years of the ResSim results removes 36 years of model results from our analysis, including a drought during the 1950's. However, the later 34 years of the simulated period appear to represent the most "critical" period for the model, as this is when reservoir levels and flows reach their lowest levels in the full 70-year simulation.

The fall rates used in the ResSim model for the 2008 BO and the 2011 BA followed the maximum fall rate schedule. However, the Corps believes that when flows are less than 10,000 cfs, the observed fall rates are more conservative than those reflected in the model due to the limitations of the equipment and careful operations to avoid violating the maximum fall rate schedule when flows are less than 10,000 cfs. Because the model has limited ability to represent the actual down-ramping operations, we requested that the Corps simulate the RIOP using a fall rate they believed to be more representative of actual operations. The RIOP continues to prescribe fall rates of <0.25 ft/day for releases less than 10,000 cfs, but the Corps simulated the RIOP using a standard 0.13 ft/day fall rate (see section 4.2.3), which is the average fall rate in this range of flows since the Corps implemented the maximum fall rate schedule in September 2006. This is consistent with previous simulations for the 2008 BO (and currently for this BO) that use a slightly higher minimum flow than 5,000 cfs (5,050 cfs) in the model simulation rules to better reflect actual conservative operations in place to avoid violating the 5,000 cfs minimum flow provision.

4.2.2 General Effects on the Flow Regime

The Corps alters the flow regime of the Apalachicola River by storing and releasing water from its reservoirs. The ResSim model of the RIOP simulates these operations using the historically measured/estimated consumptive water uses. To the extent that these consumptive use data are accurate, differences between the historically observed flows (i.e., baseline, 1975 to 2008) and the simulated flows of the RIOP are due to differences in reservoir operations, as the model is driven by the observed hydrology. The volume of water in the Corps' three largest ACF reservoirs (composite storage of Lanier, West Point, and W.F. George) is seldom stable for extended periods, and follows a general pattern of increasing storage from January through June or July, and decreasing storage thereafter. The expected general pattern of flow alteration, therefore, is depletion during the first half of the year during periods of relatively high flow and augmentation during the second half of the year during periods of relatively low flow.

Figure 4.2.2.A shows the magnitude of this annual cycle of re-fill and draw-down by comparing the January-to-June maximum composite storage level with the July-to-December minimum composite storage level for both historical operations and the RIOP for the years 1976 to 2008 (we could not use 1975 to 2008 for this comparison because composite storage values for the complete year of 1975 were not available). The primary difference between the observed historical levels and the RIOP levels is the amplitude of the annual cycle: the RIOP generally has lower maximum storage in the first half of the year, and higher minimum storage in the second half of the year. The annual average drawdown under the RIOP by this measure is 407,003 acre feet, compared to 653,772 acre feet historically, a 38% reduction in reservoir drawdown. Stored or released at a constant rate over a 6-month period (180 days), these volumes are equivalent to flow rates of 1,140 cfs and 1,831 cfs, respectively.

Figures 4.2.2.B and 4.2.2.C examine how the RIOP's change in the overall range of reservoir elevations would affect the seasonal timing and magnitude frequency of the flow of the Apalachicola River. These figures show the frequency (% of days) that daily average discharge (cfs) values are exceeded during the years 1975-2008 for each calendar month. To better view the differences between the exceedance frequencies of the historical flows and the RIOP flows, Figures 4.2.2.B and 4.2.2.C display the results of this analysis for flows that are exceeded more than 10% of the time because the highest flows are generally several orders of magnitude greater than all other flows and would require a much expanded scale for the vertical axis. Figures 4.2.2.B and 4.2.2.C also list the average of all the days included in the analysis for each month, including the highest flows, which is a measure of the total volume of water represented by the frequency/magnitude curves.

Despite the reduced amplitude of the annual reservoir refill/drawdown cycle noted above, the frequency and magnitude of simulated flows under the RIOP are generally comparable to historical flows in January through April and in December. Average flows under the RIOP for these months are within 3% of the historical baseline averages. The remaining months of the year, however, show greater departures from the historical flows. RIOP flows are higher more often in November, making average flow in November 10.7% greater under the RIOP. Average flow in October is 4.0% greater under the RIOP, with higher frequencies at flows greater than about 14,000 cfs and less than about 10,000 cfs. RIOP flows are generally lower more often in

May through September, with the greatest departures in August and September, where average flows of the RIOP are 1,053 cfs (7.4%) and 757 cfs (6.3%) lower than historical baseline flows, respectively. Lower flows during these months negatively affect mussels because the risk of exposure is higher, habitat is constricted, and water temperatures are higher.

We used the Corps' simulated RoR operation to count the number of days that reservoir operations, both historically observed and simulated under the RIOP, were either decreasing or increasing the flow into the Apalachicola River, and to quantify the volume of that depletion and augmentation. For simplicity, we counted all deviations from RoR flow as either a depletion or an augmentation, and on no days did the simulated RoR flow exactly equal the Baseline or RIOP flow. Historical ACF reservoir operations altered the flow 56.3% of the days by flow augmentation and 43.7% of the days by flow depletion, whereas the RIOP simulation is slightly more evenly divided between augmentation days (53.7%) and depletion days (46.3%). The more striking difference between the Baseline and the RIOP is in the volume of the alterations. When Baseline flow was greater than the estimated RoR flow, the average daily augmentation was 3,287 cfs, and when Baseline flow was less than RoR, the average daily depletion was 3,936 cfs. Under the RIOP, average daily augmentation was 1,801 cfs, and average daily depletion was 2,066 cfs. Operations in support of commercial navigation throughout most of the Baseline, a practice which is not simulated in the RIOP, may partially account for this difference in depletion/augmentation volumes. However, even in the more recent years of the Baseline (post 1999), during which the Corps has only occasionally stored water and made releases for navigation, the average daily flow alteration (both augmentation and depletion) is about 50 percent greater than under the same years of the RIOP simulation.

The RIOP model maintains a minimum release from Woodruff Dam of between 4,550 and 5,050 cfs, a flow range which occurs about 3.7% of the time (464 days) in the years 1975-2008. Flows less than or equal to 5,050 cfs occurred for 117 days in the Baseline record, or 0.9% of the time, and the lowest flow recorded was 3,900 cfs. The RIOP is intended to support the minimum flow 5,000 cfs until composite storage falls into the "drought zone" of Zone 4, which occurs for one month in the simulation (November, 2007). Only the 5,000 cfs minimum release (and 4,500 cfs while in the drought zone) and downramping according to the fall rate schedule are supported with releases from storage: all other minimum release provisions of the RIOP do not require flows that are greater than current levels of basin inflow. If we discount the storage required to meet the fall rate schedule, we may estimate the amount of storage required each year solely to sustain the minimum release schedule of the RIOP as the sum of daily deficits in basin inflow relative to 5,050 cfs (5,050 minus basin inflow), and relative to 4,550 cfs during drought operations (4,550 minus basin inflow in November, 2007). Figure 4.2.2.D shows the total deficits for the years 1975 to 2008 using the RoR simulation as the measure of basin inflow (actual operations use 7-day average basin inflow computed from daily local inflow for each reservoir). Most years (19 years of the 34 years, or 55.9%) have no deficit, and the non-zero deficit years vary from almost none to 702,411 ac-ft in 2007. Total storage capacity of lakes Lanier, West Point, and George is about 3.5 million ac-ft, of which 1.6 million ac-ft is considered "conservation" or "active" storage.

We examine the possible effects of these various changes to the flow regime to the listed species and their habitats in the remaining sections of this chapter.

4.2.3 Submerged Habitat Below 10,000 cfs

This section focuses on direct effects to mussels by exposure during low-flow conditions. As discussed in section 3, the Service and others documented stranding and mortality of fat threeridge mussels in 2006-2007 and 2010-2011 at elevations above 5,000 cfs, and as high as about 10,000 cfs (USFWS unpub data 2006). Fat threeridge located in moderately depositional habitat are likely moving in response to changing water levels to maintain an optimal depth or associated habitat parameter. Because we have observed fat threeridge readily recolonizing these areas, it now appears that mortality events that occur at flows above 5,000 cfs as a result of water level declines are not anomalies, as we assumed in the 2008 BO. Mussel distribution at high stages may occur following one or more years without low flows that permit mussels to move and recruit into higher portions of the stream bed. Future flows and circumstances will likely lead to mussels recolonizing areas that are vulnerable to stranding and exposure under the proposed RIOP. It is therefore appropriate to analyze the differences between the Baseline and RIOP flow regimes in the range of flows less than 10,000 cfs as a measure of the effects of the proposed action. Further, the drought contingency provisions of the RIOP stipulate flows as low as 4,500 cfs under certain circumstances, which would expose portions of the channel that have only been exposed for 130 days in the last 83 years (<0.4% of the record). This probably would not include the deeper, stable mussel habitats currently being evaluated by Gangloff (see section 3.4).

Table 4.2.3.A lists the lowest daily flow each year for the Baseline and RIOP flow regimes. The RIOP has the lowest flow in half (17 out of 34) of the years. It results in one year (out of 34; 3%) with flows less than 5,000 cfs, which occurred in the Baseline in 21% (7 out of 34) of the years. Figure 4.2.3.A shows the inter-annual frequency of flow rates less than 5,000 to 10,000 cfs in the Baseline and RIOP flow regimes. The RIOP results in a lower percentage of years with flows less than about 7,500 cfs than the Baseline flow regime. However, the inter-annual frequency of flow events between about 7,500 to 10,000 cfs is higher in the RIOP flow regime than in the Baseline regime.

We use the maximum number of days per year with flows less than 5,000 to 10,000 cfs as a measure of the most severe year for aquatic biota under each flow scenario. In this respect, both flow regimes include more than 200 days during the driest year at all flow levels except the < 5,000 level (Figure 4.2.3.B). The RIOP and the Baseline flow regimes are similar for the entire range of flows. The maximum annual duration of flow less than 5,000 cfs is lower in the RIOP than the Baseline and also lower for all flow categories from 7,000-10,000 cfs. However, the RIOP flow regime has a longer maximum annual duration of flows less than 6,000 cfs than the Baseline.

As discussed in section 3.4.1.2, some mussels may survive brief periods of exposure by closing their shells tightly or burrowing into the substrate, and the stress of exposure is most likely a function of exposure duration and temperature. In addition to the most-severe year analysis shown in Figure 4.2.3.B, we performed a most-severe event analysis by computing the maximum number of consecutive days of flow less than the 5,000 to 10,000 cfs thresholds, which is shown in Figure 4.2.3.C. The RIOP has an adverse effect at the 5,000 cfs because it has a higher maximum number of consecutive days less than 5,000 cfs than the Baseline (30 and 26 days, respectively). Although this 13% difference is not great, data from USFWS (2011) indicate that some mussel mortality can continue to occur for 27 days (or more) after exposure. The RIOP also has more than twice the maximum number of consecutive days with flows less than 6,000 cfs than the Baseline. Both flow regimes have an extreme effect on mussels at the 6,000 cfs level because mussels would be exposed for 104 days under the Baseline and 216 days under the RIOP. At the 7,000 cfs level and greater, the RIOP yields a lower maximum number of consecutive days than the Baseline flow regime.

Because moderately low flows, not just the most extreme events, constrict aquatic habitat availability and are generally stressful to mussels and other aquatic biota, it is appropriate to also consider the more common low-flow condition, *i.e.,* the magnitude and duration of low flows that occur in half the years of the flow regime. If the common low-flow conditions become even more common or more severe, it would reduce the amount of habitat available to mussels and would increase their vulnerability to exposure-related mortality, including increased predation by terrestrial predators. Figure 4.2.3.D shows the median number of days per year less than the thresholds of 5,000 to 10,000 cfs. The RIOP results in a higher median number of days than the Baseline for flows between 7,000 cfs and 9,000 cfs. The Corps provided a similar analysis in their BA that used the mean number of days per year less than the thresholds of 5,000 to 10,000 cfs (Corps 2011). However, the mean distorts what is considered typical because these data include many outliers, which strongly affect the mean. The median is not influenced by outliers and is a more appropriate measure of the central tendency of these data.

The Corps also provided an analysis of the median number of consecutive days per year of discharge less than 5,000 to 10,000 cfs (Figure 4.2.3.E) (Corps 2011). This analysis examines the more frequent, but less severe exposure events. The RIOP results in a higher median consecutive number of days at flows less than 9,000, and 10,000 cfs threshold levels. We did not include the Corps' analysis of the mean number of consecutive days per year for the reason (means are strongly affected by outliers) described above.

The maximum fall rate schedule of the RIOP (Table 1.3.A) was formulated to facilitate movement of mussels and other aquatic biota from higher to lower elevation habitats. The intent of the schedule is to avoid extreme daily declines in river stage and thereby lessen the potential for exposing or stranding listed mussels, their host fish, and other aquatic biota. The schedule limits operations to more gradual fall rates as flow declines to the river stages where listed mussels may occur. To analyze effects due to altered fall rates, we computed daily rates of stage change of the Baseline period directly from the daily average gage height values recorded for the Chattahoochee gage as the difference between each pair of consecutive daily values (previous day gage height minus current day gage height = change rate associated with current day). For the modeled RIOP, we used the Chattahoochee gage rating curve that characterizes the stage/discharge relationship during recent years (Light et al. 2006) to compute the gage heights associated with simulated daily flows, and then computed change rates in the same fashion as for the observed gage heights. Figure 4.2.3.F is a frequency histogram of the rate of change results, which lumps all stable or rising days into one category and uses the ranges that correspond to the RIOP maximum fall rate schedule as categories for the falling days (<=0.25 ft/day, > 0.25 to <= 0.50 ft/day, > 0.50 to <= 1.00 ft/day, > 1.00 to <= 2.00 ft/day, and > 2.00 ft day). Among the falling days, rates less than 0.25 ft day are the most common occurrence in each flow regime.

The RIOP has a higher percentage of days in the fall rate categories of 0.25-0.5 ft/day and 0.5-1.0 ft/day than the Baseline. This shift increases the relative risk of stranding and exposure of aquatic organisms; however, the differences are small and most of the shift is confined to the 0.25 to 0.50 ft/day category and not the more extreme category. The RIOP results in lower fall rates in the most extreme fall rate categories (>1 ft/day), which may reduce the risk of stranding of host fish.

As noted earlier, we observed mussels exposed in 2006 at stages as high as about 10,000 cfs. To determine whether an increase in the percentage of days in the greater than 0.25 ft/day ranges of fall rates might directly affect listed mussels, we performed a second analysis that focused on flows less than 10,000 cfs. For this analysis, the flow of the preceding day is associated with the rate of change to flow on the current day. Figure 4.2.3.G shows a count of days in the various rate-of-change categories when flow was less than 10,000 cfs. We use a count of days here instead of a percentage of days as in Figure 4.2.3.F because each flow regime has a different number of days less than 10,000 cfs, and this difference is relevant to the effects analysis. The number of days in the greater than 0.25 ft/day categories for the RIOP is less than the Baseline (246 and 269 days, respectively). This is beneficial because the RIOP reduces the number of days that the most extreme fall rates are occurring.

Comparing the total number days that the lowest fall rates (<0.25 ft/day) occur when flows are less than 10,000 cfs does not fully describe the relative risk of stranding to mussels, because we have observed mussels exposed at fall rates <0.25 ft/day. At the time of the 2008 BO, we believed that fall rates of <0.25ft/day were protective of mussels; however, we now know that mortality occurred in 2006 and 2010 when fall rates averaged 0.20 and 0.17 ft/day respectively. We also observed mortality in 2011 when fall rates were about 0.21 ft/day at Wewa. A better way to estimate the relative risk of fall rates to listed mussels is to examine the median and maximum fall rates in the Baseline and RIOP when flows are less than 10,000 cfs. The median fall rate when flows were less than 10,000 cfs was slower during the Baseline period (0.06 ft/day) than the RIOP flow regime (0.12 ft/day) (Table 4.2.3.B.).

It is not surprising that the median fall rate of the RIOP flow regime was 0.12 ft/day given that the model uses a fall rate of 0.13 ft/day when flows are less than 10,000 cfs. As discussed in section 4.2.1, the Corps (2012) maintains that the actual fall rates that will occur during the implementation of the fall rate schedule will be less than the maximum rates in the schedule due to the limitations of the equipment and careful operations to avoid violating the schedule. To examine this, we calculated the cumulative frequency (% of days) of fall rates when flows were less than 8,000[5] cfs that have been observed since the incorporation of the <0.25 ft/day fall rate provision at JWLD (observed flow 2006-2011), and compared these with the Baseline record (1975-2008) (Figure 4.2.3.H). This analysis illustrates that implementing the maximum fall rate schedule has decreased the percentage of days falling faster than 0.20 ft/day relative to the Baseline, but has increased the percentage of days in the fall-rate range from 0.04 to about 0.20 ft/day[6]. Fall rates less than 0.20 ft/day are likely more protective of listed mussels given that fat

[5] Even though the proposed fall rate of <0.25 ft/day applies when flows are less than 10,000 cfs, we used 8,000 cfs because the fall rate provision adopted in 2006 only required rates <0.25 ft/day when flows were less than 8,000 cfs.
[6] It should be noted that the fall rate provision of 0.25 ft/day was suspended for some of this period because drought operations occurred. This may affect these results.

threeridge can move to track slower water declines; however, slower fall rates are not likely to completely eliminate mortality, because some site slopes are too shallow for mussels to track declines (Figure 3.4.1.2.B).

During drought contingency operations, the RIOP proposes to manage river stage declines at a rate that does not exceed the rate of declining 1-day basin inflow, which could be faster than the prescribed fall rates in all categories. The initial downramping will occur at a rate no faster than 0.25 ft/day. In the 2008 BO, we analyzed the historical record of 1-day basin inflow (1976 to 2007) and computed fall rates using the stage-discharge relationship published in Light et al. (2006) to transform discharge from Woodruff Dam to stage. Because 1-day basin inflow is a snapshot of flow rates across the entire basin at one time, it is quite “flashy.” Transforming the daily changes in basin inflow to stage at the Chattahoochee gage results in a time series where 44% of the days of declining stage exceed a fall rate 2.0 ft/day, compared to 0.8% in the pre-Lanier record (1929-1955), and 38% exceed a fall rate of 2.0/ft/day when inflow rates are less than 30,000 cfs. More extreme fall rates in this data are quite common, with 864 days exceeding 4 ft/day. Therefore, it is apparent that the provision of the RIOP to manage fall rates not to exceed the fall rate of 1-day Basin inflow during drought contingency operations could result in extreme river stage declines and stranding of host fish in the floodplain. However, we do not anticipate direct effects to mussels, because they would have previously moved from (or died in) higher elevations during a drought, and it is unlikely that mussels would recolonize these habitats during short pulses of higher flows that may occur during drought contingency operations.

The comparisons of flow regime features considered in this section show both beneficial and adverse effects for the RIOP relative to the Baseline. The RIOP eliminates the most severe effects of flow less than 5,000 cfs by supporting this level as a minimum flow with releases from reservoir storage unless the basin is experiencing an exceptional drought, which occurred once in the model simulations under past hydrology and consumptive demands. Mussels and other aquatic biota will likely experience increased stress in the future as the river will experience low-flow conditions more often and for longer periods under the RIOP than under the Baseline conditions. Aquatic biota will likely benefit from lower fall rates in the most extreme categories, but there may be an increased risk of mussel stranding relative to historical operations when mussels are located at stages greater than 5,000 cfs.

4.2.4 Floodplain Connectivity and System Productivity

We analyzed the indirect effects on mussels via changes to the frequency, timing, and duration of floodplain habitat connectivity/inundation. These productive areas serve as spawning and rearing habitats for one or more of the host fishes of the listed mussels (see section 3.5.5). Floodplain inundation is also critical to the movement of organic matter and nutrients into the riverine feeding habitats of the mussels.

Our analysis uses the relationship documented by Light et al. (1998) between total area of non-tidal floodplain area inundated and discharge at the Chattahoochee gage (Figure 3.3.2.B). Figure 4.2.4.A displays a frequency analysis of the results of transforming the Baseline and RIOP daily discharge time series during the growing season months (April – October) to connected floodplain area. The overall area/frequency pattern of the RIOP is comparable to the Baseline.

The median amount of connected habitat under the RIOP (acres inundated for half of the growing season days 1975-2008) is 1,835 acres, compared to 2,286 acres for the Baseline; however, the amount of habitat connected to the main channel at a given frequency is very similar.

It is important also to consider the temporal pattern of floodplain inundation to interpret biological effects. In section 3.3.2, we explained our method for quantifying 30-day continuous floodplain habitat inundation. We extend this analysis to the RIOP flow regime in Figure 4.2.4.B. The RIOP almost always provides more annual 30-day continuous connectivity than the Baseline. The median amount of 30-day continuous connected habitat under the RIOP (acres inundated for at least 30 days in half of the years 1975-2008) is 27,601 acres, compared to 22,139 acres for the Baseline. This increase in the amount of 30-day continuous connected habitat is beneficial.

4.3 Species' Response to the Action

The previous section on Submerged Habitat Below 10,000 cfs (4.2.3) discussed the effects of flow regime alteration on the habitat of post-larval listed mussels, and the section on Floodplain Connectivity and System Productivity (4.2.4) discussed effects on an important habitat of the fishes that may serve as hosts for the mussel's larval life stage. The following sections interpret these habitat effects on the critical habitat and listed mussels in light of studies on the spatial distribution and biology of the mussels and their host fishes.

4.3.1 Critical Habitat

As described above, the PCEs that may be affected by the RIOP include permanently flowing water, water quality, and host fish. Lower flows described in section 4.2 will result in a decrease in the amount of permanently flowing water in Swift Slough and side channel swales. However, as described in section 3.5.3, data indicate that mussels persist in these areas, and the habitat is not permanently lost. As such, we do not expect that the low flows will permanently limit the ability of the designated critical habitat to function for the conservation of the species. Similarly, we expect localized water quality impacts (low DO and high temperatures) to continue to occur in the action area during periods of low flows, but these temporary changes in water quality should not permanently limited the ability of the critical habitat to function for the conservation of the species.

