Biological Opinion

Endangered Species Act
Section 7 Consultation

on the

U.S. Army Corps of Engineers
Mobile District

Update of the Water Control Manual for the Apalachicola-Chattahoochee-Flint River Basin in Alabama, Florida, and Georgia and a Water Supply Storage Assessment

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EXECUTIVE SUMMARY

The action evaluated in this consultation is the U.S. Army Corps of Engineers' (USACE) Update of the Water Control Manual (WCM) for the Apalachicola-Chattahoochee-Flint River Basin (ACF) in Alabama, Florida, and Georgia. The proposed action is primarily the operation of the five federal facilities, individually and in concert, under the WCM. The USFWS recognizes that the ACF River basin is a working river basin that provides water, transportation and livelihood for residents of three states. The USACE uses its WCM to balance these uses, for recreation, water supply, navigation, hydroelectric generation, flood control, drought reduction, fish and wildlife habitat, and endangered species.

The USACE determined in its Biological Assessment (BA) that the proposed action may adversely affect the fat threeridge, purple bankclimber, and Chipola slabshell, but is not likely to adversely affect (NLAA) their designated critical habitat. Additionally, USACE determined that the proposed action may affect, but is NLAA, the Gulf sturgeon and its designated critical habitat. The USFWS incorporated new information and analysis for Gulf sturgeon and does not concur with the USACE's determination of NLAA for the Gulf sturgeon and its designated critical habitat. Therefore, mussel and sturgeon effects on the species and their critical habitats are addressed in this biological opinion (BO).

In the WCM, the USACE adopts a modified version of its preferred alternative action (PAA) from the Draft Environmental Impact Statement (DEIS). The WCM includes actions for fish and wildlife conservation, including actions for federally-listed species (e.g., water releases below Woodruff Dam on the basis of spawning, non-spawning, and winter requirements), tailrace dissolved oxygen levels, fish passage, reservoir fish spawning, and management of Eufaula National Wildlife Refuge. The WCM also includes actions for drought operations, flood risk management, hydroelectric power generation, navigation, recreation, water quality, and water supply. Compared to existing management, the USACE proposes to modify 1) the action zones, 2) drought operations, 3) storage relocation at Lake Lanier, 4) ramping during prolonged flow, and 5) navigation.

The current status of Gulf sturgeon and the three mussel species and the critical habitat for all four species is discussed in detail in this BO. 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. In the BA, environmental baseline was defined as the observed flows of the river since the full complement of the USACE's reservoirs were completed and for which an unimpaired data set was available, so that the proposed action could be modeled (calendar years 1975 to 2012). In this BO, an alternative strategy is being employed as discussed in the Environmental Baseline – Physical Environment section. Under this approach, the modeled effects of the WCM are compared to the modeled effects of the USACE's no action alternative (NAA) for 1939-2012. The NAA includes the RIOP management implemented from 2012-present and is the baseline for this consultation.

Relative to the baseline, the proposed update to the WCM provides both beneficial and adverse effects to the species and designated critical habitats we have assessed. The WCM will negatively affect Gulf sturgeon by providing more time under which appropriate flow conditions for hydropeaking will occur during the spring spawning season and less inundation of floodplain habitats in late summer, fall, and winter. The WCM may affect four of the six primary constituent elements (PCEs) of sturgeon critical habitat: 1) food items in the riverine and estuarine environments, 2) riverine spawning areas, 3) flow regime, and 4) water quality. However, the WCM 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. It is the U.S. Fish and Wildlife Service's (USFWS) biological opinion (BO) that the proposed action: 1) will not jeopardize the continued existence of the Gulf sturgeon, and 2) will not destroy or adversely modify designated critical habitat for the Gulf sturgeon.

The WCM will negatively affect all three mussel species by providing longer durations of low flows (<5,000 cfs). The WCM may affect three of the five PCEs of mussel critical habitat: 1) permanently flowing water, 2) water quality, and 3) fish hosts. The WCM does appear to reduce the amount of floodplain habitat available to fish hosts for spawning. However, the WCM 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. It is the USFWS' 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 USACE from take under the Act. During conditions appropriate for hydropeaking during the Gulf sturgeon spawning season and during late summer, fall and winter by decreasing floodplain inundation, take of Gulf sturgeon will occur and the magnitude of this take will be estimated using surrogate measures and monitored. Hydropeaking will not occur on more than 32 days on average during the sturgeon spawning season. Floodplain inundation will not be reduced below 655,000 ac-day on average during late summer and fall or below 131 days on average during winter and spring. During each low flow event (flow reduction to 4,500 cfs and exposure at > 5,000 cfs following recolonization) and due to reduced floodplain inundation, a maximum of the following mussel species may be taken: 34,000 fat threeridge total, 90 purple bankclimbers total, and 106 Chipola slabshell total.

The biological opinion also outlines three mandatory, reasonable, and prudent measures necessary and appropriate to minimize the impacts of incidental take of Gulf sturgeon and the three mussel species. 1) Adaptive management, where USACE will identify ways to avoid and minimize take and implement alternative management strategies within the scope of the authorities of the WCM as new information is collected. For example, USACE will provide pulses of water in late summer, fall and winter months to inundate the floodplain and monitor the effects of these releases on Gulf sturgeon food production and mussel host fish populations. 2) Water flow and water quality stations, where USACE will develop and implement a monitoring program associated with permanent monitoring stations in the Apalachicola, Chattahoochee, and Flint rivers. Discharge, stage, temperature, dissolved oxygen, and salinity will be monitored related to listed species and critical habitat effects. 3) Species monitoring, where USACE will monitor the level of take associated with the WCM by monitoring the distribution, abundance, survival, growth, and fecundity of the listed mussels and Gulf sturgeon in the action area. RPMs to address the effects of hydropeaking during the Gulf sturgeon spawning season are not included as part of this BO because this activity is nondiscretionary at this time. These effects will be addressed through later consultation with the Southeast Power Administration.

This BO evaluates the WCM, with a consideration that the WCM is reviewed every 5 years pursuant to USACE South Atlantic Division policy; therefore, we issue this BO with the understanding that the WCM may be revised or updated within 5 years (i.e., in 2021), and that this BO will be reviewed, or consultation reinitiated at that time. No further consultation is needed unless the USACE operates its projects covered in the WCM in a way that is different than described in its BA, new information indicates that the WCM may affect listed species or their critical habitat to an extent not considered in the BO, a new species is listed in the basin that may be affected by the action, or if more mussels or sturgeon are taken under the USACE's operations than anticipated. Furthermore, the proactive adaptive management approach adopted under the BO will allow the USACE to continue to improve how it implements the WCM to protect endangered species and their habitats in response to changing flows, and changing climate. This is an opportunity for the USACE to better understand the impacts of its operations, and to contribute to the recovery of these species and conservation of their habitats in the ACF Basin.

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CONSULTATION HISTORY

May 22, 2012	USFWS issues BO on the USACE, Mobile District, Revised Interim Operating Plan for Jim Woodruff Dam and the Associated Releases to the Apalachicola River (RIOP)
July 19, 2013	USFWS issues letter to USACE outlining the USFWS' revised alternative for water control operations
August 29, 2013	USFWS issues Planning Aid Letter (PAL) to USACE for Apalachicola-Chattahoochee-Flint (ACF) Water Control Manual (WCM) Updates
June 19, 2014	USACE notifies USFWS of flow loss at Jim Woodruff Dam that occurred on June 11, 2014 due to a lightning strike. This strike resulted in a temporary flow loss but the daily average remained within accordance to the RIOP.
July 22, 2014	Re-consultation request for the 2012 BO
August 7, 2014	Amendment to RIOP for Chipola slabshell take exceedance
January 30, 2015	USACE's submission of the 2014 annual report
March 12, 2015	USFWS sends USACE letter requesting additional information to assist with the Fish and Wildlife Coordination Act (FWCA) report
April 20, 2015	USACE sends USFWS memo outlining phone discussion on April 17, 2015 regarding the USFWS' March 12
May 20, 2015	USACE requests, through email, temporary deviation from RIOP to begin June 1 release provisions 10 days early
May 20, 2015	USFWS agrees with temporary deviation in email
July 31, 2015	USFWS submission of Draft FWCA Report for the proposed WCM updates for the ACF River Basin
August 19, 2015	USACE responds to USFWS' Draft FWCA Report
January 29, 2016	USACE's submission of the 2015 annual report
May 31, 2016	USACE's submission of a Biological Assessment for Update of the WCM and Water Supply Storage Assessment for the ACF River Basin in Alabama, Florida, and Georgia
June 10, 2016	Letter from USFWS to USACE acknowledging receipt of May 31, 2016 request for formal consultation, but requesting additional information is needed to initiate formal consultation
June 23, 2016	Email from USACE submitting part of an amended BA
June 28, 2016	Email from USACE submitting part of an amended BA

June 30, 2016	Email from USACE submitting an amended BA
July 29, 2016	Letter from USFWS to USACE initiating formal consultation
August 12, 2016	Email from USACE submitting an amendment to the BA
August 19, 2016	Discussion with USACE and SEPA describing hydropeaking and hydropower production contract with Duke Energy and consultation
August 24, 2016	Email from USACE submitting an amendment to the BA
August 30, 2016	Email from USACE submitting an amendment to the BA

BIOLOGICAL OPINION

A Biological Opinion (BO) is the document required under section 7 the Endangered Species Act (Act) that states the opinion of the USFWS as to whether a federal action is likely to jeopardize the continued existence of listed species or result in the destruction or adverse modification of designated critical habitat. This BO addresses the effects resulting from the U.S. Army Corps of Engineers' (USACE) proposed Update of the Water Control Manual (WCM or Master Manual) for the Apalachicola-Chattahoochee-Flint River Basin (ACF) in Alabama, Florida, and Georgia, including a Water Supply Storage Assessment (WSSA) for a reallocation of storage in Lake Sidney Lanier (Lake Lanier). We analyze the effects of this proposed action on the Gulf sturgeon, fat threeridge, purple bankclimber, Chipola slabshell, and their designated critical habitats.

"*Jeopardize the continued existence of*" means to engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of the species (50 CFR §402.02).

"Destruction or adverse modification" means a direct or indirect alteration that appreciably diminishes the value of critical habitat for the conservation of a listed species. Such alterations may include, but are not limited to, those that alter the physical or biological features essential to the conservation of a species or that preclude or significantly delay development of such features (50 CFR §402.02).

This opinion supersedes the BO and associated Incidental Take Statement dated May 22, 2012, which addressed the effects of the similar Revised Interim Operating Plan (RIOP), and all other previous BOs with USACE for the ACF Basin. The USACE has described its proposed changes to the WCM and the effects of these changes in the revised amended Biological Assessment (BA) dated June 30, 2016. Where appropriate, we have incorporated its descriptions and analysis into this BO. The USFWS acknowledges the Florida v. Georgia case pending before the U.S. Supreme Court, in which Florida is seeking an equitable apportionment of the waters of the shared ACF Basin. The outcome of this case will likely influence future water use in the basin.

This BO is based on best scientific and commercial data available, including information provided in the USACE BA, analysis of modeling output, published peer-reviewed research, and additional information as cited herein. A complete administrative record of this consultation is on file in the USFWS Panama City, Florida, Ecological Services Field Office.

1 DESCRIPTION OF PROPOSED ACTION

Construction of the dams and associated impoundments in the ACF River Basin pre-date the Act. Therefore, USFWS and USACE staffs agree that the effects of those actions to federally listed species and designated critical habitats are part of the environmental baseline. The action considered in this BO is the *operation* of those facilities, individually and in concert, under the proposed WCM.

The action evaluated in this consultation is the adoption and implementation by USACE of a new WCM for the ACF (referred to in the BA as the Preferred Alternative [WCM]). This Action is limited to the updated ACF WCM and the associated Water Supply Storage Assessment at Lake Lanier. The WCM includes guidelines for continued operation of projects in the ACF Basin in a balanced manner to *achieve all authorized project purposes, while continuously monitoring the total system water availability to ensure that project purposes can at least be minimally satisfied during critical drought periods*. The intent would be to maintain a balanced use of its reservoirs in times of normal, high-flow, and drought conditions. At all times, USACE would seek to conserve the water resources entrusted to its regulation authority. USACE operates and manages those projects as a system to meet their authorized purposes, which include flood risk management, hydropower, navigation, fish and wildlife conservation, recreation, water quality, and water supply (USACE 2015 p. 1-1). The WCM is consistent with the USACE's authority as set forth in the 2012 legal opinion and described in the Draft Environmental Impact Statement (DEIS) (USACE 2015).

For reasons that will be explained and discussed in later sections of this BO, the USFWS has described the action area to include that portion of the ACF on which USACE water control projects were constructed, and their associated tailwater reaches (Figure 1.1). Table 1.1 shows the five projects which are included in this BO. Reaches of rivers upstream from the upper limits of the impoundments created by the uppermost dams (e.g., Lake Lanier, Chattahoochee River) are not included because operation and maintenance activities do not affect those upstream river reaches. No new construction is proposed as part of this action. The USACE considered other alternatives to the proposed action pursuant to the National Environmental Policy Act (NEPA) in the DEIS (USACE 2015). We do not explicitly analyze any of those alternatives or variants here, but focus solely on the operational scheme described in the new WCM, as adopted under the preferred alternative action (PAA) as modified in the amended BA (USACE 2016).

The USACE operates five dams in the ACF Basin: Buford, West Point, Walter F. George, George W. Andrews, and Jim Woodruff (Figure 1.1, Table 1.1). All are located wholly on the Chattahoochee River arm of the basin except Woodruff, the downstream-most dam, which is located at the confluence of the Chattahoochee and Flint rivers on the Apalachicola River. Andrews is a lock and dam without any appreciable water storage, and Lake Seminole formed by Jim Woodruff Dam 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 1.5 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.

The USACE operates the ACF reservoirs as a system, and releases from Jim Woodruff Dam reflect the downstream end-result of system-wide operations. The proposed action under the WCM includes:

- Fish and Wildlife Conservation including:
  - Federally-Listed Species - water releases for federally-listed, threatened, and endangered species below Jim Woodruff Dam on the basis of seasonal requirements (spawning, non-spawning, and winter),
  - Reservoir Fish Spawning,
  - Tailrace Dissolved Oxygen Levels,
  - Fish Passage,
  - Management of Project Lands (Eufaula National Wildlife Refuge),
- Drought Operations,
- Extreme Drought Operations,
- Navigation,
- Flood Risk Management,
- Hydroelectric Power Generation,
- Recreation,
- Water Quality,
- Water Supply.

1.1 Action Area

USFWS 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). The action area includes all aquatic habitats that are downstream of the USACE's upstream-most ACF project, Lake Lanier/Buford Dam, ending with and including Apalachicola Bay (Figure 1.1). Therefore, while the action area includes all aquatic habitats that are downstream of the USACE's upstream-most ACF project, Lake Lanier/Buford Dam, ending with and including Apalachicola Bay, the effects of the action to listed species and designated critical habitats are limited primarily to the aquatic habitats downstream of Woodruff Dam including Apalachicola Bay. Therefore, our use of the term “action area” hereafter 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.

Table 1.1 Reservoirs on the mainstem ACF Basin rivers including the five federal projects assessed by this consultation (USACE 2015).

Basin/river/project name	Owner/state/ year initially completed	Drainage area (sq mi)	Reservoir size (ac)	Total storage (ac-ft)[a]	Conservation storage (summer elev) (ac-ft)	Power capacity (kW)	Normal (summer) lake elev (ft)	Authorized purposes for USACE-owned projects[b]
Chattahoochee River		*8,708*						
Buford Dam/Lake Sidney Lanier	USACE/GA/1957	1,034	38,542	2,554,000	1,087,600	127,000	1,071	FRM, HP, NAV, FW, REC, WQ, WS[c]
Morgan Falls Dam/Bull Sluice Lake	GPC/GA/1903	1,360	580	2,450	0	16,800	866	
West Point Dam and Lake	USACE/GA/1975	3,440	25,864	774,798	306,131	87,000	635	FRM, HP, NAV, FW, REC, WQ
Langdale Dam and Lake	GPC/GA/1860	3,640	152	NA[d]	0	1,040	547.7	
Riverview Dam and Lake	GPC/GA/1902	3,661	75	NA[d]	0	480	530.5	
Bartletts Ferry Dam/Lake Harding	GPC/GA/1926	4,240	5,850	181,000	0	173,000	521	
Goat Rock Dam and Lake	GPC/GA/1912	4,510	1,050	11,000	0	38,600	404	
Oliver Dam/Lake Oliver	GPC/GA/1959	4,630	2,150	32,000	0	60,000	337	
North Highlands Dam and Lake	GPC/GA/1900	4,630	131	1,500	0	29,600	269	
Walter F. George Lock, Dam, and Lake	USACE/GA/1963	7,460	45,181	934,400	244,400	168,000	190	HP, NAV, FW, REC, WQ
George W. Andrews Lock, Dam, and Lake	USACE/GA/1963	8,210	1,540	18,180	0	None	102	NAV, FW, REC, WQ
Flint River		*8,456*						
Warwick Dam/Lake Blackshear	Crisp Co./ GA/1930	3,770	8,700	144,000	0	15,200	237	
Flint River Dam/Lake Worth	GPC/GA/1920	5,290	1,400	NA[d]	0	5,400	182.3	
Apalachicola River		*2,409*	*(Total ACF Basin – 19,573 sq mi)*					
Jim Woodruff Lock and Dam/ Lake Seminole	USACE/FL/1954	17,164	37,500	367,318	0	43,350	77	HP, NAV, FW, REC, WQ

Notes:
a. Measured at top of storage for flood risk management.
b. As used in this table, the term *authorized purposes* includes purposes expressly identified in the project authorizing documents; incidental benefits recognized in projection authorizations; and objectives that result from other authorities, such as general authorities contained in congressional legislation, for which USACE operates each listed project as of 2009. FRM = flood risk management; HP = hydroelectric power generation; NAV = navigation; FW = fish and wildlife conservation; REC = recreation; WQ = water quality; WS = municipal & industrial water supply.
c. USACE operates the Buford Dam/Lake Sidney Lanier project in a manner that accommodates water supply withdrawals from Lake Lanier and from the Chattahoochee River downstream of Buford Dam.
d. NA = not available.

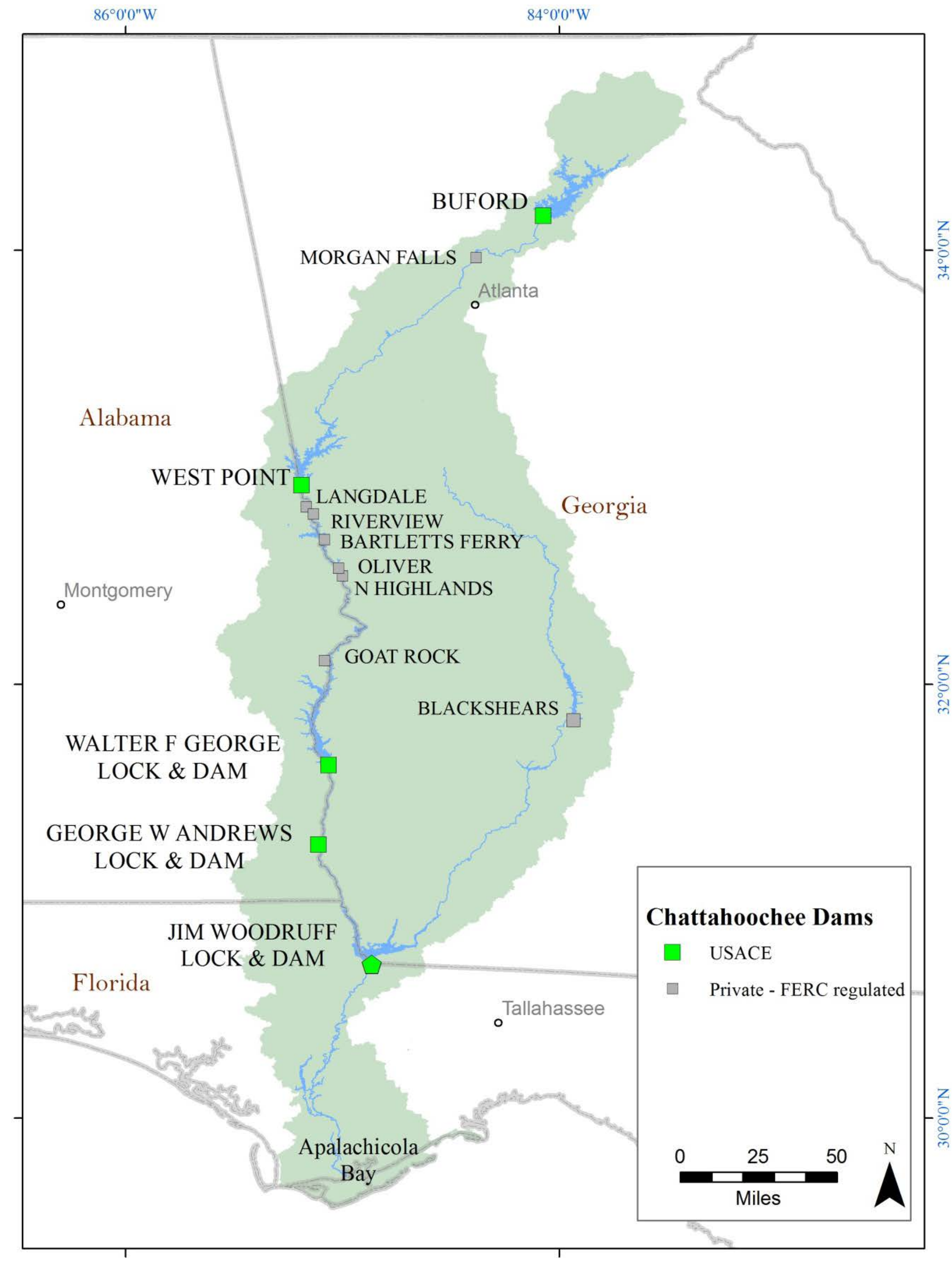


Figure 1.1 Apalachicola - Chattahoochee - Flint River Basin showing the five USACE projects included in this consultation and other federally regulated projects in the basin.

1.2 Guide Curves and Action Zones

As described in the BA, the USACE would not modify any guide curves of the ACF projects but would modify the action zones for Lake Lanier, West Point Lake, and Walter F. George Lake under the WCM. The zones are used to manage the lakes at the highest level possible while balancing the needs of all the authorized purposes. Zone 1, the highest in each lake, defines a reservoir condition where all authorized project purposes can be met. As lake levels decline, Zones 2 through 4 define increasingly critical system status where purposes can no longer fully be met. The action zones also provide guidance on meeting minimum hydroelectric power needs at each project.

The action zones were derived considering numerous factors, including the ability of the reservoirs to refill (considering hydrology, watershed size, and physical constraints of each reservoir), recreation effects and hazard levels, and the proportionality of zone drawdown between projects. Other factors or activities might cause the lakes to operate differently than the action zones are described, including exceptional flood risk management measures, fish spawn operations, approved deviations, maintenance and repair of turbines, emergency situations (such as a drowning or chemical spill), drawdowns for shoreline maintenance, releases made to free grounded barges, and other special circumstances.

The storage projects (Lanier, West Point, and Walter F. George) are operated to maintain their respective lake level in the same action zones concurrently. Because of the hydrologic and physical characteristics of the river system and factors mentioned above, there might be periods when one lake is in a higher or lower zone than another. When that occurs, the USACE conducts operations to bring the lakes into balance with each other as soon as conditions allow. By doing so, effects within the river basin are shared equitably among the projects. The action zones for the WCM are shown in Figures 1.2 through 1.4.

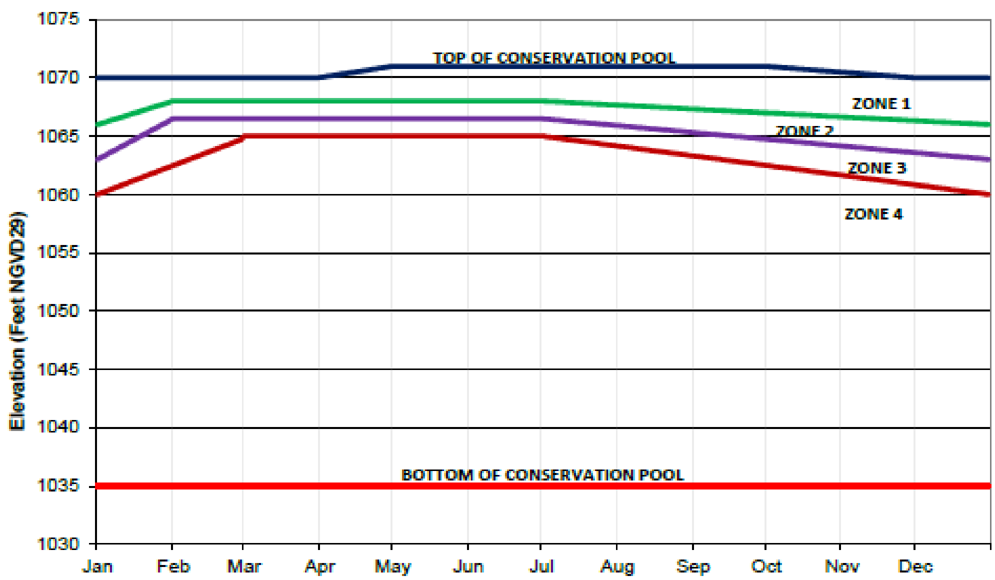


Figure 1.2 Lake Lanier Water Control Action Zones

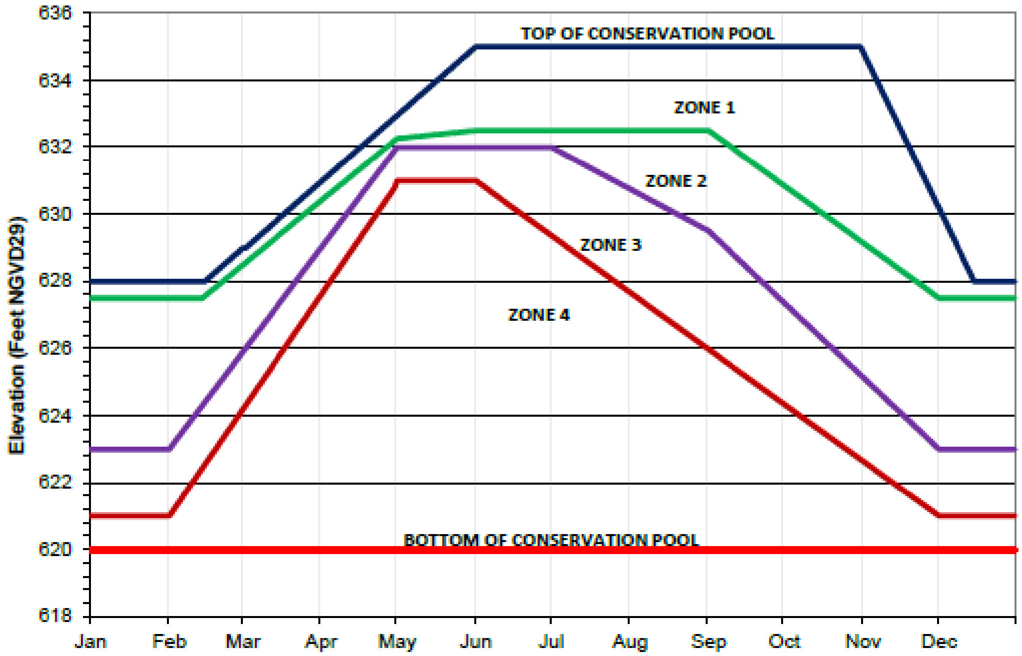


Figure 1.3 West Point Lake Water Control Action Zones

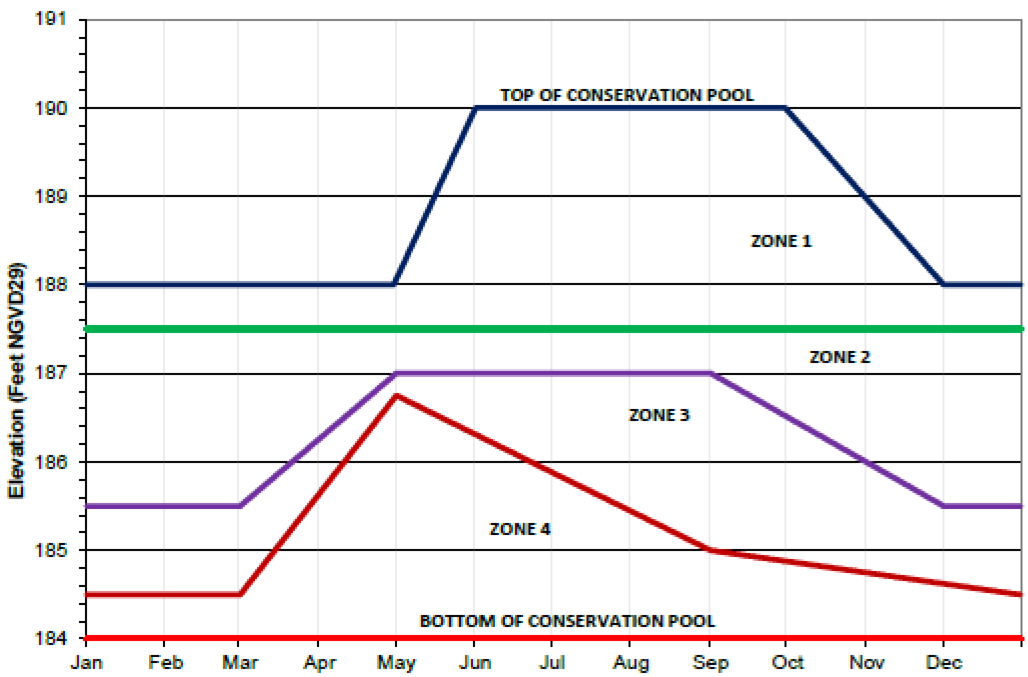


Figure 1.4 Walter F. George Lake Water Control Action Zones

1.3 Drought Operations

The drought plan included in the WCM specifies a minimum release from Jim Woodruff Dam and a temporary suspension of the normal minimum release and maximum fall rate provisions of the listed species operation, until combined reservoir storage of Lanier, West Point, and Walter F. George (hereafter referred to as composite conservation storage) in the basin are replenished to a level that could support these releases. Under the drought plan, minimum discharge is determined in relation to the composite conservation storage. The drought plan is triggered when the composite conservation storage falls below the bottom of Zone 2 into Zone 3 (Figure 1.5). At that time, all the provisions for composite conservation storage Zones 1 and 2 (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 an option for a temporary waiver from the water control plan to allow temporary storage at the Walter F. George and West Point projects to provide additional conservation storage for future needs, if conditions in the basin dictate the need for such action.

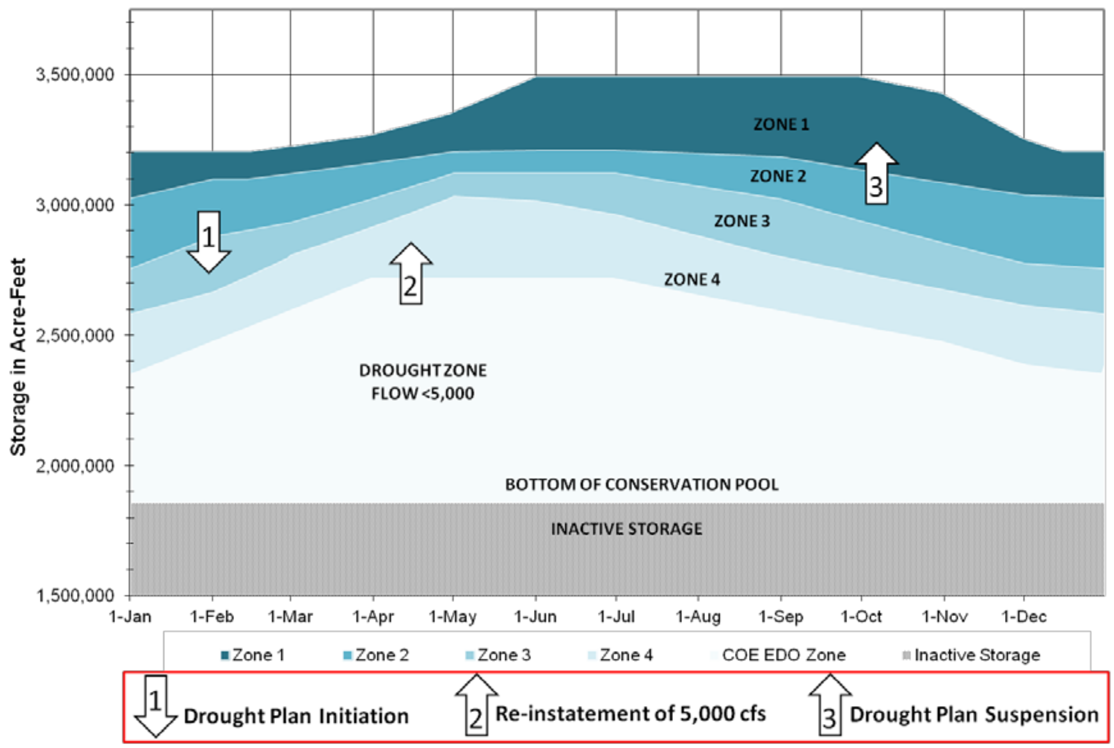


Figure 1.5 Composite Conservation Storage Zones and Drought Plan Triggers

The drought plan of the WCM prescribes two minimum releases on the basis of composite conservation storage in Zones 3 and 4 and an additional zone referred as the Drought Zone. The Drought Zone delineates a volume of water roughly equivalent to the inactive storage in Lake Sidney Lanier, West Point Lake, and Walter F. George Lake, plus Zone 4 storage in Lake Sidney Lanier. The Drought Zone line was adjusted to include a smaller volume of water at the beginning and end of the calendar year. When the composite conservation storage is within Zones 3 and 4, but above the Drought Zone, the minimum release from Jim Woodruff Dam is 5,000 cubic feet per second (cfs) and all basin inflow above 5,000 cfs may be stored. Once the composite conservation storage falls below the Drought Zone, the minimum release from Jim Woodruff Dam is 4,500 cfs and all basin inflow above 4,500 cfs may be stored. When transitioning from a minimum release of 5,000 to 4,500 cfs, fall rates are limited to 0.25 ft/day drop. The 4,500 cfs minimum release is then 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 reinstated. The drought plan provisions remain in place until conditions improve such that the composite conservation storage reaches Zone 1. At that time, the temporary drought plan provisions are suspended and all the other provisions of the basin water control plan reinstated. During the drought contingency operations, a monthly monitoring plan tracks composite conservation storage in order to determine water management operations (the first day of each month will represent a decision point) to determine which operational triggers are applied. In the event the composite conservation storage has not recovered to Zone 1 by 1 March, drought operations are extended to the end of March, unless all the federal reservoirs are full.

1.4 Extreme Drought Operations

When the remaining composite conservation storage is about 10 percent of the total capacity, additional emergency actions might be necessary. When conditions have worsened to that extent, use of the inactive storage must be considered. For example, such an occurrence could be contemplated in the second or third year of a drought. Inactive storage zones have been designated for the three reservoirs with significant storage (Figure 1.6). The "endangered species" priority for Zone 1a simply means that reservoirs would be managed to provide for minimum flows at Woodruff (USACE 2015). Table 1.2 shows the inactive storage capacity within each inactive storage zone for each project. The use of inactive storage during extreme drought conditions is based on the following actions:

1. Inactive storage availability is identified to meet specific critical water use needs within existing project authorizations.
2. Emergency uses are identified in accordance with emergency authorizations and through stakeholder coordination. Typical critical water use needs within the basin are associated with public health and safety.
3. Weekly projections of the inactive storage water availability to meet the critical water uses from Buford Dam downstream to the Apalachicola River are used when making water control decisions regarding withdrawals and water releases from the USACE reservoirs.
4. The inactive storage action zones are instituted as triggers to meet the identified priority water uses (releases will be restricted as storage decreases). Figure 1.6 lists the typical critical water uses for each inactive storage zone.
5. Dam safety considerations always remain the highest priority. The structural integrity of the dams due to static head limitations (Jim Woodruff, 38.5 feet; George W. Andrews, 26 feet; Walter F. George, 88 feet) is maintained.

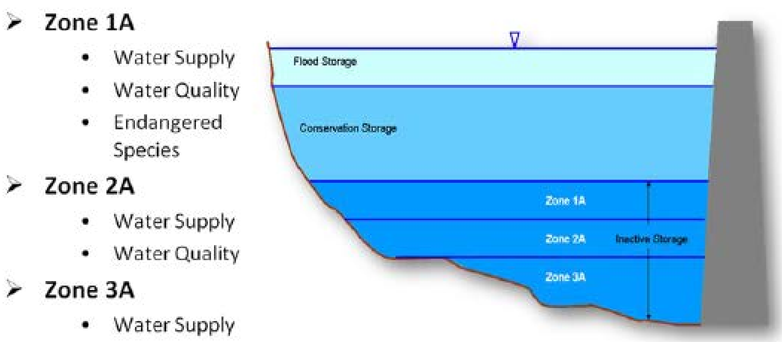


Figure 1.6 Inactive Storage Zones and Typical Water Use Needs

Table 1.2 Reservoir Inactive Storage Zone Capacities (ac-ft)

Project	Zone 1A	Zone 2A	Zone 3A	Unusable Inactive
Buford Dam	532,078	234,699	100,823	0
West Point Dam	53,620	138,331	33,344	73,101
Walter F. George Dam	314,799	178,501	0	196,700
Total	901,589	554,345	134,869	266,062

1.5 Navigation

When supported by ACF Basin hydrologic conditions, the WCM provides a reliable navigation season. The water management objective for navigation is to ensure a predictable minimum navigable channel in the Apalachicola River for a continuous period that is sufficient for navigation use.