Fish hosts may also be affected by the RIOP. As described in section 2.2, host fishes for these three mussel species that occur in the action area include the weed shiner, bluegill, redear sunfish, redbreast sunfish, largemouth bass, eastern mosquitofish, blackbanded darter, and Gulf sturgeon. Many of these species are known to extensively use floodplain habitats for spawning and rearing (section 3.5.5). Fish are affected by low-flow events due to constriction of habitat, elevated temperature, reduced dissolved oxygen in backwaters, etc. The measures of low-flow effects previously used to assess potential mussel exposure effects are also applicable to these host fish. We rely upon floodplain spawning habitat availability as the principal measure of effects to host fish over direct low-flow effects. Most fish spawning activity occurs in the growing-season months of April through October, but most floodplain inundation occurs in the months of January through April, when discharge exceeds 20,000 cfs substantially more often than in other months. Therefore, April is likely the month of greatest floodplain habitat utilization, with March and May heavily used when temperature and discharge coincide favorably.

The thresholds for retaining basin inflow in the reservoirs under the RIOP are higher in the months of March through May in recognition of fish spawning and rearing activity in the main channel and in the floodplain. Overall, the amount of habitat connected to the main channel at a given frequency is very similar, even though the median amount of connected habitat is lower under the RIOP (Figure 4.2.4.A). The RIOP almost always provides more annual 30-day continuous connectivity than the Baseline. Although there is little difference in floodplain connectivity between the RIOP and Baseline based on these parameters, we do not have enough information to determine how this may impact host fish, and as a result mussel recruitment.

4.3.2 Chipola slabshell

The recent survey conducted by Gangloff (2011) provided a population estimate of 2,645 slabshell in bank margin habitats <2 m deep; however, this estimate may be low because it is based on only 10 individuals collected at two low-density sites. No mortality due to exposure from low flows was recorded in 2006-2008 or 2010-2011. The lack of mortality may be attributed to its depth and the slope of the banks in the Chipola River, which are generally steep enough to facilitate mussel movement (section 3.4.1.2). Chipola slabshell may also be highly mobile, as other members of the genus *Elliptio* have been shown to be (Watters 1994), which may additionally facilitate movement in these areas.

As such, changes in the flow regime due to the RIOP that affect the frequency and duration of flows greater than 4,500 cfs are unlikely to affect the Chipola slabshell, except possibly through effects to host fish and system productivity (section 4.2.4). However, it is possible that the species occurs at shallower depths than reported in this BO because our sampling was limited to two locations and few individuals. It is also possible that individuals may have been stranded and overlooked during surveys from 2006-2008 and 2010-2011. If so, undetected mortality may be occurring at an undefined rate. We expect exposure mortality for the Chipola slabshell is less than for the fat threeridge or purple bankclimber because it is probably more mobile and site slopes are generally >0.20 in the Chipola River (most fat threeridge are stranded when slopes are <0.20) (section 3.4.3). Based on observations of fat threeridge in 2011, combined with the motility and locality information above, we expect that undetected mortality is far less than 1% of the population. Further, we have probably underestimated the population size of Chipola slabshell because of limited sampling at low density sites. Taken together, expected mortality of less than 1% for a population greater than 2,645 individuals, would result in less than 26 individuals being affected in the action area.

4.3.3 Purple bankclimber

The only known location where the purple bankclimber is locally abundant is the limestone shoal at RM 105 (Race Shoals), where Gangloff (unpub data 2011) estimated that about 56,000 individuals occur. Very few individuals have been collected from the remainder of the river.

We were unable to quantify the amount of mortality at elevations above 5,000 cfs in 2006-2007. We did not observe any dead purple bankclimbers at elevations above 5,000 cfs during our surveys in 2010-2011. Unlike the fat threeridge, it does not appear that purple bankclimber recolonized elevations above 5,000 cfs between 2008-2011. Movement at this site is probably very difficult for mussels due to the highly irregular and jagged nature of the limestone substrate. This is further supported by a lack of movement observed during studies in 2007. Based on Gangloff's recent surveys of the shoal, it is unlikely that there are currently any live purple bankclimbers at elevations above 4,500 cfs.

Limited purple bankclimber mortality (less than 1%) occurred in 2007 and 2011 when flows were less than 5,000 cfs (three individuals in 2007 and 6 to 39 individuals in 2011), probably because they occur in deeper habitats. Gangloff estimated that about 95% of purple bankclimbers surveyed at the shoal occurred at depths greater than 1.5 m (~5 ft) when flows were about 4,400 cfs, a flow lower than the RIOP minimum release. Mean density in these areas was $0.17/m^2$ vs. $0.48/m^2$ in water deeper than 1.5 m. Based on the current distribution of purple bankclimbers at the shoal, we do not expect that any individuals would be exposed at flows above 5,000 cfs, and it is also unlikely that any individuals would be exposed at flows above 4,500 cfs. However, it is possible that these elevations will be recolonized in the future with new recruitment if flows are higher than 5,000 cfs for sufficient periods.

Purple bankclimbers located in shallow water are at higher risk of predation and collection. It is evident that they are being harvested by fishermen and used for bait at the shoal. The mussels may be more readily available to fishermen as a result of low water levels, but it is difficult to ascertain the degree to which this may differ between the baseline and the proposed action. However, the amount of observed mortality that was attributed to fishermen was small (although not well quantified to date) relative to the total observed mortality of purple bankclimbers at the shoal. Bankclimbers in shallow water are also subjected to stress from high temperatures and low dissolved oxygen, because the shallow portions of the shoal become a nearly stagnant pool environment with excessive algae growth during extended periods of low flow. Decreasing water levels further may harm some fraction of the bankclimber population at this site, but it is difficult to determine from available information.

It is also possible that bankclimbers could become exposed at other sites throughout the river. We have found bankclimbers in very small numbers at a few of the moderately depositional sites where we find the fat threeridge, and some of these animals were situated in shallow areas that would be exposed with the reduced 4,500 cfs minimum flow under the RIOP. However, no purple bankclimbers were observed exposed at these sites in 2010 or 2011 and none have been collected during quantitative sampling to determine distribution at depth at these sites. Purple bankclimbers were also collected at one time from Swift Slough, and these would be subject to exposure at flows above 5,000 cfs. Again, it is possible that these areas will be recolonized in the future if flows are higher for sufficient periods.

If bankclimbers recolonize these habitats, they might be affected by the provision to reduce flows to 4,500 cfs and changes in the flow regime that affect the frequency and duration of flows greater than 5,000 cfs. It is difficult to quantify how many individuals might recolonize bank elevations above 4,500 cfs. The Corps estimated take of 39 individuals last summer when flows were reduced below 5,000 cfs, which is less than 0.1% of the population. If we conservatively assume that 0.1% of the population would again recolonize that area of habitat, it could potentially affect 56 individuals. Similarly, we expect that no more than 0.1% of the population would recolonize the elevations above 5,000 cfs during the timeframe of this action, so we also anticipate that 56 individuals may be affected if purple bankclimber recolonize area above elevations of 5,000 cfs and subsequent mortality occurs at low flows.

4.3.4 Fat threeridge

The current range of the fat threeridge is about 40% of its historical range (USFWS 2003), and its range may continue to decline as it now appears rare in the upper river and almost entirely absent upstream of RM 90. However, as described in section 3.4.1.2, the fat threeridge population in the action area appears stable and may be increasing in size. Estimates of the population size of fat threeridge in the action area range from about 826,000 to 1,144,000 animals. About 23-35% of the population occurs in RM40-50 reach of the river, and the largest portion of the population occurs in the Chipola Cutoff and lower Chipola River downstream of Dead Lake (49-66%). This portion of the Chipola receives about 34% of the flow from the Apalachicola River (Biendenharn 2007); therefore, flows in the Apalachicola River affect flows in the Chipola River.

The fat threeridge population was affected by low flows between 5,000 to 10,000 cfs in 2006-2007 and 2010-2011, and also by flows less than 5,000 cfs during 2007 and 2011. Mortality estimates from all of these events range from <1-2%, depending on preceding hydrologic conditions, fall rates, habitat condition, and the size of the population in Swift Slough. Since the first event was recognized in 2006, 3-4% of the total estimated population of fat threeridge may have died during these various low flow events.

We did not account for the mortality between 5,000 to 10,000 cfs impacts in the 2008 BO because no fat threeridge were known to occur at bank elevations equivalent to river stages greater than 5,000 cfs due to the drought of 2006-2008. However, the 2010 surveys indicated that substantial numbers (23% of the population) recolonized stages above 5,000 cfs. Fat threeridge located in moderately depositional habitat are likely moving in response to changing water levels to maintain an optimal depth or associated habitat parameter. Sediment deposition may also play a role. Because fat threeridge readily recolonize these areas, we now understand that mortality events that occur at flows above 5,000 cfs as a result of water level declines are not anomalies, as we assumed in the 2008 BO, and warrant evaluation. This is the new information that resulted in reinitiating the RIOP consultation.

To fully evaluate the impact of these mortality events, we needed to identify the factors that may result in mussels recolonizing higher river stages and then becoming exposed as flows decline. Together with the Corps, we examined the flow record leading up to the 2006 and 2010 events to determine when and how these events occurred, assuming that any of our three hypotheses for how they recolonize these areas was correct: (1) movement upslope over time given high enough flows, (2) movement vertically to maintain contact with the sediment surface given sediment deposition in their habitats, or (3) mechanical displacement to higher elevations and loop streams/distributaries by high flow events. Based on the similarity of conditions leading up to and between the two events, we derived two independent criteria for a low-flow event relating directly to our two hypotheses for recolonization: (1) 22 consecutive months or at least two full spawning periods with average monthly discharge > 8,000 cfs and (2) at least 24 days at bankfull discharge (72,100 cfs) per year because bankfull events move/deposit the most sediment over time. As described in section 3.4.1, sediment movement probably contributes to the changing depth distribution of fat threeridge, but horizontal movement is more likely the dominant means of redistribution; therefore, we expect that the temporal extent of flows >8,000 cfs is the primary factor.

We defined these criteria prior to our sampling in 2011; however, our study indicated that some limited fat threeridge recolonization of habitat above the September/October 2010 "ceiling" occurred within eight months and without a spawning season. As such, we examined other reports to try to refine the criteria for 22 consecutive months (or two full spawning periods). We did not detect any recolonization between the fall of 2006 and spring of 2007. Miller and Payne (2005) demonstrated that fat threeridge were distributed at higher elevations in 2003, but examination of the flow record indicates that the new "ceiling" for fat threeridge occurred in July 2002 when flows were at about 6,000 cfs most of the time. Flows increased and stayed above 10,000 cfs for 14 months (1 complete growing season), and results of their survey indicate that 37-52% of fat threeridge samples (based on the average of all sites) were distributed at flows above 6,000 cfs. It is probable longer durations of higher flows facilitate the movement of more mussels into higher habitats.

We examined the RIOP model output and the Baseline flow record to compare how often events that may facilitate recolonization of higher habitats, as defined above, occur in each scenario. There was no difference in the frequency of the bankfull-flow criterion between the RIOP and Baseline; at least 24 bankfull days occurred in three years within the 34 year record for both the RIOP and Baseline. There was also no difference in the frequency of low-flow events occurring after at least 22 consecutive months of flows greater than 8,000 cfs. These events occurred five times (probability of 0.15) in the Baseline and the RIOP. Even if the definition is modified to 12 consecutive months, the events occur six times in each flow regime. Although the RIOP does not appear to change the frequency of recolonization/mortality events as currently defined, it is important to note that these definitions are hypotheses based on limited data and formulated after-the-fact to explain past observations. Studies designed specifically to address the factors influencing recolonization and subsequent mortality are needed to determine if impacts are attributable to the Corps' discretionary actions. As described above, the RIOP results in more frequent low flows of greater duration, and in fall rates that are faster than the Baseline in some instances; therefore, until new data demonstrate otherwise, we conservatively attribute these mortality events to the Corps' discretionary actions.

Probable Impact of River Stage Decline

As discussed in section 3.4.1.2, fat threeridge move in response to declines in river stage, but mussels need time to move with declining flows. The fall rates were slower than 0.25ft/day during stranding and mortality events in 2006, 2010, and 2011. The fall rates leading up to the mortality in 2006 and 2010 averaged 0.20 and 0.17ft/day, respectively. Eighty-eight percent of the fall rates were greater than 0.06ft/day (which is the median baseline fall rate when flows are less than 10,000 cfs) leading up to the 2006 event and 89% were greater than 0.06ft/day leading up to the 2010 event. Fall rates during the beginning of the 2011 study declined at a rate of 0.21 ft/day at Wewa, followed by a more gradual decline of 0.11 ft/day from May 23-27. The sharpest increase in exposure rates occurred during the drawdown rate of 0.11 ft/day at Wewa; however, this coincided with the inadvertent release of less than the minimum flow of 5,000 cfs so it is difficult to tease out the effects of fall rates versus exceptionally low flows. Mussel mortality occurs at fall rates less than 0.25 ft/day, and slower fall rates will facilitate movement and likely reduce mortality.

During river declines, we have observed a small percentage of mussels burrow into the substrate (~8% at RM 44.3), but most move laterally towards deeper water to avoid exposure (USFWS 2011). Fat threeridge were observed moving 50-100 cm per day to keep up with falling water levels, but we documented several instances where the individual failed to move downslope and became exposed. The majority (70%) of exposed mussels survived between 1 and 6 days following exposure. Areas where mussels were stranded, received full sun for much of the day, and these sites are typical for what occurs in the Apalachicola River, especially in RM 40-50, which has the most abundant main channel populations. Some individuals that successfully moved were later found dead in the water, possibly due to stress from moving, elevated water temperatures, or low dissolved oxygen (USFWS 2011). Those not exposed by the stage decline might also move to lower elevations to avoid the higher risk of predation by terrestrial predators in shallower water.

Because the ability to track receding water levels is related to bank slope (WDNR et al. 2006; USFWS 2011), a greater number of individuals were stranded at low gradient sites during drawdowns. In general, fat threeridge habitats have slopes of less than 40%, and an average slope of about 25%. Because it is a relatively flat space, a small decline in river stage exposes a broad area of habitat. We found that sites with a mean slope of <20% were at a much higher risk of experiencing mortality >1% of the local population. Mussel sites in the Chipola River generally have slopes >20%; therefore, mortality appears to be limited in the Chipola River.

<u>Effect of Reducing Habitat Availability</u>

We do not believe that food availability is presently a limiting factor for fat threeridge in the Apalachicola River. Concentrating mussels into a narrower zone of habitat could have beneficial and/or adverse effects on the mussels. Beneficial effects could include improved reproductive success by increasing fertilization rates or concentrating fish hosts and mussels. Adverse effects could include increased vulnerability to predation, insufficient host fish health or numbers, and increased stress due to poor water quality.

It is possible that many fat threeridge would move downward in response to a stage decline and maintain about the same distribution of numbers at depth, thereby potentially moving into unoccupied and potentially unsuitable portions of the river bed. In the 2008 BO, we noted that fat threeridge and other mussels do not generally occupy this portion of the channel because it is subject to higher velocities and shear stress during higher flows. However, recent sampling (fall 2011) by Gangloff, though limited, may indicate that this is not always the case, and some stable deeper water habitat is available to, and used by, the fat threeridge. Gangloff's work is considered preliminary but ongoing to further assess this possibility. It is also possible that fat threeridge that may move into previously unoccupied habitat could be displaced from this habitat in higher spring flows and either killed or deposited in areas that may or may not constitute suitable habitat (Hastie et al. 2001). We have no way to evaluate the number of individuals that may be affected in this way. Conversely, if deeper water habitat may be suitable, we are uncertain of the amount of habitat that may be lost when flows are reduced because it could be gained in equal measure.

Evaluation of Effects of Estimated Mortality

As we describe above, the mortality due to low flows observed from 2006-2011 depends on primarily on preceding hydrologic conditions: if flows are high for long periods (2002-2006), then mortality tends to be higher (2% in 2006-2007) and if the high water periods are shorter, then mortality is lower (2008-2010, 2010 mortality <1% of the population). Mortality in the second year of an event may also be lower when low flows in the first year force the population to retreat to lower bank elevations (USFWS 2011). Therefore, it is difficult to predict the relative impact of these events in time. For the purposes of these analyses, we assume that the events from 2006-2011 have captured the range of variability in mortality rates.

It has been shown that small chronic increases in adult mortality rates, e.g., harvesting, result in population declines for mussels (Hart et al. 2004). Interpreting the significance of 1-2% mortality involves considering the life history characteristics of the species and knowledge of the environmental conditions under which the species evolved. Relative to the species' evolutionary time frame, the record of streamflow data from the Chattahoochee gage is very brief; however, flows never went below 5,000 cfs in the pre-dam period of that record. We assume mortality that occurs at flows less than 5,000 cfs would occur in addition to natural mortality. Because we have no evidence for density-dependent mortality in this species, we cannot assume that this mortality would somehow offset normal levels of natural mortality. We do know, however, that mortality events above 5,000 cfs (as defined by the hydrologic criteria discussed above) likely occurred in the past, and examination of the pre-dam data indicate that these events occurred with a similar frequency (three times over 17 years; probability 0.18).

The current range of the fat threeridge is limited to approximately 40% of its historical range (USFWS 2003), and may continue to decline still as it now appears to be almost entirely absent upstream of RM 90. Although recent population estimates suggest the population could be over one million individuals, this seemingly large number does not necessarily guarantee its survival or recovery, which depend on its demographic characteristics and the threats to its habitat. Hutchings and Reynolds (2004) cautioned against assuming that apparently high levels of abundance in populations that were formerly much more abundant assures long-term population survival. Although population abundance can appear high, population estimates do not provide the actual number of individuals that contribute genes, which is reflected by the effective population size that can be substantially lower (Nunney and Elam 1994; Frankham 1995; Vucetich et al. 1997; Turner et al. 2006). For example, Turner et al. (2002) studied the effective population size versus the population size of red drum (Sciaenops ocellatus), which is a marine fish that is similar in life history to the fat threeridge. They found that estimates of effective population size of red drum were three orders of magnitude less than the adult population size. Populations with small effective population size may suffer reduced capacity to respond to changing or novel environmental pressures, inbreeding depression, and/or accumulation of deleterious alleles (Frankham 1995; Higgins and Lynch 2001), and populations with enormous adult census numbers may still be at risk relative to decline and extinction from genetic factors (Turner et al. 2002).

As discussed in section 3.4.1.2, a PVA model for fat threeridge was recently updated to assess the status of the population (Miller 2011b). We used the PVA to assess the potential impacts of low-flow events (i.e., mortality occurring at flows > 5,000 cfs) and extreme low-flow events (i.e., mortality resulting from flows less than 5,000 cfs) on the future viability of the fat threeridge. Low-flow events were not assessed for the low baseline population growth rate derived from catch curves (pAD=0.81) because we believe this estimate already incorporates the reduction in survival caused by these low flow events since they are assumed to occur once in every six years. To model these again would result in "double-counting" the mortality and would not give an accurate prediction of fat threeridge population growth dynamics. What follows is a summary from Miller (2011b); for more detailed methods and interpretation see the full report. We asked these specific questions:

1. What is the impact of a "low-flow mortality event" occurring randomly with a probability of 0.1667[7] (once every six years) and with a range of reductions in survival of 2% (2010)[8], 6% (incorrect 2006-2007 estimate[9]), 12% (double 2006), and a worst case scenario 32% (this is a worst-case scenario as a frame of reference that assumes everything potentially affected dies)?
2. What is the impact of an "extreme low-flow mortality event" expected to occur randomly once every 69 years and with a specific reduction in survival of individuals across all age classes? This is the scenario modeled in the 2008 BO.
3. How does variation in the frequency or severity of these events impact the mussel population?
4. What is the impact of both "low-flow" and "extreme low-flow" events occurring together over time on long-term mussel population dynamics?

Results from the PVA indicate that low-flow events between 5,000 - 10,000 cfs can have a significant impact on the long-term viability of the fat threeridge population, depending on the populations' underlying demography (Table 4.3.4.A and Figure 4.3.4.A). If the population is growing only very slowly through other processes (like the roughly stable population modeled with the 0.91 adult survival rate), a low-flow event such as those studied here can cause the population to decline over the long term. Even if the population is showing robust growth, a significant low-flow event could dramatically reduce the rate of that growth, though the likelihood of long-term population decline from this process alone appears to be small.

In contrast to the low-flow event, an isolated extreme low-flow event, even with rather high severity, does not appear to pose a major threat to fat threeridge in the Apalachicola River due to the low probability of occurrence. This conclusion appears to be robust at different underlying

[7] At the time of this report, we believed the probability of such events was 0.167. Recent analysis indicates these rates occurred with a probability of 0.15.
[8] At the time of this report, we believed the 2010 event has the potential to result 2% mortality of the population. We now estimate that 2010-2011 resulted in total mortality of about 1% mortality
[9] At the time of the PVA report, we had estimated that 6% of the population potentially died in 2006-2007, but we now estimate it to be about 2%.

levels of adult survival. In addition, including an extreme low-flow event with low flow events did not appreciably decrease long-term growth dynamics compared to scenarios featuring only low-flow events. Detailed sensitivity analysis suggests that, while the severity of a flow event is a key factor, the frequency of such an event plays an even more critical role in determining the long-term impact of low-flow events. This further underscores the effect of increased agricultural and M&I-related depletions discussed in the Cumulative Effects section.

As discussed in section 3.4.1.2, our preliminary mark-recapture based estimate of adult survival (which was not available at the time of this PVA report) indicate that adult survival in the Apalachicola River is high (pAD=0.98). While this adult survival may be somewhat over-estimated because it does not account for mortality at low flows, we do not expect that this rate would be considerably lower because about half of the population occurs in the Chipola River, where mortality resulting from low flows does not appear to be substantial. This does, however, further highlight the need for more precise estimates of adult female survival in the Apalachicola River based on multiple years of data and additional locations. As discussed in Chapter 3.4.1.2, we believe the fat threeridge population in the action area is stable and probably increasing. Therefore, the PVA indicates that the population of fat threeridge in the action area would be relatively immune to mortality at flows less than 5,000 cfs occurring once in the next five years with a severity of 1-2%. The fat threeridge is also likely immune to the effects of mortality at flows between 5,000 and 10,000 cfs if they occur with a probability of once every six years and a severity of less than 2%.

4.4 Interrelated and Interdependent Actions

We must consider along with the effects of the action the effects of other federal activities that are interrelated to, or interdependent with, the proposed action (50 CFR sect. 402.02). Interrelated actions are part of a larger action and depend on the larger action for their justification. Interdependent actions have no independent utility apart from the proposed action. At this time, the Service is unaware of actions that satisfy the definitions of interrelated and interdependent actions that will not themselves undergo section 7 in the future, or that are not already included in the Baseline or our representations of flows under the RIOP.

4.5 Tables and Figures for Section 4

Table 3.2.1.A. Summary of depletions (cfs) to basin inflow upstream of Woodruff Dam used in the ResSim model of the RIOP. Values represent actual reported/estimated amounts for the years 1975-2008, averaged for dry, normal, and wet years[10], according to the Corps' classification. Negative values for reservoir evaporation indicate a net gain from precipitation.

	M&I				Agriculture				Reservoir Evaporation				Total			
	Dry	Normal	Wet	All years	Dry	Normal	Wet	All years	Dry	Normal	Wet	All years	Dry	Normal	Wet	All years
Jan	334	300	331	312	1	1	0	1	-183	-279	-416	-273	152	22	-85	40
Feb	302	263	295	276	23	3	0	7	-78	-159	-168	-141	246	107	127	142
Mar	345	254	257	276	94	41	31	53	153	-39	-197	-12	592	257	92	316
Apr	453	332	317	359	212	103	83	126	567	389	194	408	1,231	825	594	893
May	615	457	340	480	586	344	292	395	672	573	338	569	1,873	1,374	970	1,444
Jun	715	494	406	536	793	439	368	514	666	485	329	509	2,173	1,419	1,104	1,559
Jul	700	525	382	550	903	587	506	651	477	387	-61	356	2,080	1,499	827	1,557
Aug	710	532	429	562	955	578	486	656	484	409	321	416	2,149	1,519	1,236	1,634
Sep	592	500	485	520	672	328	259	401	418	358	478	386	1,682	1,186	1,222	1,307
Oct	552	466	461	486	251	130	105	156	316	315	265	310	1,119	912	831	951
Nov	435	378	388	392	192	90	70	112	33	-128	66	-67	660	339	525	437
Dec	399	337	358	354	168	79	62	98	-130	-186	-63	-158	437	230	356	293
Average	514	404	371	426	406	228	190	266	284	179	91	193	1,204	811	652	885

[10] Dry years: 1981, 1986, 1988, 1990, 1999, 2000, 2006, and 2007. Wet years: 1975, 1991, 1994, and 2003. All other years in this period were classified as "normal."

Table 4.2.3.A. Annual 1-day minimum flow (cfs) of the Apalachicola River at the Chattahoochee gage for the Baseline (observed flow 1975-2008) and RIOP (ResSim simulated flow 1975-2008).

Year	Baseline	RIOP
1975	12,400	15,077
1976	11,600	9,322
1977	9,220	7,171
1978	8,190	7,222
1979	9,590	8,176
1980	8,790	6,952
1981	4,980	5,169
1982	11,500	9,090
1983	10,800	8,877
1984	10,300	8,324
1985	8,550	7,087
1986	4,430	5,049
1987	3,900	6,228
1988	4,430	5,398
1989	9,140	8,482
1990	5,540	6,307
1991	6,580	9,082
1992	7,650	8,915
1993	5,150	6,258
1994	7,590	9,165
1995	7,130	7,238
1996	6,350	7,827
1997	6,250	6,076
1998	8,130	8,449
1999	5,280	5,050
2000	4,530	5,050
2001	5,360	5,050
2002	5,250	5,050
2003	8,050	9,012
2004	7,360	7,147
2005	8,670	9,228
2006	5,030	5,012
2007	4,760	4,550
2008	4,940	5,050

Table 4.2.3.B. Maximum and median daily fall rates (ft/day) for each fall rate category when releases from Woodruff Dam are less than 10,000 cfs under the RIOP (ResSim simulated flow 1975-2008) and Baseline (observed flow 1975-2008) flow regimes.

	Baseline			RIOP		
Fall Rate Range (ft/day)	N	Median	Max	N	Median	Max
<= 0.25	1270	0.04	0.25	1500	0.12	0.25
0.25 - 0.50	158	0.33	0.50	166	0.28	0.50
0.50 - 1.00	78	0.69	1.00	60	0.69	0.92
1.00 - 2.00	30	1.29	1.98	18	1.19	1.87
> 2.00	3	2.22	2.37	2	2.79	2.97
Overall	1539	0.06	2.37	1746	0.12	2.97

Table 4.3.4.A. Stochastic growth rate for simulated fat threeridge mussel populations incorporating low-flow events as a stochastic phenomenon (mean annual probability of occurrence = 0.1667), under alternative annual adult survival rates. Event severities of 2.0% to 32% correspond to additional mortality imposed upon the baseline levels of juvenile and adult survival rates in the baseline projection matrices. From Miller (2011b) see text for additional information on model construction and interpretation.

Event Severity (% mortality)	Annual Adult Survival, p_{Ad}	
	0.90	0.98
0.0	1.0010	1.0684
1.0	0.9988	1.0631
2.0	0.9979	1.0629
6.0	0.9907	1.0594
12.0	0.9799	1.0529
32.0	0.9418	1.0137

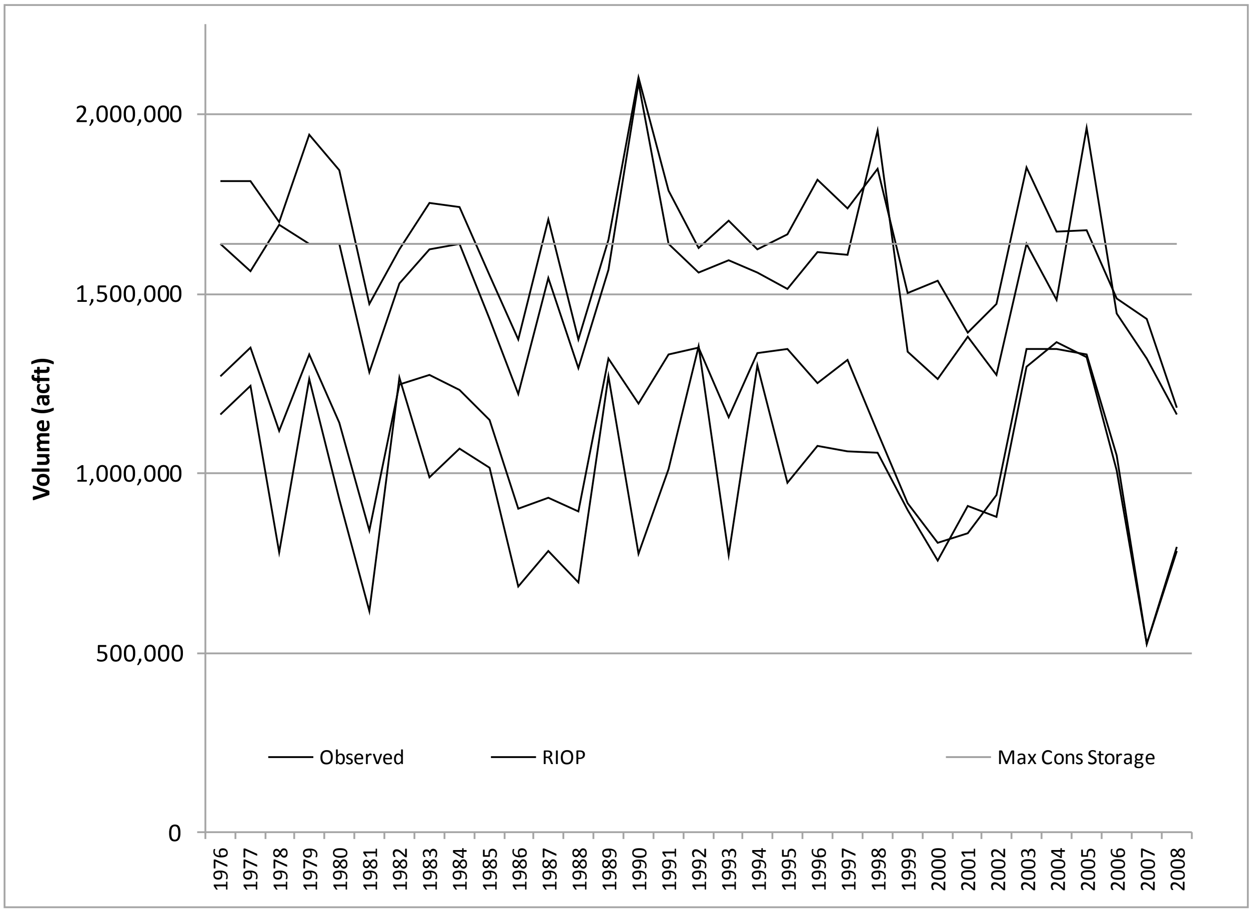

Figure 4.2.2.A. Annual range of reservoir composite storage (excluding inactive storage) as measured by the January-to-June maximum storage versus the July-to-December minimum storage level. Maximums exceeding the "Max Cons Storage" horizontal line include flood storage.

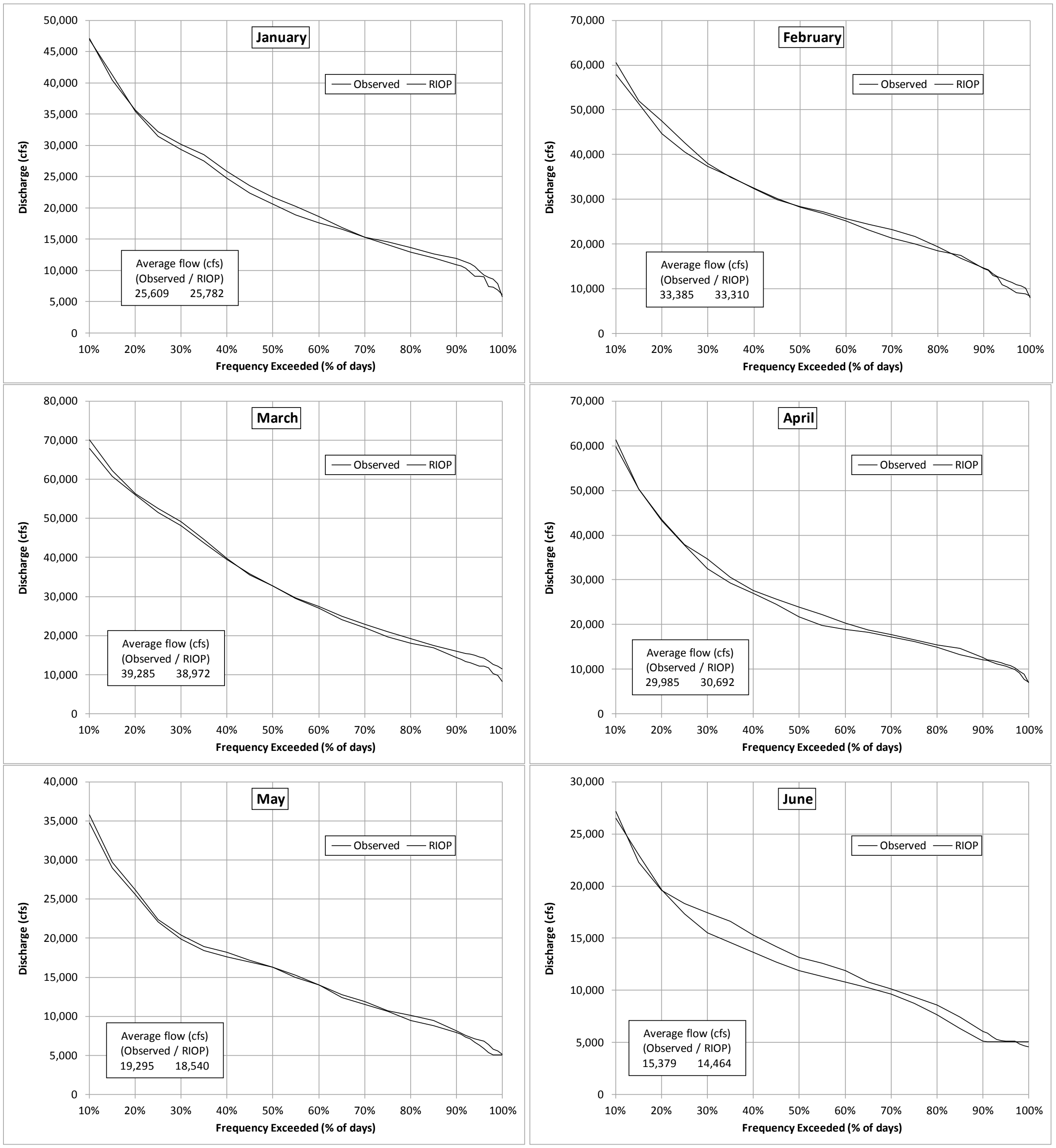

Figure 4.2.2.B. Flow magnitude (cfs) frequency (% of days exceeded) of the Apalachicola River at Chattahoochee, FL, for the Baseline (observed flow 1975-2008) and the RIOP (ResSim simulated flow 1975-2008) during the months of January through June (flows exceeded less than 10% of the days are not shown).

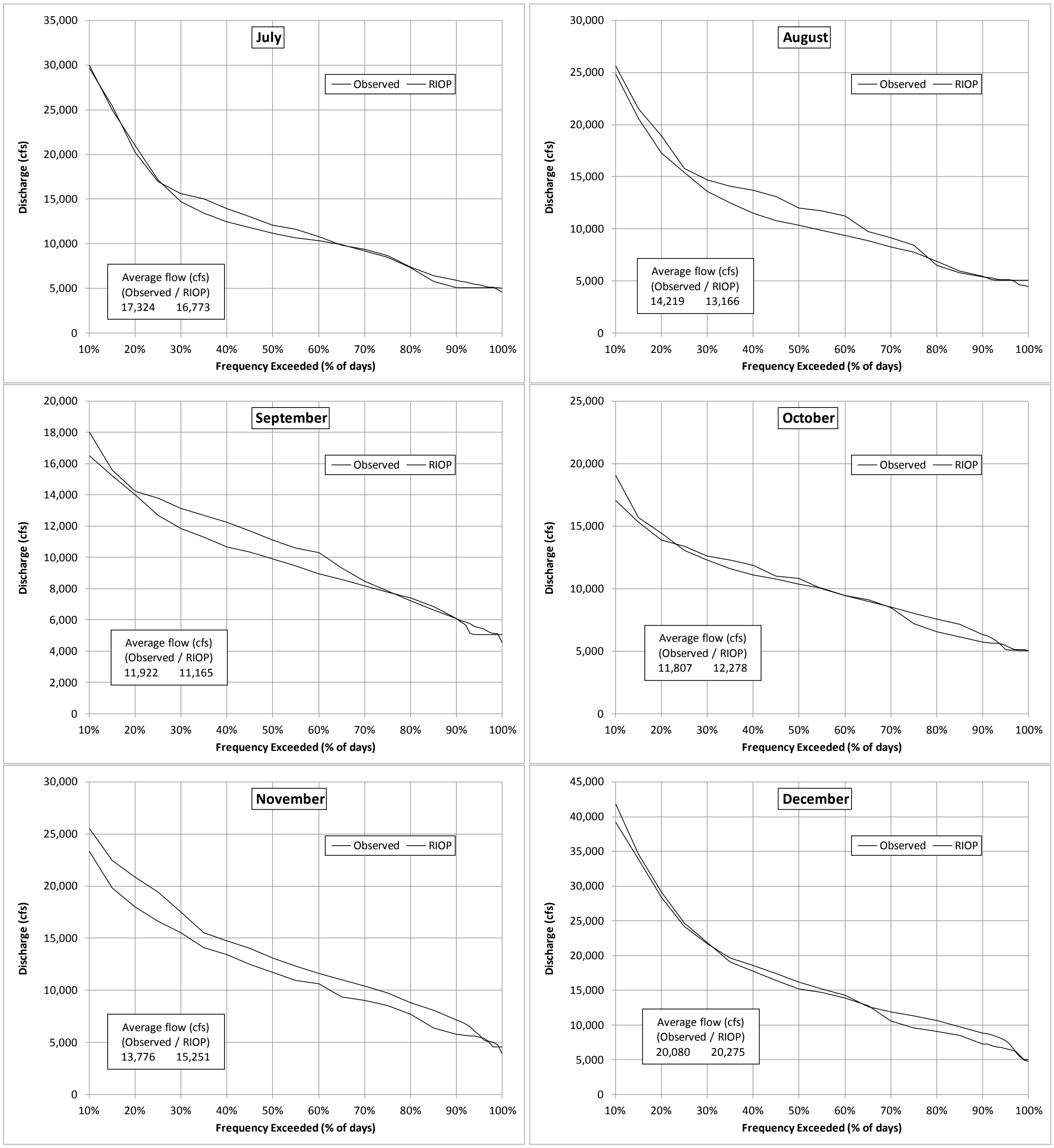

Figure 4.2.2.C. Flow magnitude (cfs) frequency (% of days exceeded) of the Apalachicola River at Chattahoochee, FL, for the Baseline (observed flow 1975-2008) and the RIOP (ResSim simulated flow 1975-2008) during the months of July through December (flows exceeded less than 10% of the days are not shown).

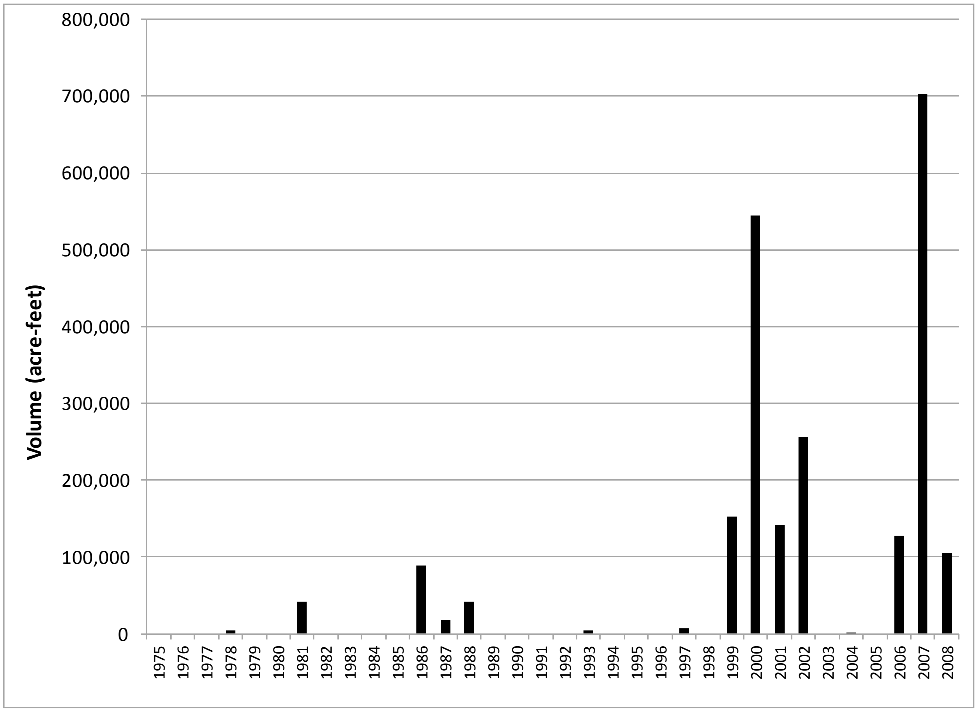

Figure 4.2.2.D. Annual volume of the basin inflow deficit relative to a minimum flow of 5,000 cfs at Woodruff Dam, 1975-2008, calculated using simulated RoR flows for this period.

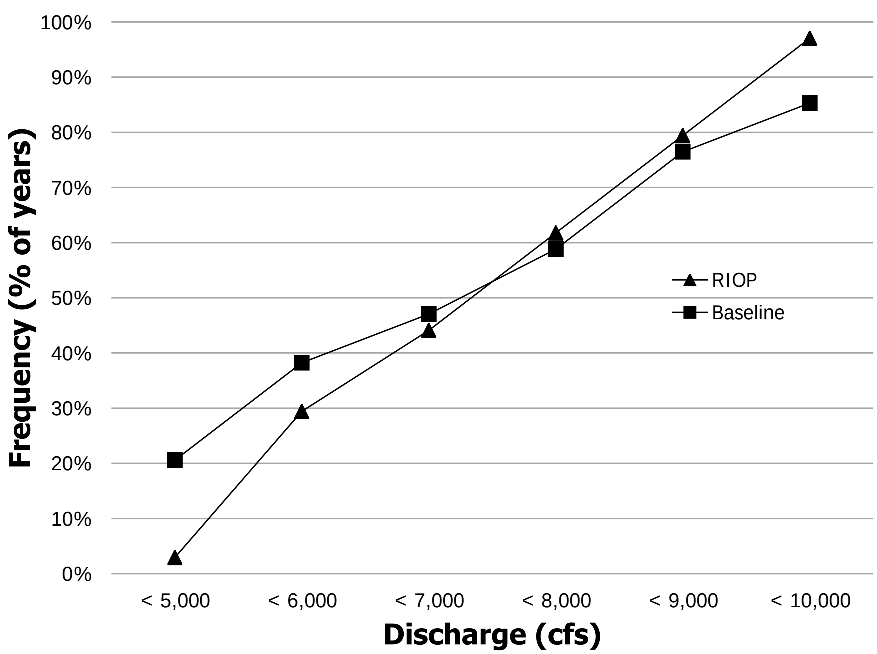

Figure 4.2.3.A. Inter-annual frequency (percent of years) of discharge events less than 5,000 to 10,000 cfs under the Baseline (observed flow 1975-2008) and RIOP (ResSim simulated flow 1975-2008).