Assuming basin hydrologic conditions allow, a typical navigation season begins in January of each year and continues 4 to 5 consecutive months (through April or May). Figure 1.7 graphically represents the navigation season and its relationship to composite conservation storage. During the navigation season, the flows at the USGS gage at Blountstown, Florida, should be adequate to provide a minimum channel depth of 7 feet. The WCM used the most recent channel survey and discharge-stage ratings to determine the flow required to sustain a minimum navigation depth during the navigation season. Flows of 16,200 cfs provide a channel depth of 7 feet. Flows of 20,600 cfs provide a channel depth of 9 feet. USACE's capacity to support a navigation season depends on actual and projected system-wide conditions in the ACF Basin before and during January, February, March, April, and May. Those conditions include the following:

- A navigation season can be supported only when ACF Basin composite conservation storage is in Zone 1 or Zone 2.
- A navigation season will not be supported when the ACF Basin composite conservation storage is in Zone 3 and below. Navigation support will resume when basin composite conservation storage level recovers to Zone 1.

- A navigation season will not be supported when drought operations are in effect. Navigation will not be supported until the ACF Basin composite conservation storage recovers to Zone 1.
- The determination to extend the navigation season beyond April depends on ACF Basin inflows, recent climatic and hydrologic conditions, meteorological forecasts, and basin-wide model forecasts. USACE analyzes those factors to determine if the navigation season will continue through part or all of May.
- Down-ramping of flow releases adhere to the Jim Woodruff Dam fall rate schedule (see Table 1.5) for federally listed threatened and endangered species during the navigation season.
- Releases that augment the flows to provide a minimum 7-foot navigation depth also depend on navigation channel conditions that ensure safe navigation.

When it becomes apparent that, because of diminishing inflows, downstream flows and depths must be reduced, the USACE will issue notices in order to give barge owners and other waterway user's sufficient time to make arrangements to lighten loads or remove their vessels before action is taken at Jim Woodruff Lock and Dam to reduce releases.

Although special releases are not standard practice, they may occur for a short duration to assist navigation during the navigation season. For instance, releases can be requested to achieve up to a 9-foot channel. USACE evaluates such requests on a case-by-case basis, subject to applicable laws and regulations and the conditions above.

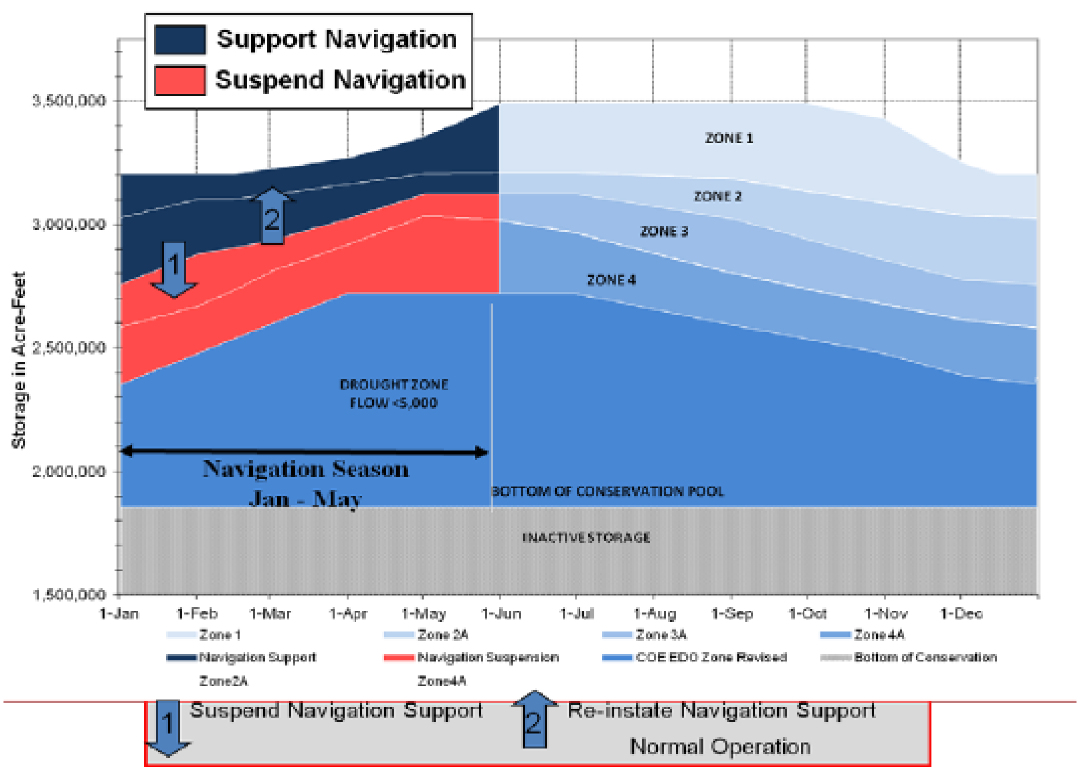


Figure 1.7 Composite Conservation Storage for Navigation

1.6 Fish Spawn/Passage Operations

According to the DEIS (USACE 2015), the USACE's South Atlantic Division Regulation DR 1130-2-16 (31 May 2010) and Mobile District Draft Standard Operating Procedure (SOP) 1130-2-9 (February 2005) were developed to address lake regulation and coordination for fish management purposes. The SOP addresses procedures necessary to gather and disseminate water temperature data and manage lake levels during the annual fish spawning period between March and June, primarily targeted at largemouth bass. The major goal of the operation is to not lower the lake level more than six inches in elevation during the reproduction period to prevent stranding or exposing fish eggs. The lake elevation that exists at the time spawning begins becomes the datum for the downward fluctuation. The beginning and ending of the spawning season is determined by the Mobile District biologists in cooperation with the fish and game personnel of the states concerned. The expected timing for fish spawning at each of the USACE lakes and the Apalachicola River ranges from mid-March through May.

In most years since the spring of 2005, USACE has operated the lock at Jim Woodruff Lock and Dam between March and May to facilitate downstream-to-upstream passage of Alabama shad (*Alosa alabamae*) and other anadromous fishes (those that return from the sea to the rivers where they were born to breed) in cooperation with pertinent state and federal agencies. In general, two fish locking cycles are performed each day between 0800–1600 hours, one in the morning and one in the afternoon. Studies are ongoing to determine the most appropriate technique and timing for the locks, but the number of lock cycles per day will not change.

1.7 Flood Risk Management

As described in the BA and DEIS, the flood risk management capabilities and capacities of reservoirs remain unchanged from present operations in the revised WCM. The flood risk management purposes at certain reservoirs require drawing down reservoirs in the fall through winter months to store possible flood waters. Because actions taken at the upstream portion of the basin affect conditions downstream, the ACF projects are operated in a coordinated manner to the maximum extent possible rather than as a series of individual, independent projects. In times of high-flow conditions, flood risk management regulation supersedes all other project functions.

As described in the DEIS, the objective of flood risk management operations on the ACF System is to store excess flows thereby reducing downstream river levels below flood stage and producing no higher stages than would otherwise occur naturally. Whenever flood conditions occur, operation to reduce flood damage takes precedence over all other project functions. Of the five USACE reservoirs, only Buford and West Point dams have storage allocated for flood risk management operations. During the principal flood season, December through April, the regulation plan at Walter F. George Lake provides for lower lake levels to ensure lower peak stages throughout the reservoir during major floods. Annual drawdown of reservoir storage is 1 foot at Lake Sidney Lanier, 7 feet at West Point Lake, and 2 feet at Walter F. George Lake in the fall through winter to provide additional capacity to protect life and property in the basin. The George W. Andrews and Jim Woodruff Dams operate to pass inflows, while the Walter F.

George Dam operates according to specified schedules for flood risk management. The timing of flood peaks in the ACF System is of considerable importance in determining the effectiveness of reservoir flood risk management operations and the degree to which such operations can be coordinated. During a flood event, excess water above normal pool elevation, or guide curve, should be evacuated through the use of the turbines and spillways in a manner consistent with other project needs as soon as downstream waters have receded sufficiently so that releases from the reservoirs do not cause flows to exceed bankfull capacity or maximum, non-damaging, channel capacities. Stored floodwater can be released up to the maximum, non-damaging, downstream channel capacities, consistent with regulation procedures, provided the releases do not exceed peak inflow of that event into the reservoir(s). Under certain instances, induced surcharge operations might be required to ensure project integrity, which could result in flows that exceed bankfull capacity.

1.8 Hydropower Peaking at Jim Woodruff Dam

The hydropower facility at Jim Woodruff Dam has a power capacity of 43,350 kilowatts. The maximum capacity for the turbines at the facility is approximately 16,000 to 18,300 cfs, above which gates are used to discharge water downstream of the dam. For inflows between 6,700 and 16,000 cfs the USACE releases water during a portion of the day when there is peak demand for electricity.

In the BA, the USACE states that the WCM includes the current hydroelectric power generation operations at West Point Dam, Walter F. George Dam, and Jim Woodruff Dam which call for a more flexible generation schedule in all action zones under non-drought conditions and a more constrained generation schedule under drier conditions. The Jim Woodruff Dam includes a limited peaking operation compared to the other two facilities, and the generation schedule for Jim Woodruff Dam is described below in an amendment to the BA.

The Jim Woodruff project is operated to provide the maximum possible load (on the line), depending on unit availability, for one hour on a daily basis. This operation meets the minimum capacity under the Southeastern Power Administration (SEPA) contract obligations. This applies only at times the power plant is operating at less than the maximum unit capacity. This operation occurs daily during the 1600 to 1700 hours (OT). Immediately prior to 1600 (OT) the unit(s) will be loaded to deliver maximum capacity and continue until 1700. The load will then be reduced to achieve the target flow as directed by Water Management.

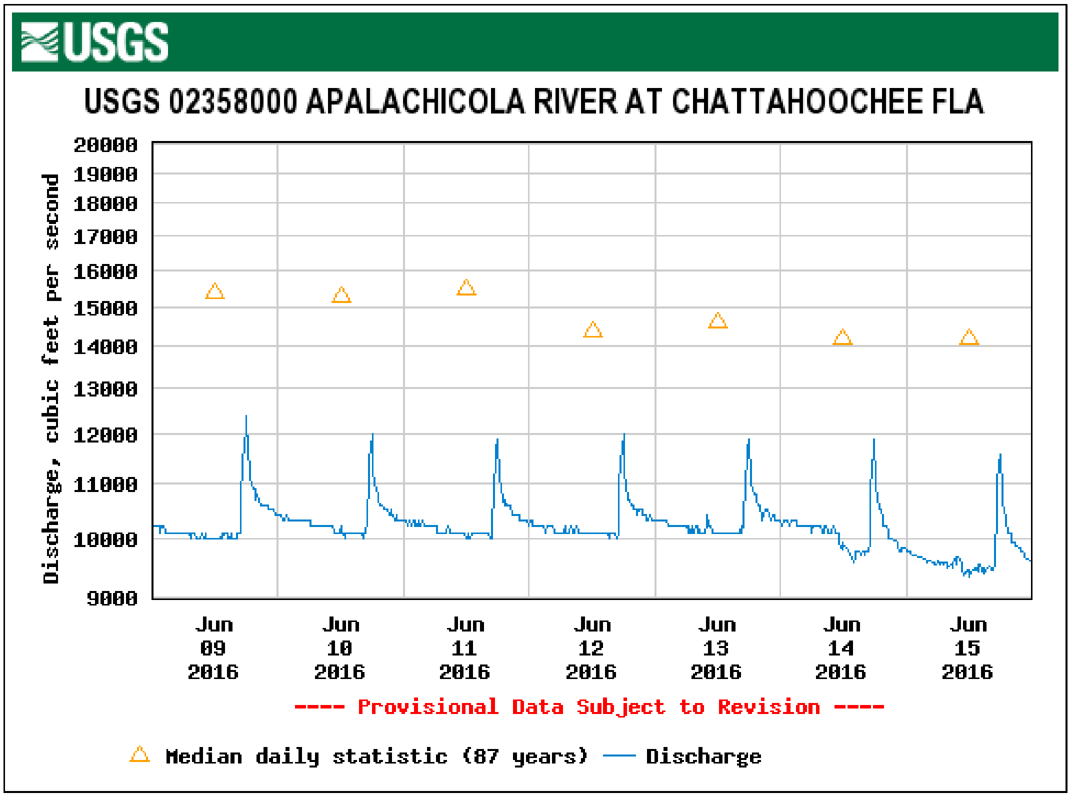
Changes in discharge to provide the one hour maximum capacity depend on the initial discharge prior to the peak operation and the operating head. The lower the initial discharge value the greater the change in discharge. For example under normal operating head if the initial United States Geological Survey (USGS) Apalachicola River at Chattahoochee, Florida gage discharge is approximately 7,000 cubic feet per second (cfs), then the discharge will increase to approximately 10,000 cfs from peak operation and if there is a higher initial discharge of approximately 11,000 cfs, then the discharge will increase to approximately 12,800 cfs from peak operation.

The river stage recorded at the Chattahoochee gage typically rises continually during the one hour peak generation. River stages at the Chattahoochee gage begin to fall once the peaking operation ends. It may take up 6-10 hours for the river to return to the stage prior to the start of the one hour peaking generation. However, the majority of the reduction in river stage takes place within the first two hours of ending peak generation.

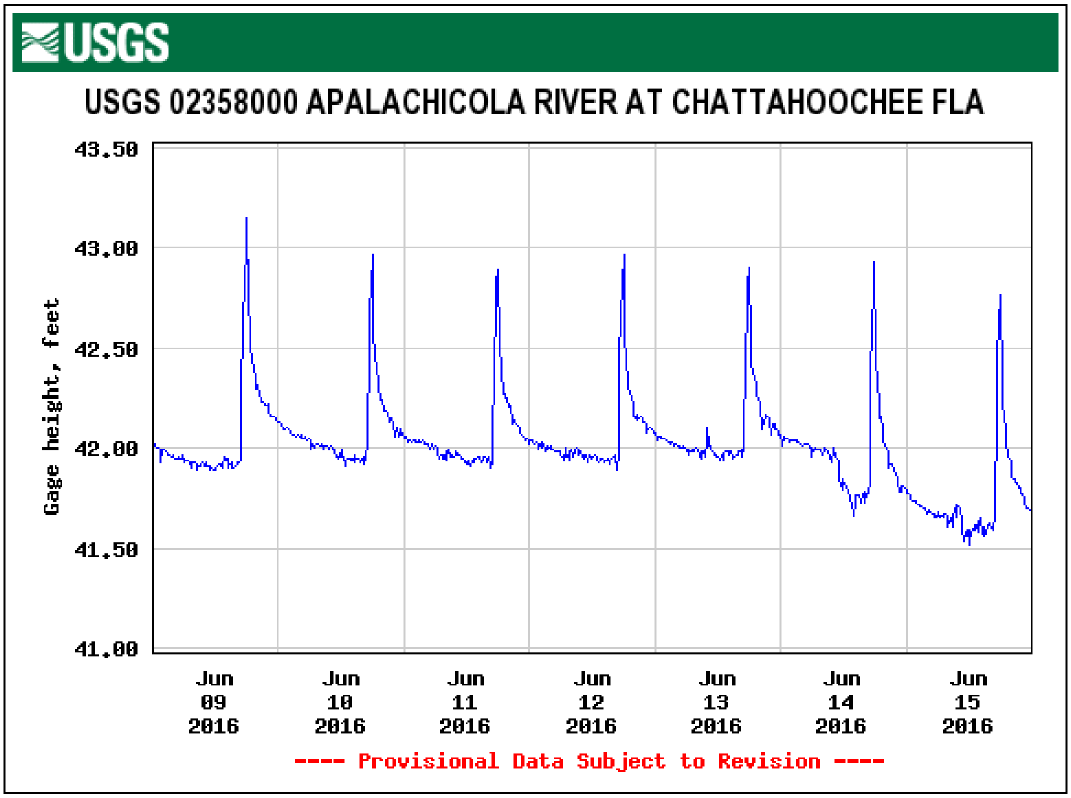
Peaking operations at the Jim Woodruff Plant are suspended as average daily releases approach 6,700 cfs, to maintain instantaneous releases greater than or equal to the 5,000 cfs minimum flow requirement. There is a range of discharges that is beyond the capacity of any one unit. One unit max is around 5,900 cfs. Two units can deliver discharges beyond 5,900 cfs. For discharges ranging from 5,900 to 6,800 cfs, an operation that combines one unit and the spillway trash gate adjacent to the powerhouse at 1/2 step is utilized. The 1/2 step provides approximately 900 to 1,000 cfs.

Whenever the reservoir inflow exceeds the discharge capacity of the turbines (about 16,000 to 18,300 cfs for three turbines) the excess will be released through the gated spillway up to its capacity in order to prevent the pool from rising above elevation 77.8 feet NGVD29 at the dam.

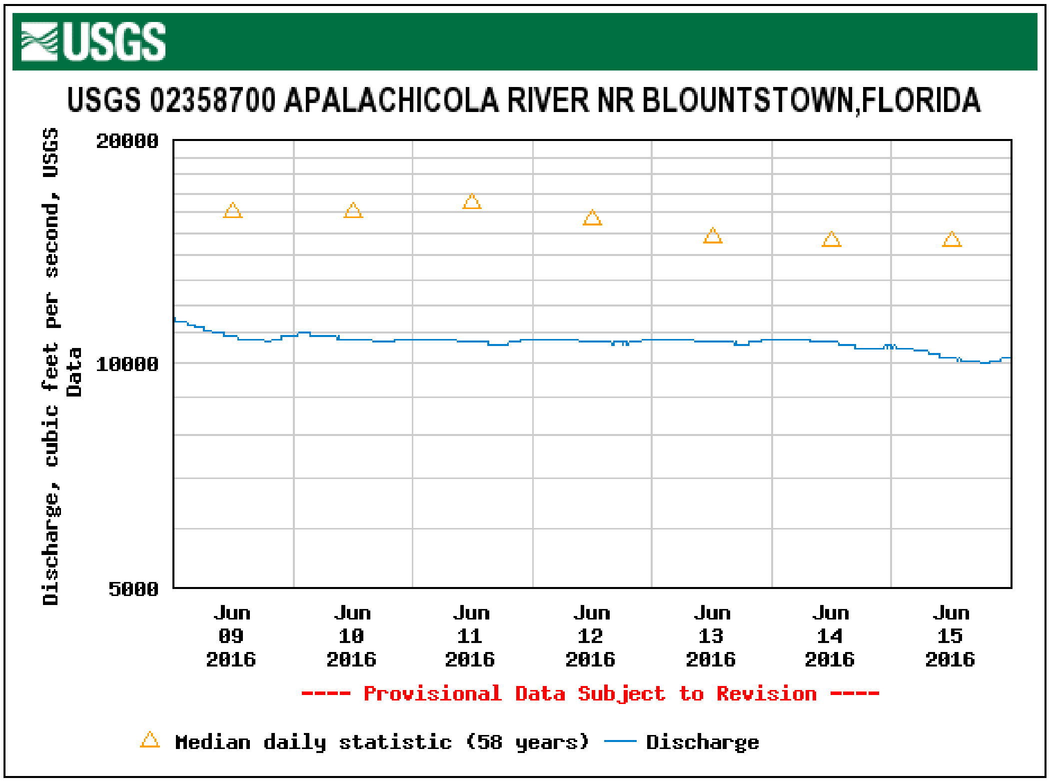
Figure 1.8A (discharge) and Figure 1.8B (stage) chart the Chattahoochee gage flow and stage conditions for June 9-15, 2016. During the peaking operation, the maximum discharge increases by about 2,000 cfs resulting in an approximate 2 feet change in stage. The change in stage is attenuated to about 0.15 feet (Figure 4) at the Blountstown gage located 28.3 miles downstream of the Jim Woodruff Dam.


USGS
USGS 02358000 APALACHICOLA RIVER AT CHATTAHOOCHEE FLA
Discharge, cubic feet per second
20000
19000
18000
17000
16000
15000
14000
13000
12000
11000
10000
9000
Jun 09 2016
Jun 10 2016
Jun 11 2016
Jun 12 2016
Jun 13 2016
Jun 14 2016
Jun 15 2016
---- Provisional Data Subject to Revision ----
Median daily statistic (87 years)
Discharge

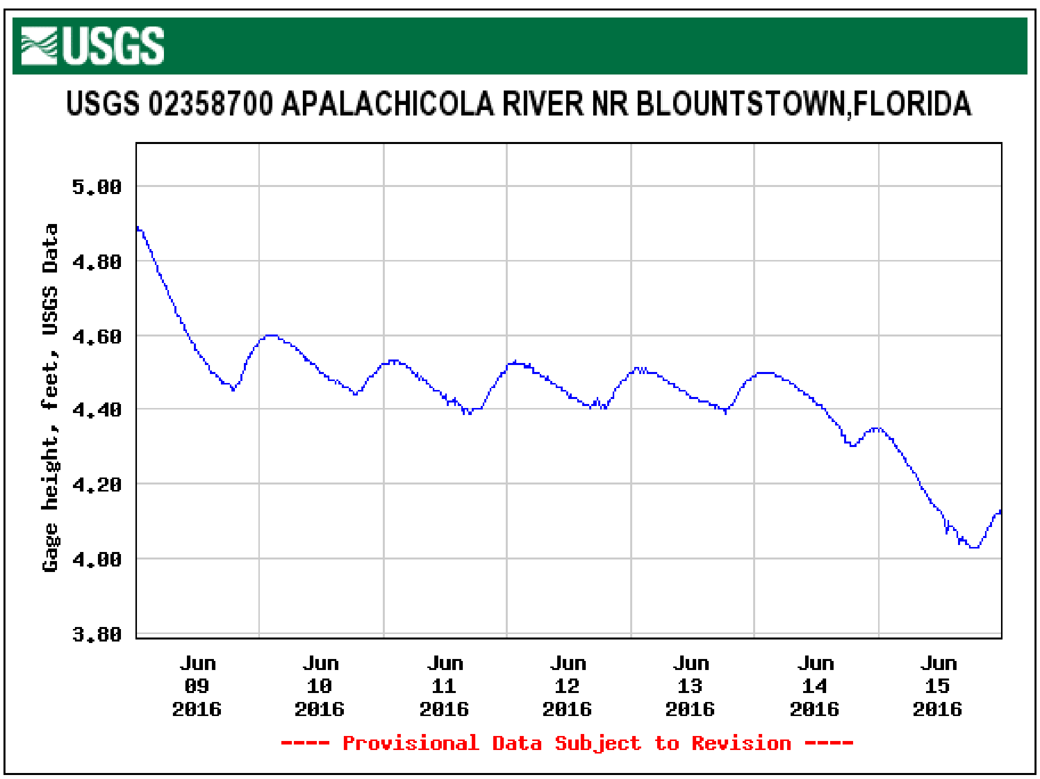
A


USGS
USGS 02358000 APALACHICOLA RIVER AT CHATTAHOOCHEE FLA
Gage height, feet
43.50
43.00
42.50
42.00
41.50
41.00
Jun 09 2016
Jun 10 2016
Jun 11 2016
Jun 12 2016
Jun 13 2016
Jun 14 2016
Jun 15 2016
---- Provisional Data Subject to Revision ----

B


USGS
USGS 02358700 APALACHICOLA RIVER NR BLOUNTSTOWN,FLORIDA
Discharge, cubic feet per second, USGS Data
20000
10000
5000
Jun 09 2016
Jun 10 2016
Jun 11 2016
Jun 12 2016
Jun 13 2016
Jun 14 2016
Jun 15 2016
---- Provisional Data Subject to Revision ----
Median daily statistic (58 years)
Discharge

C


USGS
USGS 02358700 APALACHICOLA RIVER NR BLOUNTSTOWN,FLORIDA
Gage height, feet, USGS Data
5.00
4.80
4.60
4.40
4.20
4.00
3.80
Jun 09 2016
Jun 10 2016
Jun 11 2016
Jun 12 2016
Jun 13 2016
Jun 14 2016
Jun 15 2016
---- Provisional Data Subject to Revision ----

D

Figure 1.8 An example of hydropeaking at the USGS stream gage for the Apalachicola River at Chattahoochee for discharge (A) and gage height (B) and downstream flow at Blountstown for discharge (C) and gage height (D)

1.9 Recreation

Under the PAA, operations for recreation would remain the same as current operations. Recreation benefits would be maximized at the lakes to the extent possible consistent with meeting other project purposes by maintaining full or nearly full pools during the primary recreation season which are the warm summer months. In response to meeting other authorized project purposes, lake levels could decline during the primary recreation period, particularly during drier than normal years. Recreation impact levels have been identified for various lake elevations at each of the reservoir projects (Table 6). Recreational impact levels are not applicable to the George W. Andrews project due to the lack of conservation storage and the run-of-river operation at the project.

When pool levels must be lowered, the rates at which the draw-downs occur are as steady as possible. The action zones at Lake Sidney Lanier and West Point Lake are drawn down to correlate the line between Zone 2 and Zone 3 near the IIL at the beginning of the recreation season (May through early September). This is an attempt to maximize the time these projects are above the IIL during the recreation season.

Table 1.3 Recreation Impact Levels for Federal Projects in the ACF Basin

Project	IIL[a]	RIL[b]	WAL[c]
Lake Lanier	1,066 ft	1,063 ft	1,060 ft
West Point Lake	632.5 ft	629 ft	627 ft
Walter F. George	187 ft	185 ft	184 ft

Notes:
[a.] Initial Impact Level
[b.] Recreation Impact Level
[c.] Water Access Limited Level

1.10 Water Quality

Under the WCM, Buford, West Point, and Jim Woodruff dams would provide continuous minimum flow releases that would benefit the water quality immediately downstream of the dams. There would be no minimum flow provisions downstream of Walter F. George Dam. However, when low dissolved oxygen values are observed below the dam, spillway gates would be opened until the dissolved oxygen readings return to an acceptable level. Occasional special releases would also be made at Buford Dam to ensure adequate dissolved oxygen and water temperature at the Buford Fish Hatchery downstream of the dam.

At Buford Dam, the small turbine generator would run continuously to provide a minimum flow from the dam, which would range from approximately 500 to 700 cfs, depending on head conditions. This minimum flow from Buford Dam would help meet the seasonal minimum flow requirements of 650 cfs and 750 cfs at Atlanta, Georgia, in the Chattahoochee River just upstream of the confluence with Peachtree Creek. At West Point Dam, the minimum flow requirement is 670 cfs and a similar small generating unit would provide a continuous release of approximately 675 cfs. Walter F. George Dam has two siphons on each spillway gate. The siphon discharge could range from about 15 cfs up to 200 cfs when all 12 are in use. Typically, the siphon tubes would be opened continuously from May through the end of September and all would be used at full capacity. The siphons would provide a gravity-fed, typically continuous, minimum flow that would benefit dissolved oxygen levels below the dam. A varying minimum flow from 4,500 to 25,000 cfs, dependent upon basin conditions, would be maintained as a release from the Jim Woodruff Dam to the Apalachicola River, which would assure an adequate water supply for downstream industrial use and water quality.

1.11 Water Supply

As described in the BA, the cities of Gainesville and Buford continue to withdraw water directly from Lake Lanier under reallocation agreements at rates not exceeding 8 million gallons per day (mgd) (net) and 2 mgd, respectively. Additionally, pursuant to the Water Supply Act of 1958, the WCM reallocates 252,950 acre-feet in Lake Sidney Lanier to water supply. The amount of storage is estimated to yield 222 mgd during the critical drought (i.e., during the worst drought on record at the time the agreement was executed). The severity and frequency of droughts change over time, therefore, the yield of this storage may change over time. For the purpose of managing water supply storage, USACE uses a storage accounting methodology that applies a proportion of inflows and losses, as well as direct withdrawals by specific users, to each account. The amount of water that may actually be withdrawn is ultimately dependent on the amount of water available in the storage account, which will naturally change over time.

Under the WCM, releases from Buford Dam are made to accommodate downstream water demands. Peaking hydroelectric power generation at Buford Dam generally accommodates most water supply needs of communities currently withdrawing from the Chattahoochee River; however, under the 1946 Rivers and Harbors Act, generation can occur at non-peaking times to meet the downstream water supply needs, not to exceed 379 mgd.

1.12 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.

As described in the BA, the USACE plans to make water releases for federally-listed, threatened, and endangered species below Jim Woodruff Dam on the basis of seasonal requirements (spawning, non-spawning, and winter), composite conservation storage, and basin inflows. Release requirements are dictated by composite conservation storage (Figure 1.7) in accordance with the revised action zones discussed above in the Guide Curves and Action Zones section.

The USACE manages water releases from Jim Woodruff Dam to support the federally-protected Gulf sturgeon and mussel species (fat threeridge, purple bankclimber, and Chipola slabshell) in the Apalachicola River. Daily releases to provide support for fish and wildlife conservation from Jim Woodruff Dam are dictated by two parameters: a minimum discharge (measured in cfs) and a maximum fall rate (measured in feet per day [ft/day]).

1.11.1 Minimum Discharge

Minimum discharges from Jim Woodruff Dam vary according to composite conservation storage (Figure 1.7), basin inflow per the 7-day moving average, and by month. Table 1.4 shows these minimum releases, which are measured as a daily average flow in cfs at the USGS gage at Chattahoochee, Florida. During normal and above normal hydrological conditions within the basin, releases greater than the minimum release provisions occur consistent with the maximum fall rate schedule described below, or as needed to achieve other project purposes, such as hydroelectric power generation or flood risk management.

During the spawning period (March to May), the WCM includes two sets of four basin inflow thresholds and corresponding releases according to composite conservation storage in Zones 1 and 2 or composite conservation storage in Zone 3. When composite conservation storage falls below the bottom of Zone 2 into Zone 3, the drought contingency operations would be triggered. However, since the decision to implement drought contingency operations occurs monthly, a minimum flow provision while in composite conservation Zone 3 is also included. The USACE also operates Jim Woodruff Dam to avoid potential Gulf sturgeon take (USFWS 2008, 2012). Potential Gulf sturgeon take has been defined as an 8-foot or greater drop in Apalachicola River stage over the last 14-day period (i.e., if today's stage is greater than 8 feet lower than the stage of any of the previous 14 days) when flows are less than 40,000 cfs.

The WCM includes one set of four basin inflow thresholds and corresponding releases during the non-spawning period (June to November), according to composite conservation storage in Zones 1 - 3. When composite conservation storage falls below the bottom of Zone 2 into Zone 3, the WCM drought contingency operations are triggered. However, since the decision to implement drought contingency operations occurs monthly, the WCM also includes a minimum flow provision while in composite conservation Zone 3.

During the winter season (December to February), the WCM includes only one basin inflow threshold and corresponding minimum release (5,000 cfs) while in composite conservation storage Zones 1–4. This feature of the WCM provides the greatest opportunity to refill the storage reservoirs. No basin inflow storage restrictions are in effect as long as this minimum flow is met under such conditions.

Table 1.4 Jim Woodruff Lock and Dam, Apalachicola River Minimum Discharge for Federally-Listed Species by Month and by Basin Inflow (BI) Rates

Months	Composite conservation storage zone	Basin inflow (BI)[a] (cfs)	Min. Releases from Jim Woodruff Lock and Dam[b] (cfs)	BI available for storage[a]
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	
If Drought Triggered	Zone 3	NA	= 5,000[d]	Up to 100% BI > 5,000
At all times	Zone 4	NA	= 5,000	Up to 100% BI > 5,000
At all times	Drought Zone	NA	= 4,500[e]	Up to 100% BI > 4,500

Notes:

a. Basin inflow for composite conservation storage in Zones 1, 2, and 3 is calculated using the 7-day moving average basin inflow. Basin inflow for composite conservation storage in Drought Operations, Zones 3 and 4 or lower (Drought Zone) is calculated using the one-day basin inflow.

b. Consistent with safety requirements, flood risk management purposes, and equipment capabilities.

c. Drought plan is triggered when the composite conservation storage falls into Zone 3, the first day of each month represents a decision point.

d. Once drought operation triggered, reduce minimum flow to 5,000 cfs following the maximum ramp rate schedule.

e. Once composite storage falls below the top of the Drought Zone ramp down to a minimum release of 4,500 cfs at rate of 0.25 ft/day based on the USGS gage at Chattahoochee, Florida (02358000).

1.11.2 Maximum Fall Rate

When composite conservation storage falls below the bottom of Zone 2 into Zone 3, the drought contingency operations are triggered. Within Zone 4, the minimum flow is the same as in Zone 3. When the composite conservation storage drops further into the Drought Zone, the minimum flow from Jim Woodruff Dam is reduced to 4,500 cfs. A description of the drought operations is provided in the Drought Operations section above.

The federally-listed species operations of the WCM includes a guideline for maximum fall rate, also called down-ramping rate, defined as the vertical drop in river stage (water surface elevation) that occurs over a given period of time. The fall rates are expressed in units of ft/day measured at the USGS Chattahoochee, Florida gage as the difference between the daily average river stages on consecutive calendar days. Rise rates (e.g., today's average river stage is higher than yesterday's) are not addressed. The maximum fall rate schedule is provided in Table 1.5. When composite conservation storage falls into Zone 3, the drought operations plan would be implemented, the maximum fall rate schedule would be suspended and more conservative drought contingency operations begin. Down-ramping rates are also suspended during periods of prolonged low flow (flows less than 7,000 cfs for a period of more than 30 consecutive days).

A prolonged low flow period would be considered over and down-ramping rates would be reinstated when flows are greater than 10,000 cfs for 30 consecutive days. Unless the extreme drought operations described above are triggered, fall rates under drought contingency and prolonged low flow operations would be managed to match the fall rate of the basin inflow.

Table 1.5 Maximum Down-Ramping (Fall) Rate at Jim Woodruff Dam

Approximate release range (cfs)	Maximum fall rate (ft/day)
> 30,000 [a]	No ramping restriction [b]
> 20,000 and ≤ 30,000 [a]	1.0 to 2.0
Exceeds Powerhouse Capacity (~ 16,000) and ≤ 20,000 [a]	0.5 to 1.0
Within Powerhouse Capacity and > 10,000 [a]	0.25 to 0.5
Within Powerhouse Capacity and ≤ 10,000 [a]	0.25 or less

Notes:

[a] Consistent with safety requirements, flood risk management purposes, and equipment capabilities.

[b] For flows greater than 30,000 cfs, it is not reasonable or prudent to attempt to control the down-ramping rate, and no ramping rate is required.

2 ENVIRONMENTAL BASELINE - PHYSICAL ENVIRONMENT

The environmental baseline for consultation purposes is an analysis of the effects of past and ongoing human and natural factors leading to the current status of the listed species, their habitat (including critical habitat), and ecosystem within the action area. The environmental baseline is a “snapshot” of the species’ health in the action area at the time of the consultation, and does not include the effects of the action under review. This section provides a description of the baseline physical environment that is common to all listed species and designated critical habitats considered in the BO. We provide species- and critical-habitat-specific analyses of the environmental baseline in sections that immediately follow a description of the status of each species/critical habitat.

2.1 General Description of the Action Area

As discussed above, the ACF Basin comprises 19,573 square miles in Alabama, Florida, and Georgia. USACE operates five reservoir projects in the ACF Basin: Buford Dam and Lake Lanier; West Point Dam and Lake; Walter F. George Lock, Dam, and Lake; George W. Andrews Lock, Dam, and Lake; and Jim Woodruff Lock and Dam and Lake Seminole. In this section, we discuss the changes to the ACF Basin that are included in the environmental baseline that may have ongoing effects on the basin and its aquatic communities. We focus on changes in hydrology and flow regime and how these changes have affected and may continue to affect the status of the species in the action area.

2.1.1 Major Rivers and Hydrology

Hydrologic characteristics of the basin are defined by various parameters, including precipitation and transpiration, runoff, land use, geology, and man-made structures to manage water resources. The mean annual rainfall in the Flint River Basin (Georgia) and Chattahoochee River Basin (Alabama and Georgia) generally ranges from about 50 to 55 inches per year (in/yr). In the Apalachicola River Basin (Florida), the mean annual rainfall generally is above 55 in/yr and may be as high as 66 in/yr in certain locations (USACE 2015 p. 2-2).

During the past 8 decades, the ACF Basin has experienced numerous droughts, several of which are considered severe. In recent years, droughts have been experienced in 1980-1982, 1985-1989, 1998 – 2003, 2007 – 2008 and 2011 – 2012 (USACE 2015, p 2.8 – 2.9). Since 1999, the six of the seven lowest-flow years (1999, 2000, 2002, 2007, 2011 and 2012) in terms of average annual flow in the period of record (1923 – present) for the Apalachicola River at Chattahoochee have occurred. The impacts of each drought have varied across the basin as the location, severity and duration of each drought has varied.

An important question with regard to the preparation of this document is whether the occurrence of multiple "rare events" in the past 30 years is an anomaly or should droughts of this magnitude be expected more regularly in the future with changing climate. Long-term climate records suggest that decade-long "mega-droughts" have occurred periodically during the past 1,000 years in the southeastern US, including in the ACF (Stahle et al., 2007). Projections for the ACF watershed indicate that future droughts are likely to be more intense (Yao and Georgakakos 2011). This suggests that while the recently observed droughts in 2006-2008 and 2010-2012 were exceptional based on our recent <100-year period of record, they may not be exceptional compared to historic episodes (Pederson et al., 2012). Gibson et al. (2005) used multiple future climate scenarios, combined with increasing water demand from human users, to predict that future river discharge conditions could include lower high discharge events and lower low flow events. From the 1940s to the 1990s (the majority of the period of record for gages in the ACF), the southeastern US was in a persistent, unusually wet period compared to the previous millennium (Seager et al., 2009). This is the period of time during which most of the reservoir and human development has occurred in the ACF and from which we derive flow assessments. The relative infrequency of severe drought events during this period may provide unrealistic expectations for future conditions.

Within the ACF Basin, rainfall occurs throughout the year, but is less abundant in August through November. The amount of rainfall that actually contributes to streamflow varies much more than the rainfall. Several factors such as plant growth and seasonal rainfall patterns contribute to the volume of runoff. In severe droughts in the upper Chattahoochee River Basin, the runoff from significant (3+ inches) rain events can be as low as 5 percent of the rainfall. The mountainous areas in the headwaters of the basin exhibit flashier runoff characteristics and somewhat higher percentages of runoff, ranging from about 28 to 60 percent of rainfall depending on the time of year. In contrast, runoff as a percent of rainfall between Blountstown, Florida, and Columbus, Georgia, ranges from about 16 to 53 percent depending on the time of year. In all portions of the ACF Basin, runoff as a percentage of rainfall is lowest in July through September (USACE 2015 p. 2-9).

The Apalachicola River has the highest annual discharge of any river in Florida. It is the fifth-largest river basin 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 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 (USFWS 2012).