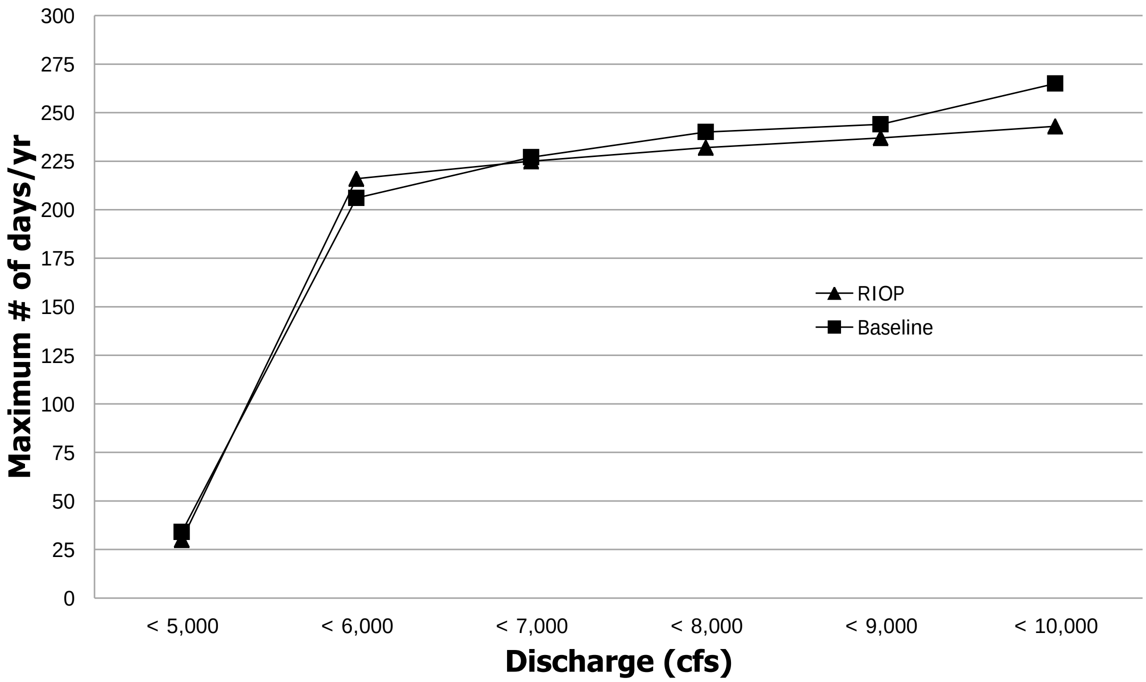

Figure 4.2.3.B. Maximum number of days per year of discharge less than 5,000 to 10,000 cfs under the Baseline (observed flow 1975-2008) and RIOP (ResSim simulated flow 1975-2008).

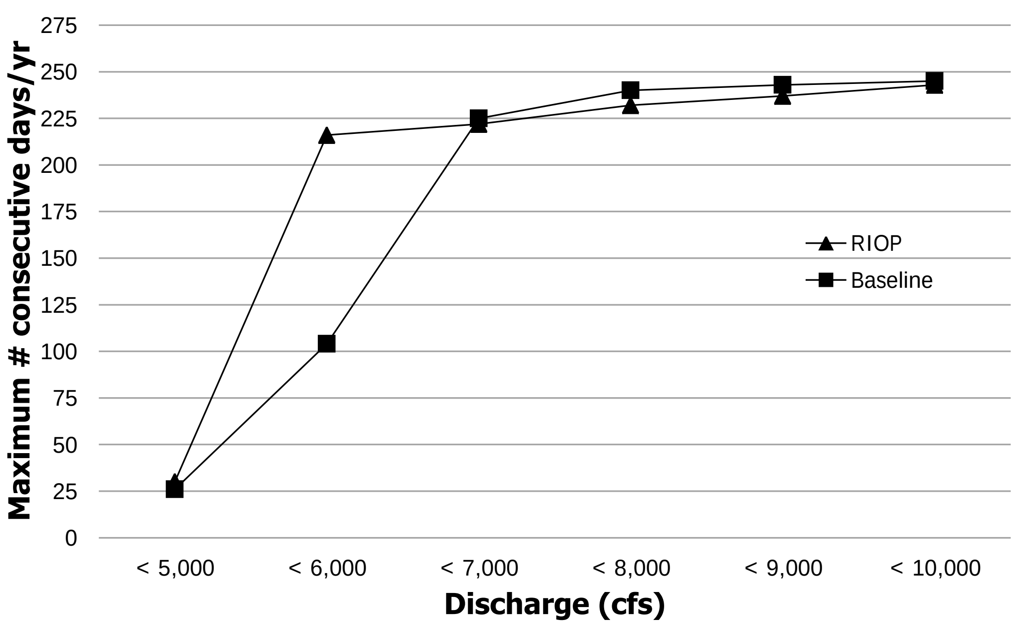

Figure 4.2.3.C. Maximum number of consecutive days per year of discharge less than 5,000 to 10,000 cfs under the Baseline (observed flow 1975-2008) and RIOP (ResSim simulated flow 1975-2008).

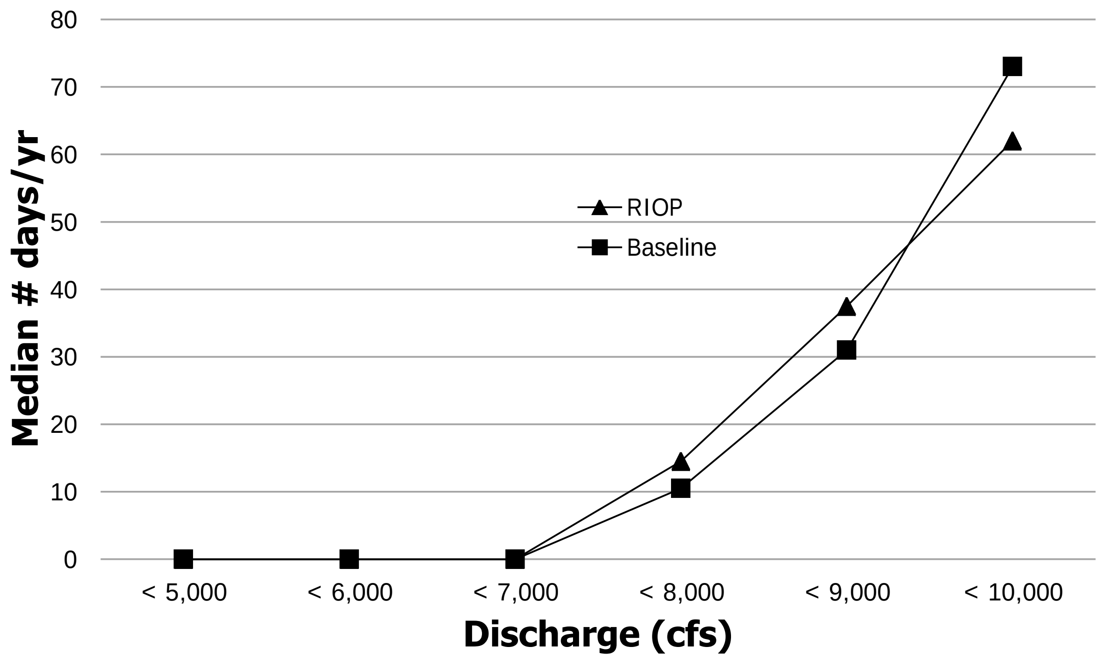

Figure 4.2.3.D. Median number of days per year of discharge less than 5,000 to 10,000 cfs under the Baseline (observed flow 1975-2008), and RIOP (ResSim simulated flow 1975-2008).

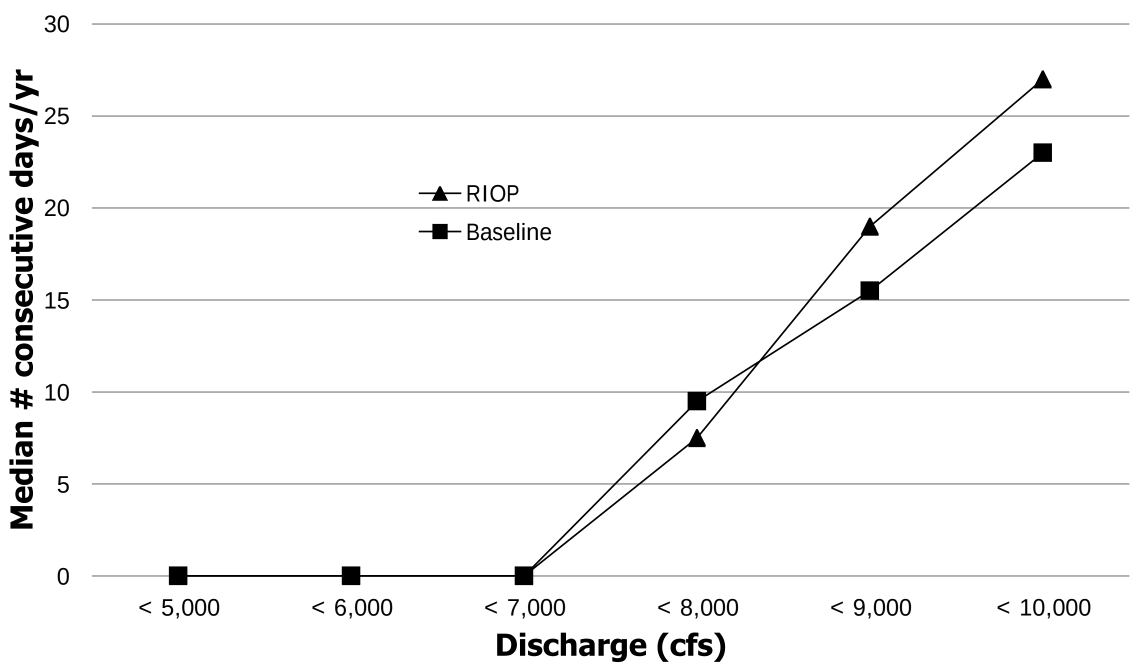

Figure 4.2.3.E. Median number of consecutive days per year of discharge less than 5,000 to 10,000 cfs under the Baseline (observed flow 1975-2008) and RIOP (ResSim simulated flow 1975-2008).

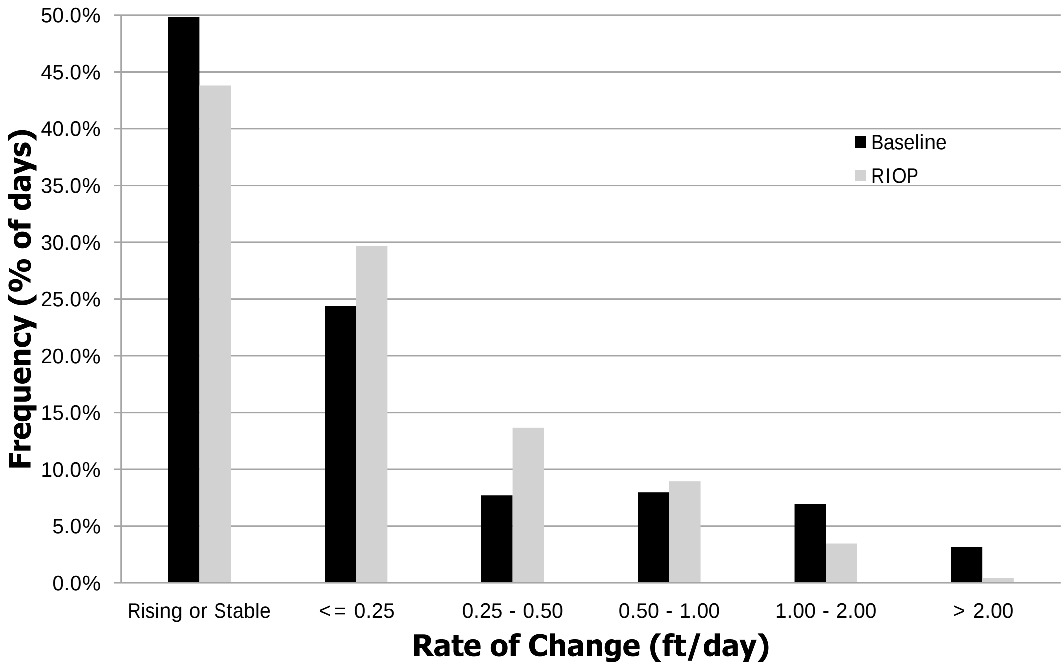

Figure 4.2.3.F. Frequency (percent of days) of daily stage changes (ft/day) under the Baseline (observed flow 1975-2008) and RIOP (ResSim simulated flow 1975-2008).

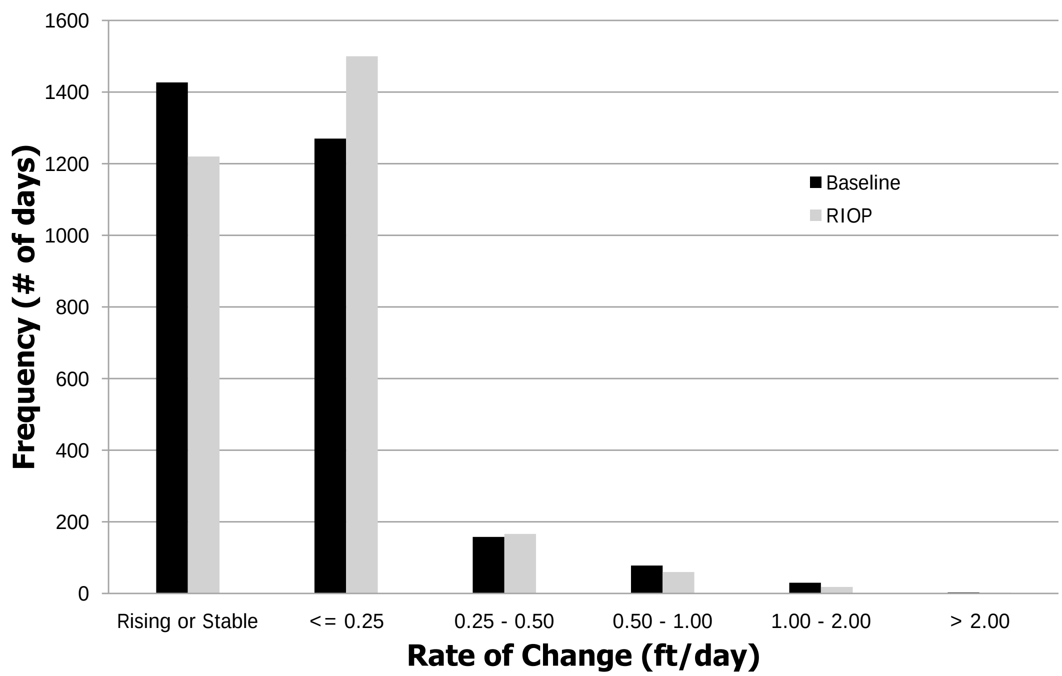

Figure 4.2.3.G. Frequency (number of days) of daily stage changes (ft/day) when releases from Woodruff Dam are less than 10,000 cfs under the Baseline (observed flow 1975-2008) and RIOP (ResSim simulated flow 1975-2008).

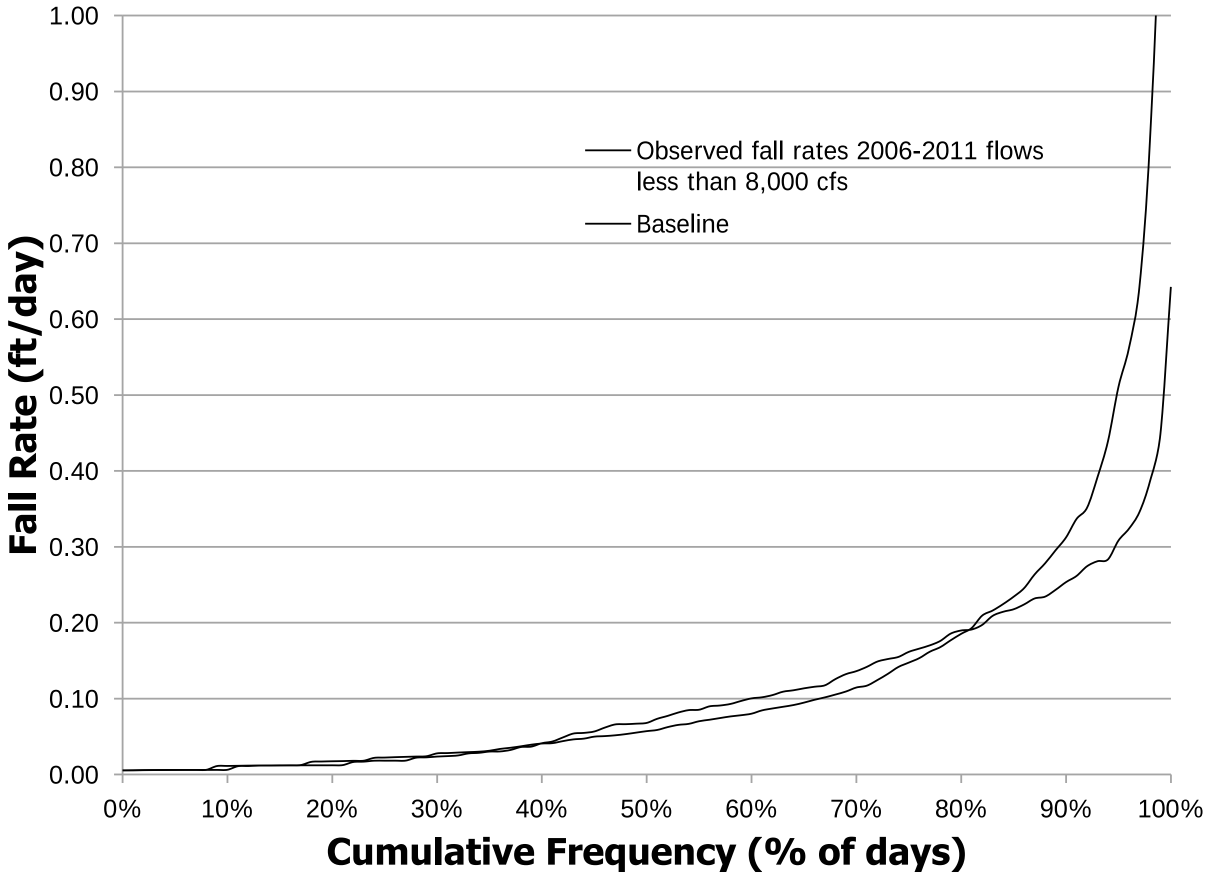

Figure 4.2.3.H. Cumulative frequency (% of days) of 24-hr fall rates (ft/day) observed when flows were less than 8,000 cfs since the incorporation of the 0.25ft/day fall rate provision at JWLD (observed flow 2006-2011). Baseline (1975-2008) fall rates are also included as a reference. It should be noted that the fall rate provision of 0.25 ft/day was suspended for some of this period because drought operations occurred. This may affect these results.

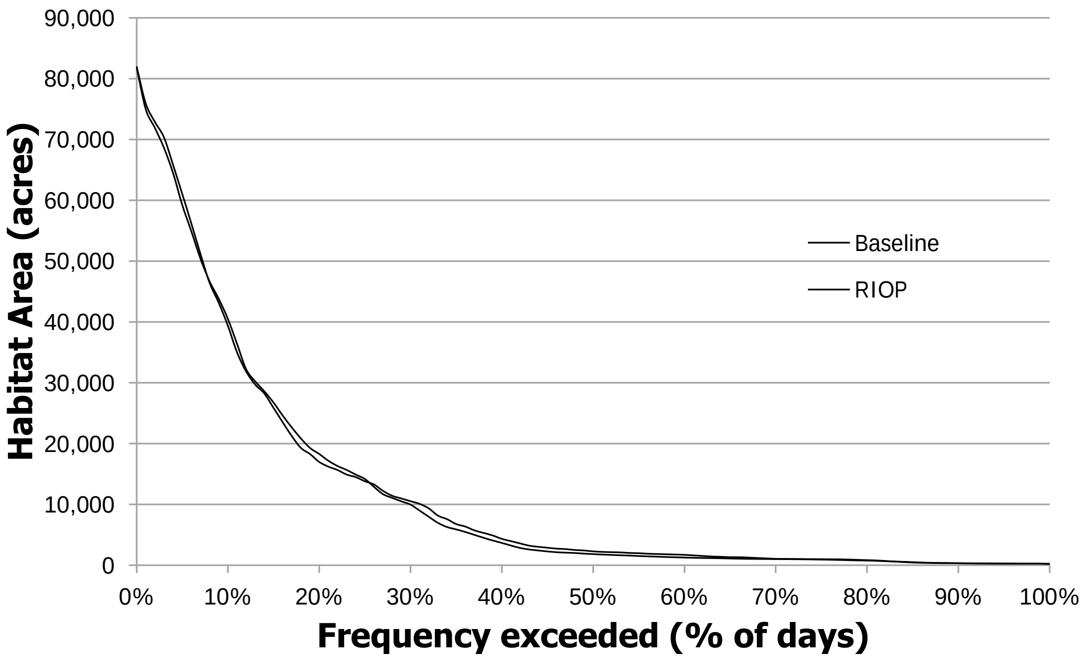

Figure 4.2.4.A. Frequency (percent of days) of growing-season (April-October) floodplain connectivity (acres) to the main channel under the Baseline (observed flow 1975-2008) and RIOP (ResSim simulated flow 1975-2008).

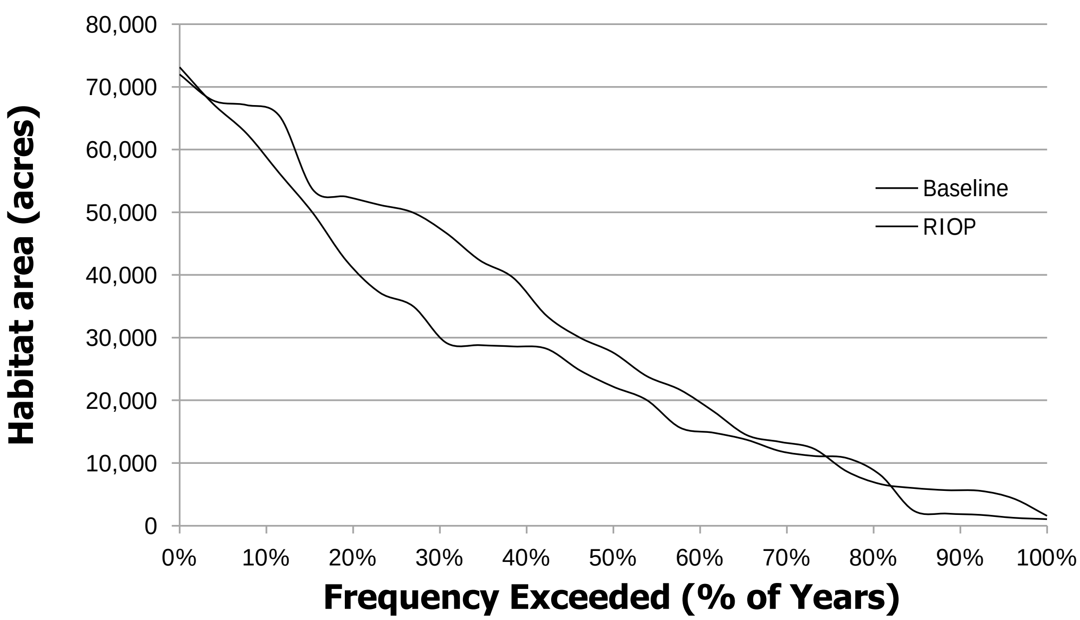

Figure 4.2.4.B. Frequency (percent of years) of growing-season (April-October) floodplain connectivity (acres) to the main channel under the Baseline (observed flow 1975-2008) and RIOP (ResSim simulated flow 1975-2008).