ACF Basin spans four level III ecoregions (Bailey 1983). The northern-most portion of the upper Chattahoochee River Basin lies in the Blue Ridge ecoregion, constituting only about 1 percent of the ACF Basin. This ecoregion is characterized by mountain ridges ranging up to about 3,500 ft in elevation. The balance of the upper Chattahoochee River Basin and the upper Flint River Basin are in the Piedmont ecoregion. Most streams in the Chattahoochee River have trellised and rectangular drainage patterns due to the Brevard fault. The Flint River and streams in its basin have dendritic drainage patterns, resembling a branching tree. The streams in the Piedmont are fast flowing and are characterized by rapids and riffles, making them ideal for hydroelectric power generation. The Southeastern Plains begin at the “Fall Line”, which is the contact point between the crystalline bedrock of the Piedmont and unconsolidated sediments of the Plains. The area is highly dissected by streams, especially in the northern Georgia Sand Hills. The Dougherty Plain district in the south is underlain by limestone, and its karst topography is very flat and has numerous sinkhole-created marshes and wetlands. Streams in the Southeastern Plains are relatively low-gradient and sandy bottomed, and rivers are wide and sinuous with large floodplains. The Southeastern Plains has little runoff because annual precipitation and evapotranspiration rates are similar. During times of heavy rainfall events, the wide floodplains are able to store large quantities of water. The Southern Coastal Plain is a flat, lowland area that contains barrier islands, coastal lagoons, marshes, and swampy lowlands. Soils in the area are generally hydric and have a high capacity to hold and store water. The Southern Coastal Plain is dominated by large alluvial rivers, such as the Apalachicola River, which has a broad floodplain that ranges from 1 to 5 miles in width and is dominated by substantial flooding (USACE 2015 p. 2-11).

Streams in the ACF basin can be deeply entrenched into aquifers, and many receive significant contributions from groundwater from one of five major aquifers including the surficial aquifer system, the Upper Floridan aquifer system, the Claiborne aquifer, the Clayton aquifer, the Providence aquifer, and the crystalline rock aquifer. The Upper Floridan aquifer is hydraulically connected to the Flint River and, consequently, groundwater discharge contributes more significantly to baseflow in the Flint River than in the Chattahoochee River. Groundwater discharge to the Chattahoochee River is roughly 20 percent of the amount discharged to the Flint River (USACE 2015 p. 2-53).

The Chattahoochee River has a drainage area of 8,708 sq mi. The drainage area of the Flint River measures 8,456 sq mi. The remaining 2,409 sq mi of the ACF Basin drain directly into the Apalachicola River. Rivers in the ACF Basin include both natural (unregulated) rivers and regulated rivers. The natural rivers exhibit a more consistent pattern, responding to precipitation and drought periods as expected with short periods of high flows and prolonged periods of low flows, respectively. Regulated streams exhibit a variable pattern, with daily variations due to hydroelectric power generation operations (most prominent below peaking projects), navigation releases, lower flood peaks, and higher sustained minimum flows through dry periods as the upstream reservoirs augment low flows. Flow patterns (i.e., mean daily discharge) for the regulated Chattahoochee River over a year are illustrated in Figure 2.1, and for the unregulated Flint River are illustrated in Figure 2.2. Although the two rivers have only slightly different drainage areas, the figures demonstrate the distinctive characteristics of flow in the two watersheds (USACE 2015 p. 2-15). These differences are the result of both the regulated nature of the Chattahoochee basin and the differences in the contribution groundwater inflow to the base flow of the watershed. The significant groundwater contribution to the Flint River complicates water management in this basin because of uncertainties in the surface-groundwater interactions in the mid to lower Flint basin as well as effects on groundwater and spring discharge from groundwater withdrawals (Jones and Torak 2006, Rugel et al. 2015). During low flow periods, the Flint basin is typically an important contributor to meeting the USACE's minimum releases to the Apalachicola River. The inability of the Flint basin to play this flow mitigation role during the 2011-2012 drought led to the record low flows experienced in Apalachicola River in 2012 (Leitman et al. 2016).

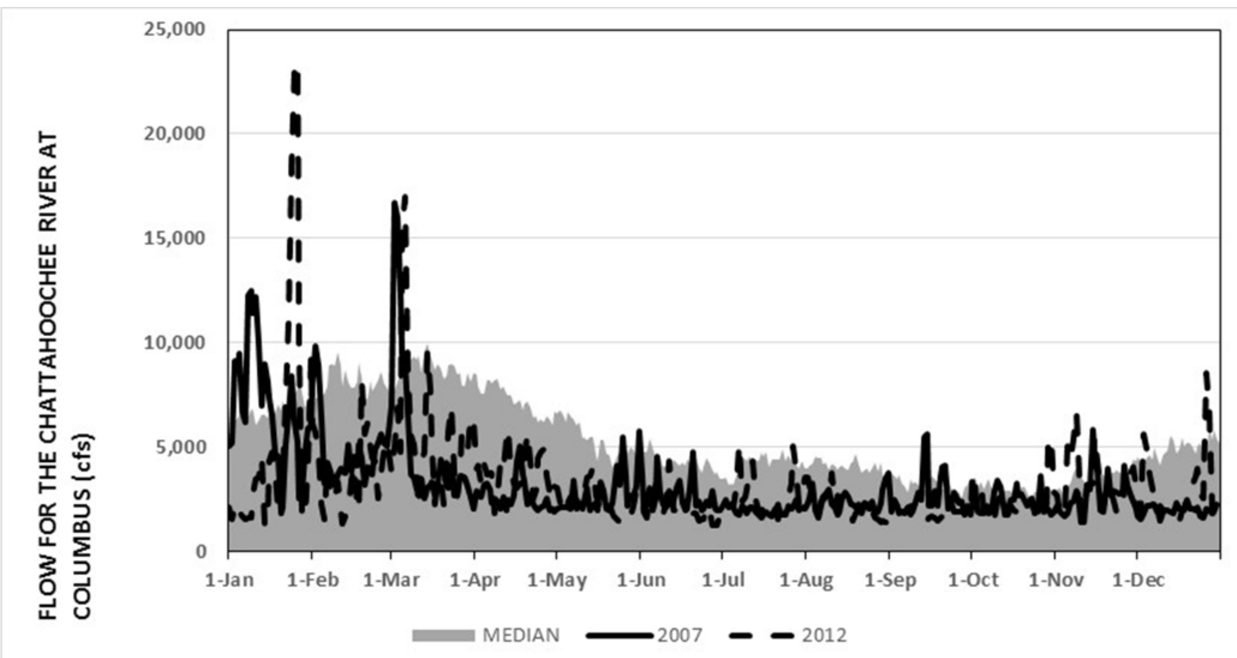


Figure 2.1 Median daily discharge from the Chattahoochee River at Columbus, GA (1939-2012) from USGS web data (http://waterdata.usgs.gov/ga/nwis).

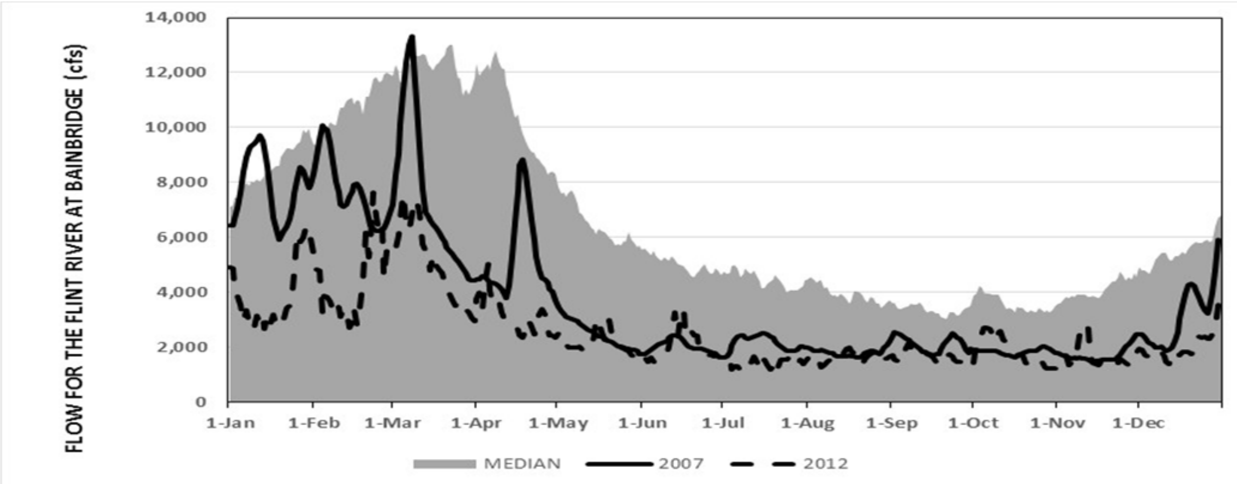


Figure 2.2 Median daily discharge from the Flint River at Bainbridge, GA (1939-2012) from USGS web data (http://waterdata.usgs.gov/ga/nwis).

The Chattahoochee River originates in the Blue Ridge Mountains of north Georgia, near the westernmost tip of South Carolina, and extends to the southwest corner of the state. The Chattahoochee River covers a distance of 434 mi from the Blue Ridge Mountains to Lake Seminole. It flows out of the mountains, past Metro Atlanta, and reaches the Georgia-Alabama border, at which point it forms the border between the two states. From there, the Chattahoochee River flows south to its confluence with the Flint River at Lake Seminole and into the Apalachicola River. Over most of its length, the mainstem of the Chattahoochee River is controlled by dams, with navigation locks and hydroelectric plants, that provide for navigational use of the river, release water for the production of hydroelectric power generation, temporarily store water for flood risk management, and serve other purposes. The slope of the Chattahoochee River for 50 mi above Buford Dam is approximately 4 ft/mi. The Chattahoochee River is free-flowing only in the headwaters upstream of Lake Lanier. Between Buford Dam and West Point Dam, the slope is fairly uniform and averages about 2.7 ft/mi. Downstream of Buford Dam, the river is affected by dam and reservoir operations. The river’s slope becomes quite steep through the Fall Line hydroelectric power generation projects, from West Point Dam to Columbus, Georgia, averaging about 10 ft/mi. Downstream of Columbus to Jim Woodruff Lock and Dam, the slope of the river is relatively flat at 1.2 to 0.6 ft/mi. The capacity of the Chattahoochee River within its banks is about 10,000 cfs between Lake Lanier and Norcross, about 18,000 cfs from Atlanta to Whitesburg, and about 47,500 cfs near West Point and Columbus. Historically, flows at the USGS gage on the Chattahoochee River at Columbus have been as low as 480 cfs (in October 1931) and as high as 120,000 cfs (in February 1961). Many of the dams and hydroelectric plants operate in a peaking mode, which can result in daily water level fluctuations in the river of 4 ft or more. Storage for flood risk management at several of the larger reservoirs reduces the peak flow in the river by storing much of the flood flow. In contrast to the mainstem of the river, the numerous tributaries of the Chattahoochee River are free flowing. These streams typically have higher sustained flows during winter months and show sharper responses to storm events throughout the year (USACE 2015 p. 2-15 - 2-16).

The Flint River originates just south of Atlanta and flows about 350 mi in a southerly direction, curving to the west to join the Chattahoochee River at Lake Seminole in the southwest corner of Georgia. The Flint River drainage basin has an average width of about 40 mi. The Flint River is generally fed by groundwater from its headwaters to its mouth, and there is a substantial groundwater-to-surface water transfer in the lower portions of the Flint River, which helps to sustain higher winter flows in the river. North of the Fall Line, the Flint River receives groundwater by diffuse leakage into the river bottom; south of the Fall Line, groundwater flow from springs becomes more prevalent. In the upper reach of the Flint River, above the Fall Line, the slope of the river averages about 2 ft/mi. For about 55 mi across the Fall Line, in the general vicinity of Thomaston, Georgia, the slope averages about 6.7 ft/mi. The lower portion of the Flint River has an average slope of about 1.0 ft/mi (USACE 2015). There are only two limited-storage-capacity reservoirs on the Flint River (i.e., Lake Blackshear and Lake Worth), and they do not substantially modify the flow in the river. The capacity of the Flint River within its banks ranges from about 30,000 cfs near Montezuma to about 35,000 cfs near Bainbridge, in the headwaters of Lake Seminole. Historically, flows at the Albany gage, which is about midway between Lake Seminole and the Flint River's headwaters, have been as low as 327 cfs (in August 1930) and as high as 119,000 cfs (in July 1994 as a result of Tropical Storm Alberto) (USACE 2015 p. 2-17).

The Flint and Chattahoochee rivers converge at Lake Seminole, which is formed by the Jim Woodruff Lock and Dam. Together, they form the Apalachicola River, which is entirely within the State of Florida and flows unimpeded for approximately 106 mi from the dam near the Florida-Georgia state line to the Gulf of Mexico at Apalachicola Bay. The river drains about 2,409 sq mi, and its shallow estuary covers about 208 sq mi. Tides in the Gulf of Mexico influence the Apalachicola River over approximately the lower 25 mi of the river. The tides have a mean range of 2 ft. The width of the river ranges from several hundred feet when confined to its banks to nearly 4.5 mi during flood flows. The discharge of the Apalachicola River accounts for 35 percent of the freshwater flow on the western coast of Florida. The slope of the Apalachicola River is fairly flat at 0.5 to 0.7 ft/mi over its entire length (USACE 2015 p. 2-22).

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.

The Chipola River is the only sizable tributary to the Apalachicola River besides the Flint and Chattahoochee rivers. The Chipola River Basin drains 1,270 sq mi, which accounts for about one-half of the Apalachicola River's drainage area in Florida. The Chipola River is a spring-fed river with baseflow derived principally from aquifers. The capacity of the Apalachicola River within its banks is approximately 100,000 cfs at Chattahoochee, Florida. Historically, flows at the Chattahoochee gage ranged from a low of 3,900 cfs (during the 1986 to 1987 drought period) to a peak of 291,000 cfs in 1929 before many of the upstream reservoirs were built. More recently, flows have been as high as 203,000 cfs in July 1994 after Tropical Storm Alberto brought heavy rains to Georgia. Mean daily discharge at two gages, Chattahoochee and Blountstown, Florida are illustrated in Figure 2.3 and 2.4 respectively. The differences in high flow between before and after reservoir construction is due to climate, not reservoir management. The volume of storage in the watershed is not adequate to store flows from rain events with runoff greater than 200,000 cfs, because: (a) the total conservation storage capacity of the basin at full summer pool is about 800,000 cfs-days; (b) the Flint basin is unregulated; and (c) the reservoir at the confluence of the Flint and Chattahoochee Rivers has very limited storage (USACE 2015 p. 2-24). Similar to the pattern exhibited by the Chattahoochee and Flint rivers, flows on the Apalachicola River are highest in spring and lowest in late summer. The large seasonal fluctuation in flow in the Apalachicola River is important to the ecological function of the river and its estuary (USACE 2015 p. 2-22).

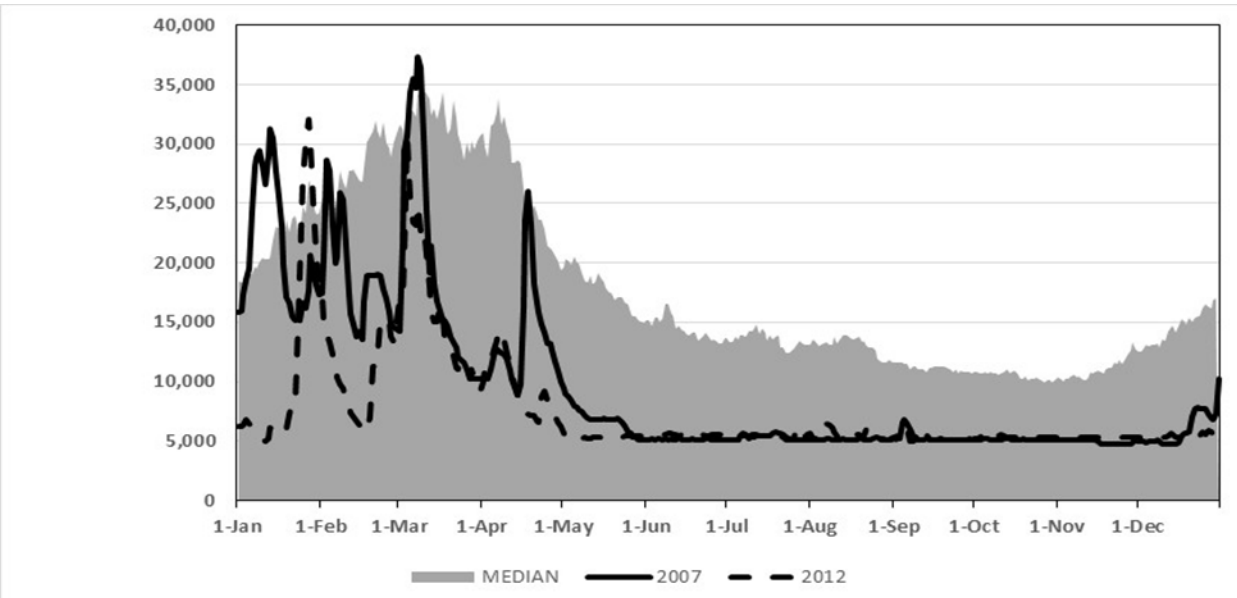


Figure 2.3 Median daily discharge from the Apalachicola River at Chattahoochee, FL (1923-2012) from USGS (http://waterdata.usgs.gov/fl/nwis/rt).

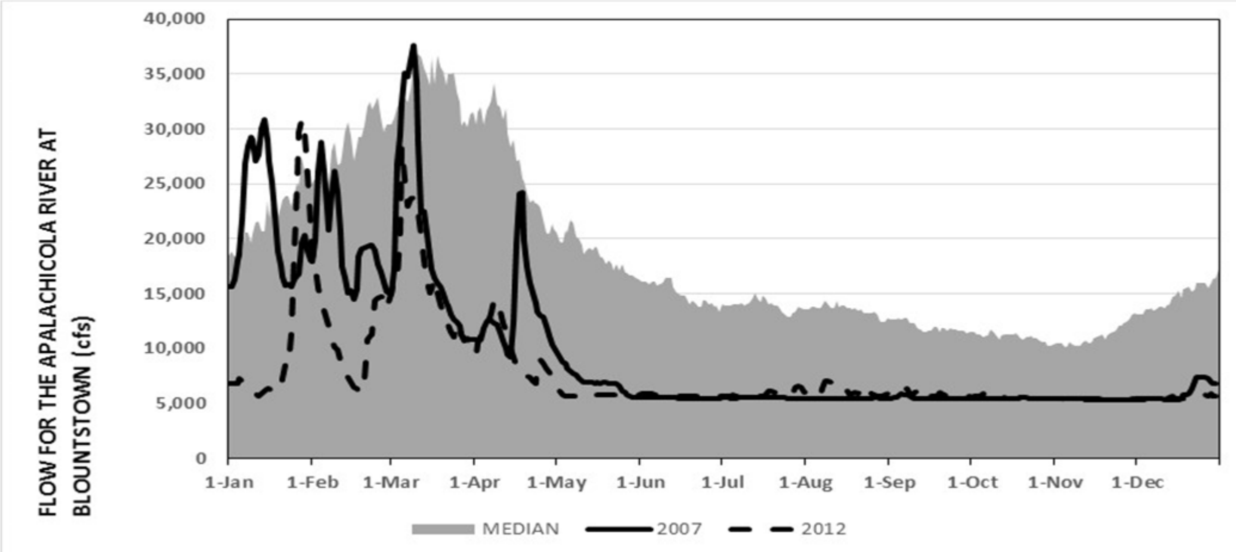


Figure 2.4 Median daily discharge from the Apalachicola River at Blountstown, FL (1939-2012) from USGS (http://waterdata.usgs.gov/fl/nwis/rt) and USACE HEC-ResSim data base.

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.

2.1.2 Land use Changes and Associated Changes in Hydrology

Nearly 50 percent of the ACF Basin is forested, down from 55 percent in the 1990s (USACE 2015). A large portion of the precipitation on forested lands is intercepted and prevented from quickly reaching surface water streams through infiltration and evapotranspiration processes. Following pine plantation harvesting, water yields can increase as much as 35 percent due to decreases in interception and evapotranspiration. Forested ecosystems have high stream baseflows and low, lengthy storm peaks compared to other common land uses because of high infiltration and permeability rates. Forest cover (e.g., leaves and mulch) reduces raindrop velocities, allowing for higher infiltration, and soils have organic concentrations with higher porosities, allowing for higher permeability. During high storm flows, wetland forests, often streamside, can store large quantities of water and reduce downstream flooding impacts. The intensity of drought and wet periods is exacerbated by changes in land use and population demand on resources. From 1970 to 1990, water use for public supply in the ACF Basin, which includes metropolitan Atlanta, more than tripled to almost 460 mgd. Demand continued to more than double between 1990 and 2010, and demand under current operations is 958 mgd (Appendix A). Severe droughts and increased development in the area have resulted in shortages and restrictions on limited surface water supplies. Concurrently, various conservation measures have been instituted and periodically strengthened to curb the increased demand and per capita water use (USACE 2015 p. 2-13).

Total agricultural land in the ACF Basin has decreased over the past two decades due to urbanization and farm abandonment, but more than 20 percent of the land cover is still used for agricultural purposes. A large majority of the irrigated area in the ACF basin above Jim Woodruff Dam occurs in Georgia, about 77% of which occurs in the Flint basin (excluding Spring Creek sub-basin), 21% in the Spring Creek sub-basin of the Flint, and only 2% in the Chattahoochee basin (Hook et al. 2010). Agriculture in the ACF Basin uses both surface water and groundwater for crop irrigation and livestock watering. In the Flint River Basin, groundwater supplies nearly all of the water needed for crop irrigation, whereas in the Chattahoochee River Basin, groundwater supplies only 44 percent of the water needed for crop irrigation. Livestock agricultural uses are throughout the basin, and farmers use both groundwater and surface water to water livestock. Water used for crop irrigation is considered to be 100 percent consumptive because it is incorporated into crops or lost through evapotranspiration. Compared to forested land use, agricultural land uses produce larger storm flows during rain events because of the reduced soil cover. The runoff rates from agricultural areas are similar to the rates from low- and medium-density residential areas (USACE 2015 p. 2-13).

Urban areas significantly affect water quantity because of the high percentage of impervious cover and increases in water consumption. Rainfall on impervious surfaces is immediately transported to streams, causing high peak flows. Urban areas also have large areas of land with significantly reduced infiltration and permeability rates, such as grassy and barren land. These areas also shed water extremely quickly during storm events. Because less infiltration occurs in residential and industrial areas, very little groundwater recharge occurs and stream baseflows are reduced (USACE 2015 p. 2-13).

Most water removed from the basin for municipal and industrial water demands is returned to the basin as treated waste, but demands can alter natural channel flow. In the Chattahoochee River Basin, approximately 82 percent of the water withdrawn is returned, although the range may be

60 to 80 percent. Water is lost from the system through evapotranspiration, interbasin transfers, and thermal water demands. Municipal water suppliers use both surface water and groundwater, depending on supply levels. Water is often returned downstream of the supply source, and groundwater is often returned to the system as surface water. Water use for hydroelectric power generation is nonconsumptive, but hydroelectric dams can alter natural flow regimes because large releases occur during peak power demand periods. Water used for thermoelectric power generation (i.e., fossil fuels and nuclear) is moderately consumptive to nonconsumptive (USACE 2015 p. 2-14).

Under the baseline (NAA) and WCM (PAA) alternatives examined in the EIS, consumptive demands for the basin are identical except for in the metropolitan Atlanta area (see Table 7 in BA). Under the baseline, releases from Buford Dam would be sufficient to provide for the current need of 277 mgd for downstream withdrawals by metropolitan Atlanta water providers, with current withdrawals of 128 mgd directly from Lake Lanier, including 20 mgd for the reallocation contracts (USACE, 2015, p. 5-12). In the BA, it is stated that under the WCM, the cities of Gainesville and Buford would continue to withdraw water directly from Lake Sidney Lanier under relocation agreements at rates not exceeding 8 mgd (net) and 2 mgd, respectively. Additionally, pursuant to the Water Supply Act of 1958, the WCM would reallocate 252,950 acre-feet in Lake Lanier to water supply. This amount of storage is estimated to yield 222 mgd during the critical drought (i.e., during the worst drought on record at the time the agreement was executed). Under the WCM, releases from Buford Dam would be made to accommodate downstream water demands. Peaking hydroelectric power generation generally accommodates most water supply needs of communities currently withdrawing from the Chattahoochee River; however, under the 1946 Rivers and Harbors Act, generation can occur at non-peaking times to meet the downstream water supply needs, not to exceed 379 mgd. Under the baseline, the total net consumptive withdrawals from the ACF basin used in the modeling of the alternatives was about 958 mgd, and under WCM, the total consumptive withdrawals was about 1,102 mgd (Appendix A).

2.1.3 Dams and Changes to River Morphology and Water Quality

The history of dam construction on the Chattahoochee River dates back to the early 1800s. Projects on the river at and above Columbus, Georgia, were built to take advantage of the natural stream gradients for power production. The earliest dam constructed and still in operation was the Langdale Dam and Lake owned and operated by the State of Georgia and Georgia Power Company in 1860. Federal interest in the ACF Basin also dates back to the 1800s. Navigation improvements were authorized under the River and Harbor Act of 1874. Later, flood control and hydroelectric power generation interests were addressed. The River and Harbor Acts of 1945 and 1946 provided for the construction of a series of locks, dams, and reservoirs within the ACF Basin by USACE as part of a general plan to provide systemwide benefits for multiple purposes including navigation, flood control (flood risk management), hydropower generation, water supply, water quality, recreation, and fish and wildlife conservation. Modifications of this plan resulted in the completion of five USACE dams—four on the Chattahoochee River and one at the confluence of the Chattahoochee and Flint rivers. Operations of the ACF system and of the individual projects within it are governed by the original authorizing legislation, as amended, and by other general authorities and applicable law. There are 14 reservoirs on the mainstems of the ACF Rivers: five are federally owned, USACE projects and nine are privately owned projects. Of the 14 reservoirs, 11 are on the Chattahoochee River, two are on the Flint River, and one is on the Apalachicola River. The five USACE projects were completed in the following years: Buford Dam and Lake Lanier in 1957; West Point Dam and Lake in 1975; Walter F. George Lock, Dam, and Lake in 1963; George W. Andrews Lock, Dam, and Lake in 1963; and Jim Woodruff Lock and Dam and Lake Seminole in 1954 (USACE 2015 p. 2-23 - 2-24).

Prior to construction of the reservoir system in the ACF Basin, aquatic communities were structured by water quality and physical habitat condition, which were driven by the physiographic region and climate described in the previous sections. The construction of the USACE reservoir system significantly altered both the water quality and physical environment of the Chattahoochee and Apalachicola Rivers. Protection of aquatic resources was generally not a consideration for many types of river projects at that time because flood control, navigation, and low-cost hydroelectric power for economic stimulation were more highly valued.

In general, the construction of the USACE's dams, which preceded the Act and the listing actions for the sturgeon and mussels and are considered a part of the environmental baseline, continue to affect the ACF Basin and its aquatic species. As with other reservoir systems throughout the Southeast, the primary impact of the reservoir system was to convert free-flowing river habitat into reservoir pools. Virtually all of the mainstem Chattahoochee River was impounded to meet project purposes and the downstream Apalachicola River was influenced by the effects of these upstream impoundments. Completion of the entire water control system (both federal and non-federal) as well as increased consumption on the Flint River and other demands on the ACF Basin described above likely resulted in the following impacts to the aquatic system:

1) conversion of riverine habitat to reservoir pool habitat;
2) loss of riverine habitat and associated species;
3) conversion of floodplain to reservoir pool;
4) loss of seasonal floodplain habitat and associated species;
5) fragmentation of riverine sections;
6) disruption of fish migrations, including the Gulf sturgeon itself and several host fishes for listed mussels;
7) seasonal fluctuations of pool levels;
8) seasonal drying of habitat which reduces abundance and diversity of species;
9) strong stratification (layering) of temperature for certain dam types and change in thermal regime for the main channel rivers;
10) stress or mortality of organisms or sensitive life stages;
11) seasonal dissolved oxygen depletion in temperature stratified water;
12) ammonia release created by presence of dissolved oxygen-depleted water;
13) disruption of stream transport of sediment;
14) trapping of sediment that would otherwise move as bed load through the system;
15) altered channel morphology;
16) capture of toxic substances associated with substrate;
17) toxic substances release created by presence of dissolved oxygen-depleted water; and

18) enrichment of nutrients (eutrophication) with consequent increases in productivity, plant and algae growth, and changes in habitat quality and associated species.

Although all 18 of these changes are important to the biota of the ACF Basin, changes in channel morphology and sediment transport and changes in the water quality of the rivers merit further discussion here, and changes in flows will be summarized in the next section.

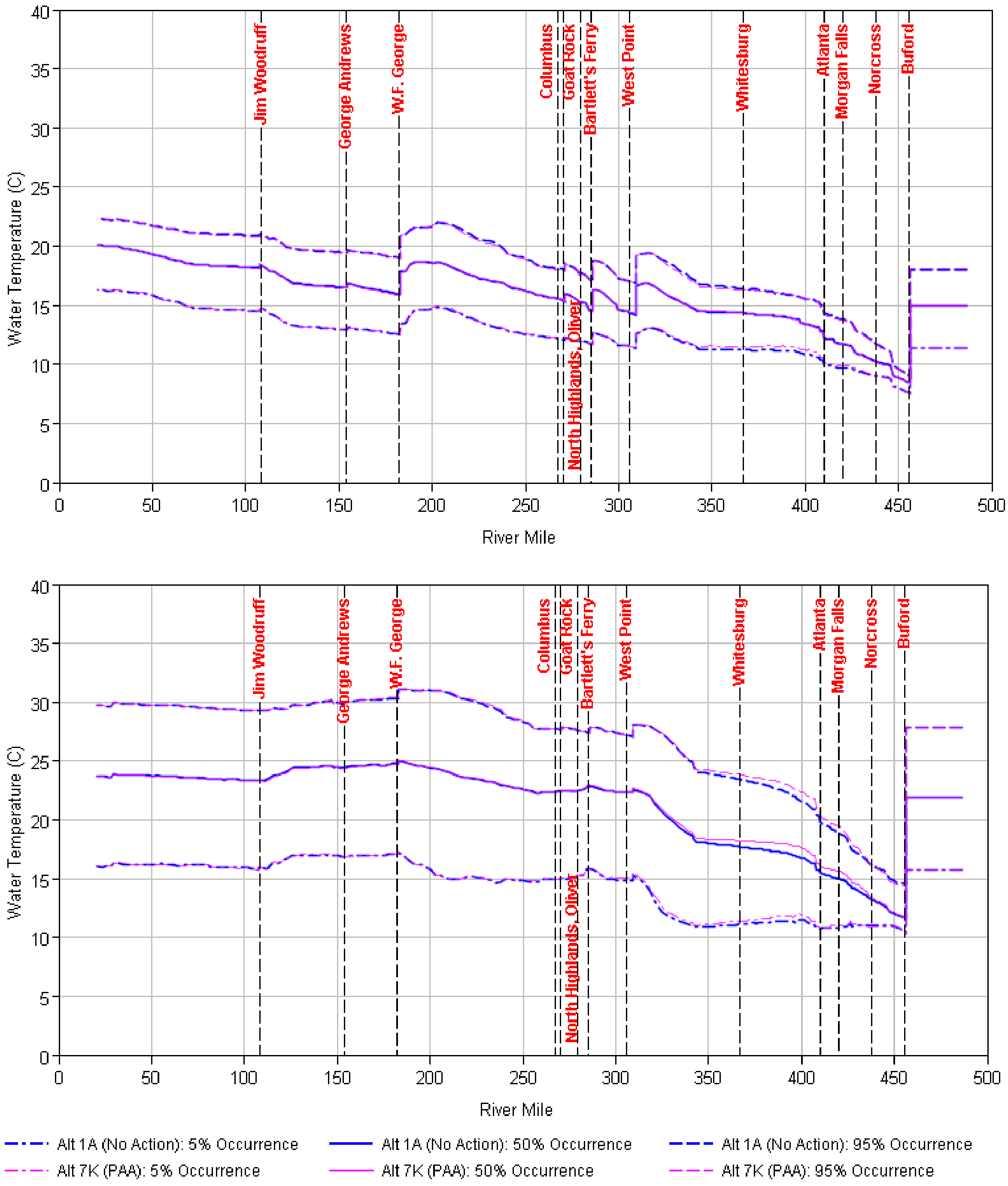
Channel morphology sets the context for the flow regime. The morphology of the Chattahoochee and Apalachicola rivers was altered by land use changes, upstream impoundments, consumptive use of water, and tectonic movement, as well as channel alterations such as the construction of dike fields, meander cutoffs, and channel dredging and snagging operations (Hupp 2000, Light et al. 2006, Price et al. 2006). The channel morphology has changed relative to the pre-dam period in the Apalachicola River. The Apalachicola River 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. However, the rate of change has slowed and appears to have entered a somewhat dynamic equilibrium condition (USFWS 2012). Mean bed elevation declined to some degree from 1960 to 2001 at 42 of 51 cross sections measured by the USACE 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. 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.

The probable cause of the channel morphology changes is sediment sequestration in the reservoirs and changes in flow regime (sediment transport patterns) following construction of dams. Additionally, the USACE previously maintained the navigational channel by snagging and dredging. However, except for limited dredging in 2001, the USACE has not maintained the channel since 1999 and dredging is not included in the action evaluated currently. Despite the loss of sediments that would naturally replenish downstream ecosystems, continued erosion appears to be part of the natural down-valley meander migration which is common to most alluvial streams and may not be the result of continuing post-dam system-wide adjustments. It appears unlikely that erosion rates will increase over time (Beidenharn 2007, Harvey 2007), and channel profile data collected in 2009 indicate a state of relative equilibrium (USACE, Mobile District, B. Zettle, pers. comm. 6/21/2016). However, USFWS does not have adequate data to assess the channel profile stability. During development of the BO, the USACE requested that the USGS review the stage/discharge data collected at the three gages in the action area (Chattahoochee, Blountstown, and Sumatra) since 2012 in order to determine if the channel morphology still reflects a somewhat dynamic equilibrium condition. These gage ratings at the

Chattahoochee gage are corrected on a regular basis. As an indicator of the state of relative equilibrium, USACE will examine the shifts in the rating curves from 2012 to present. The pattern of directional shift will be analyzed as an indicator that the state of relative equilibrium is likely to continue. The USGS has conducted a review of the measurements made at the Apalachicola River Chattahoochee, Blountstown and Sumatra gages as requested by USACE. Although several measurements have been collected at each location since 2012, the measurements are not always made in the same location. While the exact location of the measurement in the channel does not adversely affect the computed discharge for the site, it does make comparison of channel characteristics impractical. It is the USGS's opinion that a determination as to stability or degradation of the channel based upon discharge measurements cannot be made (USACE, Mobile District, B. Zettle, pers. comm. 8/26/2016).

Differences in purposes and, consequently, operation of reservoirs became important factors in determining water quality and associated impacts on resident aquatic communities downstream. Water temperature changes as it moves through river drainage system. In an unimpounded system, surface water temperature gradually warms as it moves downstream. However, surface water temperature varies greatly depending on the inputs of groundwater through the system. Little empirical data from the ACF basin on water temperature is available for analysis. In the amended BA (6/30 p. 48-51), USACE modeled water quality including water temperature throughout the basin associated with the water management alternatives and water supply storage options in the ACF Basin using the HEC-5Q model developed by the USACE Hydrologic Engineering Center. For the simulation of water quality conditions under the various alternatives, HEC-5Q inputs included main-channel flows, tributary flows, water quality data, withdrawals, and point and non-point pollutant loads to the system. The HEC-5Q model was linked with the HEC-ResSim model through an input of flows by reach. Pollutant loading included both observed and simulated data developed using the BASINS model for period of record from 2001 through 2011. The HEC-5Q model also included nontributary inflows, wastewater treatment dischargers, and cooling water returns. Inputs for wastewater treatment discharges were based on discharge monitoring reports (DMRs). When DMRs were not available, permitted limits, concentrations representative of the type of discharge, or an average of DMRs was used. The point-source inputs considered only dischargers that contributed more than 1 mgd.

This modeling indicates that the temperature regime of the river has changed since the five USACE projects were completed during both the spring (March-May; Figure 2.5A) and fall (Sept-Dec; Figure 2.5B) periods. Distinct drops in temperature can be seen downstream of Buford, West Point, W.F. George, which are managed by USACE as well as Bartlett's Ferry. These drops are from cool water released from each of these reservoirs and represent changes in water temperature that would have otherwise warmed gradually as it moved through the basin. Spring water temperature under both the baseline and the WCM generally ranges from about 15^{o}C to 21^{o}C in the reach of Apalachicola River below Jim Woodruff Dam known to support Gulf sturgeon spawning, but range from about 17^{o}C to 28^{o}C in the fall (6/30 amended BA p. 50).



A

B

Figure 2.5 HEC-5Q Simulated Water Temperature (Degrees Celsius) in Spring (A) and Fall (B) Under the WCM (PAA) and Baseline (No Action) based on ResSim simulated flow (1975-2011).

2.1.4 Changes to River Flows

Prior to dam construction, stream flow was proportional to rainfall, and flow regime followed the same trends as the annual rainfall and evapo-transpiration patterns. Flow established physical habitat conditions (e.g., depth, velocity) within a stream and maintained stream shape and other habitat condition, including substrate. Floods were common during spring, and flows decreased throughout the year with the lowest flows typically occurring August through October, the warmest part of the year. Spring flooding was an important component in the life cycles of some fish species that use flooded overbank areas for spawning or nursery areas. Meeting the purposes of USACE-system dams and reservoirs, such as water supply and flood control throughout the Chattahoochee and Apalachicola Rivers, required modifying the river environment described above to which the pre-impoundment aquatic community was adapted. For example, riverine habitat was eliminated by impoundments, and seasonal flow patterns were greatly modified by capturing high spring flows in upstream impoundments and increased late summer/fall flows with drawdown releases from those reservoirs.

To compare pre- and post-dam conditions, we used the observed 27-year pre-Lanier flow record of the Chattahoochee gage from 1929 to 1955 and the post-West Point construction period (1975-2012) flow record of the same gage (see USFWS 2012 for a more detailed comparison). Here, we summarize differences between the two time periods from that analysis in terms of annual flow, high flows, low flows, seasonality of flows, and rates of change in the system. Differences between the pre-Lanier and post-West Point periods may result from climatic as well as the anthropogenic differences described earlier. These changes due to the dams are important as context for changes to the downstream action area and as context for what the biota have experienced leading to their current status, which is reviewed in subsequent sections.

Annual Flows: To better understand the effects of climate versus operations, we begin with a general comparison of the annual flow for the two periods. Figure 2.6 shows frequency-duration curves for pre-dam and post-West Point periods for observed flows for the pre-dam period (1923 – 1955) and the post West Point construction period (1975 – 2012). This figure shows that in the pre-dam period there was relatively more flow than in the post-West Point period. In the post-West Point period, the five lowest-flow years (2000, 2002, 2007, 2011 and 2012) and seven of the 10 lowest-flow years in terms of average annual flow occur. The occurrence of these lowest-flow years in the later period may be due to differences in precipitation patterns; however, historical precipitation data (NOAA 2016) in the Chattahoochee and Flint basins 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 of 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.

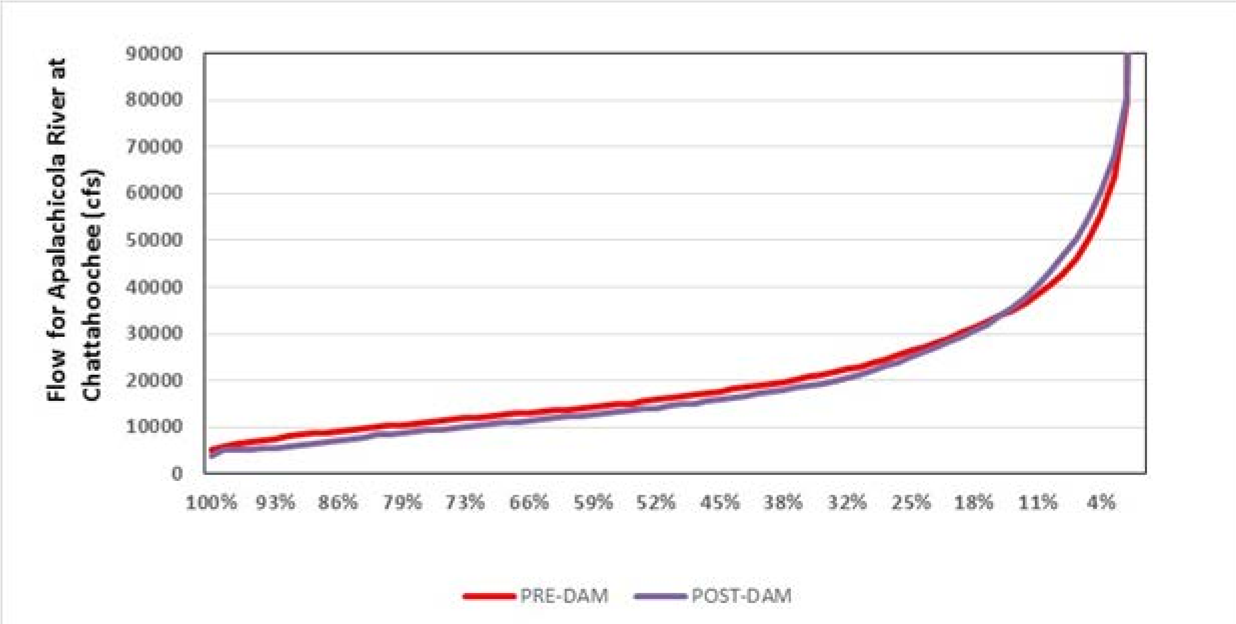


Figure 2.6 Frequency-duration curves for pre-dam and post-West Point periods for the Apalachicola River based on the Chattahoochee gage.

High Flows: High flows (e.g., flows greater than 50,000 cfs) perform many functions that are vital to the maintenance of riverine and estuarine ecological integrity, including:

1) the maintenance of channel and floodplain features by transporting sediment;
2) the export of organic matter;
3) nutrients, and organisms from the floodplain to the main channel and the estuary;
4) removing and transporting fine sediments, clearing interstitial spaces in gravel bars used for fish spawning;
5) importing woody debris into the channel, creating new high-quality habitat for fish and invertebrates;
6) scouring floodplain soils, which rejuvenates habitat for early-successional plant species;
7) 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;
8) connecting the main channel to the floodplain, providing access to spawning habitats, nursery areas, and food sources; and
9) maintaining flood-resistant, disturbance-adapted communities (USFWS and USEPA 1999).

Because of the small volume of storage in the ACF basin relative to flow in the Apalachicola River, there is a very limited capacity to influence high flows through the management of the federal reservoirs and hence through the WCM.

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), and these relatively frequent events move the greatest sediment volume over time. Bankfull flow in mid to lower portions of the Apalachicola River is about 14,000 to 15,000 cfs (Light et al. 2006; Figure 2.7). 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. Flow did not exceed 50,000 cfs, a threshold between the 1.1-1.5 peak flows, 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) (USFWS 2012). This shift in the inter-annual duration of high flows suggests a relatively greater potential for sediment transport in the later period. One effect of bed degradation and channel widening as discussed in the previous section has been to reduce the amount of floodplain inundation associated with a given discharge (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).

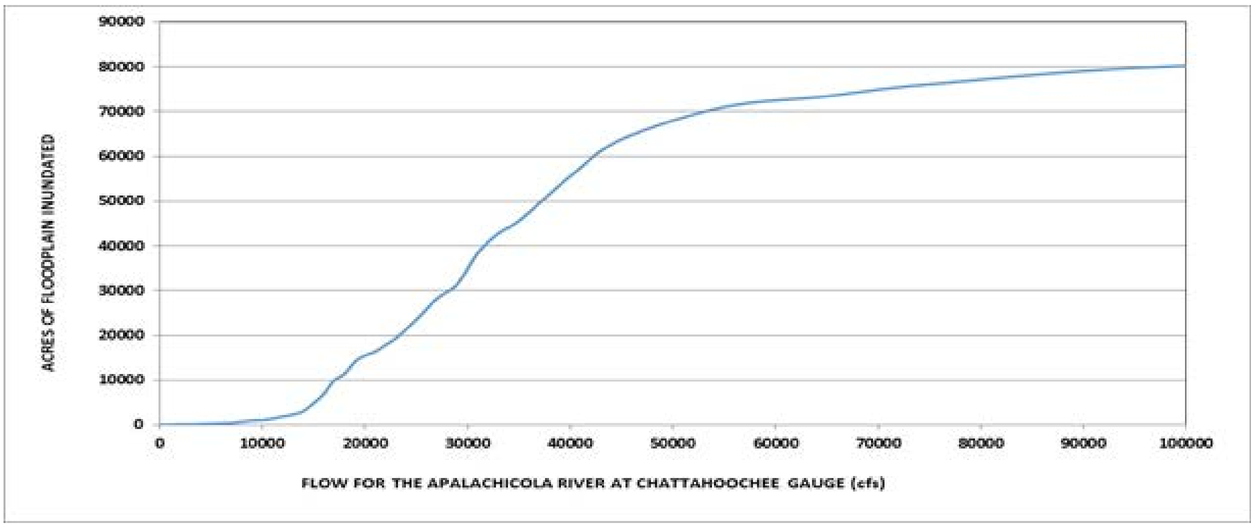


Figure 2.7 Relationship between flow and acres of floodplain inundation in the Apalachicola River based on the Chattahoochee gage (from Light et al. 1998).

Low Flows: Extreme low flows are likely among the most stressful natural events faced by riverine biota (Cushman 1985, Kingsolving and Bain 1993). Low flow constricts available habitat and portions of the channel become dry. Aquatic animals that are unable to move to remaining pools or burrow into the moisture of the streambed itself perish. 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.

Because consumptive demands are a relatively greater percentage of flow at extreme low flows, consumptive withdrawals have the greatest influence on the flow regime and the need for augmentation release at these low flows. Under the WCM, the average total consumptive withdrawals from the basin are >1,700 cfs/day or about 1/3 the minimum release called for under the 5,000 cfs drought trigger release. The average daily consumptive withdrawals under the baseline (NAA) are 1,484 cfs/day.

Seasonality: A seasonally variable flow regime is for many reasons vital to the health of the riverine ecosystem. Many riverine organisms have life history features that are adapted to seasonal patterns of river flow (Poff et al. 1997). Seasonal flow adaptations of mussels have not been investigated, but 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).

As discussed earlier, the natural seasonality in precipitation in the ACF Basin with lower flows during the late summer and early fall period (USACE 2015 p. 2-9). In general, the distributions of monthly flow for January, June, September, October, and December are similar between the two periods (see Figures 3.3.3.A and 3.3.3.B in USFWS 2012), but median monthly flow is higher in February and March and lower in April, May, July, August, and November in the post-West Point period.

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).

2.2 Baseline Flow Regime

Because the proposed action is an operational plan that prescribes the reservoir release rules which define 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 USACE's 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 WCM.

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 the dam releases and ramping rates under the WCM 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 1922, with 1923 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 only other ACF main-channel dam that has appreciable storage capacity is Bartlett's Ferry Reservoir on the Chattahoochee River. The capacity of Bartlett's Ferry is less than 10% of Lanier's capacity, and less than 5% of the total capacity of the USACE's ACF projects. The USACE's full complement of ACF projects were not completed until October 1974, when operations of West Point Reservoir began.

In the BA, the USACE presents the observed flow regime from the post-West Point years, 1975 to 2011 (37 years), as the environmental baseline for consultation purposes. This period represents the full history of the present configuration of the USACE's ACF projects through 2011, which is the last year used in simulations of alternatives for the EIS. This approach is consistent with the approach of previous BOs for the Apalachicola River (USFWS 2008, 2012). The USACE's modeling of alternatives (see Appendix A) used hydrologic data ending in 2011, but they recognize that the environmental baseline also includes the years from 2011 to the present.

The use of observed flows since 1975 as the baseline presents a challenge for interpreting the effects of management alternatives relative to no action, because USACE's operations have changed incrementally over the post-West Point period. The earliest changes were documented in a draft WCM in 1989. Additional changes in water control operations have occurred since 1989, some of which are reflected in the current operations and in the proposed WCM. 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. Also embedded in observed flows are changes in land use, water demands, and other factors. Recognizing the challenge of interpreting effects of proposed operations relative to observed flows, the USACE also provides simulated flows for NAA in the BA. The NAA flows are a model simulation of the current operations and levels of water demands used to manage the ACF projects since the 2012 BO projected onto the 1975-2011 period of record in the BA, and onto the 1939-2011 period of record in the EIS.

The USACE's modeling of the NAA and the proposed management changes in the BA (i.e., WCM), rests on the calculation of an unimpaired flow (UIF) data set. The following is an excerpt from the DEIS (USACE 2015, p 2-101).

> "The unimpaired flow data set is historically observed flows, adjusted for some of the human influences within the basin. Man-made changes influence water flow characteristics and are reflected in measured flow records. Determining critical yield [UIF] requires removing from the observed flow measurements any identifiable and quantifiable man-made changes, such as municipal and industrial water withdrawals and returns, agricultural water use, and increased evaporation and runoff due to the construction of federal surface water reservoirs. These quantities are used to extrapolate diversions, defined as the difference between water withdrawn and water returned to the system. A diversion is a net volume or quantity assumed to be permanently lost from the

> water system. The unimpaired flow data set is not a perfect representation of conditions that would exist without the influence of human activities or a precise measure of natural flow conditions. Not all human influences, such as land use changes, are accounted for, and many flow-set adjustments are estimates based on assumptions, not direct measurements of the human influences. The unimpaired flow data set in the updated 2014 analysis for the ACF Basin includes data for the period from 1939 through 2012."

Although observed flows are those that the action area, listed species, and designated critical habitat therein have actually experienced, we must recognize the advantages of comparing simulated flows for the NAA with simulated flows for the WCM (the proposed action) to estimate the effects of the proposed action. Such simulation to simulation comparisons of flows computed from the same model, both relying on the same UIF data set, removes the complication of determining whether changes apparent in the simulated flows for the WCM relative to the observed flows are due to operations, demands, and/or other factors that have varied over the period of record. Additionally, simulation comparisons from the same model will isolate the number of differences between the baseline and WCM since the only differences between the baseline and WCM will be the proposed operational changes. Historical flows have different consumptive demands each year and variable reservoir operations over time and other factors that have varied over the period of records; therefore, complicating the interpretation of the effects of the operational changes in the WCM. Using the NAA simulation as the environmental baseline allows more straightforward and clearer interpretation of the changes in management described in the WCM.

Another advantage of using simulated flows under the NAA as environmental baseline is the potential to use the full period of record for the UIF (1939-2012), which incorporates 74 years of the basins' hydrologic variability, including the lowest observed average annual flow year, 2012. Rather than focusing on the 1975-2011 period as in the USACE BA, we use the entire range of the unimpaired flow data set for the ACF Basin from 1939 through 2012. We use simulated flows for these 74 years under the no action alternative management scenario as the environmental baseline. Since flows in 2013 – 2015 were not as exceptional as in 2012, and we have no estimate of unimpaired flows for these years, we do not include these years in the baseline flow regime.

The major distinguishing feature of the 2012 drought was the extreme low discharge experienced in the Flint River basin (Leitman et al. 2016). Average annual discharge for the Flint River at Bainbridge, Georgia (USGS gage#0235800) was about 73.5 cms (cubic meters per second) (2,597 cubic feet per second), which is only 33% of the average annual flow 1939 to 2012 (this time period includes both observed and synthesized flows to fill in data gaps). This discharge is lower than in recent droughts, such as in 2007 when average annual discharge was about 69% of the average annual flow from 1939 to 2012. Although the USACE computed and provided the USFWS unimpaired flow data for 2012, the USACE did not rely on these data for the EIS or the BA, because they have not received consumptive water use data from Alabama and Florida necessary to finalize the data set (USACE, Mobile District, James Hathorn Jr., pers. comm. 6/6/2016). USFWS estimated Alabama and Florida water use data for 2012 instead based on 2011 data (Appendix A).

We have elected to use the 2012 unimpaired data provided by the USACE in our analyses for this BO. We believe that the lack of availability of the Alabama and Florida demands for 2012 does not negate the value of using the lowest-flow-year of record in our analyses. We base this decision on the following considerations regarding demands in those reaches of the basin that include Alabama and/or Florida:

1) the bulk of the demands in the Whitesburg reach (the northernmost reach affected by Alabama demands) are associated with Georgia water users, most notably the City of LaGrange, Georgia;
2) users in the West Point reach are in both Georgia and Alabama;
3) the bulk of the water use in the Columbus reach is by the City of Columbus, Georgia;
4) the bulk of the water use in the Woodruff reach is from agricultural users in the lower Flint Basin and in Spring Creek, both entirely in Georgia; and
5) all of the Florida demands are withdrawn downstream of Jim Woodruff Dam, and do not influence reservoir operations at Jim Woodruff Dam.

All of the withdrawals in the Flint Basin are associated with Georgia demands. The combined total demands for 2011, which were replicated for computing 2012 UIF data, are an annual average of 1,482 cfs, which is approximately 33% percent of the USACE's releases of 4,500 cfs during extreme drought conditions. Even if applying 2011 Alabama and Florida demands to the 2012 UIF computations is off by an order of magnitude, which is unlikely, this inaccuracy is not significant in our analysis, which compares the simulated flows under the WCM to NAA as the baseline. USACE provided USFWS with the 2012 HEC-ResSim data to facilitate comparison of model outputs under both the HEC-ResSim and ACF STELLA models (see details in Appendix A) for the full period of record (USACE, Mobile District, James Hathorn Jr., pers. comm. 8/30/2016). USFWS acknowledges that these 2012 HEC-ResSim data remain provisional until Alabama and Florida provide demand data. Any error in the estimated 2012 Alabama and Florida demands data is the same error in both simulations, and relative differences between the two inform our interpretation of the effects of the proposed action. Further, any error in the 2012 UIF data does not perpetuate through subsequent years of the simulation, since 2012 is the last year in the period of record.

2.3 Related Federal Actions

2.3.1 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 USACE's 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 USACE bypassed six miles of the main channel by widening and straightening an alternate channel through the River Styx and Moccasin Slough.

By 1881, the USACE 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.

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 USACE's application to renew its certification under section 401 of the Clean Water Act for maintaining the navigation channel. In July of 2006, the USACE 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. Supporting a seasonal navigation channel with flows is a feature of the proposed WCM. At this time, the USFWS is unaware of any intentions for the USACE to resubmit an application to maintain the navigation channel with dredging.

2.3.2 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 with the exception of Flood Risk Management, which has a dedicated flood pool at West Point and Lake Lanier. Under the Water Supply Act of 1958, the USACE 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 USACE authorize water withdrawals or provide for storage in support of water supply. 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. Significant changes in any operations described above that would appreciably alter the effects analysis of this BO would require reinitiation of this consultation.

2.4 Unrelated Federal Actions

The following section describes Federal projects in the action area that have completed formal or informal consultation under section 7 of the Act. Federal actions affecting the same species or critical habitat that have completed for which formal or informal consultation has been completed represent part of the NAA environmental baseline, as are do Federal and other actions within the action area that may benefit listed species or critical habitat.

The USACE 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 appropriate Federal agencies to determine if consultation under the Act is required. At this point, the collective effects of these actions are relatively minor compared to the USACE operations of the reservoirs of the ACF. Nevertheless, they are part of the body of activities that affect listed species and designated critical habitat in the action area.

2.5 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 USACE's 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 USACE's operations, but may influence flow downstream of Woodruff Dam. As is addressed later in this document, historical and ongoing water use, including that for agricultural, industrial, and municipal uses, has a substantial impact during droughts on the availability of water for use by the USACE in their reservoir operations.

3 GULF STURGEON - STATUS OF THE SPECIES

3.1 Species Description

The Gulf sturgeon (*Acipenser oxyrinchus desotoi*) is an anadromous fish (it breeds in freshwater after migrating up rivers from marine and estuarine environments) that inhabits coastal rivers from Louisiana to Florida during the warmer months and over-wintering in estuaries, bays, and the Gulf of Mexico. It is a nearly cylindrical primitive fish covered by bony plates or scutes. The head ends in a hard, extended snout; the mouth is inferior (bottom oriented) and protrusible (capable of being extended) and is preceded by four conspicuous barbels. The caudal fin (tail) is heterocercal (upper lobe is longer than the lower lobe). Adults range from 1.2 to 2.4 m (4 to 8 ft) in length, with adult females larger than males. The Gulf sturgeon is distinguished from the geographically disjunct Atlantic coast subspecies (*A. o. oxyrinchus*) by its longer head, pectoral fins, and spleen (Vladykov 1955, Wooley 1985). King et al. (2001) documented substantial divergence between *A. o. oxyrinchus* and *A. o. desotoi* using microsatellite DNA testing.

Within the species, Gulf sturgeon exhibit river fidelity (USFWS 1995). Stabile et al. (1996) identified five regional or river-specific stocks (from west to east): (1) Lake Pontchartrain and Pearl River, (2) Pascagoula River, (3) Escambia and Yellow Rivers, (4) Choctawhatchee River, and (5) Apalachicola, Ochlockonee, and Suwannee Rivers. Dugo et al. (2004) reported that genetic structure occurs at the drainage level for the Pearl, Pascagoula, Escambia, Yellow, Choctawhatchee, and Apalachicola rivers (no samples were taken from the Suwannee population). Additional genetic studies by Brian Kreiser at the University of Southern Mississippi indicate that there is strong population structure in all rivers across its range, and a clear difference between populations east and west of Mobile Bay. Gulf sturgeon do make some inter-river movements (USFWS unpublished data), and more genetic research is needed to determine if inter-stock movement is resulting in inter-stock reproduction.

3.2 Critical Habitat Description

The USFWS and National Marine Fisheries Service (NMFS) jointly designated Gulf sturgeon critical habitat effective April 18, 2003 (68 FR 13370, March 19, 2003). Gulf sturgeon critical habitat includes areas within the major river systems defined in each unit as the ordinary high water line on each bank of the associated rivers and shorelines that support the seven currently reproducing subpopulations and associated estuarine and marine habitats. Gulf sturgeon use river habitats during spawning, larval and juvenile feeding, adult resting and staging, and moving between the areas that support these life history components. Gulf sturgeon use the lower riverine, estuarine, and marine environment during winter months primarily for feeding and for inter-river movements.

Fourteen areas (units) are designated as Gulf sturgeon critical habitat (Figure 3.1). Critical habitat units encompass approximately 2,783 km (1,729 mi) of riverine habitats and 6,042 km^2 (2,333 mi^2) of estuarine and marine habitats, and include portions of the following Gulf of Mexico rivers, tributaries, estuarine and marine areas:

Unit 1	Pearl and Bogue Chitto Rivers in Louisiana and Mississippi;
Unit 2	Pascagoula, Leaf, Bowie, Big Black Creek and Chickasawhay Rivers in Mississippi;
Unit 3	Escambia, Conecuh, and Sepulga Rivers in Alabama and Florida;
Unit 4	Yellow, Blackwater, and Shoal Rivers in Alabama and Florida;
Unit 5	Choctawhatchee and Pea Rivers in Florida and Alabama;
Unit 6	Apalachicola and Brothers Rivers in Florida;
Unit 7	Suwannee and Withlacoochee River in Florida;
Unit 8	Lake Pontchartrain (east of causeway), Lake Catherine, Little Lake, the Rigolets, Lake Borgne, Pascagoula Bay and Mississippi Sound systems in Louisiana and Mississippi, and sections of the state waters within the Gulf of Mexico;
Unit 9	Pensacola Bay system in Florida;
Unit 10	Santa Rosa Sound in Florida;
Unit 11	Nearshore Gulf of Mexico in Florida;
Unit 12	Choctawhatchee Bay system in Florida;
Unit 13	Apalachicola Bay system in Florida; and
Unit 14	Suwannee Sound in Florida.

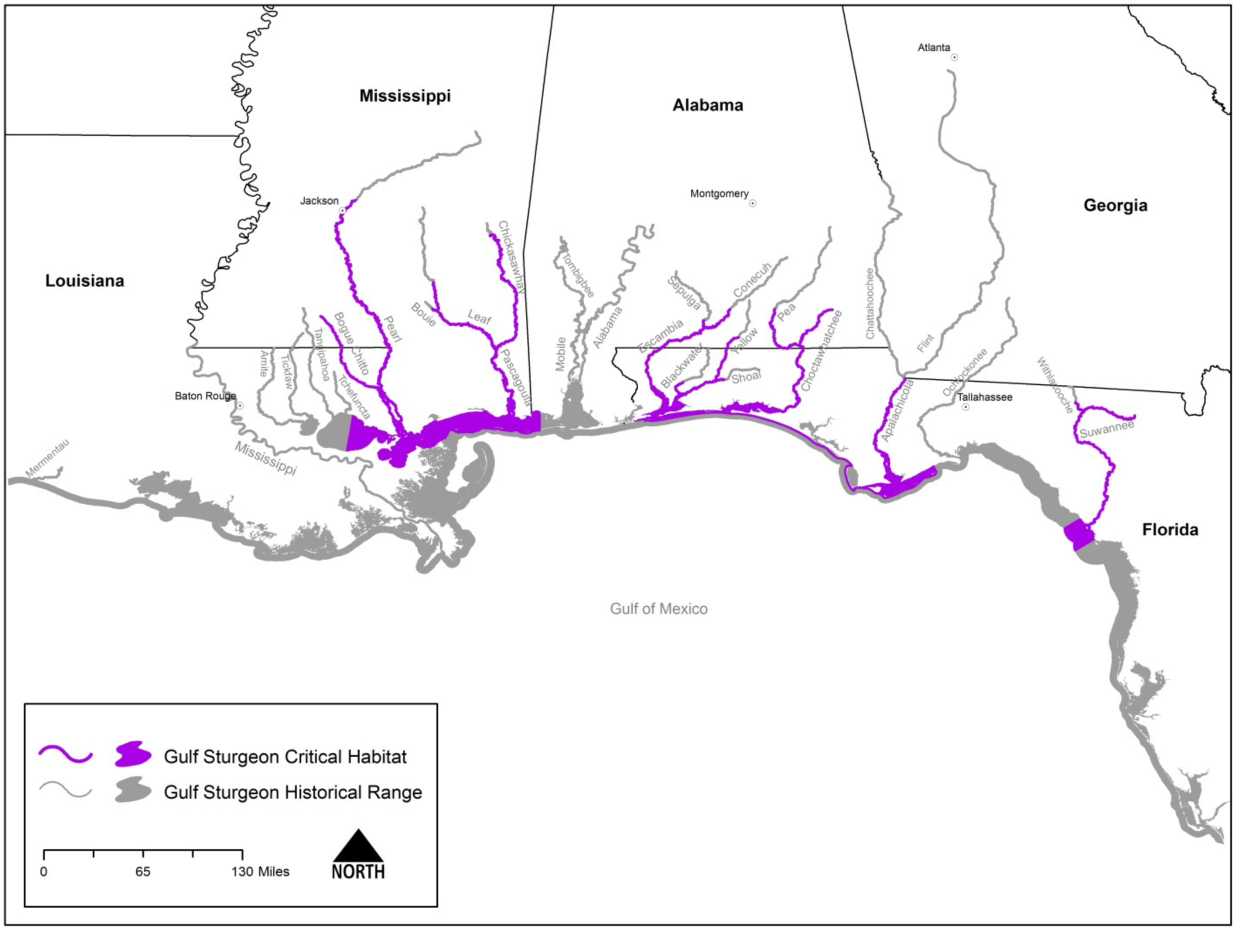


Figure 3.1. Designated critical habitat and historic range of Gulf sturgeon.

Critical habitat determinations focus on those physical and biological features (primary constituent elements [PCEs]) that are essential to the conservation of the species (50 CFR 424.12). Federal agencies must ensure that their activities are not likely to result in the destruction or adverse modification of designated critical habitats. Therefore, proposed actions that may affect designated critical habitat require an analysis of potential impacts to the PCEs. The PCEs of Gulf sturgeon critical habitat are:

- Abundant food items, such as detritus, aquatic insects, worms, and/or mollusks, within riverine habitats for larval and juvenile life stages; and abundant prey items, such as amphipods, lancelets, polychaetes, gastropods, ghost shrimp, isopods, mollusks and/or crustaceans, within estuarine and marine habitats and substrates for subadult and adult life stages;
- Riverine spawning sites with substrates suitable for egg deposition and development, such as limestone outcrops and cut limestone banks, bedrock, large gravel or cobble beds, marl, soapstone, or hard clay;
- Riverine aggregation areas, also referred to as resting, holding, and staging areas, used by adult, subadult, and/or juveniles, generally, but not always, located in holes below normal

riverbed depths, believed necessary for minimizing energy expenditures during freshwater residency and possibly for osmoregulatory functions;
- A flow regime (i.e., the magnitude, frequency, duration, seasonality, and rate-of-change of freshwater discharge over time) necessary for normal behavior, growth, and survival of all life stages in the riverine environment, including migration, breeding site selection, courtship, egg fertilization, resting, and staging, and for maintaining spawning sites in suitable condition for egg attachment, egg sheltering, resting, and larval staging;
- Water quality, including temperature, salinity, pH, hardness, turbidity, oxygen content, and other chemical characteristics, necessary for normal behavior, growth, and viability of all life stages;
- Sediment quality, including texture and other chemical characteristics, necessary for normal behavior, growth, and viability of all life stages; and
- Safe and unobstructed migratory pathways necessary for passage within and between riverine, estuarine, and marine habitats (e.g., an unobstructed river or a dammed river that still allows for passage).

3.3 Life History

Lifespan: Like most sturgeons, the Gulf sturgeon is characterized by large size, longevity, delayed maturation, high fecundity, and far-ranging movements. Gulf sturgeon typically live for 20-25 years, but can reach ages of at least 42 years old (Huff 1975). Age at sexual maturity ranges from 8-12 years for females and 7-9 years for males (Huff 1975). High fecundity has been demonstrated by Chapman et al. (1993), who estimated that mature female Gulf sturgeon weighing between 29 and 51 kg (64 and 112 lb) produce an average of 400,000 eggs, although females do not spawn annually (Sulak and Clugston 1999, Pine et al. 2001). Long-range migrations from the open Gulf of Mexico to bays and estuaries to coastal rivers are also common. Migratory behavior of the Gulf sturgeon is likely influenced by sex and reproductive status (Fox et al. 2000), change in water temperature (Wooley and Crateau 1985, Chapman and Carr 1995, Foster and Clugston 1997), and increased river flow (Chapman and Carr 1995, Heise et al. 1999a, b, Sulak and Clugston 1999, Ross et al. 2000 and 2001b, Parauka et al. 2001).

Reproduction: In general, Gulf sturgeon migrate into rivers in the spring (from late February to May), where sexually mature sturgeon spawn when the river temperature rises to between 17-25°C. Similar to Atlantic sturgeon, Gulf sturgeon are believed to exhibit a long inter-spawning period, with male Gulf sturgeon capable of annual spawning, but females requiring more than one year between spawning events (Huff 1975, Fox et al. 2000) and only a small percentage of females spawn in a given year (Sulak and Clugston 1999, Pine et al. 2001). Therefore, Gulf sturgeon population viability is highly sensitive to changes in adult female mortality and abundance (Pine et al. 2001, Flowers 2008).

Spawning occurs in the upper reaches of rivers, at least 100 km (62 miles) upstream of the river mouth (Sulak et al. 2004), in habitats consisting of one or more of the following: limestone bluffs and outcroppings, cobble, limestone bedrock covered with gravel and small cobble, gravel, and sand (Marchant and Shutters 1996, Sulak and Clugston 1999, Heise et al. 1999a, Fox et al. 2000, Craft et al. 2001, Pine et al. 2006, USFWS unpublished data). These hard bottom substrates are required for egg adherence and shelter for developing larvae (Sulak and Clugston 1998). Documented spawning depths range from 1.4 to 7.9 m (4.6 to 26 ft) (Fox et al. 2000, Ross et al. 2000, Craft et al. 2001, Pine et al. 2006, USFWS unpublished data).

Some adult Gulf sturgeon may also spawn in the fall (around September), as suggested from collection of migrating ripe males and females and length-at-age data of spring juveniles, and telemetry data in the Suwannee River, Florida (Sulak and Clugston 1998, Randall and Sulak 2012). Studies in the closely related Atlantic sturgeon have also demonstrated a fall spawning run in multiple major river drainages (Collins et al. 2000, Balazik and Musick 2015, Balazik et al. 2012, Smith et al. 2015). It is likely that Gulf sturgeon populations, throughout the range, or at least portions of some river strains, may spawn in the fall.

Eggs and larvae: Gulf sturgeon eggs are demersal (sink to or near the river bed) and adhesive, and require at least 2 to 4 days to hatch (Parauka et al. 1991, Chapman et al. 1993). After hatching, larval Gulf sturgeon are particularly sensitive to water temperatures above 25°C (Chapman and Carr 1995). Young-of-year fish disperse widely throughout the river and remain in freshwater for 10 to 12 months after spawning occurs (Sulak and Clugston 1999). They are typically found in open sand-bottom habitat away from the shoreline and vegetated habitat.

Holding areas: Throughout early spring to late autumn, Gulf sturgeon of all ages remain in freshwater until fall (6 to 9 months) (Odenkirk 1989, Foster 1993, Clugston et al. 1995, Fox et al. 2000, Sulak et al. 2009). They typically occupy discrete areas either near the spawning grounds (Wooley and Crateau 1985, Ross et al. 2001b) or downstream areas referred to as holding areas. These holding areas vary in depth, ranging from 2 to 19 m (6.6 to 62.3 ft) deep (Wooley and Crateau 1985, Morrow et al. 1996, Ross et al. 2001a, b, Craft et al. 2001, Hightower et al. 2002), and frequently near (not in) natural springs (Clugston et al. 1995, Foster and Clugston 1997, Hightower et al. 2002). The substrates consist of mixtures of limestone and sand (Clugston et al. 1995), sand and gravel (Wooley and Crateau 1985, Morrow et al. 1996), or just sandy substrate (Hightower et al. 2002).

Migration: Non-young of year begin to migrate downstream from fresh to saltwater around September (at about 23°C [73°F]) through November (Huff 1975, Wooley and Crateau 1985, Foster and Clugston 1997), and they spend the cool months in estuarine areas, bays, or in the Gulf of Mexico (Odenkirk 1989, Foster 1993, Clugston et al. 1995, Fox et al. 2002). During the fall migration, Gulf sturgeon may require a period of physiological acclimation to changing salinity levels, referred to as osmoregulation or staging (Wooley and Crateau 1985). This period may be short (Fox et al. 2002) as sturgeon develop an active mechanism for osmoregulation and ionic balance by age 1 (Altinok et al. 1998).

Feeding: With the exception of young of year fish, Gulf sturgeon do not typically feed during freshwater residency (Mason and Clugston 1993; Gu et al. 2001). Sulak et al. (2012) reported that the vast majority (~94%) of juvenile, subadult, and adult Gulf sturgeon sampled from the Suwannee River exhibited complete feeding cessation for the 8-9 month summer residency; however, a small percentage (~6%) of juveniles and subadults did feed in freshwater.

Throughout fall and winter, juveniles feed in the lower salinity areas in the river mouth and estuary (Sulak and Clugston 1999, Sulak et al. 2009), while subadults and adults migrate and feed in the estuaries and nearshore Gulf of Mexico habitat (Foster 1993, Foster and Clugston 1997, Edwards et al. 2003, Edwards et al. 2007, Parkyn et al. 2007). Some Gulf sturgeon may also forage in the open Gulf of Mexico (Edwards et al. 2003).

The Gulf sturgeon is a benthic (bottom dwelling) suction feeder; it feeds mostly upon small invertebrates in the substrate using its highly protrusible tubular mouth. The type of invertebrates ingested varies by habitat but are mostly soft-bodied animals that occur in sandy substrates. Young-of-the-year Gulf sturgeon feed on freshwater aquatic invertebrates, mostly insect larvae and detritus (Mason and Clugston 1993, Sulak and Clugston 1999, Sulak et al. 2009). Juveniles (less than 5 kg (11 lbs), ages 1 to 6 years) forage in lower salinity habitats near the river mouth and in the estuaries, and subadults and adults feed in the estuary and nearshore feeding grounds in the Gulf of Mexico (Foster 1993, Foster and Clugston 1997, Edwards et al. 2003, Edwards et al. 2007, Parkyn et al. 2007). Prey in estuarine and marine habitats include amphipods, brachiopods, lancelets, polychaetes, gastropod mollusks, shrimp, isopods, bivalve mollusks, and crustaceans (Huff 1975, Mason and Clugston 1993, Carr et al. 1996, Fox et al. 2000, Fox et al. 2002). Ghost shrimp (*Lepidophthalmus louisianensis*) and haustoriid amphipods (e.g., Lepidactylus spp.) are strongly suspected to be important prey for adult Gulf sturgeon over 1 m (3.3 ft) in length (Heard et al. 2000, Fox et al. 2002).

Marine movement, habitat, and feeding data indicate that Gulf sturgeon prefer open, sandy habitat containing high abundances of known benthic prey (Fox et al. 2002, Parauka et al. 2001, Harris et al. 2005). In bays and estuaries, Gulf sturgeon generally prefer shallow areas (depths less than 3.5 m, 11.5 ft) (Parauka et al. 2001, Craft et al. 2001) or deep holes near passes (Craft et al. 2001). Gulf sturgeon using nearshore Gulf of Mexico areas are generally found at depths less than 6-10 m (33 ft) (Ross et al. 2001a, Fox et al. 2002, Rogillio et al. 2002). Generally, fish are found in nearshore areas off Perdido Bay and between Pensacola and Apalachicola bays (Fox et al. 2002, USFWS unpublished data) and in the Mississippi Sound along the barrier islands, where they are relocated most often at the passes between islands (Ross et al. 2001a, Rogillio et al. 2002). Telemetry-tagged Gulf sturgeon from different natal river systems are regularly detected in the same marine foraging areas.

3.4 Population Status

Historically, the Gulf sturgeon occurred from the Mississippi River east to Tampa Bay (Figure 3.1). Its present range extends from Lake Pontchartrain and the Pearl River system in Louisiana and Mississippi east to the Suwannee River in Florida. Sporadic occurrences have been recorded as far west as the Rio Grande River between Texas and Mexico, and as far east and south as Florida Bay (Wooley and Crateau 1985, Reynolds 1993).

In the late 19th century and early 20th century, the Gulf sturgeon supported an important commercial fishery, providing eggs for caviar, flesh for smoked fish, and swim bladders for isinglass, which is a gelatin used in food products and glues (Huff 1975, Carr 1983). Gulf sturgeon numbers declined due to overfishing throughout most of the 20th century. The decline was exacerbated by habitat loss associated with the construction of dams and sills (low dams), mostly after 1950. In several rivers throughout the species' range, dams and sills have severely restricted sturgeon access to historic migration routes and spawning areas (Wooley and Crateau 1985, McDowall 1988).

On September 30, 1991, the USFWS and the National Marine Fisheries Service (NMFS) listed the Gulf sturgeon as threatened under the Act (56 FR 49653). Threats and potential threats identified in the listing rule included: construction of dams, modifications to habitat associated with dredging, dredged material disposal, de-snagging (removal of trees and their roots) and other navigation maintenance activities; incidental take by commercial fishermen; poor water quality associated with contamination by pesticides, heavy metals, and industrial contaminants; aquaculture and incidental or accidental introductions; and the Gulf sturgeon's long maturation and limited ability to recolonize areas from which it is extirpated.

The USFWS and NMFS conducted a 5 year status review in 2009 concluding that the following threats continue to affect Gulf sturgeon and its habitat: impacts to habitats by dams, dredging, point and nonpoint discharges, climate change, bycatch, red tide, and collisions with boats (USFWS and NMFS 2009). Additional threats may include ship strikes and potential hybridization due to accidental release of non-native sturgeon. These threats persist to varying degrees in different portions of the species range. The juvenile stage of Gulf sturgeon life history is the least understood, and perhaps the most vulnerable as this cohort remains in the river for the first years of its life and is therefore exposed to most of the threats faced by the species and its habitat. Further, the species long-lived, late-maturing, intermittent spawning characteristics make recovery a slow process.