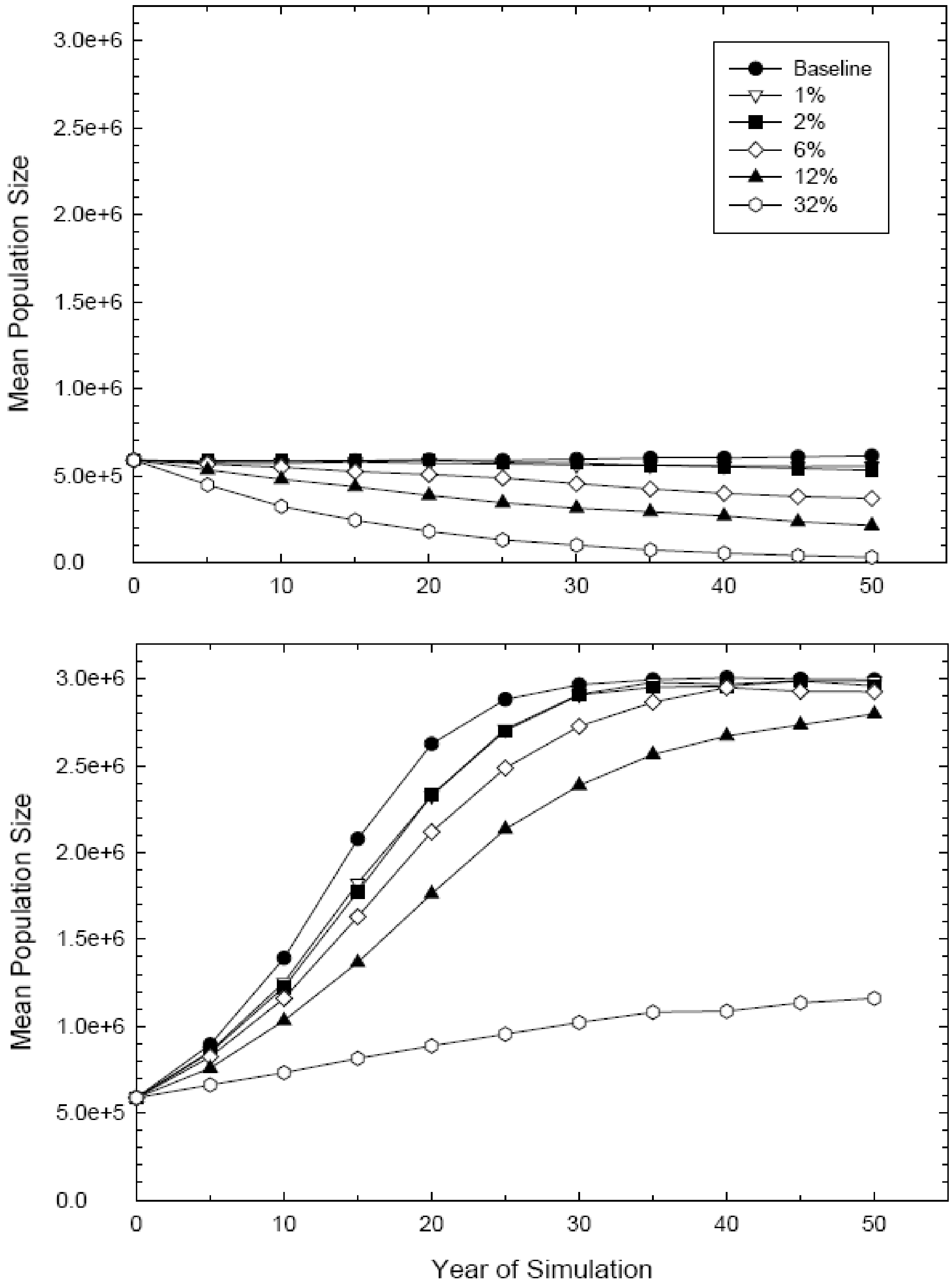

Figure 4.3.2.4.A. Fifty-year projections of mean size of simulated fat threeridge mussel populations, under conditions of intermediate (top panel) and high (bottom panel) adult survival rates. Within each panel, individual models incorporate low-flow events as stochastic phenomena (annual probability of occurrence of 0.1667) with severities of 2% – 32% additional mortality in juvenile and adult stages during the year in which the event occurs. See Miller (2011b) for additional information on model construction and interpretation.

5 CUMULATIVE EFFECTS

Cumulative effects include the effects of future State, Tribal, local or private actions that are reasonably certain to occur in the action area considered in this BO. The Corps' time frame for the applicability of the RIOP is five years pending a future update to the WCP. Therefore, we have considered potential non-federal activities that may also change the primary factors considered in section 4.1, as well as any other non-federal actions that may affect the listed species during this period. Since the basin inflow calculation is a primary input variable to the Corps' modeling, the cumulative effects evaluation focuses on this variable and how it may change in the next five years.

5.1 Water Depletions Forecast

The effect of increasing depletions is to reduce basin inflow to the Corps' reservoir projects, which affects the magnitude, frequency, and duration of releases from Woodruff Dam, and in turn affects the listed species and their habitats. The Corps has estimated year 2017 depletions for reservoir evaporation, agricultural irrigation, inter-basin transfers, and municipal and industrial (M&I) use in each reach of the ACF Basin as represented in the ResSim model. Table 5.1.A summarizes these estimates for all reaches upstream of Woodruff Dam, which amount to an annual average depletion of 1,253 cfs under the simulated hydrology of the years 1975-2008. These demands are applied to all years of the simulation, whereas the model of RIOP used in Section 4, "Effects of the Action," used historical reported/estimated demands, which increased over time and do not reach the levels estimated for 2017. The 2017 demands represent a substantial increase (41.6%[11]) over the 1975-2008 historical demands (average annual depletion 1,253 cfs versus 885 cfs [see Table 4.2.1.A]). After the Corps reviewed the draft of this biological opinion, they realized an error occurred in the estimates resulting in an additional M&I consumption of 29 cfs annually. However, this number is small in magnitude and represents a slightly more conservative evaluation of impacts from increased consumption. The 2017 depletions used in the model include large increases in M&I consumption (64%), and also in agricultural consumption (37%), but comparable losses in reservoir evaporation.

The Corps provided the results of a simulation of the RIOP using the projected 2017 depletions. The model results show that reduced basin inflow results in reduced river flows and reduced reservoir storage levels. In order to fully evaluate the effects of increased demands to listed mussels, the Corps recreated all of the figures in the Effects Analysis section of their BA using the 2017 simulations for the RIOP (Corps 2012). They also included the Baseline observed flow, RIOP simulated flow (1975-2008) and RoR simulated flow with 2017 demands for comparison. As expected, all of the analyses using 2017 demands indicated that increased water depletions would result in reduced flow during droughts and the impacts to mussels may occur with a greater frequency and intensity (Corps 2012).

Reduced basin inflow imposes a greater burden on the reservoir storage to maintain the minimum releases from Woodruff Dam. The additional instream flow deficit imposes a greater drawdown on the reservoirs, and storage enters the "drought zone" during two periods (drought

[11] The Corps' biological assessment states that 2017 depletions represented a 27% increase for M&I only (Corps 2011); however, this was an error in their assessment.

similar to that experienced in 2000 and 2007) of the RIOP simulation. Minimum releases are reduced to 4,500 cfs for about 80 days in the simulation of these extreme drought years. However, the RIOP continues to offset the impact of an increase in depletions by maintaining minimum releases of 5,000 cfs in all years except 2007.

Climate change models indicate an increase in droughts and an increase in intensity of rainfall events, but the model results are mixed (Burkett 2008). Projections for the ACF watershed indicate that future droughts are likely to be more intense (Yao and Georgakakos 2011). The 2007 drought was a 1-in-200 year event. However, most of the ACF Basin is currently experiencing an extreme drought, and the Corps is operating under the drought plan. The Corps has indicated that there is a possibility that drought operations will trigger a minimum flow reduction to 4,500 cfs during the fall of 2012.

Water conservation programs could reduce the per capita M&I consumption and/or per acre agricultural consumption and result in lesser increases in depletions. The State of Georgia has recently implemented water conservation plans (Georgia Water Stewardship Act of 2010) that are likely to reduce the risk of water depletions reaching the 2017 levels in the next five years. Data provided to us by the Atlanta Regional Commission indicates that per capita water use has declined since 2007 as a result of water conservation measures and the current economic recession (ARC 2011 unpub. data). However, due to the significance of the M&I and agriculture demands, the Corps must be vigilant regarding increases in demand and changes in climate and reinitiate consultation if necessary.

5.2 Other Factors

Government and private actions may include changes in land and water use patterns, including ownership and intensity, any of which could affect listed species or their habitat. It is difficult, and perhaps speculative, to analyze the effects of such actions, considering the broad geographic landscape covered by this BO, the geographic and political variation in the action area, extensive private land holdings, the uncertainties associated with State and local government and private actions, and ongoing changes in the region's economy. Adverse effects to riverine habitat from continued urbanization in the basin are reasonably certain to occur. However, state and local governments have regulations in place to minimize these effects to listed species, including regulations regarding construction best management practices, storm water control, and treatment of wastewater.

5.3 Federal Actions Not Considered Under Cumulative Effects

Future federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the Act. These actions include channel maintenance dredging and disposal, water quality criteria, new pesticides and/or uses, pipes in rivers for water withdrawals, small impoundments, new reservoirs, and revisions to the WCP. By notice published February 22, 2008 (FR 73(36):9780-9781), the Corps announced its intent to prepare a draft environmental impact statement for updated water control manuals for the Apalachicola-Chattahoochee-Flint (ACF) River Basin. This process is expected to take an additional two to five years from now.

The Service completed consultations on several reservoirs since the species were listed. There have been additional reservoir proposals in the ACF, but none are undergoing consultation at this time. The Glades Farm Reservoir in Hall County, Georgia is undergoing the Corps' regulatory review process and the Corps has announced they are preparing an Environmental Impact Statement to address the potential effects of this reservoir on, among other things, the Corps' ACF reservoir management. A proposal is under review for a new reservoir on Bear Creek in Fulton County, Georgia. Actions that require permitting under section 404 of the Federal Clean Water Act (CWA) or other federal approval/funding would also require compliance with section 7 of the Act, and the effects of those actions on listed species would be fully addressed separately. To the extent the construction and operation of new reservoirs may affect operation of the ACF federal reservoirs, those effects would also be considered at the time of those consultations.

5.4 Tables for Section 5

Table 4.1.A. Summary of depletions (cfs) to basin inflow upstream of Woodruff Dam estimated for the Corps' simulation of the RIOP with year 2017 demands. Municipal and industrial (M&I) values are constant between years. Values for agriculture and reservoir evaporation are variable between years and are averaged in this table for dry, normal, and wet years[12], according to the Corps' classification for the years 1975 to 2008 of the simulation. Negative values for reservoir evaporation indicate a net gain from precipitation.

	M&I	**Agriculture**				**Reservoir Evaporation**				**Total**			
	All years	Dry	Normal	Wet	All years	Dry	Normal	Wet	All years	Dry	Normal	Wet	All years
Jan	432	2	1	1	1	-182	-278	-415	-272	251	154	17	161
Feb	460	31	3	0	9	-79	-158	-167	-140	412	306	293	329
Mar	535	111	56	50	68	152	-39	-196	-13	798	552	389	591
Apr	676	255	122	107	152	565	388	194	407	1,495	1,186	976	1,234
May	909	690	436	407	493	670	572	338	567	2,268	1,917	1,654	1,969
Jun	884	981	564	516	657	662	483	328	507	2,527	1,931	1,728	2,047
Jul	853	1,140	792	752	869	472	385	-61	353	2,465	2,030	1,544	2,075
Aug	1,013	1,245	825	776	918	478	406	320	413	2,736	2,244	2,110	2,344
Sep	874	986	508	452	614	414	355	477	383	2,274	1,736	1,804	1,871
Oct	671	366	208	190	243	313	313	264	307	1,351	1,192	1,126	1,222
Nov	547	281	144	128	174	34	-128	67	-67	862	563	741	654
Dec	502	232	116	103	142	-129	-185	-63	-157	606	434	542	487
Average	698	529	317	292	364	282	177	91	192	1,509	1,192	1,081	1,253

[12] Dry years: 1981, 1986, 1988, 1990, 1999, 2000, 2006, and 2007. Wet years: 1975, 1991, 1994, and 2003. All other years from 1975-2008 were classified as "normal."

6 CONCLUSION

The proposed action provides both beneficial and adverse effects to the species and designated critical habitats we have assessed. To the extent that the consumptive use assumptions are accurate, differences between the Baseline and the simulated flows of the RIOP are due to differences in reservoir operations, as the model is driven by the observed hydrology. Therefore, we attribute all differences between the Baseline and RIOP simulated flow regime to the Corps' discretionary operations. Differences between the Baseline and RIOP are summarized in general form below (for more details, see sections 4 and 5):

Beneficial Effects

- Basin inflow is augmented when it is less than 5,000 cfs; no daily flows would be less than 5,000 cfs at the Chattahoochee gage. However, if exceptional drought provisions are triggered, this would become no days less than 4,500 cfs (Figure 4.2.3.A).
- The frequency (percent of years) of growing-season (April-October) floodplain connectivity to the main channel is increased (Figure 4.2.4.B).
- A reduction in the inter-annual frequency of flows less than 7,500 cfs (Figure 4.2.3.A).
- A decrease in the maximum number of days/year of flows at all levels except less than 6,000 cfs (Figure 4.2.3.B).
- A decrease in the maximum number of consecutive days/year of flows between 7,000-10,000 cfs (Figure 4.2.3.C).
- A decrease in the median number of days/year of flows less than 9,000 cfs (Figure 4.2.3.D).
- A decrease in the median consecutive number of days/year of flows less than 8,000 cfs (Figure 4.2.3.E).
- Lower fall rates in the most extreme categories (>1 ft/day) (Figures 4.2.3.F-H).

Adverse Effects

- RIOP flows are lower than the baseline more often in May through September, with the greatest departures in August and September (Figures 4.2.2.B-C).
- Lower minimum flows in about half the years from 1975-2008 (Table 4.2.3.A)
- An increase in inter-annual frequency of flows from about 7,500 to 10,000 cfs (Figure 4.2.3.A).
- An increase in maximum number of days per year of flows less than 6,000 cfs (Figure 4.2.3.B).
- An increase in maximum number of consecutive days per year of flows less than 6,000 cfs (Figure 4.2.3.C).
- An increase in median number of days per year of flows between 7,000 and 9,500 cfs (Figure 4.2.3.D).
- An increase in the median consecutive number of days/year of flows less than 9,000-10,000 cfs (Figure 4.2.3.E).
- An increase in percent of days with fall rates from 0.25 to 1.0 ft/day (Figure 4.2.3.F).

- An increase in the median fall rates over the Baseline rate in the range of flows where mussels occur (Table 4.2.3.B).
- Fall rates less than about 0.20 ft/day occur with greater frequency than the Baseline period (when flows are less than 8,000 cfs) since the implementation of the maximum fall rate schedule in 2006 (Figure 4.2.3.H).

Most of these effects, both the beneficial and the adverse, derive from relatively minor differences between the RIOP and Baseline. Generally, it appears that the Corps would store water more often and augment flows less often under the RIOP than has occurred historically. The RIOP uses some of this stored water to maintain a minimum flow of 5,000 cfs, but the frequency of flows less than 10,000 cfs is increased.

The remainder of this section summarizes and consolidates our findings in the previous sections for each listed species and critical habitat in the action area.

6.1 Fat threeridge

Fat threeridge located in moderately depositional habitat are likely moving in response to changing water levels to maintain an optimal depth or associated habitat parameter. Sediment deposition also likely plays a role. At the time of the 2008 BO there were no listed mussels at river stages greater than 5,000 cfs due to the drought of 2006-2008. Although we noted that take may occur when individuals occupy stages greater than 5,000 cfs, we did not anticipate take under this scenario because it was considered an anomaly related to very high flows in 2005. However, based on recent data, it appears that fat threeridge readily recolonize higher bank elevations at flows greater than 5,000 cfs, where they could be at risk of stranding and mortality when flows decline.

Mortality during these events was highest in the Wewa reach of the Apalachicola River where the main channel populations are the most abundant and slopes are shallow. Some mortality occurred in the Chipola River, but it appears to be limited. Mortality estimates from these all of these events range from <1% to 2% depending on preceding hydrologic conditions, fall rates, habitat condition, and the size of the population in Swift Slough. Since the first event was recognized in 2006, 3-4% of the total estimated population of fat threeridge may have died during these various low flow events. We may be over-estimating the relative amount of mortality because we are likely underestimating the total population of fat threeridge in the action area.

Channel morphology changes have likely contributed to a substantial decline of the species distribution in the upstream-most 30 miles of the river. It is abundant in moderately depositional habitat in the Wewa reach and the Chipola River and the population is relatively large. There is evidence of good recruitment in the Wewa and Lower reaches, but more information is needed to determine the status of recruitment in the Chipola River.

Based on best available information, we believe the population of fat threeridge in the action area is stable and possibly increasing. The population appears to be doing well despite the principal effects to the fat threeridge in the action area that we described in section 3, Environmental

Baseline. The inter-annual frequency and the intra-annual duration of low flows in the pre-Lanier period substantially increased in the post-West Point period. Flows under the RIOP will further increase the frequency and duration of low flows. Flows less than 5,000 cfs were not recorded in the pre-Lanier period. The RIOP supports a minimum flow of 5,000 cfs, which benefits the fat threeridge, except when exceptional drought operations are triggered and minimum-flow support is reduced to 4,500 cfs. Supporting a minimum flow of 5,000 cfs in the future with less basin inflow as demands increase would require greater storage releases from the reservoirs, which could trigger the 4,500 cfs minimum flow provision of the RIOP more frequently. The results of the PVA indicate that the population can sustain reductions of 1-2% that we estimate occurred in the population recently if such reductions occur with a probability of once every 6 years, and if similar reductions occur when flows are reduced to 4,500 cfs, with a probability of once every 69 years. However, the PVA also indicates that increasing the frequency of such events results in a greater impact to long-term population viability. As such, we need to continue to monitor the frequency and severity of these events. If the events occur with greater frequency, it may be necessary to reinitiate consultation.

Therefore, our analysis indicates that the RIOP would have a negative, but not appreciable, impact on the survival and recovery of the fat threeridge due to mortality and other adverse effects if flows are reduced to 4,500 cfs or if additional recolonization and subsequent mortality occurs at flows above 5,000 cfs.

6.2 Purple bankclimber

Although the population of purple bankclimbers at the Race Shoals (the limestone shoal at RM 105) is relatively large (about 30,000 individuals), the species is apparently rare in the rest of the river and may be experiencing poor recruitment. A whole river population estimate is not available, but the species is much more detectable and probably much more abundant in other parts of its range, such as the Flint River and the Ochlockonee River. The principal effects to the purple bankclimber in the action area are those we described in section 3, Environmental Baseline. Channel morphology changes may have contributed to a decline of the species in the upstream-most 30 miles of the river, although the species is still found in this reach in relatively high numbers at Race Shoals. Flow regime alterations discussed above (section 6.1) for the fat threeridge apply also to the bankclimber, but probably to a lesser extent, because this species appears to occur more often in deeper portions of the stream channel than the threeridge. As such, we have observed limited mortality of the population during low flows since 2008.

Therefore, our analysis indicates that the RIOP would have a negative, but not appreciable, impact on the survival and recovery of the purple bankclimber due to mortality and other adverse effects if flows are reduced to 4,500 cfs or if additional recolonization and subsequent mortality occurs at flows above 5,000 cfs. Bankclimbers are rarely found at stages greater than 4,500 cfs in the Apalachicola River.

6.3 Chipola slabshell

Recent surveys (1990 to present) have documented many new subpopulations but found the species generally occurs in relatively low abundance. We have no evidence that these populations are currently declining and we consider the Chipola slabshell status to be stable. Many of the effects we described in section 3, Environmental Baseline, do not apply to the Chipola slabshell, as its known range within the action area is limited to the Chipola River downstream of the Chipola Cutoff. Most of the species range is in the Chipola River upstream of the action area. Channel morphology appears less altered in the Chipola River than the Apalachicola River. Flow regime alterations discussed above (section 6.1) for the fat threeridge apply also to the slabshell, but probably to a lesser extent in the narrower channel and higher bank slopes of the Chipola. No slabshell mortality has been documented during the low flows of 2006-2008 and 2010-2011. We also expect the mortality of the Chipola slabshell to be less than the expected for the fat threeridge or purple bankclimber because of its expected higher mobility.

Therefore, our analysis indicates that the RIOP would have a negative, but not appreciable, impact on the survival and recovery of the Chipola slabshell due mortality and other adverse effects if flows are reduced to 4,500 cfs or if additional recolonization and subsequent mortality occurs at flows above 5,000 cfs.

6.4 Critical Habitat

Designated critical habitat for the fat threeridge and purple bankclimber in the action area includes most of the Apalachicola River unit, and the downstream-most part of the Chipola River Unit. Designated habitat for the Chipola slabshell only occurs within the downstream-most part of the Chipola River Unit. In the effects analysis, we discussed how the RIOP may affect the three of the five PCEs of the mussel critical habitat: 1) permanently flowing water; 2) water quality; and 3) fish hosts. The RIOP does not appear to reduce the amount of floodplain habitat available to fish hosts, some of which likely rely upon floodplain habitats for spawning and rearing habitat. Droughts substantially change the nature of all of these PCEs compared to normal flows, but our analysis does not show that the RIOP would appreciably change the quantity or quality of the PCEs relative to the Baseline under the drought conditions represented in the 1975-2008 record.

While the RIOP may also negatively affect mussel habitat primary constituent elements by reducing minimum releases to 4,500 cfs, the circumstances triggering this action would occur infrequently (probability of 1 in 69 years). We do not anticipate that increasing the frequency and duration of low flows or reducing minimum releases to 4,500 cfs at this frequency would alter or affect the critical habitat in the action area to the extent that it would appreciably diminish the habitat’s capability to provide the intended conservation role for the three mussel species. In addition, the nature of these effects is dynamic and would not produce permanent or static alterations to any PCE.

6.5 Determinations

After reviewing the current status of the listed species and designated critical habitat, the environmental baseline for the action area, the effects of the proposed action, and the cumulative effects, it is the Service's biological opinion that the proposed action: 1) will not jeopardize the continued existence of the fat threeridge, purple bankclimber, and Chipola slabshell; and 2) will not destroy or adversely modify designated critical habitat for the fat threeridge, purple bankclimber, and Chipola slabshell.

The RIOP is intended to apply until a new WCP is adopted. Given the Corps' current timeline, the findings of this BO shall apply for 5 years until May 22, 2017, or until amended through a reinitiation of consultation or superseded with a new opinion for a new proposed action.

7 INCIDENTAL TAKE STATEMENT

Section 9 of the Act and federal regulations pursuant to section 4(d) of the Act prohibit the take of endangered and threatened species without special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Harm is further defined by the Service to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering. Harass is defined by the Service as intentional or negligent actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding or sheltering [50 CFR §17.3]. Incidental take is defined as take that is incidental to, and not the purpose of, an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to and not intended as part of the agency action is not considered prohibited taking under the Act provided that such taking is in compliance with the terms and conditions of an Incidental Take Statement (ITS).

The measures described below are non-discretionary, and the Mobile District Corps must insure that they become binding conditions of any contract or permit issued to carry out the proposed action for the exemption in section 7(o)(2) to apply. The Mobile District Corps has a continuing duty to regulate the action covered by this incidental take statement. If the Mobile District Corps: (1) fails to assume and implement the terms and conditions or, (2) fails to require any contracted group to adhere to the terms and conditions of the incidental take statement through enforceable terms that are added to the permit or grant document, the protective coverage of section 7(o)(2) may lapse. In order to monitor the impact of incidental take, the Mobile District Corps must report the progress of the action and its impact on the species to the Service as specified in the ITS [50 CFR §402.14(I)(3)].

7.1 AMOUNT OR EXTENT OF TAKE ANTICIPATED

The Service anticipates that fat threeridge, purple bankclimber, and Chipola slabshell could be taken between now and May 22, 2017, as the result of this proposed action. This ITS supersedes the ITS from the 2008 BO. The extent of the take is described below.

Take of listed mussels due to the RIOP may occur when conditions are such that the Corps reduces the releases from Woodruff Dam below 10,000 cfs. The form of this take is mortality that results from habitat modification leading to oxygen stress, temperature stress, and/or increased predation. These conditions may result in immediate or delayed mortality, and as such, mussels that are able to move and remain submerged may still be found dead in the water after the reduction in flows. The take may occur in microhabitats that become exposed or isolated from flowing water when releases from Woodruff Dam are less than 10,000 cfs. In addition, take includes harm that occurs as a result of reduced growth and/or reproduction due to the high temperatures and low dissolved oxygen that has been shown to occur in these habitats.

Our data indicate that fat threeridge move in response to changing flow conditions, but their ability to move is limited by the bank slope and fall rate. We have not observed movement of purple bankclimbers or Chipola slabshell, but the slabshell is likely to move given the proven ability of other species in the genus *Elliptio* to effectively move. Mortality due to water level declines occurs when mussels are not successful at remaining within flowing water and are exposed to the air or to stagnant water long enough to expire from lack of oxygenated water, excessive temperature, and/or predation. Mussels that are able to move and track the water level decline are also subject to delayed mortality resulting from stress and predation. Mortality, reduced growth and/or reproduction may also occur when mussels move in response to water level declines into areas that are unsuitable as habitat, such as portions of the channel where shear stress is excessive during high flows.

The RIOP influences flows relative to the Baseline by increasing the frequency and duration of flows that are less than 10,000 cfs. Incidental take attributable to the Corps also occurs when flows are reduced to less than 5,000 cfs and possibly when the Corps is storing water during drought operations. Although no storage is occurring at basin inflows of <10,000 cfs outside of drought operations, the fall rate analysis when flows are less than 10,000 cfs indicates that incidental take attributable to the Corps occurs when the RIOP results in more days with faster fall rates than the Baseline operations. This is an adverse effect because mussels located at stages greater than 5,000 cfs would experience more days when they would have to move faster to track the water level decline.

Model results provided by the Corps indicate that the probability of implementing a reduction in flows less than 5,000 cfs is once in 69 years (0.01), because the 1939-2008 simulations trigger the exceptional drought provision of the RIOP one time (in 2007). However, the current extreme drought in the basin, coupled with reduced refill in the winter and spring of 2012, indicate that the 4,500 cfs flows may be triggered in the fall of 2012. Therefore, we expect that incidental take of listed mussels attributable to the reduction in minimum flow to 4,500 cfs could at most consist of one event in the foreseeable future. We also anticipate that mussels could recolonize habitats greater than 5,000 cfs and be incidentally taken during subsequent low flows. Based on examination of the hydrology preceding the mortality events in 2006-2008 and 2010-2011, we estimate that mortality events that occur at flows greater than 5,000 cfs occur with a probability of 0.15 (events may have occurred 5 times in the 34-year baseline record). One mortality event of this nature is likely to occur at flows above 5,000 cfs during the 5-year window for this consultation.

The result of these impacts is observable individual mortality but also unquantified reductions in growth and/or reproduction. Based on available information, a reliable and quantifiable estimate of take stemming from reduced growth and/or reproduction potential is not possible at this time. As a result, take has been estimated to date based on observed mortality, and we believe this to be the most accurate and repeatable measure of take. Therefore, the best way to monitor the incidental take is to count the number of exposed individuals.

Incidental take would be greatest in the RM40-50 reach of the main channel of the Apalachicola River where densities of the fat threeridge are high and bank slopes are low to moderate. It is difficult to assign a level of incidental take because the mortality has varied under the recent events depending on the preceding hydrologic conditions. We expect that the number of fat threeridge exposed at flows above 5,000 cfs is approximately the same as would occur if flows were reduced to 4,500 cfs because we have observed their affinity for a given depth and demonstrated their ability to move. The highest number of individuals that has ever been estimated to have died during any of these events is about 20,200 in 2006-2007 when flows were at or above 5,000 cfs. That number is high because it includes substantial mortality in Swift Slough. Mortality estimates from other years that do not include mortality in Swift Slough range from about 1,469 (Corps 2007 EDO take) to about 5,880 (2011 event which includes take of an estimated 1,091 fat threeridge at flows <5,000 cfs). Based on our current understanding of fat threeridge movement and habitat conditions that lead to exposure and subsequent mortality, we expect that sites with slopes >20% will exhibit little if any mortality. As such, we expect little mortality in the Chipola River.

We estimate that there are currently about 283,200-587,900 fat threeridge in moderately depositional habitat in the Apalachicola River (estimate does not include the Chipola River). Although we expect little mortality in higher slope habitats, we cannot completely discount this impact and assign a mortality expectation of 1% to the habitat areas with > 20% bank slopes (2/3 of the lower population estimate of 283,200 using the highest probable take percentage), which yields a take of 1,900 individuals. About 1/3 of sites sampled in the Apalachicola River have sites <20%; therefore, we estimate the remaining 1/3 of the fat threeridge in the Apalachicola River are at risk. The maximum local mortality observed at a site was 7%. If we assume a maximum of 7% mortality (highest site observation) of 1/3 (lower slope areas) of the population during these events, we anticipate incidental take of no more than 6,600 individuals. Combined with the potential take for higher slope habitat (1,900 mussels), we have 8,500 fat threeridge subject to incidental take in moderately depositional habitat in the Apalachicola River. This estimate does not include Swift Slough.

We have information that limited numbers of fat threeridge in Swift Slough survived the drought from 2006-2008. Based on survival of 2% of the population estimated in 2006 (Ted Hoehn 2007 pers. comm.), we assume 362 individual survived. We have documented recent recruitment in the slough. If we assume the population has been growing at a rate of 6% per year (based on the PVA simulations with an adult survival rate of 0.98) since 2007, then by the end of the consultation period, there would be about 650 individuals in the slough. Therefore, we expect that incidental take of no more than a total of 9,150 individuals will occur in the action area (including the Chipola River and Cut) within the next 5 years as a result of low flows above 5,000 cfs. We expect that the number of fat threeridge exposed at flows above 5,000 cfs is approximately the same as would occur if flows were reduced to 4,500 cfs because we have demonstrated their affinity for a given depth and ability to move; therefore, we also expect that incidental take of no more than 9,150 individuals will occur in the action area within the next 5 years as a result of low flows above 4,500 cfs.

We do not have a population estimate for the purple bankclimber in the whole Apalachicola River, but Gangloff (2011 unpub. data) estimated that about 30,000 individuals may occur at

Race Shoals. The species is much more detectable, and probably much more abundant, in other parts of its range, such as the Flint River and the Ochlockonee River. We anticipate incidental take of a small number (less than 30) of purple bankclimbers if flows are reduced to 4,500 cfs, primarily at Race Shoals. This is based on the Corps' estimate of incidental take of 39 individuals last summer when flows were inadvertently reduced below 5,000 cfs, which is less than 0.1% of the population. If we conservatively assume that 0.1% of the population again recolonize that area of habitat, reducing flows to 4,500 cfs could potentially result in incidental take of 30 individuals (0.1% of the total population estimate of about 30,000 individuals at the shoal). Similarly, we expect that no more than 0.1% of the population would recolonize the elevations above 5,000 cfs during the timeframe of this action, so we also anticipate that 30 individuals would be incidentally taken if purple bankclimber recolonize area above elevations associated with flows of 5,000 cfs and subsequent mortality occurs at low flows.

We expect that the Chipola slabshell is less vulnerable to low-flow related mortality than the fat threeridge or purple bankclimber because of its thinner shell and likely higher mobility and the generally steeper bank slopes (>20%) in the Chipola River. Although we have not observed Chipola slabshell mortality, we assume that some low-flow mortality may be occurring. Based on limited recent survey data, we assume that flow reductions to 4,500 cfs could affect less than 1% of the slabshell population (section 4.3.2). Our current population estimate of about 2,650 is likely an under-estimate in the action area. Applying a 0.1% take rate to the vulnerable portion of the population (as was used for the bankclimber, also with little mortality observed throughout much of the system) would likely overestimate low-flow-related mortality. In combination, these assumptions provide a basis for a conservative, not-likely-to-exceed, take estimate that recognizes the data uncertainties. Therefore, we anticipate take of not more than 3 Chipola slabshell if flows are reduced to 4,500 cfs, and 3 if they recolonize areas above elevations associated with flows of 5,000 cfs and are exposed when flows are again reduced to >= 5,000 cfs.

In summary, we expect a maximum of 30 purple bankclimbers may be exposed on the rock shoal near RM 105 and at a few locations elsewhere in the action area during each of these events (flow reduction to 4,500 cfs, and exposure at stages > 5,000 cfs following recolonization) (60 total); and a maximum of 3 Chipola slabshell (6 total) may be exposed in the Chipola River downstream of the Chipola Cutoff. A maximum of 9,150 fat threeridge (18,300 total) may be exposed in the Apalachicola River, Chipola Cutoff, and Chipola River downstream of the Chipola Cutoff when the minimum flow is reduced to 4,500 cfs or when individuals recolonize habitats greater than 5,000 cfs followed by stranding during subsequent low flows. Exceeding this level of incidental take for these three species shall prompt a reinitiation of this consultation.

7.2 EFFECT OF THE TAKE

In the accompanying BO, the Service determined that the level of anticipated take for declining fall rates and reductions in flow as low as 4,500 cfs, or when individuals recolonize habitats greater than 5,000 cfs, would not result in jeopardy to the species or destruction or adverse modification of designated or proposed critical habitat, assuming one such event of each type occurs within the duration of the BO.

7.3 REASONABLE AND PRUDENT MEASURES

The Service believes the following reasonable and prudent measures are necessary and appropriate to minimize the impacts of incidental take of fat threeridge, purple bankclimber, and Chipola slabshell on the Apalachicola River. The measures described below supersede the measures described in previous BOs. The numbering system used in this opinion includes the year in order to avoid confusion with the previous opinions.

RPM 2012-1. Adaptive management. Identify ways to minimize harm as new information is collected.

Rationale. Additional information will be collected about the listed species and their habitats in the action area, water use upstream, and climatic conditions. This information needs to be evaluated to determine if actions to avoid and minimize take associated with the Corps' water management operations are effective or could be improved.

RPM 2012-2. Chattahoochee Gage Maintenance. Implement monthly monitoring of the stage/discharge relationship at the Chattahoochee gage. If the latest measurement suggests that a gage height less than the current unshifted rating curve value corresponds to a discharge of 5,000 cfs, do not reduce releases until the USGS verifies discharge via field measurement or until coordination with the Service and USGS indicates that a discharge measurement is unnecessary.

Rationale. An estimated take of about 1,091 fat threeridge and 39 purple bankclimbers occurred during May and June of 2011 when flows were less than 5,000 cfs as a result of an adjustment to the rating curve for the USGS Chattahoochee gage. We recently completed an analysis of the rating table and field verification discharge measurements, and shifts have been occurring relatively frequently since 2009. Since 2000 when this rating curve was adopted, the average gage height associated with 5,010 cfs was 39.08 ft, which almost matches the rating table value of 39.07 ft. However, several recent shifts have resulted in lower gage heights associated with 5,010 cfs, and recent exposure and take of listed mussels. At lower flows, mussel movement and exposure is probably influenced more by the water level (i.e., gage height) than a specific discharge, especially if that discharge varies at a specific gage height depending on shifts to the rating table. Based on USGS' recommendation, the Corps has agreed to have USGS measure discharge once a month. We recognize that this could still result in mussels being exposed for 30 days between measurements. Our data collected last summer indicate that the vast majority of exposed mussels survive less than 6 days of exposure. However, in case a shift has occurred between the 30-day measurements, the Corps has agreed not to reduce releases below the unshifted rating curve value until USGS verifies discharge via field measurement or until coordination with the Service and USGS indicates that a discharge measurement is unnecessary. This should prevent unintentional take resulting from inconsistencies between the gage height and discharge.

RPM 2012-3. Monitoring. Monitor the level of take associated with the RIOP and evaluate ways to minimize take by studying the distribution and abundance of the listed species in the action area.

Rationale. Take of mussels due to exposure from declining minimum releases needs to be monitored within 4 days to ensure that the anticipated level of take (section 7.1) is not exceeded. Further, as habitat conditions change, it is necessary to monitor the numbers and spatial distribution of the populations to determine the accuracy of the take estimates. Monitoring populations and relevant habitat conditions will also serve the Corps' information needs for future consultations on project operations, water supply contracts, hydropower contracts, etc.

7.4 TERMS AND CONDITIONS

In order to be exempt from the prohibitions of section 9 of the Act, the Corps must comply with the following terms and conditions, which implement the reasonable and prudent measures described above. These terms and conditions are mandatory. Studies and other outreach programs in the RPMs and conservation measures are subject to the availability of funds by Congress. The Corps will exercise its best efforts to secure funding for those activities. In the event the necessary funding is not obtained to accomplish the RPM activities by the dates established, the Corps will reinitate consultation with USFWS. These terms and conditions supersede those of the previous BO and its amendments. These terms and conditions are effective until replaced by a BO on a new proposal for managing the releases from Woodruff Dam.

7.4.1 Adaptive management (RPM 2012-1)

a) The Corps shall organize semi-annual meetings with the Service to review implementation of the RIOP and new data, identify information needs, scope methods to address those needs, including, but not limited to, evaluations and monitoring specified in this Incidental Take Statement, review results, formulate actions that minimize take of listed species, and monitor the effectiveness of those actions.
b) The Corps shall assume responsibility for the studies and actions that both agencies agree are reasonable and necessary to minimize take resulting from the Corps' water management actions.
c) The Corps shall provide an annual report to the Service on or before January 31 each year documenting compliance with the terms and conditions of this Incidental Take Statement during the previous federal fiscal year, any conservation measures implemented for listed species in the action area; and recommendations for actions in the coming year to minimize take of listed species.
d) The Corps shall provide by email or other electronic means to the Service on a monthly basis the status of RIOP implementation including the hydrology of the system, composite system storage, and any data related to any other adopted criteria.

7.4.2. Chattahoochee Gage Maintenance (RPM 2012-2).

a) Implement monthly monitoring of the stage/discharge relationship at the Chattahoochee gage. If the latest measurement suggests that a gage height less than the current unshifted rating curve value corresponds to a discharge of 5,000 cfs (under rating table 36.1, that gage height is 39.07 ft), do not reduce releases until the USGS verifies discharge via field measurement or until coordination with the Service and USGS indicates that a discharge measurement is unnecessary.

b) By June 31, 2012, submit the additional SOP that was to be drafted and implemented to accelerate recognition and response to mechanical failures, including provisions requiring project operators to regularly evaluate the Chattahoochee gage data and other mechanisms to avoid releases less than the daily average minimum flow.

7.4.3 Monitoring (RPM 2012-3)

In consultation with the Service, the Corps shall plan and implement the following monitoring efforts relative to the listed species and their habitats that will develop information necessary to understand the impact of incidental take and to ensure that the authorized levels of incidental take are not exceeded.

a) By August 15, 2012 and in coordination with the Service, the Corps shall update its previous study plan for estimating mussel take following minimum release reductions and the hydrologic events that could lead to the recolonization of listed mussels. Given the current uncertainties about these hydrologic events that could lead to take above 5,000 cfs, this plan shall further define the conditions under which such take monitoring is required. Within 4 days of a reduction in minimum releases from Woodruff Dam to flows less than 5,000 cfs, or following the occurrence of a hydrologic event that could lead to the recolonization of listed mussels, the Corps will implement the listed mussels take monitoring plan.
b) By October 31, 2012, the Corps shall provide a new study plan for conducting an investigation into the triggers and conditions required for mussel movement into higher elevations. The Corps will implement this study plan as soon as practicable thereafter.
c) By October 31, 2012, the Corps shall update its previous study plans for: 1) identifying listed mussels age structure at various depths; 2) estimating age-specific survival rates; 4) estimating age-specific-fecundity rates; 5) identifying other anthropogenic factors that may affect mussel habitat; and 6) characterizing the habitat of the purple bankclimber and Chipola slabshell in the action area. The Corps will implement these study plans as soon as practicable thereafter.

The reasonable and prudent measures, with their implementing terms and conditions, are designed to minimize the impact of incidental take that might otherwise result from the proposed action. The Service believes that the action will result in the mortality of no more than 6 Chipola slabshell, 60 purple bankclimber, and 18,300 fat threeridge, if minimum flows are reduced to 4,500 cfs or if mussels recolonize habitats greater than 5,000 cfs and are taken during subsequent low flows. If, during the course of the action (until May 22, 2017), the level of incidental take is exceeded, such incidental take represents new information requiring the reinitiation of consultation and review of the reasonable and prudent measures provided. The Corps must immediately provide an explanation of the causes of the taking, and review with the Service the need for possible modification of the reasonable and prudent measures.

8 CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the Act directs Federal agencies to use their authorities to further the purposes of the Act by conducting conservation programs for the benefit of endangered and threatened species. Towards this end, conservation recommendations are discretionary activities that an action agency may undertake to minimize or avoid the adverse effects of a proposed action, help implement recovery plans, or develop information useful for the conservation of listed species. The following conservation measures are an update of the measures listed in our previous opinions.

The Service recommends that the Mobile District of the U.S. Army Corps of Engineers:

1. Work with the Service to formulate alternatives to the RIOP for operating the reservoirs that may form the basis of alternatives for the WCP.

2. Continue to fund the ongoing study to estimate Gulf sturgeon recruitment rates and potential relationship to flows in the Apalachicola River.

3. Work in consultation with the states and other stakeholders to assist in identifying ways to reduce overall depletions in the ACF basin, particularly the Flint River. For example, if water users and managers can work together to identify alternatives to agricultural use or incentives to reduce agricultural use of water in the Flint River basin, inputs from the Flint River will increase base flow to the Apalachicola River. This would improve the status of the listed mussel species and reduce the Corps' reliance on upstream system storage to meet minimum flows below Jim Woodruff Dam.

4. Improve the public understanding of water management of the ACF system, the related conservation needs of listed species, and the management of the multiple purposes of the federal reservoirs. For instance, there is a pervasive misunderstanding regarding the changes in reservoir levels, particularly at Lake Lanier, where a combination of evaporation, withdrawals from the reservoir, and releases to meet metro Atlanta water supply and water quality needs are likely to reduce reservoir levels by 6 to 9 feet during years with precipitation that is less than normal.

5. Assist stakeholders to plan future water management to reduce trends in water consumption so that listed mussel mortality due to low flows does not become a chronic or annual source of mortality.

6. Consider alternatives that would increase flexibility in the management of reservoir storage including the feasibility of flood control alternatives (e.g. moving structures from the floodplain, land acquisition) and providing for recreational access at a variety of pool elevations.

7. Provide additional data and hydrodynamic models that would assist in determining areas that should be surveyed for listed mussels.

8. Fund the purchase and placement of informational signs in the stream-bank near Race Shoals that warn fishermen that the harvest of listed mussels for bait is illegal.

9. Implement freshwater mussel recovery actions including developing habitat suitability indices, conducting life history and population studies of the listed mussels of the Apalachicola River, restoring reaches to provide suitable habitat, assessing sediment quality including possible chemical contamination, and validating aging techniques for these species.

10. Implement Gulf sturgeon recovery actions including assessing fish passage needs, developing habitat suitability indices, conducting life history and population studies of Apalachicola River and Bay, restoring reaches to provide suitable habitat, assessing sediment quality including possible chemical contamination, and validating aging techniques for these species.

11. Establish a clearinghouse for biological and water resource information about the ACF system and make such information readily available in several key locations in the basin.

12. Encourage and jointly lead stakeholder discussions to develop a long-term biological monitoring program for the ACF system and support, as feasible, implementation of a long-term program.

13. Update, as soon as practicable, tools for assessing the effects of ongoing and future system operations, including estimates of basin inflow and consumptive demands. The tools should assist in identifying flows that provide sufficient magnitude, duration, frequency, and rate of change to support the survival and recovery of the listed species in the ACF.

In order for the Service to be kept informed of actions minimizing or avoiding adverse effects or benefiting listed species or their habitats, the Service requests notification of the implementation of any conservation recommendations in the annual report required in 7.4.1.d.