Currently, seven rivers are known to support reproducing populations of Gulf sturgeon. There is little interchange of individuals across rivers, so it is important to maintain populations within each of the rivers. Table 3.1 lists these rivers and most-recent estimates of population size. Abundance numbers indicate a roughly stable or slightly increasing population trend over the last decade in the eastern river systems (Florida), with a much stronger increasing trend in the Suwannee River and a possible decline in the Escambia River. Populations in the western portion of the range (Mississippi and Louisiana) have never been nearly as abundant in recent history, and their current status is unknown because comprehensive surveys have not occurred in the past ten years.

At this time, the USFWS characterizes the overall status of the species, and the status of the Apalachicola River system population, as "stable", although the status of populations in the Pearl and Pascagoula rivers is uncertain. We do not have current population estimates for these two rivers that have recently been threatened by flooding and riparian alteration from the effects of hurricanes, the Deepwater Horizon oil spill, and a recent pot-liquor spill in the Pearl River. The Gulf sturgeon continues to meet the definition of a threatened species. While some riverine populations number in the thousands, abundance of most populations is estimated in the hundreds. Loss of a single year class could be catastrophic to some riverine populations with low abundance. Data are not yet available to determine if Gulf sturgeon recovery is currently most limited by factors affecting recruitment (e.g., spawning habitat quantity or quality), adult survival (e.g., incidental catch in fisheries directed at other species), or the late-maturing, intermittent reproductive characteristics of the species.

Table 3.1. Estimated size of known reproducing subpopulations of Gulf sturgeon.

River	Year of data collection	Abundance Estimate*	Lower Bound 95% CI	Upper Bound 95% CI	Source
Pearl	2001	430	323	605	Rogillio et al. 2001
Pascagoula	2000	216	124	429	Ross et al. 2001
Escambia**	2015	373	241	576	USFWS unpublished data
Yellow	2011	1,036	724	1,348	USFWS unpublished data
Blackwater***	2013	437	362	550	USFWS unpublished data
Choctawhatchee	2008	3,314	NR	NR	USFWS 2009
Apalachicola	2014	1,288	1,081	1,606	USFWS unpublished data
Suwannee	2012	7,228	5,375	9,771	Randall 2013

*CI = confidence interval. NR = not reported.
**This estimate includes only fish >90 cm fork length.
***The Blackwater River is not one of the seven known reproducing subpopulations. It is considered part of the Yellow River spawning population.

3.5 Analysis of the Species/Critical Habitat Likely to be Affected - Gulf sturgeon

This BO addresses effects of the USACE's water management operations under the WCM and the associated releases to the Apalachicola River on the Gulf sturgeon and its designated critical habitat. 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 and Apalachicola Bay are designated as critical habitat for the Gulf sturgeon. Of the 14 designated critical habitat units, the Apalachicola River is identified as Unit 6, and Apalachicola Bay is Unit 13 (68 FR 13370, March 19, 2003). Unit 6 includes the Apalachicola and Brothers Rivers in Florida. Unit 13 includes the main body of Apalachicola Bay and its adjacent sounds, bays, and the nearshore waters of the Gulf of Mexico. Therefore, we limit this analysis of effects on Gulf sturgeon critical habitat to Unit 6, and those portions of Unit 13 affected by operation of Woodruff Dam under the WCM.

4 GULF STURGEON - ENVIRONMENTAL BASELINE

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. In the case of an ongoing water project, such as USACE's update to the WCM, 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, forms the environmental baseline (USFWS 1998b). Within the action area, various federal, state, and private actions affect the ACF basin ecosystem and the listed species considered in this opinion. Section 2 and Appendix A of this opinion have a detailed description of the effects of past and ongoing human and natural factors representing the physical baseline of the action area including hydrology, land use, river morphology, and water quality. This section describes current status of the species, its habitat (including designated critical habitat), and ecosystem, within the action area and is intended to set the stage for the analysis of the effects of the action.

4.1 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.

Current Distribution in the Action Area

Our knowledge of the status and distribution of Gulf sturgeon in the action area is continually updated with regular population monitoring and increased efforts in mark-recapture, passive acoustic monitoring, and side scan sonar since the original IOP BO in 2006 on flow management from Jim Woodruff Dam and subsequent consultations on revisions to the interim operating procedures (USFWS 2006, 2008, 2012).

Population Status and Trends in the Action Area

Total ACF Population

- 2014 data - 1,288 (95% CI = 1,081to 1,606; includes all Age 1+ fish, does not include young-of-the-year)
- Population considered stable – no downward/upward population trends will be considered in baseline
- Population abundance considered below recovery objectives; population considered to be small relative to historic abundance

Total Spawning Adults

- Males can spawn every year
- Females require more than one year between spawning events
- Small percentage of females spawn in a given year

Eggs

- Number of eggs not identified in baseline

- Female produces average of 400,000 eggs

Young-of-the-year

- Unknown numbers produced in recent cohorts; methods to reliably estimate YOY abundance not available at this time

Juveniles

- Juveniles represent Age 1 to 6
- Year class abundance has been estimated at Age 1 for the past 4 years (2013-2016); cohort abundance ranges from ~50-200 fish per year

4.2 Factors Affecting Species Environment within the Action Area

Gulf sturgeon spawning: The life cycle of the Gulf sturgeon begins at spawning. Gulf sturgeon deposit adhesive eggs onto hard bottom substrates such as limestone, claystone, cobble, and gravel primarily during spring (Sulak and Clugston 1999). Recent work has provided some evidence of possible spawning during the fall in the Suwannee River (Randall and Sulak 2012). Studies conducted 2006-2008 identified nine discrete areas of hard bottom substrate in the upper Apalachicola River; spawning was confirmed at 3 of these locations by collecting sturgeon eggs (Flowers et al. 2009, Parauka and Giorgianni 2002, Pine et al. 2006, Scollan and Parauka 2008, Wooley et al. 1982, 1985, Ziewitz 2006; Table 4.1).

Table 4.1 Known spawning sites and areas of hard bottom substrate appropriate for spawning.

	Site	RM
1*	Woodruff Tailrace – Race Shoals*	104.7 -106.3
2	Jackson County Port	103.5
3*	Flat Creek / I-10	100.2 – 100.3
4*	Aspalaga Landing	99.0 – 99.2
5	Short Creek	95.2
6	Ocheesee	93.48 – 93.5
7	Rock Bluff Landing	92.2 – 92.7
8	Alum Bluff	83.7 – 84.5
9	Bristol Bluff	80.3 – 81.2

* known spawning sites

Post-spawning early life stages- egg incubation to larval dispersal and foraging: Gulf sturgeon have been observed to spawn in the Apalachicola within a range of temperatures of 17 to 25 C (USFWS 2008); spawning in the Suwannee River has been observed between 17 and 23 C (Sulak and Clugston 1999). Using water temperature data from the Chattahoochee gage, analyzed and presented in USFWS (2008), the mean date by which water temperature rises to 17 C in the Apalachicola River is March 26 (range: January 23 to April 14) and to 25 C is May 23 (range: May 12 to June 29) (Figure 4.1). Based on the average dates, Gulf sturgeon egg deposition potentially encompasses this 58-day period. The USACE in their BA developed a HEC-5Q model to analyze WCM effects to water temperature. Figure 2.5 provides a representation of WCM annual effects to stream temperature in spring and fall. There is anecdotal evidence of a fall spawning run in the Apalachicola River (USFWS unpublished data). The temperatures experienced by sturgeon during the fall spawning season (Sept.-Nov.) are near lethal limits during the fall. Additional data on temperature fluctuations are needed to assess this possible effect.

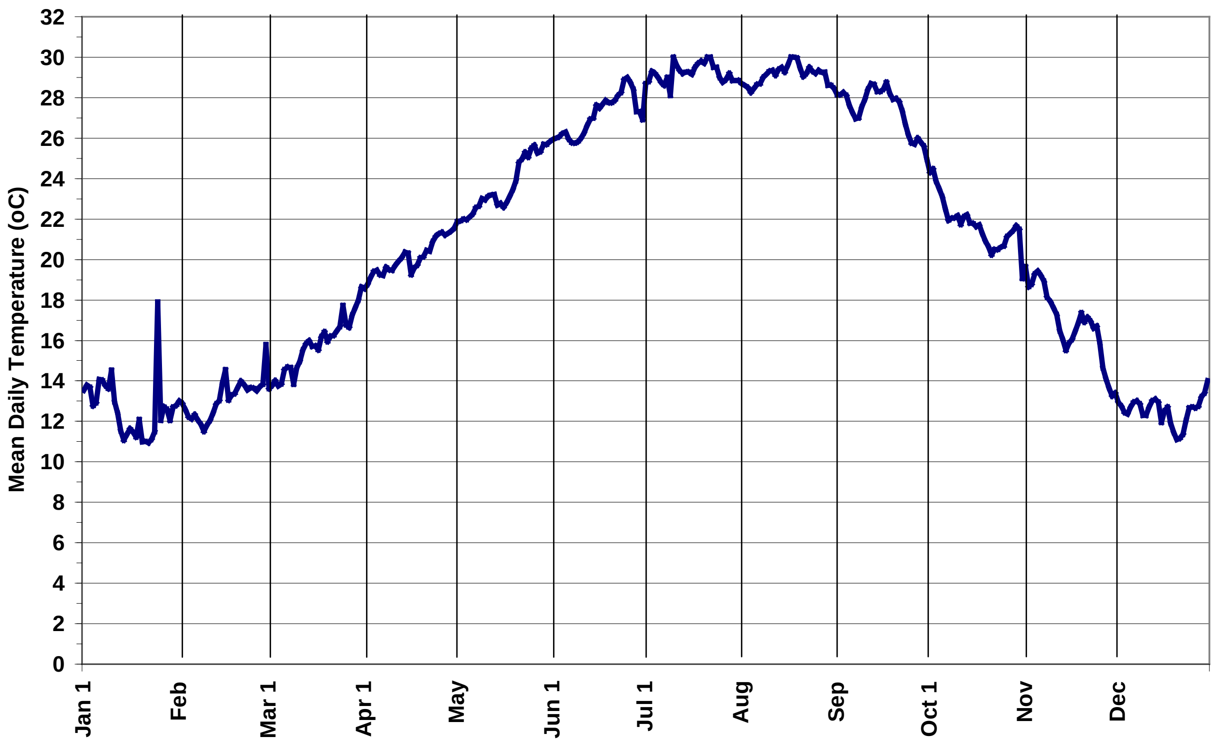


Figure 4.1 Mean daily water temperature (°C) by calendar date of the Apalachicola River near Chattahoochee, FL, calculated from available records 1974-1978 and 1996-1997 (source: USGS).

After deposition, Gulf sturgeon eggs hatch following an incubation period of a few days. Development of sturgeon eggs and embryos is likely to be most influenced by water temperature (Hardy and Litvak 2003), an association common to fish (Chambers and Leggett 1987). Hatching time for artificially spawned Gulf sturgeon eggs ranged from 85.5 hr at 18.4 C to 54.4 hr at 23.0 C (Parauka et al. 1991) and 3.5 d at 20.0 C (Chapman et al. 1993). Chapman and Carr (1995) reported high mortality of Gulf sturgeon eggs (28% hatched) and embryos (those that hatched subsequently died) at an incubation temperature of 25 C. In contrast, eggs incubated at a temperature of 20 C exhibited a hatching success of 48.5%, and eggs incubated at 15 C had a hatching success of 73% (Chapman and Carr 1995). Gulf sturgeon were observed by Scollan and Parauka (2008) to spawn in the Apalachicola River as late as May 14 (2008) at a median daily temperature of 24.22 C. These authors reported the greatest number of eggs collected on egg pads on April 18, 2008 (107 eggs) at a mean water temperature of 19-20 C; within 7 days mean water temperature at the spawning sites had reached 23 C. Pine et al. (2006) reported temperatures ranging from 20.27 to 25.31 C on days when sturgeon eggs were collected in the Apalachicola River. The successful hatching of eggs deposited during warmer water periods in the Apalachicola River is unknown, but questionable, based on laboratory evidence. Along these lines, Sulak and Clugston (1999) suggested that years of protracted, cooler conditions during the spawning period may result strong year classes of sturgeon.

Upon hatching, Gulf sturgeon embryos likely remain on the bottom in the substrate and develop into exogenously feeding larvae after 110.3 Cumulative Temperature Units (CTUs) (Parker and Kynard 2004). According to this relationship, embryos would develop into larvae in 5 days if reared at a mean daily temperature of 22 C. Parker and Kynard (2004) reported hyperactivity, cessation of feeding activity, equilibrium loss, and even some mortality of day 70-80 juvenile sturgeon when temperature increased from 21 to 23 C over a 5-hour period in the laboratory, thus the sensitivity of young sturgeon to elevated water temperatures may extend well past the larval stage.

Considering spawning observations and laboratory results, stream temperature may be critically important to sturgeon survival during the period of egg deposition, incubation and hatching, and early rearing of larval Gulf sturgeon within the upper reaches of the Apalachicola River. The importance of stream temperature to early life history stages requires an evaluation of the realized effects of water control operations on stream temperature in the zone of spawning and rearing habitat. Data on seasonal stream temperature in the Apalachicola River are limited. In order to evaluate stream temperature effects on early life stages of Gulf sturgeon we need to establish a long-term water quality monitoring program in the upper Apalachicola River.

In the amended BA, USACE provided results of water temperature simulations (see Figure 2.5 above). Although this analysis showed no difference between the WCM and baseline in terms of simulated water temperatures below Jim Woodruff Lock and Dam, the resolution of the analysis (i.e., scaled to the entire river basin), and lack of empirical, fine-scale (temporal and spatial) data feeding the analysis, suggests this assessment was inadequate to evaluate potential effects of the WCM on Gulf sturgeon within the spawning and rearing reaches of the upper Apalachicola River. The simulation results do illustrate, however, the anticipated warming of ambient water temperature that occurs as the Chattahoochee River transitions into Lake Seminole and through Woodruff Lock and Dam, between river miles ~120 to 106 (Figure 2.5). Water temperatures are likely elevated as a result of increased solar radiation acting upon the surface of the reservoir, and the change in retention time (i.e., a significant decrease in rate of streamflow through the reservoir and to the outlet at the dam). The simulation results suggest an increase in median water temperature of ~2 degrees C occurring at the Jim Woodruff Dam outlet. This warm water is subsequently released by USACE operations during the spawning and rearing period of Gulf sturgeon; the release of water with elevated temperatures is likely to affect the survival of early life stages of Gulf sturgeon, potentially resulting in a mismatch in spawning cues, egg/larval development, and/or prey availability. This warming is most prevalent in the fall, and a fall spawning run has not been documented in the ACF Basin.

The survival of Gulf sturgeon eggs and embryos at spawning sites is likely influenced by the quality and availability of heterogeneous, rocky substrates that provide adequate interstitial spaces (i.e., crevices) for hiding from predators and shelter from high flows (Crossman and Hildebrand 2014). Gulf sturgeon develop into larvae within ~8 days following egg deposition, although this rate is influenced by ambient water temperature. Importantly, sturgeon eggs and embryos remain in the substrate at the spawning site for this entire period of development (Sulak and Clugston 1999, Kynard and Parker 2004). Much of the documented spawning habitat utilized by Gulf sturgeon in the upper Apalachicola can be characterized as scoured, limestone outcroppings. Many of these outcropping were subject to historical dredging efforts for purposes of maintaining a navigation channel, an activity that may have reduced the quality and availability of heterogeneous rocky matrices for the successful development of sturgeon eggs and embryos. Unfortunately, access to a myriad of rocky patches that include gravel, cobble, and boulder substrates upstream in the Flint River (Kaeser et al. 2013) is currently blocked by Jim Woodruff Lock and Dam.

Enhancement of spawning substrate via the addition of various rocky materials (e.g., gravel, cobble, boulder) has been shown to increase the retention and growth of sturgeon embryos (McAdam 2010, Crossman and Hildebrand 2014), and provide benefits to all life history stages (Dumont et al. 2011, Roseman et al. 2011). Flows alterations during egg incubation and embryonic development may influence the retention and survival of early life stages of Gulf sturgeon, particularly in sub-optimal benthic habitats. The consequences of flow alteration (e.g., hydropeaking) during these life history phases is unknown in the upper Apalachicola River.

Upon developing into larvae, Gulf sturgeon were observed to begin slowly moving downstream, with no early peak in migration intensity as observed in other sturgeon species (Kynard and Parker 2004). These authors also observed that larval sturgeon suspended above the bottom of the artificial stream channel, exhibiting what they described as “the strongest response for this behavior we have seen in any sturgeon population”. They further suggested that this behavior may be an adaptation for feeding upon drifting invertebrates in the water column during the early stages of downstream migration; this adaptation may be a response to limited benthic forage in rearing reaches occupied by Gulf sturgeon larvae. Since larval Gulf sturgeon cannot migrate upstream past Jim Woodruff Dam, they must obtain adequate nutrition by consuming organisms in the drift or along the river bottom. Given the behavior of larval sturgeon during early exogenous foraging and dispersal, this life history stage may be particularly vulnerable to the effects of flow alteration (e.g., hydropeaking). Flow alteration may manifest in impacts to 1) the availability of habitat for invertebrate prey, 2) the timing, density, and ability to capture drifting invertebrate prey, and 3) a disruption and/or mechanical displacement of larval sturgeon in the downstream direction as they attempt to disperse from spawning areas. To date, little data are available to evaluate the effects of environmental conditions on the foraging success, survival, and dispersal of larval Gulf sturgeon in a field setting.

Gulf sturgeon larvae from the first day of dispersal are good swimmers and their downstream movement is directed swimming (Boyd Kynard, BK-Riverfish LLC, pers. comm. 8/19/16). They actively swim downstream alternating moving to the bottom to forage for several minutes with swimming downstream in the water column within a meter of so of the bottom. All evidence from shortnose sturgeon (which we have studied larval behavior for several generations) is that the duration of dispersal (number of days) is genetically set, so fish in different populations , same species, will disperse for 5-7 days, or 12-17 days, etc. (e.g., Richmond and Kynard 1995, Kynard and Horgan 2002). Natural selection likely selects for dispersal time, but like many genetic behaviors, one can reasonably hypothesize that river flow in the form of velocity detected by larvae can affect dispersal time (and thus, dispersal distance). Without a feedback mechanism from river flow (i.e., velocity), larvae might move too far downstream in high flows, enter saline water, and die. No data are available on the ability of larvae of any sturgeon species to detect and alter dispersal rate in response to flow or velocity.

Despite the lack of information on early life stages in the Apalachicola River system, the effects of flow alteration and regulation on aquatic organisms, including early life stages of other species, has been the focus of much research and discussion in the literature. Aquatic invertebrates, and habitat for these organisms, are sensitive to both long-term and short-term/episodic changes in river hydrology (Bunn and Arthington 2002, Graf 2006, Dewson et al. 2007, Bruno et al. 2010, Bruno et al. 2013, Castro et al. 2013, Bruno et al. 2016, Poff and Schmidt 2016). A study of invertebrate communities in rivers affected by dams and associated hydropeaking operations with velocity changes from ~700-7,000 cfs found that such systems are often characterized by a simplified invertebrate community (Kennedy et al. 2016). Changes in the density and abundance of certain clades of invertebrates were associated with hydropeaking operations and the effect of these operations on cycles of inundation and drying of river margin habitat (Kennedy et al. 2016). Additional effects of hydropeaking operations include coarsening of the river bed substrate, and a reduction in the supply of fine sediments and particulate organic matter to downstream areas; these effects reduce the amount of stable, fine sediment habitat inhabited by infaunal invertebrates such as oligochaetes and chironomids, and reduce the supply of organic matter that forms the base of the food web for these organisms (Merritt and Cummins 1996). The effects of hydropeaking on larval sturgeon food resources, and the subsequent effects on the growth and survival of larval Gulf sturgeon has not been examined; these are critical data gaps for Gulf sturgeon.

The dispersal of larval Gulf sturgeon within an artificial stream environment was described by Kynard and Parker (2004). These authors observed that larval Gulf sturgeon begin downstream movements after completing the free embryo stage. Some larvae moved slowly downstream for months, whereas others discontinued downstream dispersal. Movements were directed as larvae migrated head first downstream rather than drifting passively. Kynard and Parker (2004) suggested that this dispersal behavior is likely to result in the occurrence of larval and juvenile sturgeon throughout the river system; this conceptual model is supported by field observations of YOY sturgeon in natal rivers.

While making directed movements downstream, larval sturgeon may be affected by unexpected and sharp increases in discharge associated with hydropeaking operations. Hydropeaking was observed to influence the movement of juvenile White sturgeon in a field setting (Geist et al. 2005), and the probability of pallid sturgeon occurrence was lower with variability in diel flow patterns, such as when hydropeaking was present (Hamel et al. 2014). The magnitude and consequences of these effects in the Apalachicola River system has not been investigated, however the relationship between discharge and/or flow regulation and embryonic or larval sturgeon dispersal and recruitment success, and juvenile sturgeon habitat use has been discussed or examined for other sturgeon species (Kynard 1997, Beamesderfer and Farr 1997, Duke et al. 1999, Braaten et al. 2008, Hamel et al. 2014), and for other imperiled or native fishes and their habitat (Poff et al. 1997, Humphries and Lake 2000, Freeman et al. 2001, Schiemer et al. 2001, Bowen et al. 2003, Schiemer et al. 2003, King et al. 2005, Schludermann et al. 2012). Generally, sturgeon show both behavioral, physiological and population level effects to hydropeaking with velocity changes as low as 308 cfs (Aeur 1996). These effects are similar to the results in other fish and invertebrate species (Table 4.2), but responses to velocity changes as low as 176 cfs have been documented in wild populations (Leibig 1999).

Gulf sturgeon are likely to experience high mortality during their first year of life. Gross et al. (2002) highlighted the high potential for increasing population growth rate of sturgeons by focusing on improving survival of the YOY age class. These authors discussed the relevance of habitat improvements that increase survival of YOY and other juvenile age classes for improving overall population growth. Habitat improvements may include recommendations that alter the current flow management guidelines in a way that improves the overall survival of YOY Gulf sturgeon. Research is currently directed toward improving our knowledge of juvenile Gulf sturgeon in the Apalachicola River system, yet our understanding of effects prior to reaching Age 1 remains limited. Thus far, the year class abundance of Age 1 sturgeon observed during the second summer of life (~12-16 month old fish) is low relative to some Atlantic sturgeon populations that have been similarly monitored (Marbury 2016), indicating that the population may be experiencing one or more bottlenecks during early life phases.

Table 4.2 Summary of hydropeaking (A) and flow alteration effects (B) on sturgeon and other aquatic organisms.

A

Common name	Scientific name	Type of study	Location	Description of species effect	Citation
			Sturgeons		
White sturgeon	*Acipenser transmontanus*	Field, analysis of flow juvenile response	Snake River, Idaho	behavior and physiologial, distances moved similar at all flows; oxygen use doubled	Geist et al. 2005
Pallid sturgeon	*Scaphirhynchus albus*	Field sampling and model, adult presence	lower Platte and Loup River, Nebraska	occurrence was always lower when variability in diel flow patterns was high (i.e. hydropeaking)	Hamel et al. 2014
Lake sturgeon	*Acipenser fulvenscens*	Field, adult sampling	Sturgeon River, Michigan	management with run of river flows resulted in less time at spawning sites, 74% increase in abundance, and 68% increase in number of females	Auer 1996
			Other fishes and their habitat		
Native fish and benthic invertebrates		Field, fish and aquatic invertebrate sampling	several Austrian rivers	Biomass - reduction in benthic invertebrate biomass of between 75 and 95% was observed within the first few kilometres of river length; reduction of between 40 and 60% of biomass compared with undisturbed areas could be detected within the following 20–40 km; reduction of the fish fauna is within the same order of magnitude and correlates well with the amplitude of the flow fluctuations	Moog 1993
Brown trout	*Salmo trutta*	Field, fish sampling	River Oriege, France	reduced densities of juveniles and changed habitat use up to 700 m below dam	Liebig 1999
Native fishes		Field, response of young of year native fishes to flow regulation for hydropower	Tallapoosa River, Alabama	abundances were negatively correlated with 1-h maximum flow in summer (five species). all correlations >-0.9	Freeman et al. 2001
Zoobenthic community		Field, aquatic invertebrate sampling	Noce Bianco stream, Trentino, Italy	Abundance and species composition - As a mean value, total density decreased by 13 times downstream; loss of adult of all species; loss of 4 species entirely	Maiolini et al. 2007
Atlantic salmon	*Salmo salar*	Synthesis	Newfoundland, Canada	flow changes are energetically costly potentially affecting over-winter survival which is related to energy reserves obtained during summer	Scruton et al. 2008
Rainbow trout	*Oncorhynchus mykiss*	Field, fish sampling and Lab, otolith analysis	Colorado River, Arizona	behavioral and growth -catch rates of age-0 rainbow trout in nearshore areas were at least two- to fourfold higher at the daily minimum flow than at the daily maximum; atypical increments in otoliths were 25% wider than the adjacent increments and were indicative of significant short-term increases in otolith growth that corresponded to a reduction in the extent of hourly flow fluctuations on Sundays during the growing season	Korman and Campana 2009
Rainbow trout	*Oncorhynchus mykiss*	Field, telemetry and modeling	American River, California	behavioral and physiological - fish swimming speed estimates increased during the increasing flow stage, while the associated mean oxygen consumption rates also increased at this stage;	Cocherell et al. 2011

A (cont.)

Common name	Scientific name	Type of study	Location	Description of species effect	Citation
River fishes		Review and meta-analysis		behavioral - positive effect of river discharge on non-migratory movements; fishes made larger and (or) more frequent movements during periods of elevated discharge. Furthermore, non-salmonids were more affected by river flow than salmonids.	Taylor and Cooke 2012
Brown trout and rainbow trout	*Salmo trutta, Oncorhynchus mykiss*	Field, fish sampling and modeling	29 rivers in western US	recruitment was negatively correlated with high water velocity and daily fluctuations in flow 37 (i.e., hydropeaking)	Dibble et al. 2015
Aquatic Insects		Review, synthesis; Experiment and model	western US	dessication of eggs due to peaking waves; aquatic insect diversity was strongly and negatively related to the degree of hydropeaking across the 16 rivers	Kennedy et al. 2016

B

Common name	Scientific name	Type of study	Location	Type of effect	Description of flow change	Description of species effect	Citation
				Sturgeons			
Shovelnose and pallid sturgeon	*Scaphirhynchus platorynchus* and *S. albus*	Field experiments and model, larval drift	Missouri River, Montana	Habitat, flow	experimental water velocity in side channels	drift rate and distance depended on velocity	Braaten et al. 2012
Shortnosed sturgeon	*Acipenser brevirostrum*	Review, status review	Eastern US	Habitat, flow	High discharge during spawning season	Reduced spawning behavior	Kynard 1997
All North American species		Review, metaanalysis and expert elicitation	North America	Habitat, flow	Restore hydrograph	2nd ranked action by experts to restore sturgeon habitat	Beamesderfer and Farr 1997
White sturgeon	*Acipenser transmontanus*	Review, recovery planning	Kootenay River Basin	Habitat, flow	multi-day pulse of water	reduced survival due to reduced cover and food resources	Duke et al. 1999
				Other fishes and their habitat			
Large river fish and aquatic organisms		Review and synthesis		Habitat, flow	Rapid changes in river stage, Increased variation in magnitude and frequency	Wash-out and stranding of aquatic species	Poff et al. 1997
Large river fishes		Field, analysis of flow regime and fish community	Murray-Darling Basin, Australia	Habitat, diversion of flows for irrigation	Summer diversion of flows	loss of species from basin; loss of larval fish presence and reduced abundance due to change in daily flow patterns	Humphries and Lake 2000
Large river fish and aquatic organisms		Field, analysis of physiographic conditions within the inshore zone	Austrian Danube	Habitat, structural properties and retention of the inshore zone	Changing water levels will lead to wash-out effects, causing high mortality and a unidirectional, downstream shift of the fish fry population	reduced productivity of riverine zooplankton, larval fish-growth, and the downstream export and population loss of 0+ fish due to drift and wash-out effects.	Schiemer et al. 2001
Large river fishes		Field, habitat mapping	Yellowstone River and Missouri River	Habitat, availability of shallow habitat patches with slow current velocity (SSCV)	Regulation of flow in rivers results in reduced SSCV	Indirect; reduced food resources and reduction in survival of age 0 fish	Bowen et al. 2003
Nase carp	*Chondrostoma nasus*	Review	River Danube, Austria	Habitat, flow	current velocity in the inshore microhabitats swimming costs and an increased risk of wash-out effects.	key factor for growth and survival of the larvae of riverine fish related to higher food availability for drift feeding larvae vs. increased	Schiemer et al. 2003

B (cont.)

Common name	Scientific name	Type of study	Location	Type of effect	Description of flow change	Description of species effect	Citation
Large river fishes		Field, egg and larval fish sampling in regulated rivers	Murray and Goulburn Rivers, Australia	Habitat, diversion of flows for irrigation	Regulation of flow in rivers results in loss of recruitment	no eggs or larvae sampled in Golden Perch and Silver Perch	King et al. 2005
Nase carp	*Chondrostoma nasus*	Field experiment and model, analyzed the influence of the hydraulic conditions on larval dispersal	River Danube, Austria	Habitat, flow	differences in the temporal drift pattern were due to significant differences in the hydrodynamic characteristics of the release location	behavioral, dispersal and drift influenced by hydraulics	Schludermann et al. 2012

In this section, we have outlined several areas of inquiry associated with environmental conditions at or near the spawning sites, and YOY survival. Beyond impacts related to temperature during spawning, incubation, and embryonic development, and the availability of drifting and benthic forage for larval sturgeon, the potential effects of flow on other key processes like larval dispersal into suitable habitats, the provision of fine particulate organic matter for invertebrate nutrition, and other key water quality parameters like dissolved oxygen warrant future investigation. In addition, the suitability of interstitial substrate habitat that provides cover for eggs and embryos from predators and protects against flow displacement, and the potential effects of predator concentration at the few, regularly utilized spawning sites also deserves investigation. Given that spawning areas in the fragmented ACF were altered by in-channel dredging and rock removal, the potential to enhance these habitats should be investigated, with a restoration goal of providing ample substrate with suitable cover for early life stages in mind.

Juvenile sturgeon riverine foraging: Juvenile Gulf sturgeon appear to distribute widely throughout the entire mainstem river channel during the period following hatching based upon behavior observed in laboratory studies (Parker and Kynard 2004) and empirical observations of young-of-year sturgeon in river systems (Sulak and Clugston 1998, 1999). Exhaustive surveys using a variety of gear types have resulted in few captures of young of year sturgeon; these juveniles are usually captured individually (i.e., their distribution is not aggregated). In addition, Gulf sturgeon have not been reported in off-channel, inundated areas of the floodplain (Light et al. 1998). While young of year sturgeon are distributed throughout the main channel, likely seeking benthic prey, we would potentially find juvenile sturgeon in areas where stable organic matter accumulations provide the habitat to support invertebrate communities. Under this conceptual model, we suspect that our comparisons of floodplain inundation during the Winter-Spring period, and during the late growing season, may be used to assess the role that stream regulation under the WCM plays in recruiting organic matter to the main channel, and recruiting additional nutrients and phytoplankton to the main channel thereby stimulating or enhancing the production of benthic invertebrate prey in main channel habitats.

Juvenile sturgeon estuarine foraging - abiotic and biotic conditions: Access to high-quality benthic foraging habitat in the upper estuary, particularly during the first year of life, may affect the growth, survival, and resulting Age-1 year class strength of Gulf sturgeon (Sulak et al. 2007). Ability to access foraging habitat is thought to be influenced by the abiotic conditions of the upper estuary environment during the winter period. Importantly, very young juvenile (i.e., 55-

day old) Gulf sturgeon have a lower tolerance for saline conditions than sub-adult or adult sturgeon (Foster et al. 1994). Kynard and Parker (1994) observed 100% mortality of 72 day old juvenile sturgeon when exposed to 10 ppt salinity. Age 1+ juvenile sturgeon are believed to accompany sub-adults and adult sturgeon during the migration from riverine habitats to the upper estuary between late fall to early winter (Sulak and Clugston 1998). Unlike older juveniles, Sulak and Clugston (1998) found that young of year (9-10 month old) Gulf sturgeon relocated to the river mouth/estuary environment in late winter (late January-February). Thus abiotic conditions (i.e., lower salinity in foraging areas) during late winter may be vitally important to the growth and survival of young of year juvenile sturgeon during their first winter of life.

In a laboratory study of 4-month old juvenile Gulf sturgeon (~8 cm long), Altinok and Grizzle (2001) observed that growth and energy absorption efficiency was highest at both 3 and 9 parts per thousand (ppt) salinity. In a separate laboratory study, Altinok et al. (1998) observed that juvenile sturgeon (Age 13 months) were capable of slowly acclimating to higher salinity; the ability to adapt to saltwater appeared to be related to body size, with larger fish adapting more easily. Therefore, juvenile sturgeon may grow best during winter foraging in lower salinity environments. In turn, the growth of a juvenile sturgeon, and its overall body size (not age) when it first encounters a more saline environment, may affect its tolerance and ability to forage into more saline portions of the upper estuary, or under conditions of more rapidly fluctuating salinity levels.

It remains unclear whether juvenile sturgeon will choose to venture into higher salinity environments after a period of acclimation, or whether foraging will be primarily carried out in areas that offer salinity less than some threshold (e.g., 10 ppt). Age $\leq$2 juveniles likely do not venture into higher salinity environments, and some very limited observations based on telemetry of 3 juvenile sturgeon in Apalachicola Bay indicated that fish remained close to the river and distributary mouths, and within East Bay (typically a lower salinity area of the upper estuary) during the winter of 2006-2007 (Sulak et al. 2009). The average daily flow for November 2006 through March 2007 was about 16,200 cfs, compared with an average for the period of record (1922 – 2012) of 26,400 cfs. Discharge during winter 2006-2007 was typically below median values, with peak flows of only ~33,000 cfs observed at the Sumatra gage (USGS gage 02359170). USFWS has scheduled research for the winter 2016-2017 and 2017-2018 to better understand these relationships.

Low salinity in the benthic environment may simply provide access to foraging habitat in the upper estuary. Once there, juvenile sturgeon must find and consume benthic prey to meet their nutritional needs for growth and survival. The standing crop of invertebrate prey, or sturgeon food items, is likely to be influenced by estuarine conditions occurring prior to the winter foraging period.

Studies of the invertebrate fauna in Apalachicola Bay reported highest invertebrate biomass in regions of the upper estuary, associated with muddy sediments and lower salinities (USFWS 2008, see also Sulak et al. 2009). Benthic organisms near the river mouth/upper estuary setting of the Apalachicola River system (i.e., secondary producers) appear to rely on both allochthonous input of detritus from the river, and on *in-situ* phytoplankton production within the estuary (Livingston et al. 1997). The timing of inputs of organic matter and nutrients to the estuary is relatively important. High flows during winter-spring sequesters allochthonous detritus from the floodplain and delivers this organic material to the estuary at a time when high turbidity limits *in-situ* primary productivity. Freshwater input in late summer and early fall delivers nutrients to the upper estuary to stimulate autochthonous, phytoplankton production (Chanton and Lewis 2002).

Freshwater delivery of nutrients to the estuary during the period of high estuarine primary productivity (i.e., summer-early fall), in concert with the effects on salinity regime and trophic food-webs, may control the production of sturgeon prey resources through a “bottom-up” pathway in concert with predator/prey interactions. Nutrients are converted to primary production (phytoplankton), which stimulates secondary production of invertebrates (Livingston et al. 1997) that are prey to juvenile Gulf sturgeon including: infaunal polychaete worms, amphipods, isopods, bivalve mollusks, lancelets, shrimp, and gastropods.

The relationship between freshwater input to Apalachicola Bay, and the trophic organization and density and biomass of prey items like infaunal macroinvertebrates is complex. In a long term study of trophic organization in East Bay (one area suspected to be foraging habitat for juvenile Gulf sturgeon), Livingston (1997) and Livingston et al. (1997) documented a substantial increase in the biomass and proportional representation of infaunal macroinvertebrate herbivores (i.e., sturgeon prey) at 1 to 1.5 years into a drought cycle. The authors attributed this increase to bottom-up processes mediated by increased light penetration and stimulation of primary production resulting from reduced freshwater inflow. At a lag time of about 2 years into the drought phase, herbivore biomass plummeted; the authors postulated that nutrient limitation ultimately occurred following prolonged decrease in freshwater nutrient delivery. These effects highlight the complexity of trophic dynamics in the estuary that may play a role in the availability of food for juvenile Gulf sturgeon. The effects of drought may actually increase the food available to juvenile fish, provided that lower salinities occur at some point during the winter to permit access. In other river systems, the lagged effects of prolonged drought, as nutrient limitations affect the trophic organization of the estuary, may manifest in years following the drought, perhaps depending on the duration, frequency, timing, and magnitude of freshwater delivery to the estuary following the cessation of the drought (e.g., Schemel et al. 2004, Valett et al. 2005, Wrona et al. 2007).

Riverine aggregation areas and trophic dormancy during summer: In late spring through early fall (May-October), Gulf sturgeon aggregate in discrete reaches of river systems during a prolonged period of trophic dormancy (i.e., they do not feed). Many reports indicate that adult and subadult Gulf sturgeon lose a substantial percentage of their body weight while in freshwater (Wooley and Crateau 1985, Mason and Clugston 1993, Clugston et al. 1995) and then compensate the loss during winter-feeding in the estuarine and marine environments (Wooley and Crateau 1985, Clugston et al. 1995). Gu et al. (2001) tested the hypothesis that subadult and adult Gulf sturgeon do not feed significantly during their annual residence in freshwater by comparing stable carbon isotope ratios of tissue samples from subadult and adult Suwannee River Gulf sturgeon with their potential freshwater and marine food sources. A large difference in isotope ratios between freshwater food sources and fish muscle tissue suggests that subadult and adult Gulf sturgeon do not feed significantly in freshwater. The isotope similarity between Gulf sturgeon and marine food resources strongly indicates that this species relies almost entirely on the marine food web for its growth (Gu et al. 2001).