9 REINITIATION NOTICE

This concludes formal consultation on the action outlined in the BO. As provided in 50 CFR §402.16, reinitiation of formal consultation is required where discretionary Federal agency involvement or control over the action has been retained (or is authorized by law) and if: (1) the amount or extent of incidental take is exceeded; (2) new information shows that the action may affect listed species in a manner or to an extent not considered in this BO; (3) the action is subsequently modified in a manner that causes an effect to the listed species not considered in this BO; or (4) a new species is listed or critical habitat designated that may be affected by the action. In instances where the amount or extent of incidental take is exceeded, any operations causing such take must cease pending reinitiation.

10 FISH AND WILDLIFE COORDINATION ACT PLANNING ASSISTANCE

In accordance with the planning aid provisions of the Fish and Wildlife Coordination Act (FWCA), the Service has been coordinating with you and the States on the development of updated WCP for the ACF River Basin. The Service's fish and wildlife concerns, planning objectives, recommendations and requested analyses have been previously described in detail to the Corps in our April 2, 2010, Planning Aid Letter (PAL) and March 1, 2011, PAL addendum. We also submitted a draft FWCA report (FWCAR) on May 31, 2011. We understand that the alternatives we analyzed in the draft FWCAR report will be now revised in accordance with the recent appellate court ruling on Phase I of the ACF litigation. Most of our recommendations still apply, and we encourage the Corps to follow the recommendations and conservation measures included in these documents. We encourage the Corps to work closely with us to develop alternatives that are protective of fish and wildlife resources in the ACF River Basin, and we stand by ready to assist.

We appreciate the cooperation of your staff in preparing this BO. We look forward to working closely with you in implementing its provisions and other conservation actions for the listed species and critical habitat of the Apalachicola River and Bay ecosystem.

Sincerely,

//s//Dr. Donald W. Imm

Dr. Donald W. Imm
Project Leader

11 LITERATURE CITED

Amyot, J. P. and J.A. Downing. 1998. Locomotion in Elliptio complanata (Mollusca: Unionidae): a reproductive function? Freshwater Biology 39: 351-358.

Angermeir, P.L. 1987. Spatiotemporal variation in habitat selection by fishes in small Illinois streams. Pages 52-60 *in*: W. Matthews and D. Heins, eds. Community and Evolutionary Ecology of North American Stream Fishes. University of Oklahoma Press, Norman, Oklahoma.

Anthony J. L., D. H. Kesler, W. L. Downing, J. A. Downing. 2001. Length-specific growth rates in freshwater mussels (Bivalvia: Unionidae): extreme longevity or generalized growth cessation. Freshwater Biology 46: 1349–1359.

Arnold, E.A, N.M. Rankin, K.J. Herrington, M. Brenner, J.H. Curtis, A. Dutton. 2011. Comparison of the oxygen isotope method and the internal line technique for age determination in *Amblema neislerii* mussels. Unpublished final report submitted to the U.S. Fish and Wildlife Service, Panama City Field Office, pp. 20.

Athearn, H.D. 1970. Discussion of Dr. Heard's paper. Pages 28-31 in: A.H. Clarke, ed. Proceedings of the American Malacological Union symposium on rare and endangered mollusks. Malacologia 10(1).

Augspurger T., A. Keller, M. Black, W. Cope, and F. Dwyer. 2003. Water quality guidance for protection of freshwater mussels (Unionidae) from ammonia exposure. Environmental Toxicology and Chemistry 22(11):2569–2575.

Balfour, D.L., and L.A. Smock. 1995. Distribution, age structure, and movements of the freshwater mussel Elliptio complanata (Mollusca: Unionidae) in a headwater stream. Journal of Freshwater Ecology 10:254-268.

Barnhart, C.M., Haag, W.R., Roston, W.N. 2008. Adaptations to host infection and larval parasitism in Unionoida. Journal of The North American Benthological Society. 27(2):370–394

Bartsch, M. R., D. L. Waller, W. G. Cope, and S. Gutreuter. 2000. Emersion and thermal tolerances of three species of unionid mussels: survival and behavioral effects. Journal of Shellfish Research 19:233–240.

Biedenharn, D.S. 2007. Cursory geomorphologic evaluation of the Apalachicola River in support of the Jim Woodruff Dam Interim Operations Plan. Summary of Findings, pp. 13.

Bogan, A.E. 1993. Freshwater bivalve extinctions (Mollusca: Unionoida): a search for causes. American Zoologist 33:599-609.

Bonvechio, T. F., and M. S. Allen. 2004. Relations between hydrological variables and year-class strength of sportfish in eight Florida waterbodies. Hydrobiologia 532:193-207.

Brim Box, J. 1999. Community structure of freshwater mussels (Bivalvia: Unionidae) in Coastal Plain streams of the southeastern United States. Unpublished Ph.D. Dissertation, University of Florida, Gainesville. 107 pp.

Brim Box, J., and J. Mossa. 1999. Sediment, land use, and freshwater mussels: prospects and problems. Journal of the North American Benthological Society 18(1):99-117.

Brim Box, J., and J.D. Williams. 2000. Unionid mollusks of the Apalachicola Basin in Alabama, Florida, and Georgia. Bulletin of the Alabama Museum of Natural History No. 22. 143 p.

Bruenderman, S.A., and R.J. Neves. 1993. Life history of the endangered fine-rayed pigtoe, *Fusconaia cuneolus* (Bivalvia: Unionidae) in the Clinch River, Virginia. American Malacological Bulletin 10(1):83-91.

Burkett, V.R. 2008. Statement of chief scientist for global change research before the Committee on Energy and Natural Resources regarding findings of the U.S. Climate Change Science Program Study (SAP 4.7: Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I) May 13, 2008.

Chamberlain, T.K. 1931. Annual growth of freshwater mussels. Bulletin of the U.S. Bureau of Fisheries 46:713-739.

Clench, W.J., and R.D. Turner. 1956. Freshwater mollusks of Alabama, Georgia, and Florida from the Escambia to the Suwannee River. Bulletin of the Florida State Museum, Biological Sciences 1(3):97-239.

Coker, R.E., A.F. Shira, H.W. Clark, and A.D. Howard. 1921. Natural history and propagation of freshwater mussels. Bulletin of the U.S. Bureau of Fisheries 37:77-181.

Coon, T.G., J.W. Eckblad, and P.M. Trygstad. 1977. Relative abundance and growth of mussels (Mollusca: Eulamellibranchia) in pools 8, 9, and 10 of the Mississippi River. Freshwater Biology 7:279-285.

Cushman, R. M. 1985. Review of ecological effects of rapidly varying flows downstream from hydroelectric facilities. North American Journal of Fisheries Management 5: 330-339.

Di Maio, J., and L.D. Corkum. 1995. Relationship between the spatial distribution of freshwater mussels (Bivalvia: Unionidae) and the hydrological variability of rivers. Canadian Journal of Zoology 73:663-671.

Downing, J.A., J.-P. Amyot, M. Pérusse, and Y. Rochon. 1989. Visceral sex, hermaphroditism, and protandry in a population of the freshwater mussel *Elliptio complanata*. Journal of the North American Benthological Society 8(1):92-99.

Dunne, T., and L.B. Leopold. 1978. Water in environmental planning. W.H. Freeman Company, San Francisco. 818 pp.

Dutterer, A. C., C. Mesing, R. Cailteux, M. S. Allen, W. E. Pine III, and P. A. Strickland. 2011. Fish recruitment is influenced by river flows and floodplain inundation at the Apalachicola River, Florida. Unpublished final report submitted to the Florida Fish and Wildlife Conservation Commission. 24 pp.

EnviroScience. 2006a. Freshwater mussel and habitat surveys of the Apalachicola River, Chipola River and selected sloughs/tributaries. Unpublished final report submitted to the Florida Department of Environmental Protection.

EnviroScience. 2006b. Swift Slough Population (Abundance) Estimate for the federally endangered *Amblema neislerii* (Fat Threeridge) and federally threatened Elliptoideus sloatianus (Purple Bankclimber). Unpublished draft report submitted to the Fish and Wildlife Conservation Commission.

EnviroScience. 2011. Status Report: 2010 Swift Slough Habitat and Population Status Survey for the federally endangered *Amblema neislerii* (Fat Threeridge). Unpublished final report submitted to the Fish and Wildlife Conservation Commission.

Etnier, D.A. 1997. Jeopardized southeastern freshwater fishes: a search for causes. Pages 87-104 in G.W. Benz and D.E. Collins, editors, Aquatic Fauna in Peril. Southeast Aquatic Research Institute, Special Publication 1, Lenz Design and Communications, Decatur, GA.

Florida Department of Environmental Protection (FDEP). 2002. Division of Water Resource Management, Basin Status Report, Northwest District, Group 2 Basin, Apalachicola-Chipola.

Florida Department of Environmental Protection (FDEP). 2005. Division of Water Resource Management, Water Quality Assessment Report, Northwest District, Group 2 Basin, Apalachicola-Chipola.

Florida Fish and Wildlife Conservation Commission (FFWCC). 2011. The Impact of Reduced Flows on the Apalachicola River and Bay Ecosystems. Letter from Harold Vielhauer to (FFWCC) to Dr. Donald Imm (USFWS) and Major General Todd Semonite (Corps) dated February 22, 2011.

Frankham, R. 1995. Effective population-size adult-population size coalescent methods in wildlife: a review. Genet. Res. 66: 95–107.

Frick, E.A., D.J. Hippe, G.R. Buell, C.A. Couch, E.H. Hopkins, D.J. Wangsness, and J.W. Garrett. 1998. Water quality in the Apalachicola-Chattahoochee-Flint River basin, Georgia, Alabama, and Florida, 1992-95. U.S. Geological Survey Circular 1164. 38 p.

Fuller, S.L.H. 1974. Clams and mussels (Mollusca: Bivalvia). Pages 215-273 in: C.W. Hart and S.L.H. Fuller, editors, Pollution ecology of freshwater invertebrates. Academic Press, New York.

Fuller, S.L.H., and D.J. Bereza. 1973. Recent additions to the naiad fauna of the eastern Gulf drainage (Bivalvia: Unionoida: Unionidae). Association of Southeastern Biologists Bulletin 20(2):53.

Gangloff, M.M. 2011. Fat threeridge (*Amlema neislerii*) and Chipola slabshell (*Elliptio chipolaensis*) population size and depth distribution study in the Apalachicola and Lower Chipola rivers. Unpublished draft report prepared for U.S. Army Corps of Engineers, Mobile District, Mobile, AL. and Aerostar Environmental Services, Inc., Jacksonville, FL.

Garner, J.T., T. Tarpley, M. Buntin, S.W. McGregor. 2007. Chipola River headwaters mussel survey. Section 6 fiscal year 2006-2007 annual report. Alabama Department of Conservation and Natural Resources Division of Wildlife and Freshwater Fisheries and Geological Survey of Alabama.

Gatenby, C.M., R.J. Neves, and B.C. Parker. 1996. Influence of Sediment and Algal Food on Cultured Juvenile Freshwater Mussels. Journal of the North American Benthological Society 15(4):597-609.

Golladay, S.W., P. Gagnon, M. Kearns, J.M. Battle, and D.W. Hicks. 2004. Response of Freshwater Mussel Assemblages (Bivalvia:Unionidae) to a Record Drought in the Gulf Coastal Plain of Southwestern Georgia. Journal of the North American Benthological Society 23(3):494-506.

Golladay, S.W., D.W. Hicks, and T.K. Muenz. 2007. Stream flow changes associated with water use and climatic variation in the lower Flint River Basin, southwest Georgia. Proceedings of the 2007 Georgia Water Resources Conference, held March 27–29, 2007, at the University of Georgia.

Guillory V. 1979. Utilization of an inundated floodplain by Mississippi River fishes. Florida Scientist 42:222–228.

Gutreuter S., A. D. Bartles, K. Irons, M. B. Sandheinrich. 1999. Evaluation of the flood-pulse concept based on statistical models of growth of selected fishes of the upper Mississippi River. Canadian Journal of Fisheries and Aquatic Sciences 56:2282–2291.

Haag, W.R. and A.M. Commens-Carson. 2008. Testing the assumption of annual shell ring deposition in freshwater mussels Canadian Journal of Fisheries and Aquatic Science, 65, 493–508.

Haag, W. R. and J. L. Staton. 2003. Variation in fecundity and other reproductive traits in freshwater mussels. Freshwater Biology 48: 2118-2130.

Haag, W.R., and M.L. Warren, Jr. 1997. Host fish and reproductive biology of six freshwater mussel species from the Mobile Basin, USA. Journal of the North American Benthological Society 16:576-585.

Haag, W.R., and M.L. Warren, Jr. 1998. Role of ecological factors and reproductive strategies in structuring freshwater mussel communities. Canadian Journal of Fisheries and Aquatic Sciences 55:297-306.

Haag, W.R. and M.L. Warren 2008. Effects of severe drought on freshwater mussel assemblages. Transactions of the American Fisheries Society 137:1165–1178, 2008.

Haag, W.R., R.S. Butler, and P.D. Hartfield. 1995. An extraordinary reproductive strategy in freshwater bivalves: prey mimicry to facilitate larval dispersal. Freshwater Biology 34:471-476.

Haag, W.R. and A.L. Rypel. 2010. Growth and longevity in freshwater mussels: evolutionary and conservation implications. Biological Reviews, 86, pp. 225–247.

Hardison, B.S, and J.B. Layzer. 2001. Relations between complex hydraulics and the localized distribution of mussels in three regulated rivers. Regulated Rivers: Research and Management 17:77-84.

Hart, R.A., J.W. Grier, and A.C. Miller. 2004. Simulation models of harvested and zebra mussel colonized threeridge mussel populations in the Upper Mississippi River. American Midland Naturalist 151:301–317.

Hartfield, P.D. 1993. Headcuts and their effect on freshwater mussels. Pages 131-141 *in*: K.S. Cummings, A.C. Buchanan, and L.M. Koch, eds. Conservation and management of freshwater mussels. Proceedings of an symposium, October 1992, St. Louis, Missouri. Upper Mississippi River Conservation Committee, Rock Island, Illinois.

Hartzog, A. 2011. Host fish assessment and gravidity for the mussel *Elliptoideus sloatianus.* Unpublished final report prepared for the US Fish and Wildlife Service, Warm Springs National Fish Hatchery, Warm Springs, Georgia.

Harvey, M.D. 2007. Cursory fluvial geomorphic evaluation of the Apalachicola River in support of the Jim Woodruff Dam Interim Operations Plan: Summary of Findings, pp. 25.

Hastie, L.C., P.J. Boon, M.R. Young, and S. Way. 2001. The effect of a major flood on an endangered freshwater mussel population. Biological Conservation 98:107-115.

Heard, W. H. 1975. Determination of the endangered status of freshwater clams of the Gulf and Southeastern United States. Terminal Report for the Office of Endangered Species, Bureau of Sport Fisheries and Wildlife, U.S. Department of the Interior (Contract 14-16-000-8905).

Heard, W.H. 1979. Identification manual of the freshwater clams of Florida. Unpublished report, Florida Department of Environmental Regulation Technical Series 4. 83 pp.

Higgins, K. and M. Lynch. 2001. Metapopulation extinction caused by mutation accumulation. Proceedings of the National Academy of Sciences. Published on line 10.1073/pnas.031358898.

Holland, D. F. 1991. Prolonged emersion tolerance in freshwater mussels (Bivalvia: Unionidae): interspecific comparison of behavioral strategies and water loss rates. Master's thesis. University of Texas, Arlington.

Hove, M.C., and R.J. Neves. 1994. Life history of the endangered James spinymussel *Pleurobema collina* (Conrad, 1837) (Mollusca: Unionidae). American Malacological Bulletin 11(1):29-40.

Hutchings, J.A. and J.D. Reynolds. 2004. Marine fish population collapses: consequences for recovery and extinction risk. BioScience 54:297-309.

Hupp, C.R. 2000. Hydrology, geomorphology, and vegetation of coastal plain rivers in the south-eastern USA. Hydrological Processes 14:2991-3010.

IPCC (Intergovernmental Panel on Climate Change). 2007. Climate Change 2007: A synthesis report. IPCC Plenary XXVII (Valencia, Spain, 12-17 November 2007),

Isely, J. J. and T. B. Grabowski. 2007. Age and Growth. Pages 187-228 *in*: C.S. Guy and M. L. Brown, eds. Analysis and Interpretation of Freshwater Fisheries Data. American Fisheries Society, Bethesda, Maryland.

Isom, B.G., and R.G. Hudson. 1982. In Vitro culture of parasitic freshwater mussel glochidia. The Nautilus 96(4):147-151.

Janac, M., M. Ondrackova, P. Jurajda, Z. Valova, and M. Reichard. 2010. Flood duration determines the reproduction success of fish in artificial oxbows in a floodplain of a potamal river. Ecology of Freshwater Fish 19:644-655.

Jeanne, D.G. 2002. A history of the Mobile District Corps of Engineers, 1815-1985. U.S. Army Corps of Engineers, Mobile District. 119+pp.

Johnson, P.M., A.E. Liner, S.W. Golladay, and W.K. Michener. 2001. Effects of drought on freshwater mussels and instream habitat in coastal plain tributaries of the Flint River, southwest Georgia (July-October, 2000). Jones Ecological Research Center, unpublished report to The Nature Conservancy dated February 1, 2001, Newton, GA.

Jones, D S., D.F. Williams, and M.A. Arthur. 1983. Growth history and ecology of the Atlantic surf clam, *Spisula solidissima* (Dillwyn), as revealed by stable isotopes and annual shell increments. Journal of Experimental Marine Biology and Ecology 73:225-242.

Kilgore, K.J., and J.A. Baker. 1996. Patterns of larval fish abundance in a bottomland hardwood wetland. Wetlands 16(3):288-295.

Kingsolving A. D., M. B. Bain. 1993. Fish assemblage recovery along a riverine disturbance gradient. Ecological Applications 3:531–544.

Kraemer, L.R. 1979. *Corbicula* (Bivalvia: Sphaeriacea) *vs*. indigenous mussels (Bivalvia: Unionacea) in U.S. rivers: a hard case for interspecific competition? American Zoologist 19:1085-1096.

Lefevre, G., and W.C. Curtis. 1912. Studies on the reproduction and artificial propagation of freshwater mussels. Bulletin of the U.S. Bureau of Fisheries 30:105-201.

Leff, L.G., J.L. Burch, and J.V. McArthur. 1990. Spatial distribution, seston removal, and potential competitive interactions of the bivalves *Corbicula fluminea* and *Elliptio complanata*, in a Coastal Plain stream. Freshwater Biology 24:409-416.

Leopold, L.B. 1994. A view of the river. Harvard University Press, Cambridge, MA. 298 pp.

Leopold, L.B. and M.G. Wolman. 1957. River channel patterns: braided, meandering, and straight. U.S. Geological Survey, Professional Paper 282B.

Lewis, J.B., and P.N. Riebel. 1984. The effect of substrate on burrowing in freshwater mussels (Unionidae). Canadian Journal of Zoology 62:2023-2025.

Lidstone and Anderson, Inc. 1989. An Investigation of the Effects of Apalachicola River Training Dikes on Sediment Transport and Bank Erosion. Unpublished final report submitted to the U.S. Army Corps of Engineers.

Light, H.M, M.R. Darst, and J.W. Grubbs. 1998. Aquatic habitats in relation to river flow in the Apalachicola River floodplain, Florida. U.S. Geological Survey Professional Paper 1594.

Light, H.M., Vincent, K.R., Darst, M.R., and Price, F.D. 2006. Water-Level Decline in the Apalachicola River, Florida, from 1954 to 2004, and Effects on Floodplain Habitats: U.S. Geological Survey Scientific Investigations Report 2006-5173, 83 p., plus CD.

McCann, M.T. 2005. Survey for the threatened purple bankclimber (Elliptoideus sloatianus) in the middle reach of the Flint River, Georgia. Abstract from the 4th Biennial Symposium of the Freshwater Mollusk Conservation Society, St. Paul, Minnesota, May 15-18, 2005.

McCuaig, J. M. and R. H. Green. 1983. Unionid growth curves derived from annual growth rings: a baseline model for Long Point Bay, Lake Erie. Canadian Journal of Fisheries and Aquatic Sciences 40:436-442. Miller, A.C. 1998. An analysis of freshwater mussels (Unionidae) at dredged material disposal areas along the Apalachicola River, FL. U.S. Army Corps of Engineers Waterways Experiment Station, Technical Report EL-98-16, Vicksburg, Mississippi. 56 p.

McMahon, R. F. & A. E. Bogan. 2001. Mollusca: Bivalvia. *In* J. H. Thorpe & A. P. Covich. Ecology and Classification of North American Freshwater Invertebrates, 2nd edn. Academic Press, 331–429.

McMahon, R. F., and A. E. Bogan. 2001. Bivalves. Pp 331–428 in J.H. Thorp and A.P. Covich, Eds. Ecology and classification of North American freshwater invertebrates, second edition. Academic Press, New York, NY.

McMahon, R. F. 1979. Response to temperature and hypoxia in the oxygen consumption of the introduced Asiatic freshwater clam, Corbicula fluminea (Muller). Comparative Biochemistry and Physiology 63A:383-388.

Metcalf, A. L. 1983. Mortality in unionacean mussels in a year of drought. Transactions of the Kansas Academy of Science 86:89–92.

Metcalf, C. K., S. D. Wilkerson, and W.A. Harman. 2009. Bankfull regional curves for North and Northwest Florida streams. Journal of the American Water Resources Association 45(5): 1260-1272.

Miller, A.C. 2011a. Comments on the reinitiated consultation concerning the U.S. Army Corps of Engineers' Revised Interim Operations Plan for Jim Woodruff Lock and Dam. Letter from to Dr. Donald Imm (USFWS) dated August 21, 2011.

Miller, A.C. and B.S. Payne. 2007. Factors determining abundance and distribution of the endangered fat threeridge mussel, Amblema neislerii, in the Apalachicola River, Florida. Ecological Applications Tallahassee, Florida, and Environmental Laboratory, US Army Engineer Research and Development Center, Vicksburg, Mississippi.

Miller, A.C. and B.S. Payne. 2006. The fat threeridge (Amblema neislerii), the surprisingly common endangered mussel in the Apalachicola River, Florida. Environmental Laboratory, U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi.

Miller, A.C. and B.S. Payne. 2005. Depth distribution of the fat threeridge mussel *Amblema neislerii*, during low flow stages on the Apalachicola River. U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, Mississippi. Unpublished draft report, 31 p.

Miller, P.S. 2008. Preliminary Population Viability Analysis for Fat Threeridge Mussel (Amblema neislerii). Unpublished final report. IUCN / SSC Conservation Breeding Specialist Group. 21 pp.