In summer, aggregation areas are important as thermal refugia for Gulf sturgeon and likely affect bioenergetics, fitness, and survival (Foster 1993, Foster and Clugston 1997, Hightower et al. 2002). During the summer period, sub-adult and adult sturgeon do not actively feed and progressively lose body mass, thus this is a period of trophic dormancy and energy conservation for Gulf sturgeon. Several interrelated features appear to be associated with aggregation area selection including (but not limited to) channel slope, water depth, velocity, and temperature. Summer aggregation areas are variably occupied by sturgeon within season and across years; movement between areas is common and has been extensively documented. Aggregations of sturgeon can number in the tens to hundreds of fish. In the Apalachicola River system, these so-called holding or resting areas have been identified in a variety of ways including fishing, observation of jumping sturgeon, sonic telemetry, and side scan sonar surveys. There are approximately 12 discrete reaches where Gulf sturgeon are known to aggregate in the Apalachicola system; 4 of these areas are located in the Brothers River, a tributary (Table 4.3).

Table 4.3 Known riverine aggregation sites in the Apalachicola River and tributaries.

	Site Name	RM
1	Lower Brothers River	1-2
2	Bearman Creek (Brothers R.)	3-4
3	Houseboats (Brothers R.)	5-6
4	Lillypads (Brothers R.)	8.5-9.5
5	Powerlines (Brothers R.)	11.5-13.5
6	Owl Creek to Brushy Creek	24-26
7	Bluff	94-95
8	Ocheesee Landing	96
9	Jackson Blue Spring	100
10	Below Interstate 10	101
11	Gulf Power Plant	105
12	Jim Woodruff Lock and Dam	108

The preference and selection of discrete holding areas may involve multiple variables and scales, with trade-offs among interrelated factors (affecting bioenergetics, fitness, and survival) such as water depth, 3D current velocity profiles, water temperature, dissolved oxygen, water chemistry and clarity, ease of access, longitudinal position in the river system, site history (e.g., recent fishing activity), learned behavior, and in-situ group behavioral dynamics. Through telemetry and behavioral observations, species experts surmise that sturgeon know exactly how to locate the holding areas; in many cases sturgeon that have been captured and relocated will immediately return to the exact point of capture following their release.

An investigation of the multivariate factors associated with holding area habitat selection across the range of Gulf sturgeon has yet to be conducted. In addition, the influence of river flows and regulation on the suitability of holding area habitat is largely unknown at this time. Resting habitat use does vary within season and across years, presumably in response to fluctuating environmental conditions.

Outmigration to marine environments and winter foraging: In response to declining water temperature and/or increased discharge, Gulf sturgeon sub-adults and adults emigrate from freshwater coastal rivers in late September through November to overwinter and feed in estuarine areas, bays, and the Gulf of Mexico (Sulak and Clugston 1999). There are currently no known physical impediments to outmigration from the Apalachicola River system, although the role of freshwater delivery to the estuary during the fall outmigration period when sturgeon must acclimate to higher salinity conditions has not been investigated.

Inmigration to riverine environments and spawning runs: Most adult and sub-adult sturgeon return to freshwater river systems from March through May. Adult Gulf sturgeon spawn in the upper reaches of rivers, at least 100 km (62 miles) upstream of the river mouth (Sulak et al. 2004), when water temperature rises to between about 17-25 °C. Gulf sturgeon eggs are demersal (they are heavy and sink to the bottom), adhesive, and vary in color from gray to brown to black (Huff 1975, Parauka et al. 1991). Chapman et al. (1993) estimated that mature female Gulf sturgeon weighing between 29 and 51 kg (64 and 112 lb) produce an average of 400,000 eggs.

River flow may serve as an environmental cue that governs both sturgeon migration and spawning (Chapman and Carr 1995, Ross et al. 2001b). If the flow rate is too high, sturgeon in several life-history stages can be adversely affected. Data describing the sturgeon’s swimming ability in the Suwannee River strongly indicates that they cannot continually swim against prevailing currents of greater than 1 to 2 m per second (3.2 to 6.6 ft per second) (Wakeford 2001). If the flow is too strong, eggs might not be able to settle on and adhere to suitable substrate (Wooley and Crateau 1985). Flows that are too low can cause clumping of eggs, which leads to increased mortality from asphyxiation and fungal infection (Wooley and Crateau 1985). Flow velocity requirements for YOY sturgeon may vary depending on substrate type. Chan et al. (1997) found that YOY Gulf sturgeon under laboratory conditions exposed to water velocities over 12 cm/s (0.4 ft/s) preferred a cobble substrate, but favored water velocities under 12 cm/s (0.4 ft/s), and then used a variety of substrates (sand, gravel, and cobble).

5 GULF STURGEON - EFFECTS OF THE ACTION

This section is an analysis of the effects of the WCM on the species and its critical habitat. In most consultations, the USFWS typically evaluates a project that has not been constructed or implemented. In this consultation, the USFWS is evaluating the effects of adoption of a new system of operation of already constructed facilities that is an ongoing refinement of existing protocols. The previous “Environmental Baseline” section described the effects of all past activities, including the effects of past construction and operation of the USACE ACF projects, current non-federal activities, and federal projects with completed section 7 consultations. For purposes of this section the analysis of charts will compare the effects of operation under the proposed WCM to the baseline.

5.1 Factors to be Considered

The USFWS has applied concepts from Jacobsen et al. (2015), which developed a conceptual ecological model for pallid sturgeon. The model identified the unique life stages for the pallid sturgeon and identified factors that would affect the ability to of individuals to transition from one life stage to the next. For example, a reduction of spawning habitat may limit pallid sturgeon egg laying.

The environmental baseline was used to identify the critical life stages for Gulf sturgeon. The USFWS then reviewed the BA and available scientific literature to itemize the potential effects of the WCM that could limit the ability of an individual Gulf sturgeon to transition to the subsequent life stage. The following summarizes the relationship between Gulf sturgeon life stages and potential effects of the WCM that we assess in section 5.2.

Spawning Adult to Egg

- Potential increase/decrease in eggs deposited due to WCM increase/decrease of spawning habitat
- Duration of potential effect - March 1 through May 31

Egg to Young of Year

- Egg hatching is generally not limited by flow quantity where spawning habitat is deep (except extreme reduction in flows that lead to stranding and desiccation of nests with eggs or larvae in shallower spawning habitat). Hatching success evaluated for hydropeaking.
- Potential change egg hatch rates due to change in stream temperatures in the Apalachicola River
- Duration of potential effect - March 1 through May 31

Young of Year to Juvenile (Age 1 to Age 6)

- Potential beneficial/adverse effects to body condition and/or WCM effects to food production in the Apalachicola River
    - Duration of potential effect - Majority of the year except early summer (June-July)
- Potential beneficial/adverse effects to body condition and/or mortality from WCM effects to low salinity, estuarine habitat
    - Duration of potential effect - January 1 through March 15
- Potential beneficial/adverse effects in body condition and/or mortality due to WCM hydropeaking-related forage limitations in the Apalachicola River
- Potential change in mortality rates due to WCM effects to stream temperatures in the Apalachicola River

Juvenile to Non-Reproductive Adult

- Potential beneficial/adverse effects to body condition and/or mortality from WCM effects to invertebrate food production in the Apalachicola River
  - Duration of potential effect - Majority of the year except June 2 through July 14
- Potential beneficial/adverse effects to body condition and/or mortality from WCM effects to low salinity, estuarine habitat
  - Duration of potential effect - November 1 through March 15

Non-Reproductive Adult to Spawning Adult

- Potential beneficial/adverse effects to body condition and/or mortality from WCM effects to low salinity, estuarine habitat
- Potential beneficial/adverse effects to body condition and/or mortality from WCM effects to invertebrate food production in the estuary as delivered via the Apalachicola River
- Potential beneficial/adverse effects to reproductive potential due to WCM effects to invertebrate food production in the estuary as delivered via the Apalachicola River

5.2 Analysis for Effects of the Action

We describe our analytical approach using the STELLA and ResSim models and the general changes to the flow regime due to the action in detail in Appendix A. In general, we used both models to look for greatest negative effect on Gulf sturgeon and its critical habitat. The following section evaluates the effects of the WCM to Gulf sturgeon hydroecological metrics (Table 5.1).

Table 5.1 Summary of the hydroecological metrics and the effect of the WCM on Gulf sturgeon.

Metric ID	Hydroecological Metric Title	Species Ecology	Interpretation	WCM effect
GS 1	Floodplain Inundation and Organic Matter Supply (Total Days) - Nov 24-Jun 1	Estuarine Invertebrate Production	more days of inundation beneficial	negative
GS 2	Floodplain Inundation and Organic Matter Supply (Total Acre-days) - Nov 24-Jun 1	Estuarine Invertebrate Production	more acre-days of inundation beneficial	no effect
GS 3	Floodplain Inundation and Nutrient Supply (Total Days) - July 15 - Nov 24	Estuarine Invertebrate Production	more days of inundation beneficial	no effect
GS 4	Floodplain Inundation and Nutrient Supply (Total Acre-days) - July 15 - Nov 24	Estuarine Invertebrate Production	more acre-days of inundation beneficial	negative
GS 5	Floodplain Inundation and Nutrient Supply (Total Pulses) - July 15 - Nov 24	Estuarine Invertebrate Production	more inundation pulses beneficial	slight negative

GS 6	Low Salinity for all Juvenile Access to Foraging Habitat (Total Days) - Nov 1-Mar 15	Habitat Suitability	more days of flows >threshold beneficial	positive/ no effect
GS 7	Low Salinity for YOY Access to Foraging Habitat (Total Days) - Jan 1-Mar 15	Habitat Suitability	more days of flows >threshold beneficial	positive/ no effect
GS 8	Low Salinity for all Juvenile Access to Foraging Habitat (Max Consecutive Days) - Nov 1-Mar 15	Habitat Suitability	fewer consecutive days < threshold beneficial	positive/ no effect
GS 9	Spawning Habitat Inundation (ac)	Spawning Habitat Availability & Quality	flows with greater depths better for spawning	no effect
GS Q1	Hydropeaking at Woodruff	Spawning Habitat Availability & Quality	more stability in daily flows better for survival, recruitment, growth	negative
GS Q2	Temperature changes downstream of Woodruff	Spawning Habitat Availability & Quality	temps below lethal limits good	negative

We assessed floodplain inundation for organic matter supply estuarine invertebrate production during the winter and spring months (GS2), floodplain inundation for organic matter supply estuarine invertebrate production during the summer and fall months (GS 3), and flows to maintain adequate depth over spawning substrate for reproduction during the spawning season (GS9). However, we found no differences or slight positive effects of the WCM compared to baseline, and we do not discuss them further. We also assessed effects on habitat suitability by providing low salinity environment in the bay for juvenile access to foraging habitat in the winter months (GS6-GS8). We found little effect to a slightly beneficial effect in these metrics, and holding flows for navigation may have an ancillary beneficial effect by providing a lower salinity environment in the bay for juvenile sturgeon (GS6-GS8). We do not discuss these effects further. We discuss analyses of estuarine invertebrate production (GS1, GS4, GS5) and spawning habitat availability and quality (GSQ1, GSQ2) below.

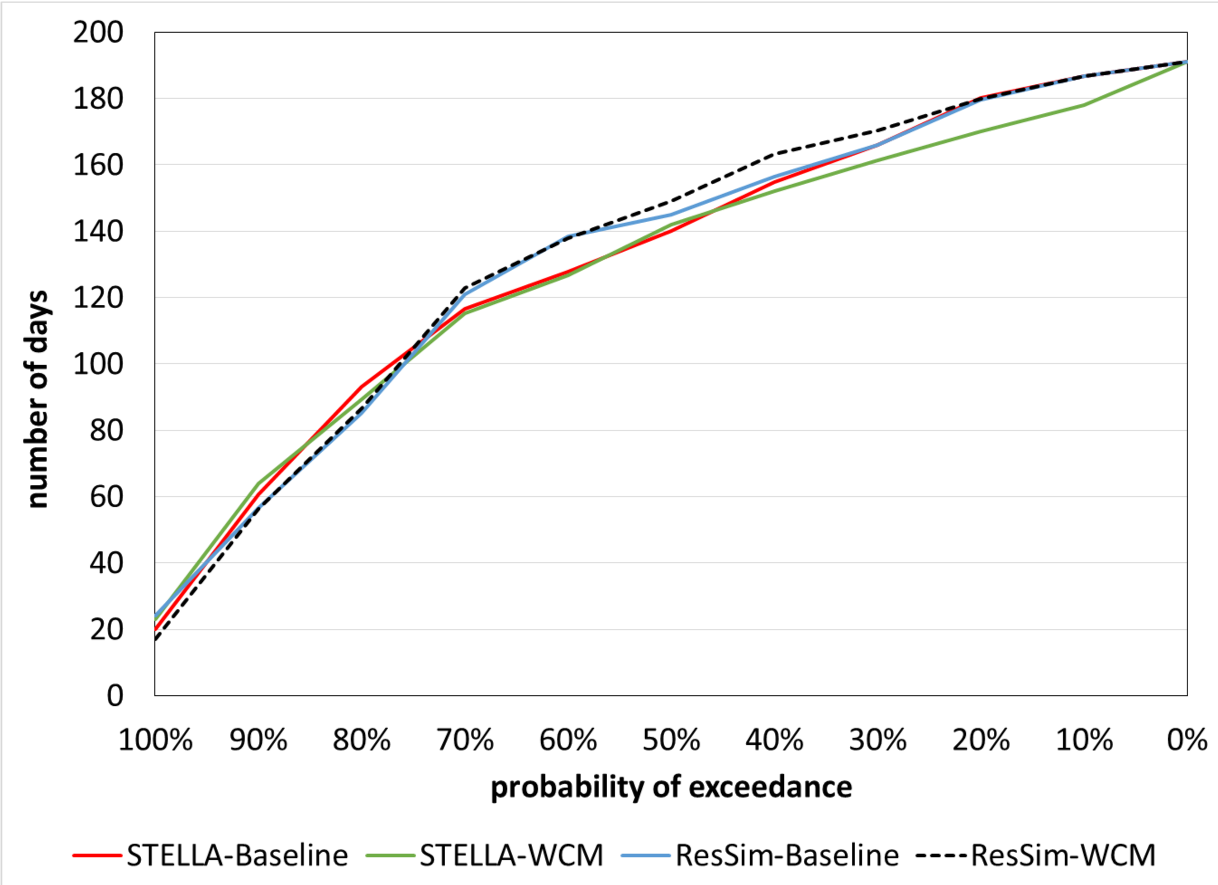
5.2.1 Flows for Estuarine Invertebrate Production

Gulf Sturgeon Hydroecological Metric 1 (GS 1) - General Floodplain Forest Inundation and Organic Matter Supply (Total Days)

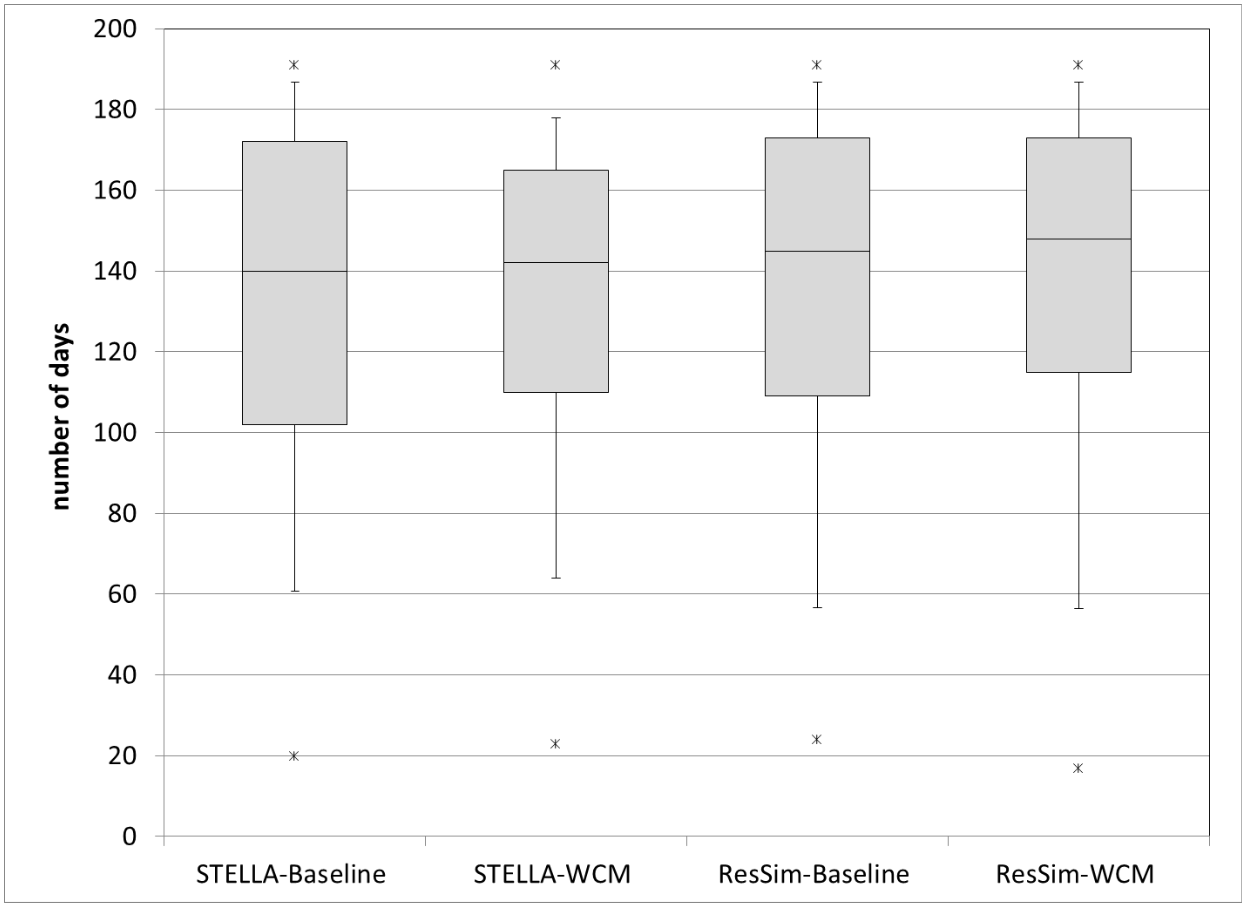
Description of Metric: We are concerned that changes in the supply of organic material from the Apalachicola River floodplain could reduce prey base for Gulf Sturgeon foraging in the estuary. To evaluate the potential effects of the proposed action on the supply of organic material to the upper estuary we determined the total number of days between November 24 and June 1 (per annual cycle) when discharge at Chattahoochee, FL was ≥16,200 cfs. At 16,200 cfs, approximately 10% of the available floodplain is inundated (Light et al. 1998). November 24 represents the median date of the first freeze observed at Quincy, FL (Light et al. 1998), considered here to be the first day of the dormant season. Episodes of floodplain inundation between November 24 and June 1 were assumed to sequester detrital organic material that had accumulated on the forest floor during the dormant season.

Our analysis emphasized the importance of floodplain inundation to the entrainment of organic material and export of this material to the estuary; organic matter supply to the estuary supports growth and production of infaunal and epifaunal invertebrates (i.e., sturgeon food). We focused on the duration, or total amount of time the floodplain is inundated. We considered that more days of floodplain inundation would deliver greater quantities of organic matter to the estuary, thereby supporting the production of a larger standing crop of benthic invertebrates. Thus, a greater total number of days of floodplain inundation was considered a benefit to Gulf sturgeon; fewer days of floodplain inundation was considered an adverse effect.

Results: The total number of days of Apalachicola River floodplain inundation (Woodruff discharge ≥16,200 cfs) between November 24 and June 1 is presented as a probability of exceedance plot (Figure 5.1A). The ResSim model showed no difference between the baseline and WCM, but the STELLA model showed an overall decrease of 176 days (of 14,060 across 74 years) and an average decrease from 133.4 days under the baseline to 131.0 days under the WCM. According to this model, we observed very little discernable difference in the number of days of inundation between the WCM and baseline management plans during years characterized by fewer days of floodplain inundation (i.e., range of 50-100% exceedance probability). During years of greater floodplain inundation, we observed a reduction in the total number of days of inundation under the WCM relative to the baseline. A maximum difference of approximately 7 days of floodplain inundation was observed between the WCM and baseline; this difference occurred within the 10-20% probability of exceedance range. The box plots provided in Figure 5.1B further illustrate the reduction in total number of days of inundation during wet years; the upper 75th and 90th percentiles represent fewer days of inundation under the WCM plan versus the baseline.


200
180
160
140
120
100
80
60
40
20
0
number of days
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
probability of exceedance
STELLA-Baseline
STELLA-WCM
ResSim-Baseline
ResSim-WCM

A



B

Figure 5.1 Total days inundated for all flows ≥16,200 cfs during the period of November 24 to June 1.

Interpretation: Operation under the WCM reduced the total number of days of floodplain inundation, especially during years with higher inundations (i.e., wetter years). The WCM caused a 1% reduction (avg. 2.4 days or 12.1 days over 5 years) of floodplain inundation. Fewer days of floodplain inundation may result in a reduction of organic matter supply to the estuary needed to support the production of benthic invertebrates consumed by juvenile Gulf sturgeon during winter foraging.

Gulf Sturgeon Hydroecological Metric 4 (GS 4) - General Floodplain Forest Inundation and Nutrient Supply (Cumulative Acre-days)

Description of Metric: We estimated the cumulative amount of floodplain acres inundated between July 15 and November 24, per year when discharge at Chattahoochee, FL was ≥16,200 cfs, in order to evaluate the potential effects of the proposed action on the supply of nutrients to the upper estuary. To calculate the quantity of acres inundated on a daily basis we used the relationship between discharge at Chattahoochee, FL and floodplain acres inundated as determined by Light et al. (1998). We estimated the cumulative number of acres inundated during each day between July 15 to November 24. The result is expressed in terms of cumulative acre-days. At discharges of 16,200 cfs from Woodruff, approximately 10% of the available floodplain is inundated (Light et al. 1998; Figure 2.7). We selected July 15 to represent a mid-summer date that coincided with both the end date for our Mussel Recruitment Metric, and a beginning date for the late growing season period. November 24 represents the median date of the first freeze observed at Quincy, FL (Light et al. 1998), considered here to be the last day of the late growing season. Episodes of floodplain inundation between July 15 and November 24 were assumed to sequester nutrients from the floodplain and deliver these nutrients downstream to the estuary.

Floodplain inundation is important to the entrainment of nutrients and export of nutrients to the estuary; nutrient supply to the estuary during the late growing season supports growth and production of infaunal and epifaunal invertebrates (i.e., sturgeon food). Designed to complement metric GS-3, we focused our analysis on the magnitude of floodplain inundation in terms of total acres inundated. Greater areas of floodplain inundation deliver greater quantities of nutrients to the estuary, thereby supporting the production of a larger standing crop of benthic invertebrates. Thus, we considered a greater cumulative total of floodplain acres inundated as a beneficial effect on the Gulf sturgeon; fewer acres of inundated floodplain was considered an adverse effect.

Results: The total number of acre-days of floodplain inundation at ≥16,200 cfs between July 15 and November 24 occurring under the two management alternatives is presented as a probability of exceedance plot in Figure 5.2. Overall, the WCM reduced ac-days of floodplain inundation under both the ResSim and STELLA models (1,398,900 of app. 781 mil or 0.13%, ResSim; 691,412 of app. 781 mil or 0.11%, STELLA). Based on the ResSim model, 654,284 ac-days/yr on average are inundated and this represented an average reduction of 18,904 ac-days/yr. During years characterized by lower (>83% exceedance) as well as average to higher (<61%) seasonal flows, operation under the WCM provided on average 23,093 ac-days (4.7%) less floodplain inundation than the baseline, but this reduction ranged up to 98,781 ac-days or 20%. Most importantly, in the years with already low floodplain inundation (>83% exceedance), the WCM reduced inundation by 6.3%. In summary, we would expect an approximately 92,125 ac-day reduction during the WCM in 5 years, and this is expected to be an adverse effect to Gulf sturgeon food production.

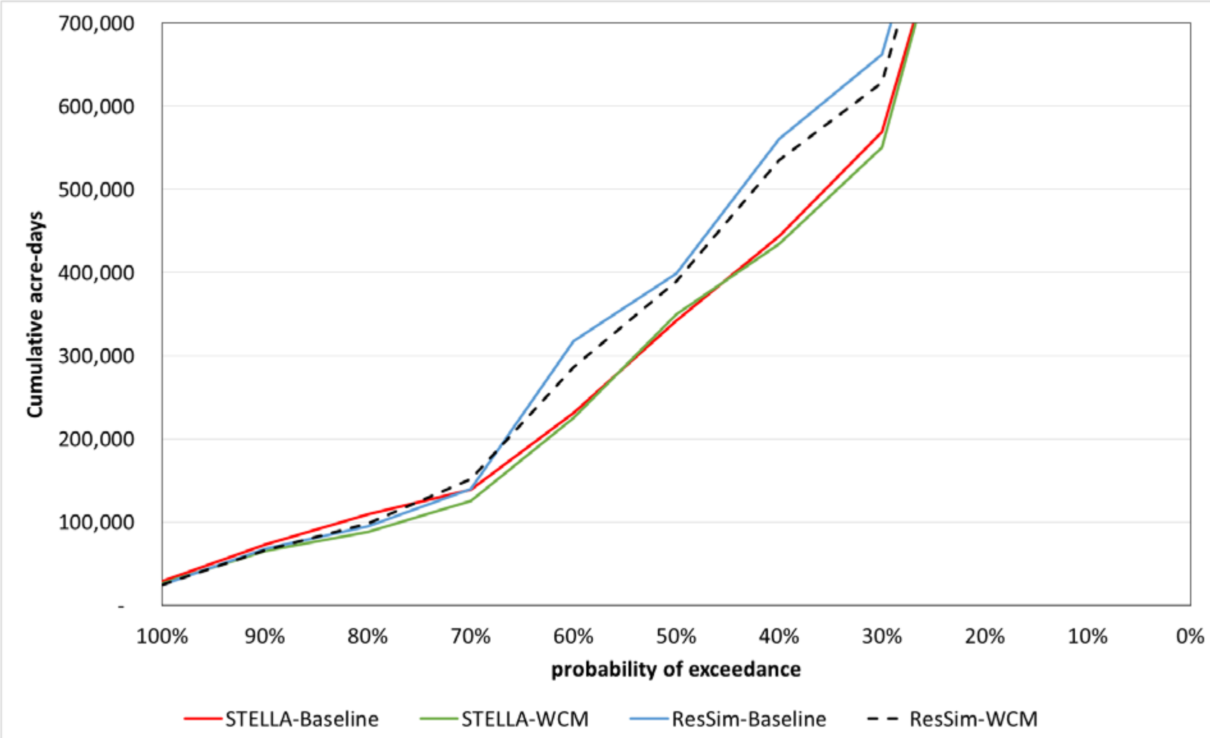


Figure 5.2 Total number of acre-days of floodplain inundation at $\geq$16,200 cfs between July 15 and November 24 under baseline and WCM

Interpretation: During July 15 - November 24, the WCM provides less floodplain inundation than the baseline. The reduction is most prevalent at years with the lowest flows and intermediate to higher flows and averages 4.7%. Given the importance of freshwater delivery of nutrients to the estuary during seasonal dry periods of the year (i.e., the late growing season) to support the production of forage for juvenile sturgeon, reduced floodplain inundation under the WCM has an adverse effect on Gulf sturgeon. A 6.3% reduction in area inundated occurs in the driest 17% of years, which in turn would reduce food production during those dry years (or those with lower inundation anyway).

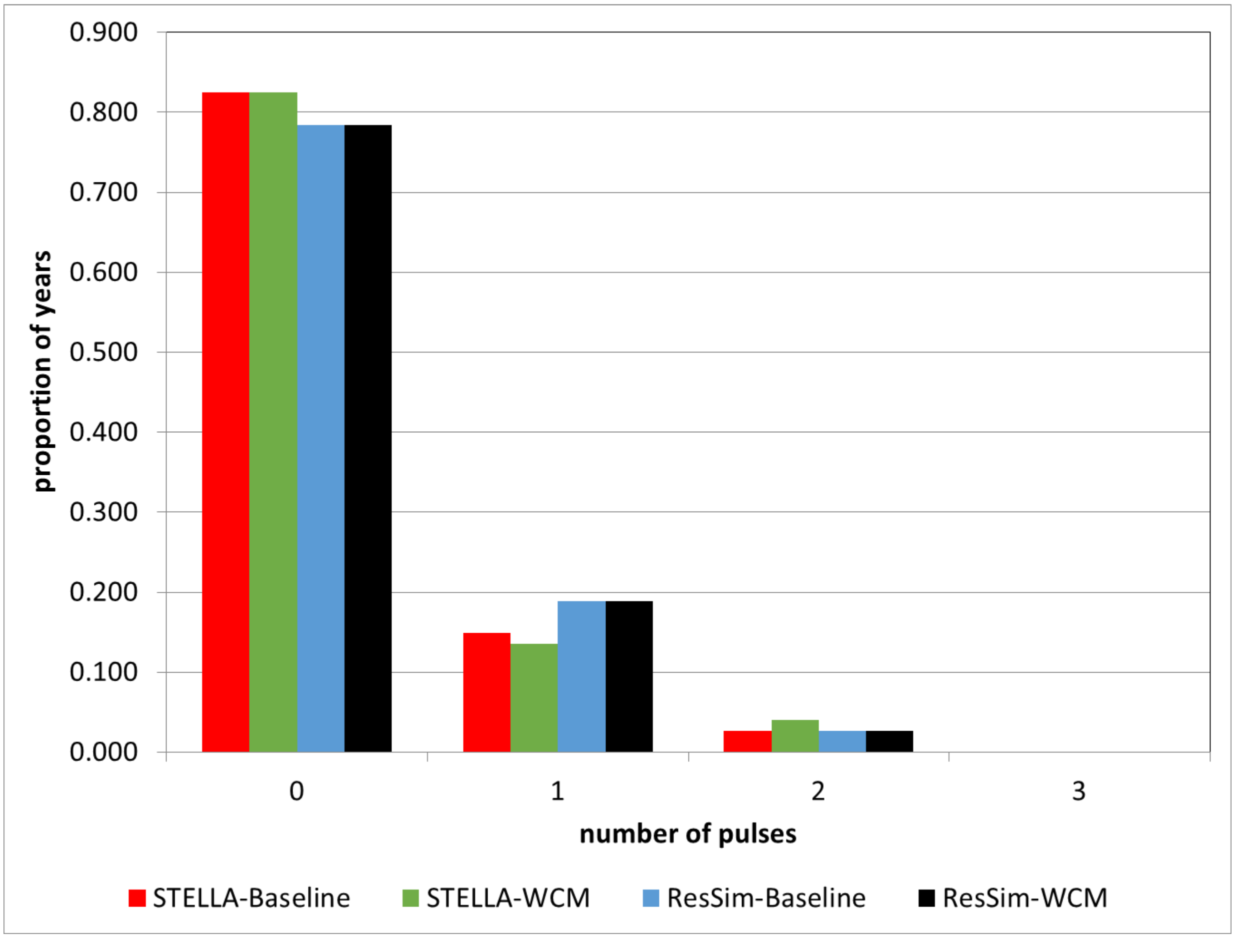
The combination of food and access, based on appropriate salinity conditions, during the first winter of life is critical for Gulf sturgeon. These effects may lead to increased foraging demand on juvenile sturgeon. The annual cohort of juvenile Gulf sturgeon that experience this increased foraging demand will have lower body condition, reduced growth, and potentially lower survival over the winter period.

Gulf Sturgeon Hydroecological Metric 5 (GS 5) - Pulsed Floodplain Forest Inundation and Nutrient Supply (Number of pulses)

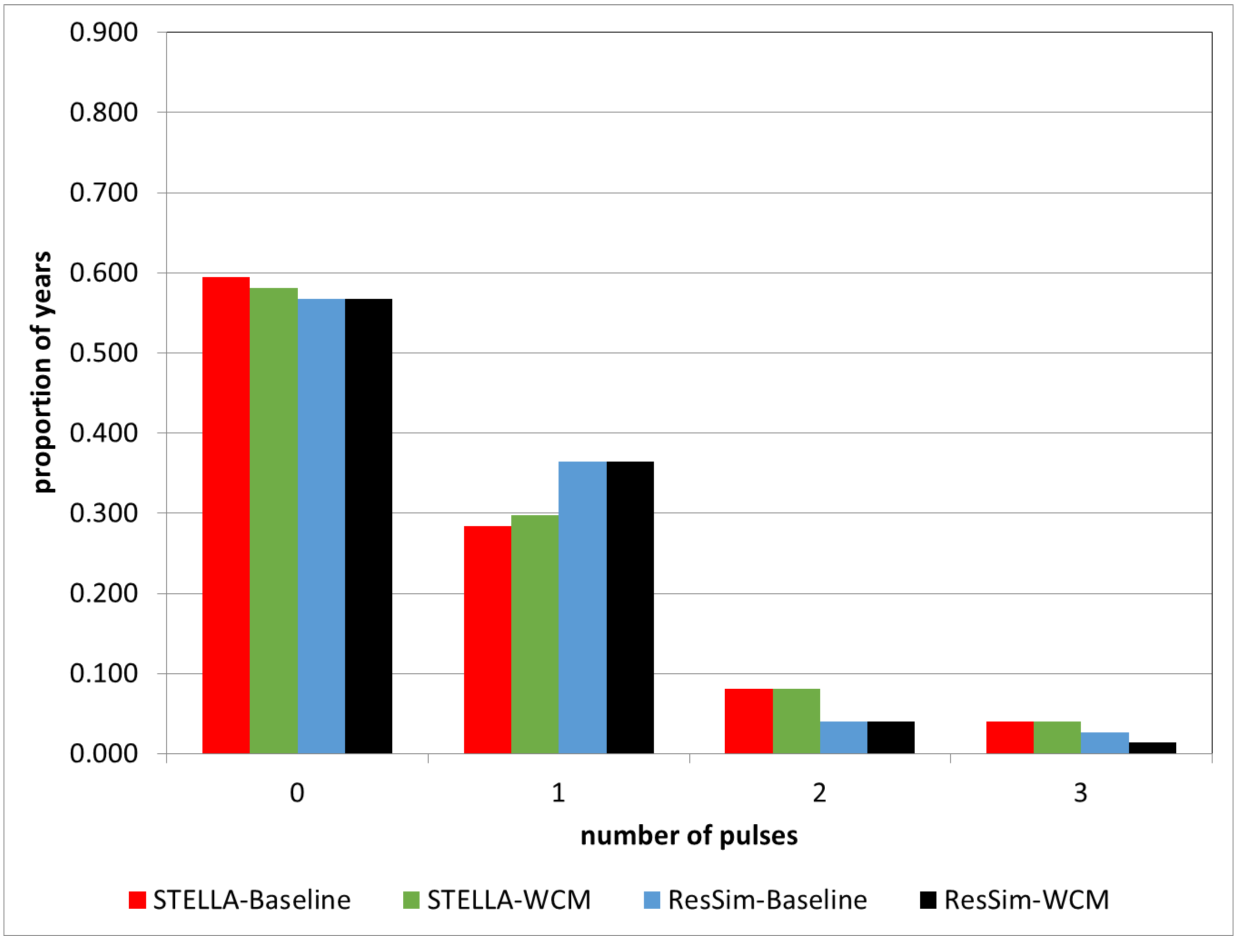
Description of Metric: In order to evaluate the potential effects of the proposed action on the supply of nutrients to the estuary, we determined the total number of floodplain pulses occurring between July 15 and November 24 each year. We defined a flood pulse as a discrete discharge event with flows exceeding 16,200 cfs for a period of at least 15 days, followed by a period of flows <16,200 for a period of at least 7 days. At 16,200 cfs, approximately 10% of the available floodplain is inundated (Light et al. 1998). We selected July 15 to represent a mid-summer date that coincided with both the end date for our Mussel Recruitment Metric, and a beginning date for the late growing season period. November 24 represents the median date of the first freeze observed at Quincy, FL (Light et al. 1998), considered here to be the last day of the late growing season. Episodes of floodplain inundation between July 15 and November 24 were assumed to sequester nutrients from the floodplain and deliver these nutrients downstream to the estuary.

Regular floodplain inundation is important to the entrainment of nutrients and export of nutrients to the estuary; nutrient supply to the estuary during the late growing season supports growth and production of infaunal and epifaunal invertebrates (i.e., sturgeon food). Designed to complement other floodplain metrics (GS 1 & 2), our analysis focused on the total number of floodplain inundation pulses. More floodplain inundation pulses deliver greater quantities of nutrients to the estuary, thereby supporting the production of a larger standing crop of benthic invertebrates. Thus, a larger number of inundation pulses benefit Gulf sturgeon; fewer pulses were considered an adverse effect.

Results: The proportion of years with 30-day (A) and 15-day (B) floodplain pulses between July 15 and November 24 occurring under the 2 flow regimens (baseline, WCM) is presented in Figure 10.7. The models showed differing results, and the ResSim model showed a negative effect. The WCM and baseline provided the same number of years with at least one 30-day pulse across the 74 year record (16 years or 22% of the time during the WCM), but the WCM provided one less year with a 15-day pulse compared to the baseline (31 years or 42% of the time). Across the 74-year record, the WCM provided one less year with three 15-day pulses (1.4% of the time during the WCM) than the baseline.


0.900
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
proportion of years
0
1
2
3
number of pulses
STELLA-Baseline
STELLA-WCM
ResSim-Baseline
ResSim-WCM

A



B

Figure 5.3 The proportion of years in the 74 year period of record with 30-day (A) and 15-day (B) floodplain pulses between July 15 and November 24 occurring under the baseline and WCM flow regimes

Interpretation: Although these are rare events in the record, providing one less year with three 15-day pulses once every 74 years (1.4% decrease) is slightly negative effect of the WCM. Under the WCM (as well as the baseline), we expect 1 year with at least a 30-day pulse and 2 years with a 15-day pulse in 5 years. We expect that slight decrease in the frequency of floodplain pulses will decrease the supply of nutrients to the estuary to support the production of invertebrate prey for sturgeon.

5.2.2 Effects on Spawning Habitat Availability and Quality

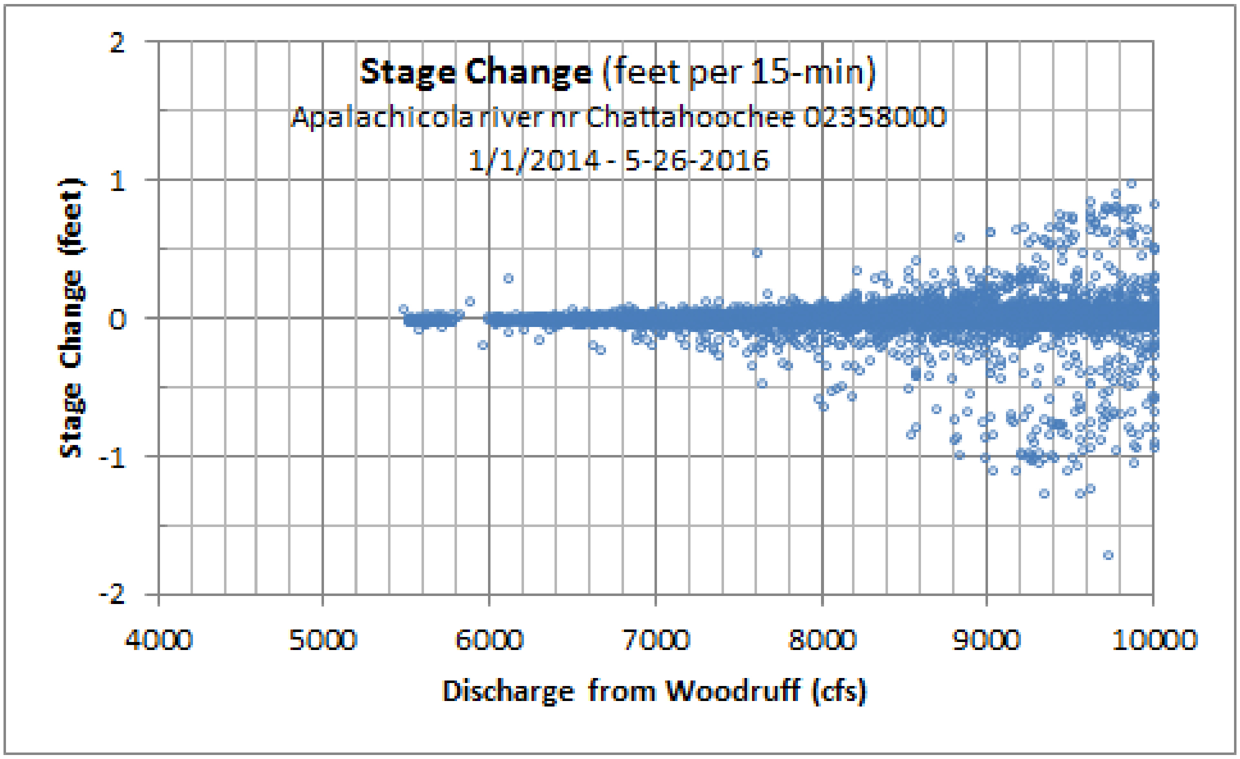
Gulf Sturgeon Egg and Fry Exposure and Survival during Hydropeaking (GS Q1)

Description of Metric: In order to evaluate the potential effects of the proposed action on exposure, and survival of eggs and recently hatched fry during hydropeaking, we calculated the frequency (in percent of days) of 15-minute stage changes (ft/15-min) for all flows during the sturgeon spawning season (March 1-May 31) and when releases from Jim Woodruff Dam are

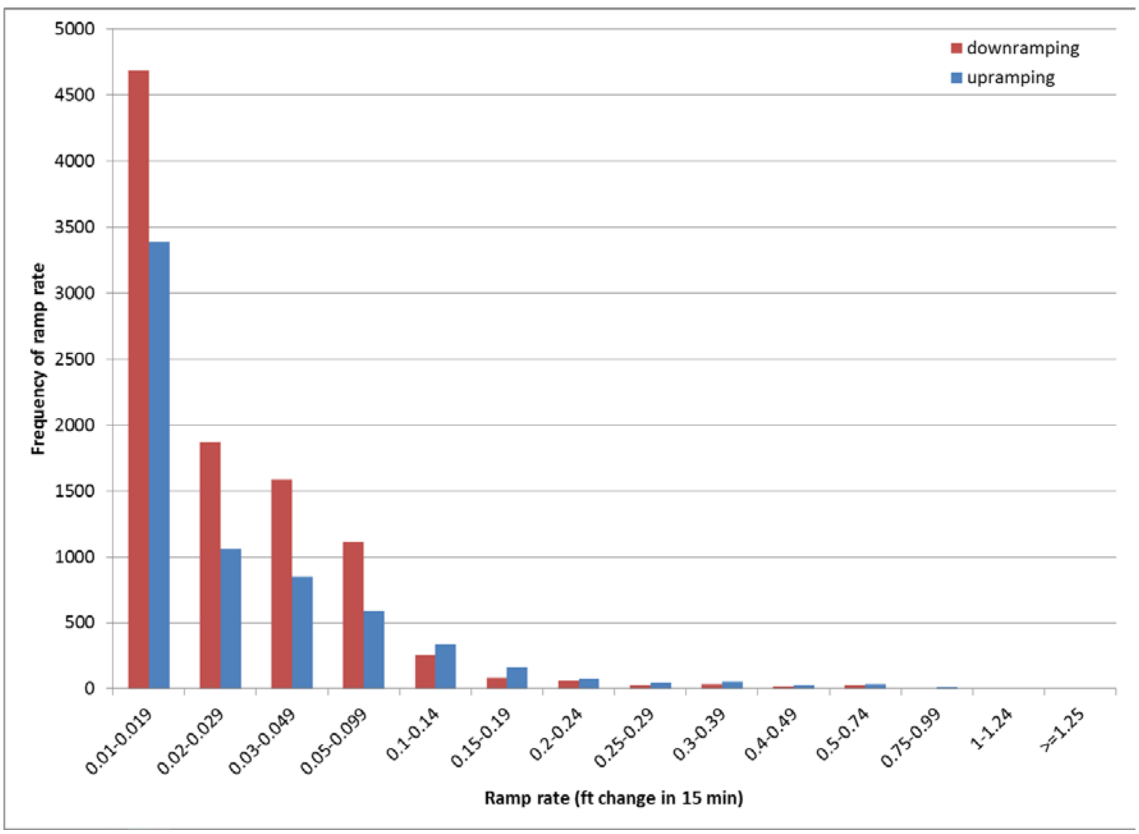
6,700-18,300 cfs based on 15-minute gage height data from 2008-2015 at the Chattahoochee gage. In order to evaluate how often conditions for hydropeaking occur during the sturgeon spawning season (March 1-May 31), we calculated the annual number of days between two thresholds (6,700 cfs and 18,300 cfs) for the Apalachicola River by year of record using the ACF STELLA model and 74-year record.

As discussed in section 1, peaking operations at Jim Woodruff Dam occur between 6,700 cfs and 18,300 cfs. We used 15-minute data from USGS gage 02358000 to analyze the effect of peaking activity on stage and discharge each afternoon (i.e., short durations of increases and decreases in flows lasting 2-6 hrs) from approximately 4:00 p.m. to 10:00 p.m. The large, rapid changes in volume of water from hydropeaking may adversely modify the flow regime PCE for Gulf sturgeon critical habitat and may affect sturgeon egg and fry survival as well as behavior and growth (Table 4.2).

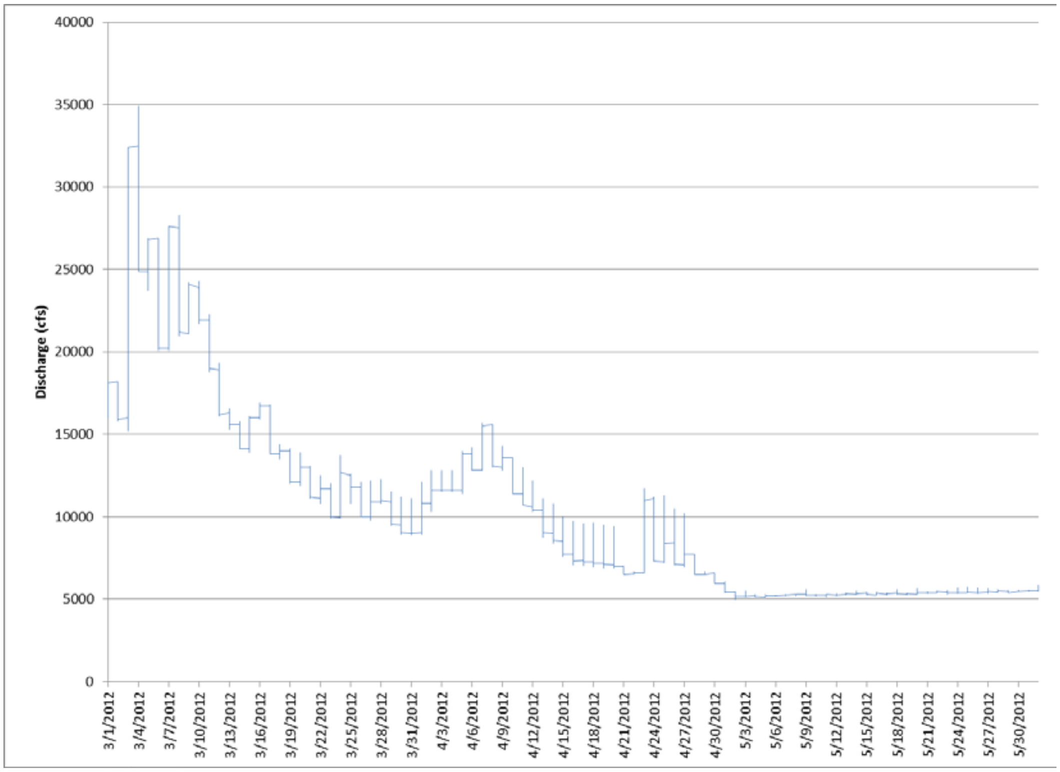
Results: Examples of evidence of peaking operations and effects on sturgeon habitat are presented in Figure 5.4. In general, stage changes of nearly 2 feet in 15 minutes occur when discharges are below 10,000 cfs (Figure 5.3A). Sub-daily, 15-minute discharge and gage height data from the Chattahoochee gage for 8 years (2008-2015) show down ramping rates of up to 0.98 ft/15 min and up ramping rates of up to 1.33 ft/15 min overall and when flows are between 6,700 and 18,300 cfs during the spawning season (Figure 5.4B). In general, discharge changes of 2000-3000 cfs in 15 minutes exist when discharges are between 6,700 and 18,300 cfs as the example of 2012 sturgeon spawning season shows (Figure 5.4C), and days with appropriate conditions to hydropeak occurred on 238 of 736 days (34%) during the 8 spawning seasons. We summarized these data in order to quantify the prevalence and magnitude of peaking activity for hydropower production on sturgeon each afternoon between 4 pm and 10 pm from Mar. 1 – May 31 (Figure 5.4D). This analysis showed down ramp rates up to 3.02 ft/6 hrs and up ramping rates of up to 3.19 ft/6 hrs while hydropeaking activities are occurring, and 86% of down ramps and 73% of up ramps are above 0.25 ft/day, the daily ramp rate threshold. Further, some change of flow occurred during the peaking window of time each afternoon approximately 70% of the time when flows are between 6,700 and 18,300 cfs during the spawning season. These abrupt changes in stage may be an adverse effect of the WCM.



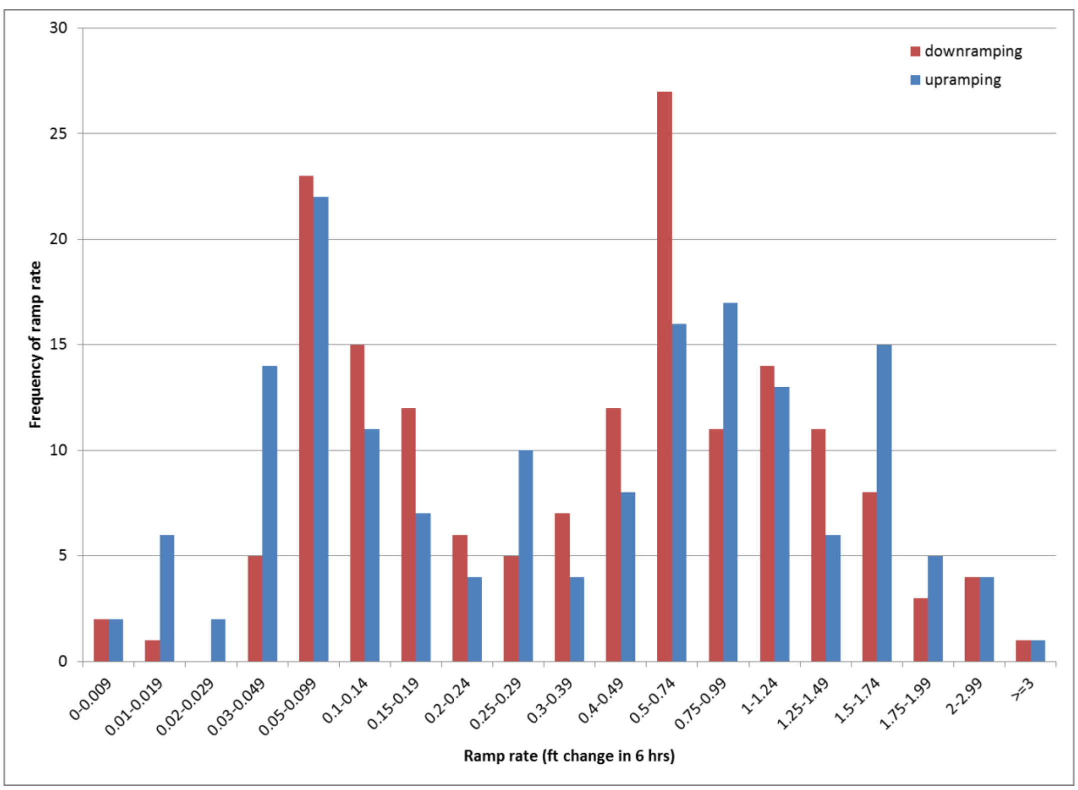
A. Example stage changes below 10,000 cfs.



B. Sturgeon season 15-minute ramp rates



C. 2012 sturgeon season discharges showing peaking



D. Sturgeon spawning season peaking ramp rates

Figure 5.4 Examples of peaking operations when flows are 5,900-18,300 cfs at Jim Woodruff Dam based on available USGS data.

The correlation among daily average flows from the Chattahoochee and Blountstown gages is 0.983 for the same period, but drops to 0.974 for 15-minute data analyzing the available 15-minute data for Blountstown gage (Aug. 2013 - Oct. 2015) (Figure 5.5). This reduction in correlation may be attributed to tributary input, floodplain effects and other factors, but also supports attenuation of peaking waves.

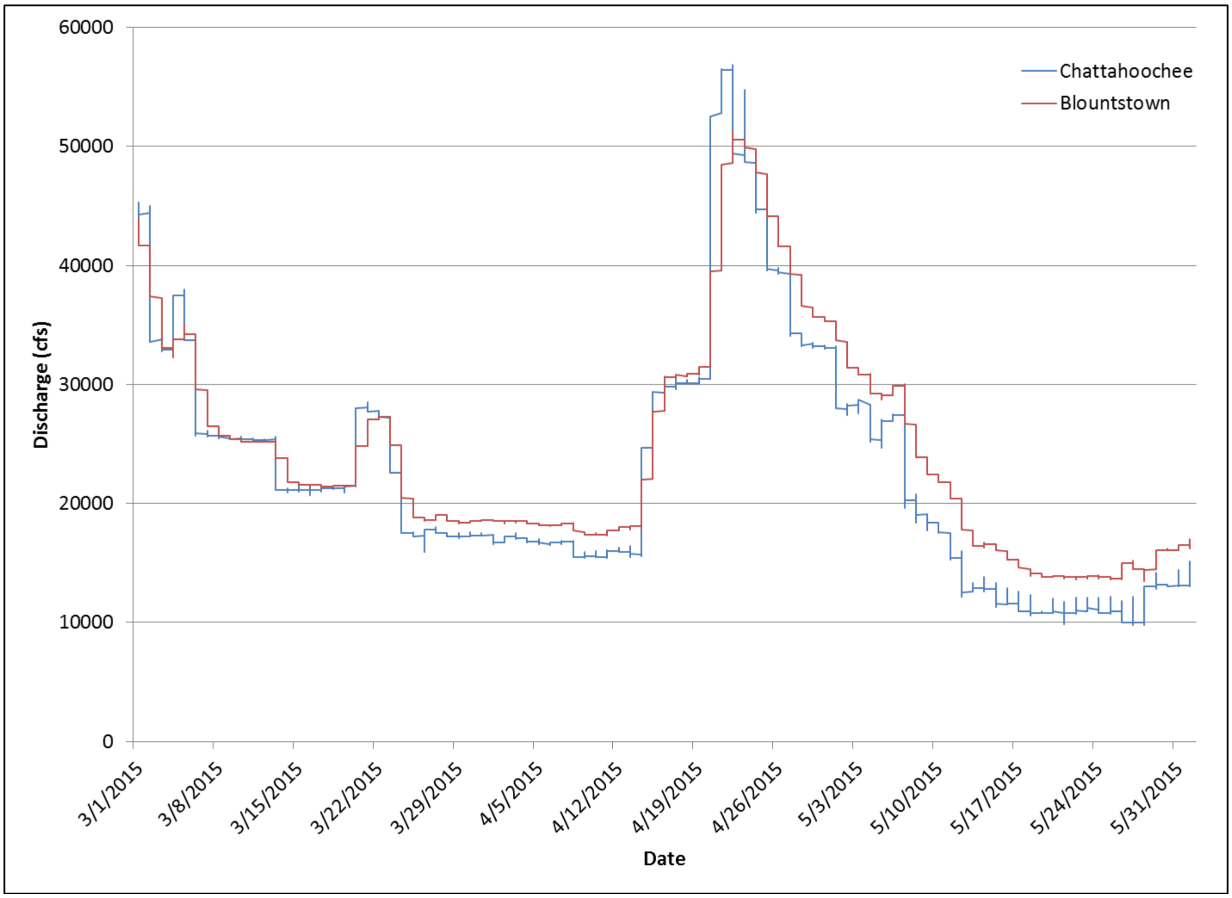
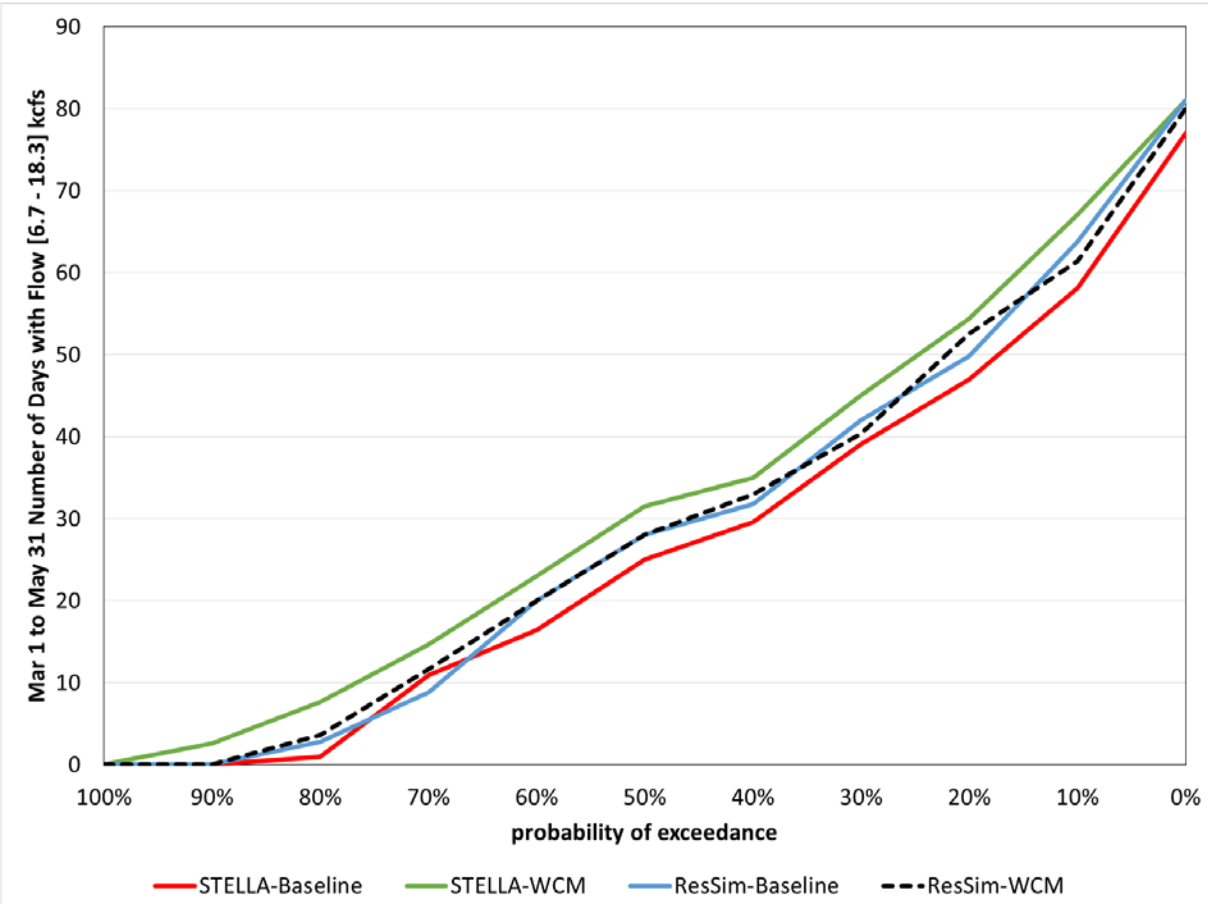
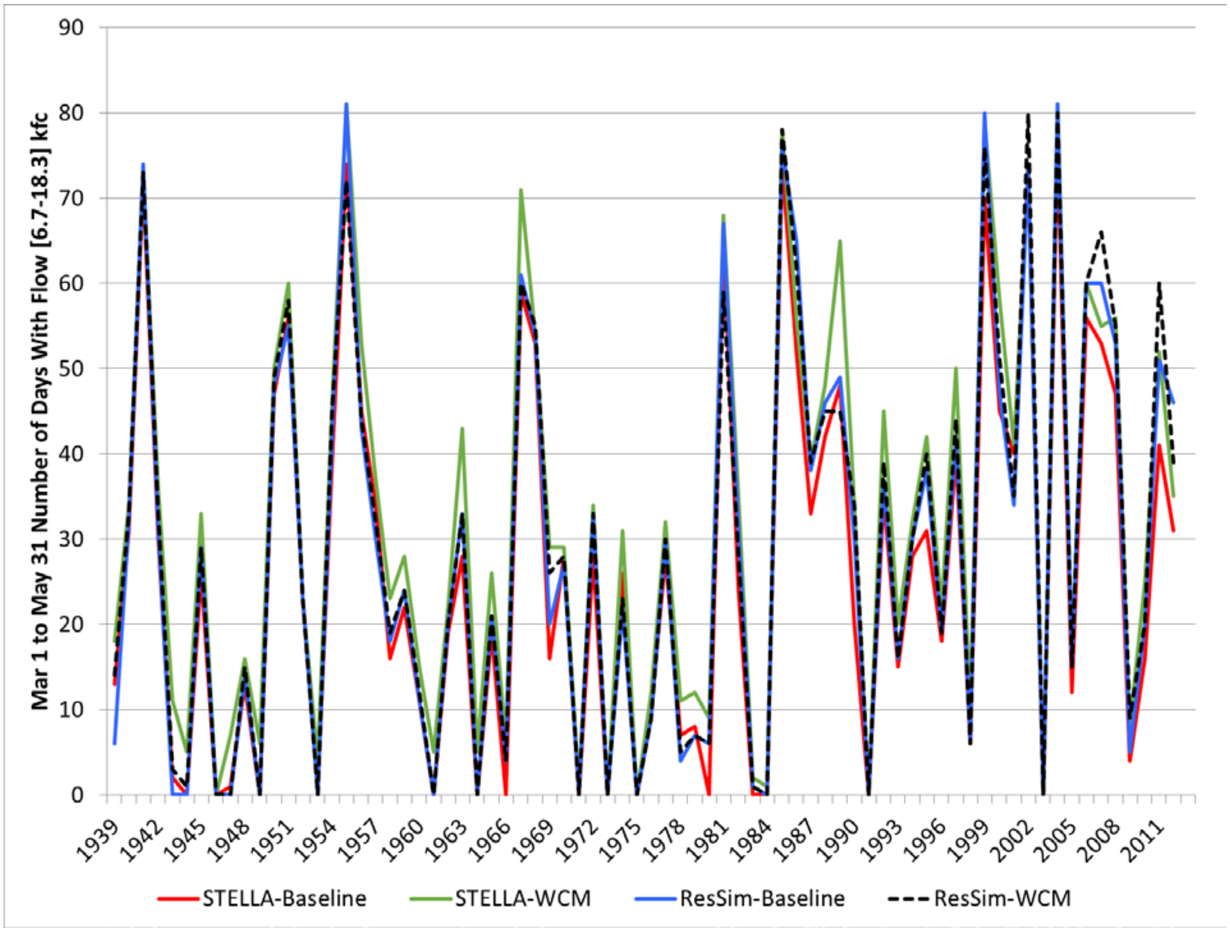


Figure 5.5 Chattahoochee and Blountstown gage comparison for March 1-June 1 2015.

The total number of days at flows between 6,700 and 18,300 cfs between March 1 and May 31 occurring under the 2 flow regimens (baseline, WCM based on both models) is presented as a probability of exceedance plot (Figure 5.6A) and a summary of the days per year (Figure 5.6B). Both models showed the same pattern (i.e., that the WCM increased the amount of time appropriate for hydropeaking), but the STELLA model showed the greater effect. According to this model, the WCM provides 395 days more of appropriate conditions for hydropeaking compared to the baseline across the 74 years (i.e., 5.3 days on average or 26 day average increase during the WCM). Additionally, the WCM increases the probability of conditions when hydropeaking may occur at least once during the year by about 12% (81% to 93% at zero intercept), and overall, from 29% to 35% (2377 of 6808 days). Therefore, we expect the chance of hydropeaking to increase from 4 of 5 years under the baseline to a 4.7 of 5 years of the WCM and expect hydropeaking to occur on average 32 days each year (160 days over 5 years). This may be an adverse effect for the sturgeon population by increasing the time when conditions are appropriate for hydropeaking during the sturgeon spawning season.



A



B

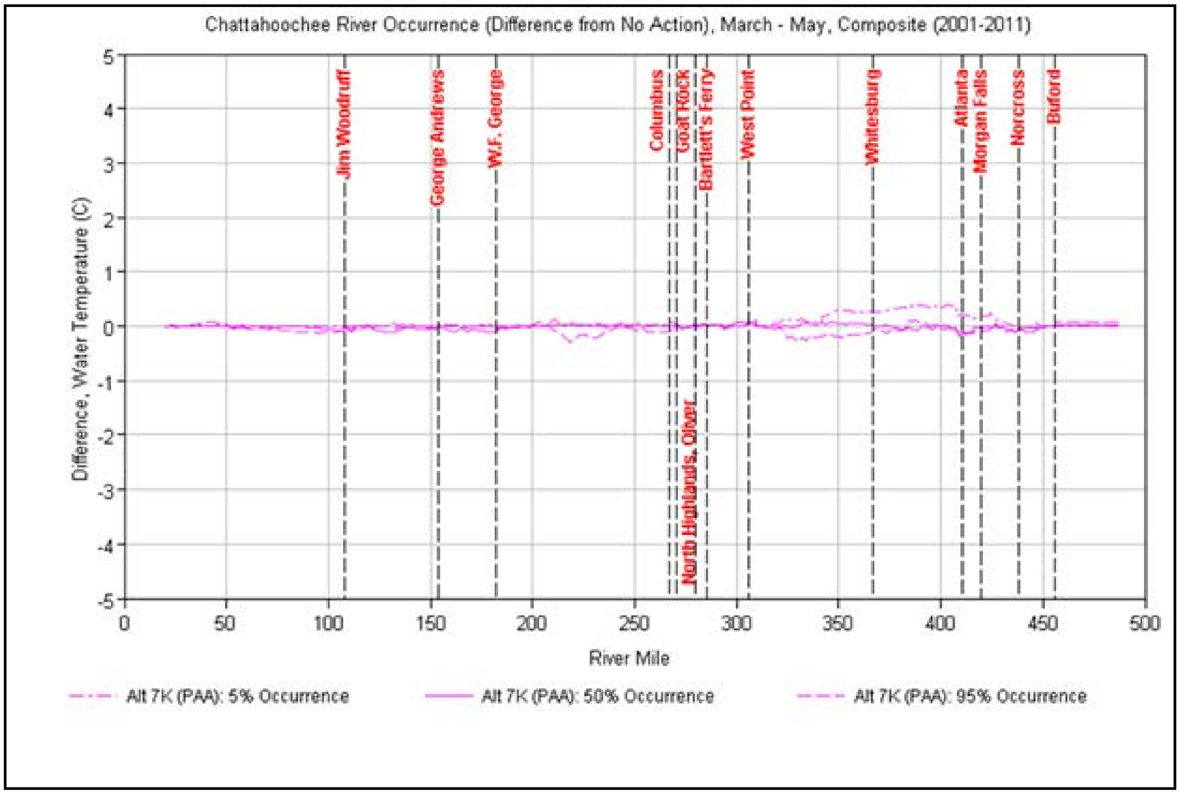
Figure 5.6 Number of days when conditions are correct to allow peaking operations at Jim Woodruff Dam during the 92-day sturgeon spawning season presented as a probability of exceedance plot (A) and count of days (B).

Interpretation: Operation of the hydropower units in peaking mode results in short-term water level fluctuations (i.e., stage changes) that affect the food and flow regime PCEs for Gulf sturgeon and may have the most influence at the known spawning locations. While these short-term variations in water stage and discharge attenuate further downstream, the known spawning sites for Gulf sturgeon are immediately downstream of Woodruff Dam, at limestone outcrops found within the channel from river mile RM 86 to RM 105. Between 6,500 and 18,500 cfs there are 11.1-19.3 ac of spawning habitat of the appropriate depth (8.5 to 17.8 ft). Based on the discharge-spawning habitat acreage relationship developed for GS9, a 3,000 cfs change in discharge in this range of flows may change the spawning habitat available for spawning from -1.1 ac to 5.6 ac for 6-10 hours. This may disrupt egg laying cues by adult females. The food PCE for Gulf sturgeon requires abundant food items, and drifting invertebrates that are key resources for larval sturgeon are adversely affected by hydropeaking. The flow regime PCE for Gulf sturgeon requires a regime (i.e., the magnitude, frequency, duration, seasonality, and rate-of-change of freshwater discharge over time) necessary for normal behavior, growth, and survival of all life stages in the riverine environment, including migration, breeding site selection, courtship, egg fertilization, resting, and staging, and for maintaining spawning sites in suitable condition for egg attachment, egg sheltering, resting, and larval staging. The hydropeaking operation under the WCM likely modifies these PCEs of critical habitat immediately downstream of the dam. Hydropeaking could affect Gulf sturgeon during the spawning season, especially while larvae are dispersing from the spawning sites. Peaking operations during the spawning season may affect survival, development, and growth of sturgeon larvae and juveniles approximately 5 days after hatching when fry begin dispersal from spawning sites. Larvae may experience reduced survival by being washed downriver into unsuitable habitat during late spring and early summer peaking releases and experience reduced growth and development by have drifting invertebrate prey reduced. However, additional data are needed to assess the magnitude these effects.

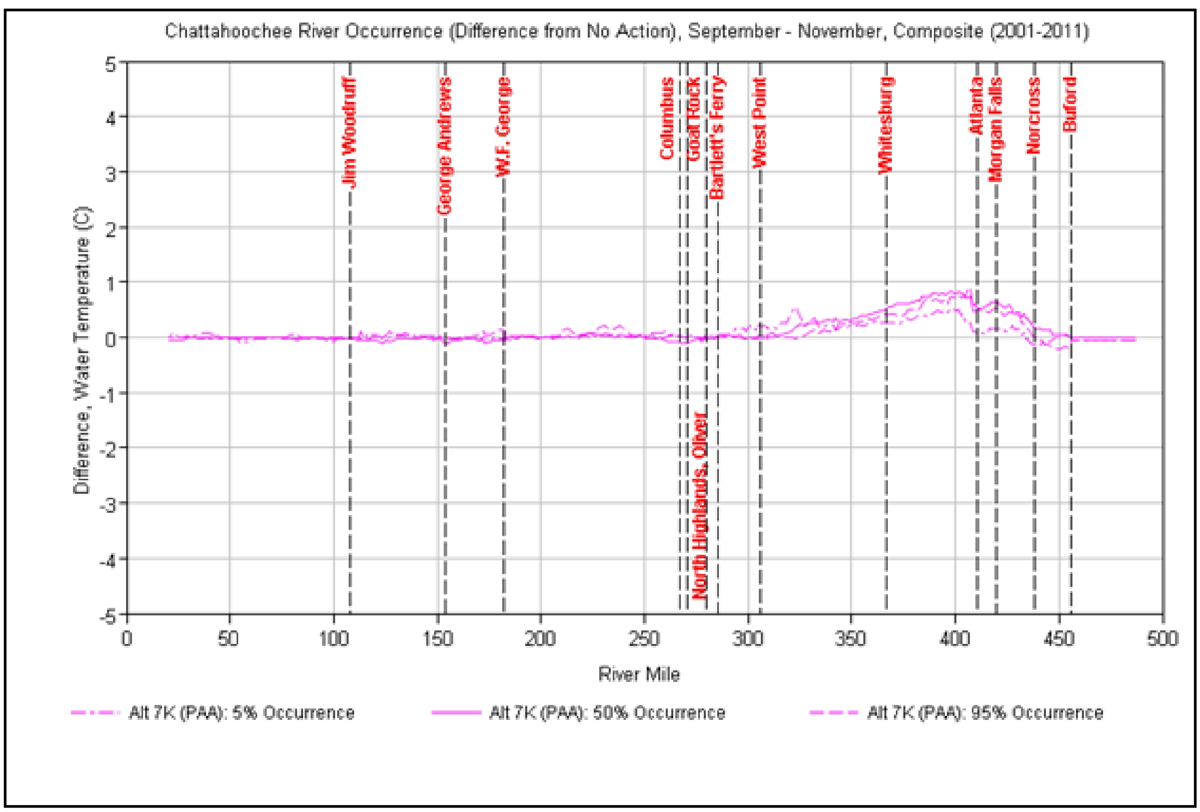
Although the daily average stage limits evaluated in the BA obscure the actual conditions experienced by sturgeon eggs and larvae in the Apalachicola River, increasing the time when conditions are appropriate to hydropeak by an average of 5.3 days (or 26 days for the WCM in 5 years) as well as the probability that conditions will be appropriate to hydropeak at least once during the spawning season by 12% and overall by 6% are adverse effects of the WCM on Gulf sturgeon. These may also be adverse effects to purple bankclimber because Gulf sturgeon is a key host fish for this mussel species.

River Temperatures on Gulf Sturgeon Spawning (GS Q2)

The USACE in its BA developed a HEC-5Q model to analyze WCM effects to water temperature. Figure 2.5 (above) provides a representation of WCM annual effects to stream temperature in spring and fall. Figure 5.7 shows the difference between the WCM (labeled as PAA) and no action (i.e., baseline) at Jim Woodruff Dam. WCM operations are predicted to result in changes to temperatures of less than 1 degrees C both in spring (Figure 5.7A) and fall (Figure 5.7B). The temperatures experienced by sturgeon during the fall spawning season in other rivers (Sept.-Nov.) are near lethal limits. Additional data on temperature fluctuations are needed to assess this possible effect.


Chattahoochee River Occurrence (Difference from No Action), March - May, Composite (2001-2011)
Difference, Water Temperature (C)
River Mile
Jim Woodruff
George Andrews
W.F. George
Columbus
Goat Rock
Bartlett's Ferry
West Point
Whitesburg
Atlanta
Morgan Falls
Norcross
Buford
North Highlands, Oliver
Alt 7K (PAA): 5% Occurrence
Alt 7K (PAA): 50% Occurrence
Alt 7K (PAA): 95% Occurrence

A


Chattahoochee River Occurrence (Difference from No Action), September - November, Composite (2001-2011)
Difference, Water Temperature (C)
River Mile
Jim Woodruff
George Andrews
W.F. George
Columbus
Goat Rock
Bartlett's Ferry
West Point
Whitesburg
Atlanta
Morgan Falls
Norcross
Buford
North Highlands, Oliver
Alt 7K (PAA): 5% Occurrence
Alt 7K (PAA): 50% Occurrence
Alt 7K (PAA): 95% Occurrence

B

Figure 5.7 Difference in Water Temperature (Degrees Celsius) Between the Baseline and WCM (labeled as PAA) (Sep-Dec) based on ResSim simulated flow 1975-2011 in spring (A) and fall (B).

5.3 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 USFWS is aware of only two actions that satisfy the definitions of interrelated and interdependent actions. These will both undergo section 7 consultation in the future, but are worthy of mention because they address possible reasonable and prudent measures and terms and conditions for addressing effects of hydropeaking and salinity in distributary rivers of the Apalachicola River. The contract between Southeast Power Administration and Duke Energy will undergo section 7 in the future. This contract addresses hydropower production and hydropeaking at Jim Woodruff Dam and other USACE dams in this consultation. The USACE operations for maintenance of the Gulf Intracoastal Waterway from Apalachicola Bay to Lake Wimico will undergo section 7 in the future.

6 GULF STURGEON - 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. Future federal actions that are unrelated to the action are not considered in this section because they require separate consultation under section 7 of the Act. Based on the USACE policy for review of WCMs, the timeframe for the applicability of the WCM is five years. Therefore, we have considered potential non-federal activities that may also change the primary factors considered in Appendix A, as well as any other non-federal actions that may affect the listed species during this five-year period. Cumulative effects for the ACF Basin are discussed below. These cumulative effects are expected be similar for all listed species.

Non-federal 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 in the basin from continued urbanization in the Atlanta metropolitan area as discussed in section 2 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, and these regulations are reviewed in the DEIS (USACE 2015, p. 2-123 – 2-149).