Miller, P.S. 2011b. Revised Population Viability Analysis for the Fat Threeridge Mussel (Amblema neislerii). Unpublished final report. IUCN / SSC Conservation Breeding Specialist Group. 23 pp.

Morales, Y., L. J. Weber, A.E. Mynett, and T.J. Newton. 2006. Effects of substrate and hydrodynamic conditions on the formation of mussel beds in a large river. Journal of the North American Benthological Society 25(3):664-676.

Murchie, K. J., K. P. E. Hair, C. E. Pullen, T. D. Redpath, H. R. Stephens, and S. J. Cooke. 2008. Fish response to modified flow regimes in regulated rives: research methods, effects and opportunities. River Research and Applications 24:197-217.

NOAA (National Oceanic and Atmospheric Administration). 2011. National Climatic Data Center. < http://www.ncdc.noaa.gov/oa/climate/onlineprod/drought/xmgr.html>. Asheville, NC. Accessed October 2011.

Negus, C.L. 1966. A quantitative study of growth and production of unionid mussels in the River Thames at Reading. Journal of Animal Ecology 35:513-532.

Neves, R.J. 1993. A state-of-the-unionids address. Pages 1-10 *in*: K.S. Cummings, A.C. Buchanan, and L.M. Koch, eds. Conservation and management of freshwater mussels. Proceedings of an Upper Mississippi River Conservation Committee symposium, October 1992, St. Louis, Missouri. UMRCC, Rock Island, Illinois.

Neves, R.J., and S.N. Moyer. 1988. Evaluation of techniques for age determination of freshwater mussels (Unionidae). American Malacologica Bulletin, Vol. 6(2) (1988): 179-188.

Neves, R.J., and J.C. Widlak. 1987. Habitat ecology of juvenile freshwater mussels (Bivalvia: Unionidae) in a headwater stream in Virginia. American Malacological Union Bulletin 5(1):1-7.

Neves, R.J., and J.C. Widlak. 1988. Occurrence of glochidia in stream drift and on fishes of the upper North Fork Holston River, Virginia. American Midland Naturalist 119(1):111-120.

Neves, R.J., L.R. Weaver, and A.V. Zale. 1985. An evaluation of host fish suitability for glochidia of *Villosa vanuxemi* and *V. nebulosa* (Pelecypoda: Unionidae). American Midland Naturalist 113(1):13-19.

Neves, R.J., A.E. Bogan, J.D. Williams, S.A. Ahlstedt, and P.D. Hartfield. 1997. Status of aquatic mollusks in the southeastern United States: a downward spiral of diversity. Pages 43-85 in: G.W. Benz and D.E. Collins, editors, Aquatic fauna in peril: the southeastern perspective. Southeast Aquatic Research Institute, Special Publication 1, Lenz Design and Communications, Decatur, GA.

Newton, T, S. Zigler, B. Kennedy, A. Hunt, M. Davis and P. Ries. 2011. Response of native mussels to water level manipulation in the Upper Mississippi River. Presentation given at the Freshwater Mollusk Conservation Society symposium in Louisville, KY.

Nunney, L., and D.R. Elam. 1994. Estimating the Effective Population Size of Conserved Populations. Conservation Biology, 8:175-184.

O'Brien, C.A., and J. Brim Box. 1999. Reproductive biology and juvenile recruitment of the shinyrayed pocketbook, *Lampsilis subangulata* (Bivalvia: Unionidae) in the Gulf Coastal Plain. American Midland Naturalist 142:129-140.

O'Brien, C.A. and J.D. Williams. 2002. Reproductive biology of four freshwater mussels (Bivalvia: Unionidae) endemic to the eastern Gulf Coastal Plain drainages of Alabama, Florida, and Georgia. American Malacological Bulletin 17(1/2):147-158.

Perles, S. J., A. D. Christian, D. J. Berg. 2003. Vertical migration, orientation, aggregation, and fecundity of the freshwater mussel Lampsilis siliquoidea. Ohio Journal of Science 103(4): 73-78.

Petts, G.E. 1984. Impounded rivers: perspectives for ecological management. John Wiley and Sons, New York.

Pine, W.E and M.S. Allen. 2005. Assessing the impact of reduced spawning habitat on Gulf sturgeon recruitment and population viability in the Apalachicola Bay system. Unpublished final report to the U.S. Fish and Wildlife Service. Agreement NO: 401814G069 34 pp.

Pine III, W. E., O. T. Burgess, S. J. Walsh, A. C. Dutterer. 2006. Examination of fish spawning, movement, and habitat utilization patterns in the Battle Bend region of the Apalachicola River, Florida. Unpublished final report to the Florida Fish and Wildlife Conservation Commission, Tallahassee, FL p. 39.

Poff, N. L., and J. V. Ward. 1989. Implications of streamflow variability and predictability for lotic community structure: a regional analysis of streamflow patterns. Canadian Journal of Fisheries and Aquatic Sciences 46:1805-1818.

Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegaard, B.D. Richter, R.E. Sparks, and J.C. Stromberg, 1997. The Natural Flow Regime. BioScience 47:769-784.

Price, F.D., Light, H.M., Darst, M.R., Griffin, E.R., Vincent, K.R., and Ziewitz, J.W. 2006. Change in channel width from 1941 to 2004, and change in mean bed elevation from 1960 to 2001, in the nontidal Apalachicola River, Florida. U.S. Geological Survey website http://fl.water.usgs.gov/Water_data/ApalachRchannel_change.html

Priester, L. 2008. Life History Observations and Determination of Potential Host Fish Species for Chipola Slabshell, *Elliptio chipolaensis*. Masters Thesis, Columbus State University, Columbus, Georga, pp. 51.

Raibley, P.T., T.M. O'Hara, K.S. Irons, K.D. Blodgett, and R.E. Sparks. 1997. Largemouth bass size distributions under varying annual hydrological regimes in the Illinois River. Transactions of the American Fisheries Society 126:850-856.

Ribeiro, F., P.K. Crain, and P.B. Moyle. 2004. Variation in condition factor and growth of young-of-year fishes in floodplain and riverine habitats of the Consumnes River California. Hydrobiologia 527(1):77-84.

Roe, K.J. and P.D. Hartfield. 2005. Hamiota, a new genus of freshwater mussel (Bivalvia: Unionidae) from the Gulf of Mexico drainages of the southeastern United States. Nautilus 119(1):1-10.

Rogers, M. W., M. S. Allen, and M. D. Jones. 2005. Relationship between river surface level and fish assemblage in the Ocklawaha River, Florida. River Research and Applications 21:501-511.

Ross, S.T., and J. A. Baker. 1983. The response of fishes to periodic spring floods in a southeastern stream. American Midland Naturalist 109(1):1-14.

Rypel, A.L., W.R. Haag, and R.H Findlay. 2008. Validation of annual growth rings in freshwater mussel shells using crossdating. Canadian Journal of Fisheries and Aquatic Science, 65, 2224–2232.

Sammons, S. M., and M. J. Maceina. 2009. Effects of river flows on growth of redbreast sunfish Lepomis auritus (Centrarchidae) in Georgia rivers. Journal of Fish Biology 74: 1580-1593.

San Migel, E., S. Monserrat, C. Fernandez, R. Amaro, M. Hermida, P. Ondina, and C. R. Altaba. 2004. Growth models and longevity of freshwater pearl mussels (Margaritifera margaritifera) in Spain. Canadian Journal of Zoology 82: 1370-1379.

Schlosser, I. J. 1985. Flow regime, juvenile abundance, and the assemblage structure of stream fishes. Ecology 66: 1484-1490.

Secor, D.H. and E.J. Niklitschek. 2001. Hypoxia and sturgeons. Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science. Technical Report Series, No. TS-314-01-CBL.

Slipke, J. W. and M. J. Maceina. 2001. Fishery analysis and simulation tools (FAST 2.0) manual. Auburn University, Alabama.

Smith, S. M., J. S. Odenkirk, and S. J. Reeser. 2005. Smallmouth bass recruitment variability and its relation to stream discharge in three Virginia rivers. North American Journal of Fisheries Management 25:1112-1121.

Sparks, B.L. and D.L. Strayer. 1998. Effects of low dissolved oxygen on juvenile Elliptio complanata (Bivalvia: Unionidae). Journal of the North American Benthological Society 17(1):129-134.

Stanford, J. A., and J. V. Ward. 1983. Insect species diversity as a function of environmental variability and disturbance in streams. In Stream Ecology:Application and Testing of General Ecological Theory, Barnes, J. R., and G. W.Minshall (editors). Plenum Press: New York; 265-278.

Stansbery, D.H. 1971. Rare and endangered molluscs in the eastern United States. Pages 5-18 in: S.E. Jorgensen and R.W. Sharpe, eds. Proceedings of a symposium on rare and 121 endangered mollusks (naiads) of the United States. U.S. Fish and Wildlife Service, Twin Cities, Minnesota.

Strayer, D.L. 1999. Use of flow refuges by unionid mussels in rivers. Journal of the North American Benthological Society 18(4):468-476.

Strayer, D.L., and J. Ralley. 1993. Microhabitat use by an assemblage of stream-dwelling unionaceans (Bivalvia), including two rare species of *Alasmidonta*. Journal of the North American Benthological Society 12(3):247-258.

Strayer, D.L., J.A. Downing, W.R. Haag, T.L. King, J.B. Layzer, T.J. Newton, and S.J. Nichols. 2004. Changing perspectives on pearly mussels, North America's most imperiled animals. BioScience 54:429–439.

Surber, T. 1912. Identification of the glochidia of freshwater mussels. U.S. Bureau of Fisheries Document No. 771. 10 pp.

Sylvester, J.R., L.E. Holland, and T.K. Kammer. 1984. Observations on burrowing rates and comments on host specificity in the endangered mussel *Lampsilis higginsi*. Journal of Freshwater Ecology 2(6):555-559.

Tramer, E. J. 1978. Catastrophic mortality of stream fishes tapped in shrinking pools. American Midland Naturalist 115:667-695.Rood, S.B., J.M. Mahoney, D.E. Reid, and L. Zilm. 1995. Instream flows and the decline of riparian cottonwoods along the St. Mary River, Alberta. Canadian Journal of Botany 73:1250-1260. Stansbery, D.H. 1961. The naiads (Mollusca, Pelecypoda, Unionacea) of Fishery Bay, South Bass Island, Lake Erie. Sterkiana 5:1-37.

Turner, T.F., J.P. Wares, and J.R. Gold. 2002. Genetic effective size is three orders of magnitude smaller than adult census size in an abundant, estuarine-dependent marine fish (Sciaenops ocellatus). Genetics 162: 1329–1339.

Turner, T.F., M. J. Osborne, G.R. Moyer, M.A. Benavides, and D. Alò. 2006. Life history and environmental variation interact to determine the effective population to census size ratio. Proceedings of the Royal Society Series B 273: 3065-3073.

U.S. Army Corps of Engineers (Corps). 2011. Amended Biological Assessment: Modifications to the Revised Interim Operations Plan (RIOP) for Jim Woodruff Dam and the Associated Releases to the Apalachicola River. Prepared by the Mobile District, Planning and Environmental Division, Mobile, Alabama. 59 p.

U.S. Army Corps of Engineers (Corps). 2012. Revised Amended Biological Assessment: Modifications to the Revised Interim Operations Plan (RIOP) for Jim Woodruff Dam and the Associated Releases to the Apalachicola River. Prepared by the Mobile District, Planning and Environmental Division, Mobile, Alabama. 17 p.

U.S. Fish and Wildlife Service. 1998a. Endangered and threatened wildlife and plants; determination of endangered status for five freshwater mussels and threatened status for two freshwater mussels from the eastern Gulf Slope drainages of Alabama, Florida, and Georgia. Federal Register 63:12664-12687.

U.S. Fish and Wildlife Service. 1998b. Final Endangered Species Act Section 7 Consultation Handbook, March 1998. U.S. Government Printing Office ISBN 0-16-049596-2.

U.S. Fish and Wildlife Service (USFWS). 2003. United States Fish and Wildlife Service. Recovery plan for endangered fat threeridge (*Amblema neislerii*), shinyrayed pocketbook (*Lampsilis subangulata*), Gulf moccasinshell (*Medionidus penicillatus*), Ochlockonee moccasinshell (*Medionidus simpsonianus*), and oval pigtoe (*Pleurobema pyriforme*); and threatened Chipola slabshell (*Elliptio chipolaensis*), and purple bankclimber (*Elliptoideus sloatianus*). Atlanta, Georgia.

U.S. Fish and Wildlife Service (USWFS). 2006. Biological opinion and conference report on the U.S. Army Corps of Engineers, Mobile District, interim operation plan for Jim Woodruff Dam and the associated released to the Apalachicola River. Prepared by the USFWS Panama City Field Office, Florida. 165 p.

U.S. Fish and Wildlife Service (USFWS). 2007a. Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for Five Endangered and Two Threatened Mussels in Four Northeast Gulf of Mexico Drainages. Federal Register 72:64286-64340.

U.S. Fish and Wildlife Service (USFWS). 2007b. United States Fish and Wildlife Service. Fat Threeridge (*Amblema neislerii*) Shinyrayed Pocketbook (*Lampsilis subangulata*) Gulf Moccasinshell (*Medionidus penicillatus*) Ochlockonee Moccasinshell (*Medionidus simpsonianus*) Oval Pigtoe (*Pleurobema pyriforme*) Chipola Slabshell (*Elliptio chipolaensis*) Purple Bankclimber (*Elliptoideus sloatianus*); 5-Year Review: Summary and Evaluation.

U.S. Fish and Wildlife Service (USFWS). 2011. An investigation of movement, exposure, and mortality of fat threeridge mussels (*Amblema neislerii*) at Apalachicola and Chipola River sites. Prepared by A. J. Kaeser and K. J. Herrington of the USFWS Panama City Field Office, Florida. 28 p.

U.S. Fish and Wildlife Service (USFWS) and U.S. Environmental Protection Agency. 1999. Instream flow guidelines for the Act and ACF Basins interstate water allocation formula. USFWS and USEPA, Atlanta, GA, unpublished report transmitted to L. Thomas, Federal Commissioner, Act and ACF River Basins Commissions, by letter dated October 25, 1999. 13 p + appendices.

Vannote, R.L., and G.W. Minshall. 1982. Fluvial processes and local lithology controlling abundance, structure, and composition of mussel beds. Proceedings of the National Academy of Sciences 79:4103-4107.

Van Den Avyle, M. J., and R. S. Hayward. 1999. Dynamics of exploited fish populations. Pages 127–166 in C. C. Kohler and W. A. Hubert, editors. Inland fisheries management in North American, 2nd edition. American Fisheries Society, Bethesda, Maryland.

van der Schalie, H. 1940. The naiad fauna of the Chipola River, in northwestern Florida. Lloydia 3(3):191-206.

van der Schalie, H. 1970. Hermaphroditism among North American freshwater mussels. Malacologia 10(1):93-112.

Villella, R.F., D.R. Smith, and D.P Lemarie. 2004. Estimating survival and recruitment in a freshwater mussel population using mark-recapture techniques. American Midland Naturalist 151:114-133.

Vucetich, J.A., T.A. Waite, and L. Nunney. 1997. Fluctuating population size and the ratio of effective to census population size. Evolution 51:2017-2021.

Walsh, S. J., W. B. Tate, M. A. Burgess. 2006. Fishes of the Apalachicola River floodplain: role of habitat and hydrology to recruitment. U. S. Geological Survey. Unpublished final report submitted to the Florida Fish and Wildlife Conservation Commission. 124 pp.

Walsh, S.J., Buttermore, E.N., Burgess, O.T., and Pine, W.E., III, 2009, Composition of Age-0 Fish Assemblages in the. Apalachicola River, River Styx, and Battle Bend, Florida. U.S. Geological Service Open-File Report. 2011-1145. 28 pp.

Warren, M.L., Jr., P.L. Angermeier, B.M. Burr, and W.R. Haag. 1997. Decline of a diverse fish fauna: patterns of imperilment and protection in the southeastern United States. Pages 105-164 in G.W. Benz and D.E. Collins, editors, Aquatic Fauna in Peril. Southeast Aquatic Research Institute, Special Publication 1, Lenz Design and Communications, Decatur, GA.

Watters, G.T. 1992. Unionids, fishes, and the species-area curve. Journal of Biogeography 19:481-490.

Watters, G.T. 1994. An annotated bibliography of the reproduction and propagation of the Unionoidea (primarily of North America). Ohio Biological Survey Miscellaneous Contributions No. 1. 158 pp.

Watters, G.T. 1997. Individual-based models of mussel-fish interactions: a cautionary study. Pages 45-62 in: K.S. Cummings, A.C. Buchanan, C.A. Mayer, and T.J. Naimo, editors, Conservation and management of freshwater mussels II: initiatives for the future. Proceedings of an Upper Mississippi River Conservation Committee symposium, October 1995, St. Louis, MO.

Watters, G.T., and S.H. O'Dee. 2000. Glochidial release as a function of water temperature: beyond bradyticty and tachyticty. Pages 135-140 i*n*: R.A. Tankersley, D. Warmolts, G.T. Watters, B. Armitage, P.D. Johnson, and R.S. Butler eds. Freshwater Mollusk Symposia Proceedings--Part I: Conservation, Captive Care, and Propagation symposium, March 1998, Columbus, Ohio. Ohio Biological Survey, Columbus, Ohio.

Watters G. T., O'Dee S. H., Chordas S. 2001. Patterns of vertical migration in freshwater mussels (Bivalvia: Unionida). Journal of Freshwater Ecology 16: 541-550.

Welcomme, R.L. 1979. Fisheries ecology of floodplain rivers. Longman. New York, New York, USA.

White, D. S. 1979. The effects of lake level fluctuations on Corbicula and other pelecypods in Lake Texoma, Texas and Oklahoma. Pages 82–88 in J. C. Britton, editor. Proceedings of the first international Corbicula symposium. Texas Christian University Research Foundation, Fort Worth.
Williams, J.D., and R.S. Butler. 1994. Class Bivalvia, freshwater bivalves. Pages 53-128, 740-742 *in*: R. Ashton, ed. Rare and endangered biota of Florida. Volume 6. Invertebrates. University of Florida Press, Gainesville.
Williams, J.D., M.L. Warren, Jr., K.S. Cummings, J.L. Harris, and R.J. Neves. 1993. Conservation status of freshwater mussels of the United States and Canada. Fisheries 18(9):6-22.
Williams, J.D., Garner, J.T., and Bogan, A.E. 2008. Freshwater mussels of Alabama and the Mobile Basin in Georgia, Mississippi & Tennessee. The University of Alabama Press; Tuscaloosa, Alabama.
Wisconsin Department of Natural Resources (WDNR), Minnesota Department of Natural Resources and the U. S. Army Corps of Engineers, St. Paul District. 2006. Preliminary Report on the Effects of the 2005 Pool 5, Mississippi River Drawdown on Shallow-water native mussels.
Witdaard, R., M.I. Jenness, K. Van Der Borg, and G. Ganssen. 1994. Verification of annual growth increments in *Arctica Islandica* L. from the North Sea by means of oxygen and carbon isotopes. Netherlands Journal of Sea Research 33: 91-101.
Wisniewski, J. 2007. Summary of Lower Flint River Basin Trip. Georgia Department of Natural Resources.
Yao, H. and A. Georgakakos. 2011. ACF river basin: climate and demand change impacts and mitigation measures. Proceedings of the 2011 Georgia Water Resources Conference, Apri1 11-13, 2011, at the University of Georgia.
Yeager, B.L., and R.J. Neves. 1986. Reproductive cycle and fish hosts of the rabbit's foot mussel, *Quadrula cylindrica strigillata* (Mollusca: Unionidae) in the upper Tennessee River drainage. American Midland Naturalist 116:329-340.
Yeager, B.L., and C.F. Saylor. 1995. Fish hosts for four species of freshwater mussels (Pelecypoda: Unionidae) in the upper Tennessee River drainage. American Midland Naturalist 133:1-6.
Yeager, M.M., D.S. Cherry, and R.J. Neves. 1994. Feeding and burrowing behaviors of juvenile rainbow mussels, Villosa iris (Bivalvia: Unionidae). Journal of the North American Benthological Society 13(2):217-222.
Zale, A.V., and R.J. Neves. 1982. Fish hosts of four species of lampsiline mussels (Mollusca: Unionidae) in Big Moccasin Creek, Virginia. Canadian Journal of Zoology 60:2535-2542.

Unpublished Data

ARC. 2011. Unpublished Data. Atlanta Regional Commission, Atlanta, GA.
EnviroScience. 2006, 2007, 2011. Unpublished Data. (G. Zimmerman, Vice President) Stow, OH.
FFWCC. 2007, 2011. Unpublished data. Florida Fish and Wildlife Conservation Commission, Tallahassee, FL.

Gangloff, M. 2011. Unpublished Data. Research Assistant Professor. Appalachian State University, Boone, NC.
Stringfellow, C. 2006. Unpublished Data. Assistant Professor. Columbus State University, Columbus, GA.
USFWS. 2006-2011. Unpublished Data. US Fish and Wildlife Service. Panama City Field Office, Panama City, FL.

Personal Communication

Butler, R.S. 2003. Personal Communication. Aquatic Fauna Recovery Specialist. U.S. Fish and Wildlife Service, Asheville, NC.
Fritts, A. 2012. Personal Communication. Ph.D. Candidate. University of Georgia, Athens, GA.
Haag, W.R. 2008. Personal Communication. Fisheries Research Biologist. U.S. Forest Service. Oxford, MS.
Hoehn, T. 2007. Personal Communication. Biologist. Florida Fish and Wildlife Conservation Commission, Tallahassee, FL.
Light, H. 2012. Personal Communication. Retired. U.S. Geologic Survey, Tallahassee, FL.
Moyer, G. 2011. Personal Communication. Regional Geneticist. U.S. Fish and Wildlife Service, Warm Springs, GA.
Stringfellow, C. 2011. Personal Communication. Assistant Professor. Columbus State University, Columbus, GA.
Wisniewski, J. 2009 and 2011. Personal Communication. Biologist. Georgia Department of Natural Resources, Athens, GA.
Zettle, B. 2011. Personal Communication email. Chief, Inland Environment Team. U.S. Army Corps of Engineers, Mobile, AL.
Zimmerman, G. 2007. Personal Communication. Vice President. EnviroScience Inc., Stow, OH.