7 GULF STURGEON - CONCLUSION

The proposed action provides both beneficial and adverse effects to Gulf sturgeon and designated critical habitats we have assessed. We attribute all differences between the baseline and WCM simulated flow regime to the USACE's discretionary operations, with the acknowledgement that the Rivers and Harbors Act release requirements for water supply in downstream Atlanta are not discretionary. Differences between the baseline and WCM are summarized in general form below (for more details, see sections 4 and 5).

7.1 Summary of Effects

Spawning Adult to Egg:

- Spawning habitat inundation
    - ***Neutral*** – no effect on 30-day inundation (GS 9)

Egg to Young of Year:

- Increased opportunity for hydropeaking at Woodruff from Mar 1-May 31 (GS Q2)
    - ***Negative*** – increase conditions for hydropeaking and chance of washing fry from foraging areas after hatching and larvae begin swimming (GS Q1)
- Operational effects to stream temperature
    - ***Neutral*** - No distinguishable differences in WCM operation on stream temperatures in the Apalachicola River (GS Q2)

Young of Year to Juvenile:

- Forage availability while in freshwater from Nov 24 to Jun 1 (190 days)
    - ***Negative*** – Floodplain inundation (total days) (GS 1)
        - Negative effect in 10% of the years
        - During times of high flow (10-20% probability of exceedance range)
        - Up to 10 days reduction for the 190 day period
    - ***Neutral*** – Floodplain inundation (acre days) (GS 2)
- Forage availability while in freshwater from Jul 15 to Nov 24 (183 days)
    - ***Neutral*** – Floodplain inundation (total days) (GS 3)
    - ***Negative*** – Floodplain inundation (acre days) (GS 4)
        - At >83% exceedance probability
            - Average of 6.3% less floodplain inundation per year
        - Overall
            - Average of 18,904 acre days less floodplain inundation per year
    - ***Slight negative*** – Floodplain inundation (total pulses) (GS 5)
        - One fewer 15-day pulse across the 74-yr record
    - ***Negative*** – Hydropeaking at Woodruff from Mar 1-May 31 (GS Q2)
        - Under WCM operations, changes in river stage of up to three feet have been observed within a six hour time period and peaking conditions increased to about 35% of the spawning season.
- Young of Year Access to Foraging Habitat from Jan 1 through Mar 15 (74 days)

    - ***Neutral/Positive*** **–** young of year access to foraging habitat (GS7)

Juvenile to Non-Reproductive Adult:

- Estuarine Invertebrate Production from Nov 24 to Jun 1 (190 days)
    - ***Negative*** **–** Floodplain inundation (total days) (GS 1)
        - Negative effect in 10% of the years evaluated
        - Negative effect occurs during times of high flow (10-20% probability of exceedance range)
        - Up to 10 days reduction in floodplain inundation for the 190 day period
    - ***Neutral*** **–** Floodplain inundation (acre days) (GS 2)
- Estuarine Invertebrate Production while in freshwater from Jul 15 to Nov 24 (183 days)
    - ***Neutral*** **–** Floodplain inundation (total days) (GS 3)
    - ***Negative*** **–** Floodplain inundation (acre days) (GS 4)
        - At >83% exceedance probability
            - Average of 6.3% less floodplain inundation per year
        - Overall
            - Average of 18,904 acre days less floodplain inundation per year
    - ***Slight negative*** **–** Floodplain inundation (total pulses) (GS 5)
        - One fewer 15-day pulse across the 74-yr record
    - ***Negative*** **–** Hydropeaking at Woodruff from Mar 1-May 31 (GS Q2)
        - Under WCM operations, changes in river stage of up to three feet have been observed within a six hour time period and peaking conditions increased to about 35% of the spawning season.
- Juvenile Access to Foraging Habitat from Nov 1 through Mar 15 (135 days)
    - ***Neutral/Positive*** **–** General Low Salinity Conditions for Access to Foraging Habitat (GS 6)
    - ***Neutral/Positive*** **–** Unsuitable Salinity Conditions for Access to Foraging Habitat (GS 8)
        - Reduced the consecutive number of days flows below 16,200 cfs
        - Improvements for the hydroecological metric were realized for approximately 20% of the years evaluated

The current population of Gulf sturgeon in the Apalachicola River appears to be stable, although this population is not showing the patterns of recovery and increasing trends in adjacent rivers. The principal effects to the Gulf sturgeon in the action area are:

1) Woodruff Dam precludes migratory movements to additional spawning habitat located in the Flint and Chattahoochee basins.
2) Substantial changes to both the low and high ends of the flow regime in the post-West Point period compared to the pre-Lanier period may have adversely affected estuarine habitat availability and/or suitability for sturgeon feeding.
3) The analysis shows a small adverse effect that is measurable and detectable on estuarine invertebrate production (GS1, GS4, GS5), but it is difficult at this time evaluate this change in terms of reduced growth, survival, or distribution of juveniles because data on this period of sturgeon life history are lacking.

4) The magnitude of reduction in benthic invertebrates (i.e., sturgeon food) that results from a reduction in floodplain inundation in the Apalachicola River is unknown, and the WCM may have slightly beneficial effects by increasing the number of pulses and increasing the number of consecutive days/year ≥ 16,200 cfs in the winter months. Until better data is available, we could conclude that this effect on estuarine invertebrate production is insignificant. Therefore, we anticipate only minor changes in salinity regimes or estuarine habitat due to the WCM. The effect of depletions on the sturgeon's estuarine habitats in the distributary rivers of the Apalachicola is unknown at this time pending results of studies of sturgeon use of the bay and estuary and application of appropriate hydrodynamic models and water quality monitoring that may predict and validate salinity regime changes and benthic food resource responses. The only existing model by Dr. Peter Sheng is based on salinity monitoring at three points in the bay and may not accurately predict the flow and salinity relationship in the Gulf sturgeon's estuarine habitats in the distributary rivers of the Apalachicola.
5) Take of Gulf sturgeon eggs and larvae due to the WCM may occur when river conditions are between 6,700 and approximately 18,000 cfs in March through May due to hydropeaking flow. The effects of the proposed WCM on spawning habitat were not analyzed with fine scale daily fluctuation data, but previous flow-habitat relationships illustrate the sensitivity of these habitats to changes in discharge, especially during low-flow events (Flowers et al. 2009, Ziewitz 2006). In turn, these habitat conditions may influence Gulf sturgeon courtship and spawning behavior, fertilization rates, egg and larval development, and age-class representation in the population. Some of these sites may be exposed and desiccated at lower discharges from Woodruff (Figure 7.1). We are unable to reliably estimate the extent of Gulf sturgeon take due to hydropeaking at this time. The following calculation is an example of the data required to be able to calculate take of the population due to hydropeaking. USFWS (unpublished data) captured and sized 295 sturgeon in 2014 and of these 96 fish (33%) were of adult breeding size (>150 cm fork length). The 2014 population estimate of 785 fish yields 255 fish of breeding size. If we use fecundity information from the Suwanee River that 0.25-1% of the population are females in spawning condition (USGS, Ken Sulak, pers. comm. 8/22/16), then 1-3 females per year spawn. If each of these females lays 400,000 eggs, then 400,000-1.2 million eggs are laid in the river. From 2013-2015, USFWS (unpublished data) captured 51-200 juvenile sturgeon after 1 year, which would indicate a survival rate of 0.0043-0.05% in the river. Of this theoretical >99.9% mortality, it is unknown what proportion is due to hydropeaking as opposed to other factors that may affect survival during this first year of life including food availability in the river, food availability in the estuary, predation, and water quality.

Figure 7.1 Race shoals spawning site (RM 104.7) exposed at lower discharges (app. 5500-5700 cfs) from Woodruff Dam. (USFWS, Sept. 10, 2010)

The change in metrics (GS1, GS4, GSQ1) will be used as surrogate measures of take for this consultation (i.e., days and ac-days of floodplain inundation, day of hydropeaking conditions). However, we believe it is necessary to further evaluate the effects of hydropeaking and floodplain inundation on sturgeon eggs and larval survival in the next spawning seasons when peaking occurs and next winters when foraging effects may occur. The effects of hydropeaking may affect spawning and riverine site conditions and food resources and survival of Gulf sturgeon swimming larvae after hatching. This altered flow regime may also alter the normal behavior of adults during site selection, courtship, egg fertilization at shallower areas of spawning sites and may affect the growth and survival of eggs during egg attachment and development, and larval staging. USFWS will work with USACE to monitor the effects of the WCM on spawning, hatching, larval growth and juvenile growth for Gulf sturgeon.

7.2 Critical Habitat

As discussed above, designated critical habitat for the Gulf sturgeon in the action area includes the Apalachicola River unit, and the Apalachicola Bay unit. In the effects analysis, we discussed how the WCM may affect four of the PCEs of sturgeon critical habitat: 1) food items in both the riverine and estuarine environments; 2) riverine spawning areas; 3) flow regime, and 4) water quality. Of the effects of WCM, hydropeaking has the potential to affect food resources in the river for young (5-day old) sturgeon larvae and the reduction in floodplain inundation in the fall and winter has the potential to further reduce food resources for juvenile sturgeon overwintering for the first time in the bay and estuary. Spawning areas may be affected by the sub-daily flow and velocity changes from hydropeaking. The flow regime may be altered by operations under the WCM by changing floodplain inundating flows and sub-daily fluctuations from hydropeaking. The water quality, especially salinity, in the distributary rivers may affect the ability to effectively forage by young of year and juveniles in the winter. However, the WCM 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.

7.3 Determination

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 USFWS' biological opinion that the proposed action: 1) will not jeopardize the continued existence of the Gulf sturgeon; and 2) will not destroy or adversely modify designated critical habitat for the Gulf sturgeon.

The WCM is intended to apply until a new WCM is adopted. Given the USACE's current timeline, the findings of this BO shall apply for five years until September 14, 2021, or until amended through a reinitiation of consultation or superseded with a new opinion for a new proposed action.

8 MUSSELS - STATUS OF THE SPECIES

8.1 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 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).

8.2 Critical Habitat Description

On November 15, 2007 (72 FR 64286), the USFWS designated 11 stream segments (units) as critical habitat for the endangered fat threeridge, and the threatened Chipola slabshell and purple bankclimber pursuant to the Act (USFWS 2007a). These units include 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 approximately 1,909 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 8.1). 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 8.1). 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 8.1). This unit encompasses approximately 228.8 km (142.2 mi) of river in the Chipola River Basin in Alabama and Florida.

Table 8.1 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*

Primary Constituent Elements

Each of the designated critical habitat units for these three listed mussels contains one or more of the PCEs that the USFWS 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.

8.3 Life History

8.3.1 Lifespan

In general, 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, 1971). 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 (e.g., Margaritiferidae, Amblemini, Pleurobemini, and Quadrulini) being longer lived than fast growing species (e.g., Andontini).

Fat threeridge

The USFWS has studied age of fat threeridge, primarily aging shells by counting internal shell annuli via thin-sectioning, but also through validation with stable oxygen isotope variability in the shell. Our data indicate that the internal line method may overestimate age by counting less significant growth bands (false annuli) interspersed within larger growth increments (greater accuracy in younger individuals). However, 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). 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.

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. To date, the USFWS 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. Our results indicate that the fat threeridge exhibits low to moderate growth and intermediate longevity relative to other mussel species (Haag and Rypel 2010).

Purple bankclimber

EnviroScience, Inc. (2006a) 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 (see Figure 2.3.2.B in USFWS 2012).

Chipola slabshell

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

8.3.2 Reproduction

The fat threeridge, purple bankclimber and Chipola slabshell are bivalve mussels of the family Unionidae. Sexes in unionid mussels are usually separate (van der Schalie 1970, Downing et al. 1989). Most unionid mussel species have a parasitic stage during which the immature mussels, called glochidia, must attach to a host to transform into a juvenile (Figure 8.1). Females release glochidia either separately or in masses termed "conglutinates", depending on the mussel species.

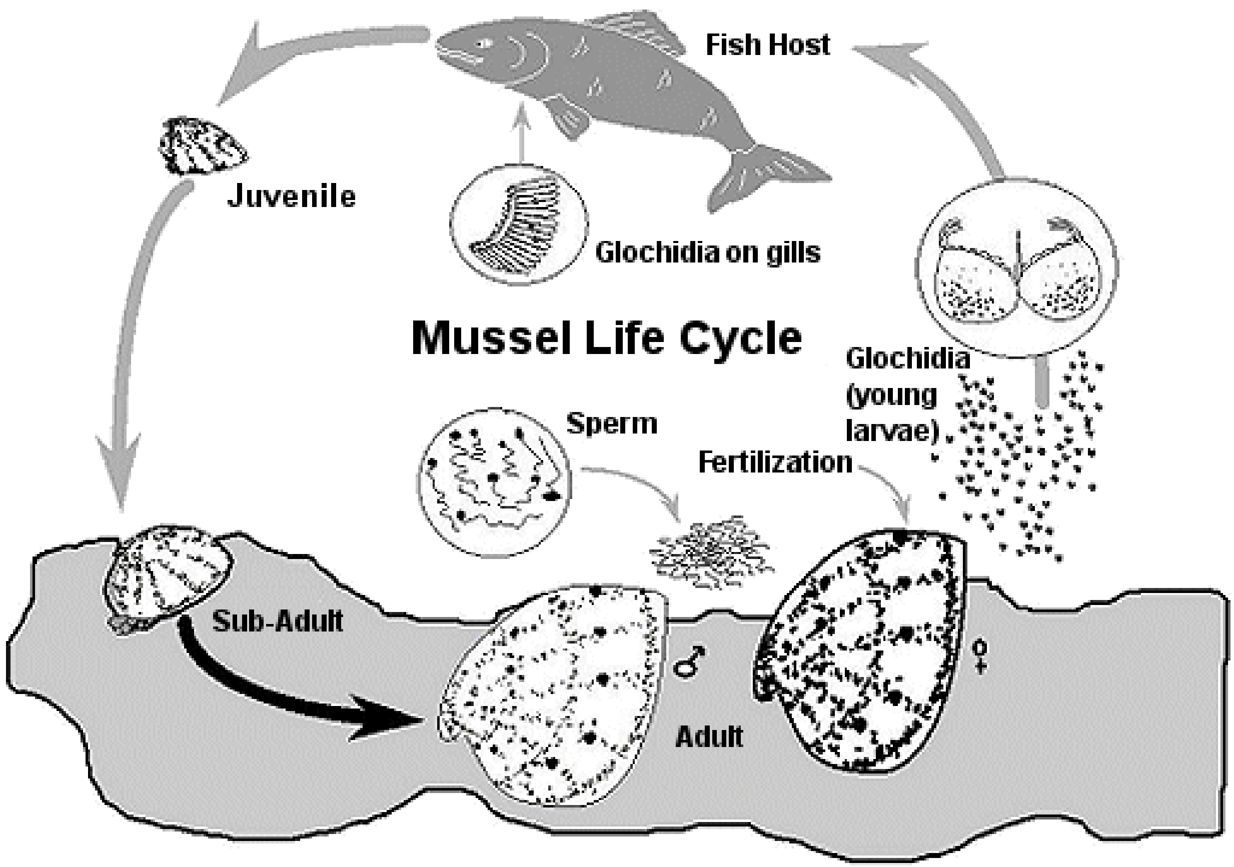


Figure 8.1 Freshwater mussel life cycle (IMT 2002).

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 1993), 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 and 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 and 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 lifespan 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 23.9°C, 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 seven different fish families, albeit with varying degrees of success to transformation (O'Brien and Williams 2002, Fritz and Bringoff 2014). Fritz and Bringolf (2014) reported transformation of fat threeridge on 23 species of fish, including such commonly occurring species as bluegill (*Lepomis macrochirus*) and largemouth bass (*Micropterus salmoides*). Potential host fishes with the highest transformation success (Fritz and Bringoff 2014) included: the migratory striped bass (*Morone saxatilus*), the percids swamp darter (*Etheostoma fusiforme)*, turquoise darter (*E. inscriptum)*, and tesselated darter (*E. olmsteadi)*, the centrarchids green sunfish (*Lepomis cyanellus*), and longear sunfish (*L. megalotis*), and the cyprinids flagfin shiner (*Pteronotropis grandipinnis*) and yellowfin shiner (*Notropis lutipinnis*). Transformation of the glochidia on host fishes required 10 to 18 days (O'Brien and Williams 2002, Fritz and Bringoff 2014). Fritz and Bringoff (2014) confirmed earlier work that the fat threeridge is a host generalist.

Fat threeridge age and growth data suggest females reach sexual maturity at three years of age (USFWS unpublished data). 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).

Purple bankclimber

Female 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; 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).

Fishes that have effectively transformed glochidia of the purple bankclimber during laboratory infections include the eastern mosquitofish (*Gambusia holbrooki*), blackbanded darter (*Percina nigrofasciata*), halloween darter (*Percina crypta*), 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 et al. 2012, 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 et al. 2012, Hartzog 2011). The highest rate of transformation occurred in the four sturgeon species which ranged from 79 to 89%. 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, Preister 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 (Preister 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 (Preister 2008).

Feeding: 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).

8.4 Habitat and Population Status

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. Finally, Smit (2014) and Smit and Kaeser (in press) and additional work by USFWS resulted in a comprehensive and quantitative study via the use of side scan sonar habitat mapping to create species distribution models for the fat threeridge in Apalachicola and the Chipola rivers. Following is a summary of this information, and of other recent studies.

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.

Distribution: The USFWS listed the fat threeridge as an endangered species in 1998 (USFWS 1998a). Currently, the fat threeridge is found throughout much of its historical range (Figure 8.2); however, it is extirpated from localized portions of the Apalachicola and Chipola rivers. The fat threeridge presumably no longer occurs in the portion of the Apalachicola and Flint rivers that is now unsuitable habitat, 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, Gangloff 2011, USFWS unpublished data). It was extirpated from much of 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).

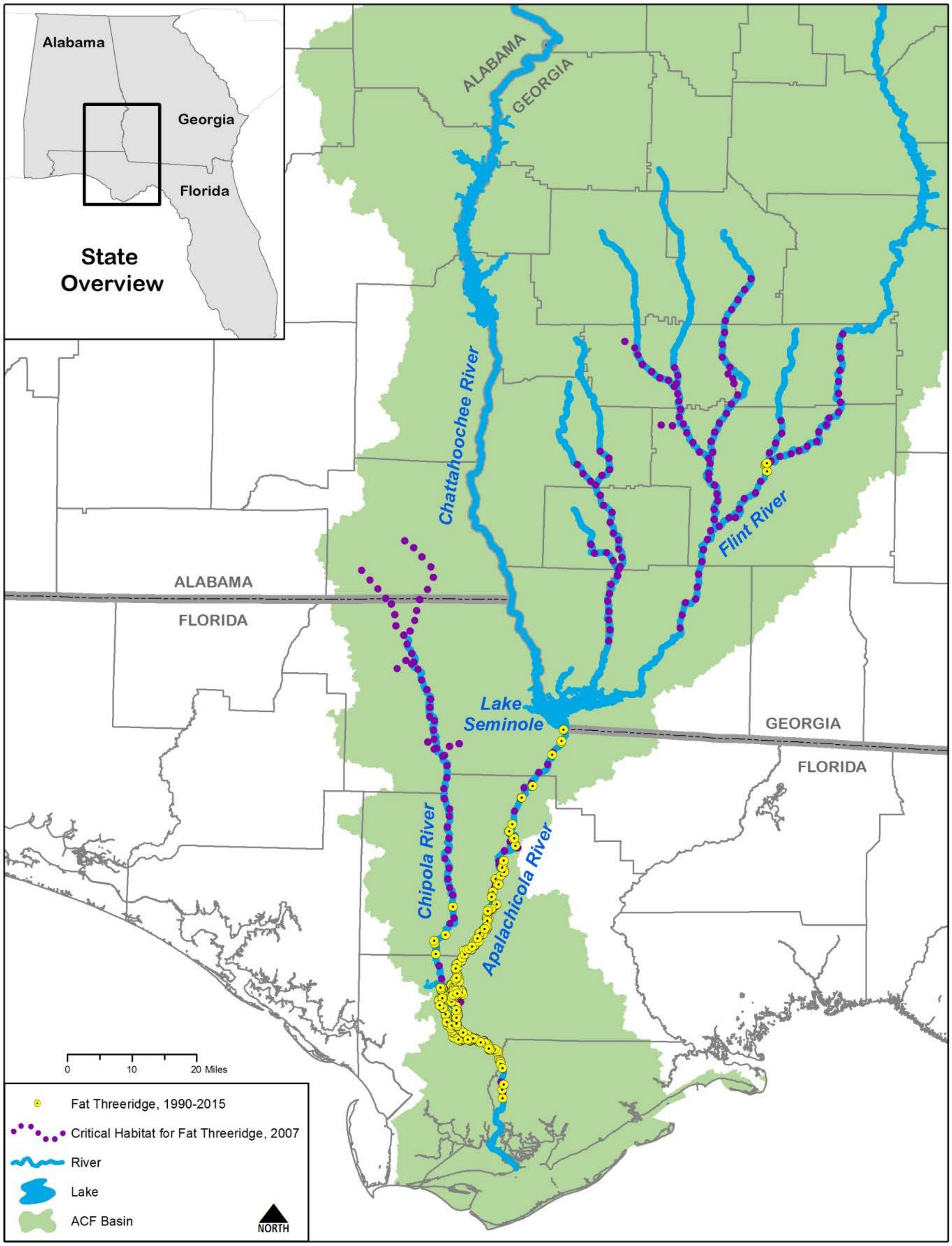


Figure 8.2 Current (1990-2015) occurrences of fat threeridge throughout its range.

Although the species persists in the Flint River, it appears to be extremely rare and localized. Since 2006, biologists from the Georgia Department of Natural Resources (GDNR) and USFWS found live adults near the Highway 37 bridge. 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.

Habitat: 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, 2011, and 2016; Gangloff in 2008, 2010 and 2011, and the USFWS in the years 2006 thru 2015. In most instances, these studies took place during drought conditions when water levels were moderately to extremely low.

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). Earlier work found the most abundant populations in moderately depositional areas along bank margins at depths of around 1 meter (3.3 ft.) (Miller and Payne 2005, Miller and Payne 2006, EnviroScience 2006a; Gangloff 2011). However, recent studies have expanded on our knowledge of fat threeridge mesohabitat use, and mussels were documented in mesohabitats (Garcia et al. 2012) not well sampled in past studies such as pool/outerbank mesohabitat (Smit 2014, Smit and Kaeser *in press*). The pool/outerbank mesohabitat which occurred at depths between 2.3-8.5m was defined as the second largest class identified in the river, characterized by imagery with a smooth/plane bedform and presence of large woody debris (Smit 2014, Smit and Kaeser *in press*). The average density in this mesohabitat class was nearly equal to densities of other known habitat types (inner and outer recirculation zones described earlier by others as moderately depositional areas), and this knowledge, as well as, documentation in other mesohabitat types (main channel and point bar) resulted in a population estimate in the Apalachicola river (Smit 2014).

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 later sections.

Abundance: The fat threeridge is locally common, the population is seemingly large, and recruitment is occurring. Although periodic drought-induced mortality may cause some localized population declines, we currently consider the species' status to be stable or improving. In suitable habitat, the fat threeridge is common to abundant and recruitment is occurring.

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, as well as 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 USFWS listed the purple bankclimber as a threatened species in 1998 (USFWS 1998a).

Distribution: Presently, the purple bankclimber occurs in much of it historical range (Figure 8.3); 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 until 2001, when a single, live and old specimen was found in the upper portion of Goat Rock Reservoir. Within the Flint and Ochlockonee river drainages, the species is relatively common, but occurs at fewer sites than historically due in part to two mainstem dams and reservoirs 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 unsuitable habitat, 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.”

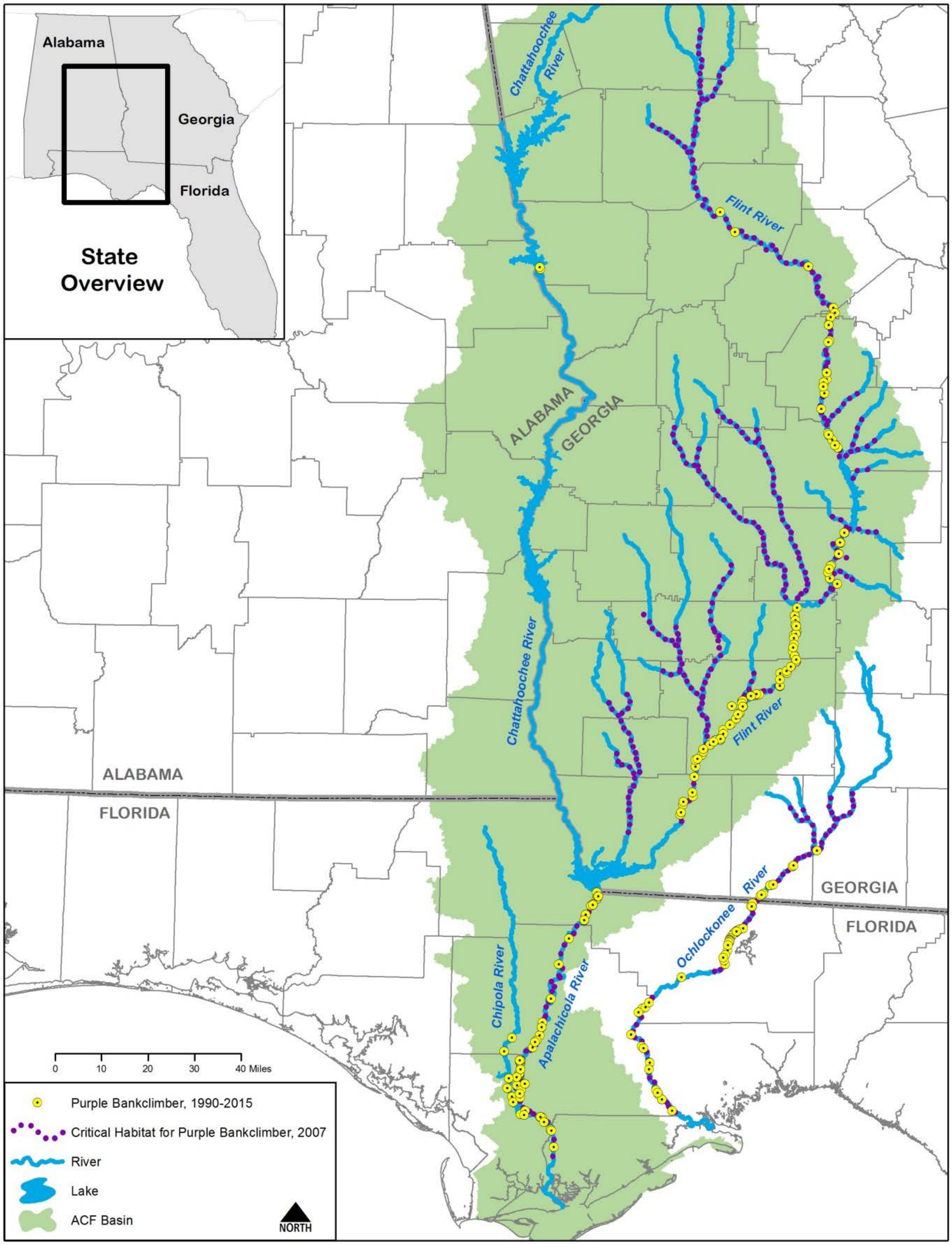


Figure 8.3 Current (1990-2015) occurrences of purple bankclimber throughout its range.

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).

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. 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). 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 unpublished data). Recent (2015) sampling efforts by USFWS to quantify mussels in the Apalachicola River resulted in very few purple bankclimber collected in the study area.

Like 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 later sections. Drought-induced mortality was also observed on the Flint and Ochlockonee rivers in 2011.

Abundance: 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 purple 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 mainstem 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. In 1998, the USFWS listed it as a threatened species (USFWS 1998a).

Distribution: Currently, the Chipola slabshell occurs in nearly all of its historical range, with the exception of Howards Mill Creek (Figure 8.4). 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, since 2010, live individuals and fresh dead have been collected in the Apalachicola River main channel near the Chipola Cutoff.

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.

Abundance: 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.

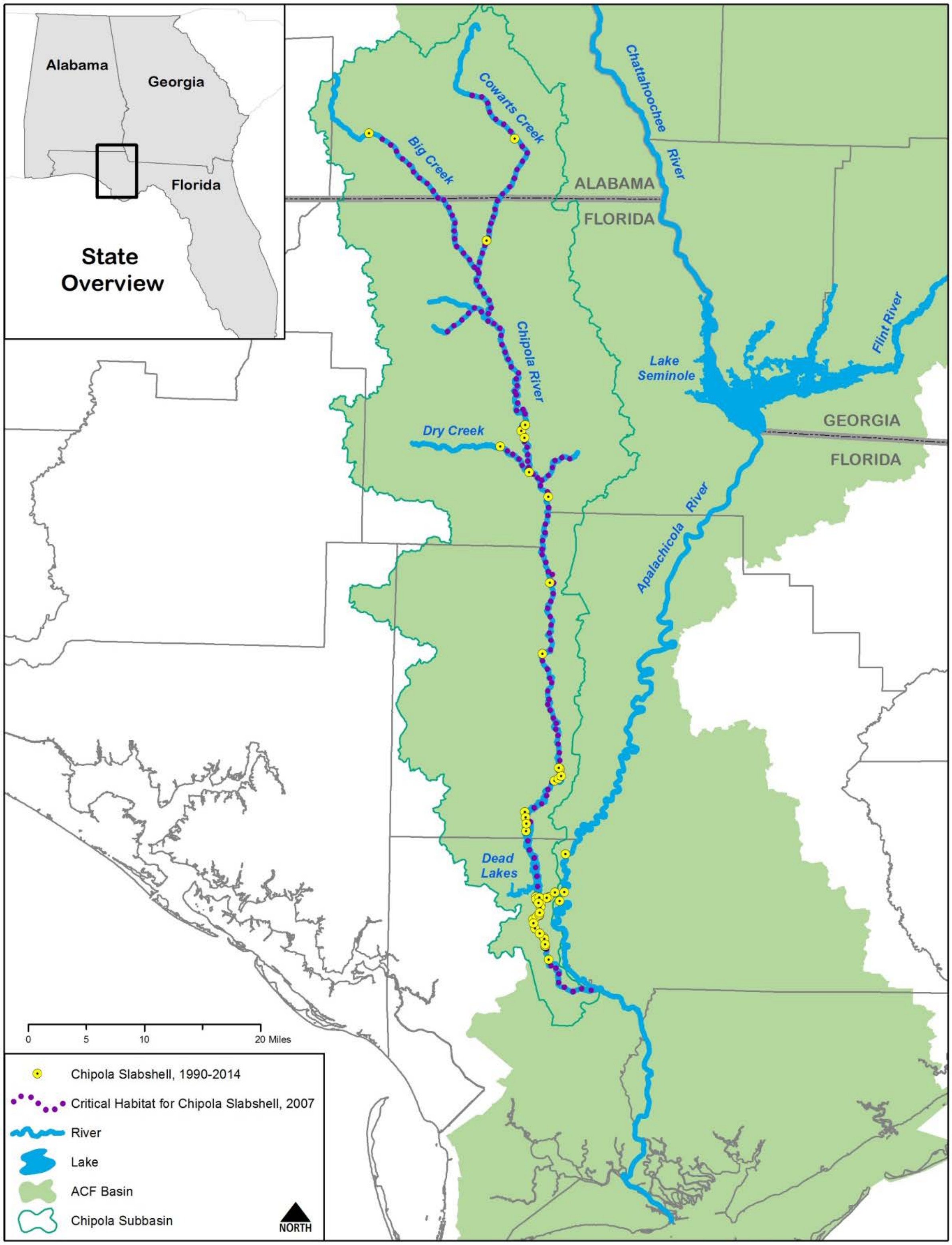


Figure 8.4 Current (1990-2014) occurrences of Chipola slabshell throughout its range.

8.5 Analysis of the Species/Critical Habitat Likely to be Affected for Mussels

This BO addresses effects of the USACE's water management operations under the WCM and the associated releases to the Apalachicola River on the fat threeridge, purple bankclimber, and Chipola slabshell and their designated critical habitats. 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 mainstem 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. It is part of Unit 2, which includes the Chipola River mainstem and several of its tributaries, including the portion of the Chipola River that is within the action area downstream of Dead Lake and the Chipola Cutoff. Therefore, we limit our analysis of effects to critical habitat to Unit 8 (fat threeridge and purple bankclimber) and Unit 2 (fat threeridge and Chipola slabshell).

9 MUSSELS - ENVIRONMENTAL BASELINE

9.1 Status of the Species within the Action Area

9.1.1 Fat threeridge

Our knowledge of the status and distribution of fat threeridge in the action area has improved in recent years. Recent survey techniques using SCUBA and habitat mapping using side-scan sonar have resulted in much higher estimates of population size, and a better understanding of the habitat for and vertical distribution of fat threeridge (Smit 2014, Smit and Kaeser *in press*). The sonar mapping approach identified twice as many patches and ten times the quantity of suitable habitat than identified using traditional approaches. This BO considers the most current distribution and status information that has been collected since the 2012 BO. The status of fat threeridge is scheduled to be fully reviewed and evaluated in 2019.

9.1.1.1 Current Distribution in the Action Area

Almost the entire currently occupied range of the fat threeridge falls within the action area of this consultation. The current range of the fat threeridge is about 75% of its historical range, and it is locally rare in the upper Apalachicola River (e.g., upstream of RM 90) and locally abundant in middle and lower portions of the Apalachicola River. Two portions of the species' current range are outside the action area: the upstream end of Dead Lake on the Chipola River, and sites on the lower Flint River, may be less affected by USACE actions than other areas. 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 8.2) 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 (Preister 2008), FFWCC (2007, 2011, 2016 unpublished data), Gangloff (2008, 2011), and USFWS (unpublished data, Smit 2014, Smit and Kaeser *in press*). 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, USFWS 2012, USFWS unpublished data). During 2012-2015 surveys by Smit (2014) and continued by USFWS staff, 7,454 individuals were collected from the middle (Table 9.1) and lower (Table 9.2) Apalachicola River and lower Chipola River (Table 9.3). The largest portion of the population (61%) occurs in the Chipola Cutoff and lower Chipola River downstream of Dead Lake, and 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 and fat threeridge populations in this area. The remaining population occurs in the middle (34%), lower (5%), and upper (<1%) Apalachicola River.

Table 9.1 Mussel species collected during surveys of the middle Apalachicola River in 2012-2014.

			Relative frequency of occurrence			
Species*	Total collected	% freq of total collected	Among samples from IRZ, ORZ, and POB	% freq	Among samples from MC and PB	% freq
Amblema neislerii	3958	0.345	90	0.882	8	0.129
Elliptoideus sloatianus	24	0.002	13	0.127	0	0
Elliptio chipolaensis	1	0.0001	1	0.010	0	0

*Mussels are listed in order of decreasing relative frequency of occurrence among samples collected in the Inner Recirculation Zone (IRZ), Outer Recirculation Zone (ORZ), and Pool/Outer Bend (POB) mesohabitats. The acronyms MC and PB refer to the Mid channel and Pool/Outer Bend mesohabitats, respectively. Each sample represents a collection of mussels within a 10 m^2 radial plot.

Table 9.2 Mussel species collected during surveys of the lower Apalachicola River in 2015.

			Relative frequency of occurrence			
Species*	Total	% freq of	Among	% freq	Among	%

	collected	total collected	samples from SBA		samples from MC	freq
Amblema neislerii	265	0.32	34	0.56	0	0
Elliptoideus sloatianus	2	0.0024	2	0.033	0	0

*Mussels are listed in order of decreasing relative frequency of occurrence among all samples. The acronyms SBA and MC refer to the Smooth/Bank Attached and Mid Channel mesohabitats, respectively. Each sample represents a collection of mussels within either a 5 or 10 m^2 radial plot.

Table 9.3 Mussel species collected during surveys of the lower Chipola River in 2012-2014.

			Relative frequency of occurrence			
Species*	Total collected	% freq of total collected	Among samples from SBA	% freq	Among samples from MC	% freq
Amblema neislerii	3591	0.7011	55	0.89	3	0.3
Elliptio chipolaensis	64	0.0125	18	0.29	0	0
Elliptoideus sloatianus	5	0.0010	3	0.05	1	0.1

*Mussels are listed in order of decreasing relative abundance among all samples. The acronyms SBA and MC refer to the Smooth/Bank Attached and Mid Channel mesohabitats, respectively. Each sample represents a collection of mussels within a 5 m^2 radial plot.

Recently, fat threeridge were found in deeper habitats in depths of up to 5 meters (16.4 ft.) (Gangloff 2011). Smit (2014) and continued work by USFWS (unpublished data) documented that fat threeridge can occur at much deeper water depths. 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). These results indicate that the species may have a greater range of habitat and thus may be relatively less susceptible to mortality during falling water levels.

Smit (2014) and Smit and Kaeser (*in press*) used side-scan sonar to identify the following 5 distinct habitat classes as occurring within the main river channel of the study area in the middle and lower Apalachicola (river mile 65-35): Point Bar (PB), Inner Recirculation Zone (IRZ), Outer Recirculation Zone (ORZ), Mid-Channel (MC), and Pool/Outer Bend (POB) (Figure 9.1; Table 9.4).

Sampling of MC and PB habitats by Smit (2014) and Smit and Kaeser (*in press*) typically resulted in either no mussels (47/62 samples) or very few individuals collected (138 mussels of all species total; 1.2% of total collection). When mussels were encountered in these habitats, *A. neislerii*, was one of the most common. When mussels were found in the MC, the sampling locations were typically very close to a smooth-bedform mesohabitat boundary. Five of the 7 MC samples containing mussels were < 5 meters from a boundary; the maximum distance from a boundary was 7.6 meters. Mussels of all species were commonly encountered in IRZ, ORZ, and POB habitats; 94% of all samples collected from these habitats contained mussels. Total mussel counts (all species) varied widely among smooth/plane bedform habitats, from a low of 0 mussels to a maximum of 1,011 mussels (i.e., 101 mussels/m^2) collected at a single IRZ sampling location.

In August 2016, FFWCC, in cooperation with USFWS, sampled 31 sites at reaches of the lower Apalachicola River that were sampled in 2012 and 2015. Generally, some sites showed densities similar to previous work (e.g., RM 46.3-46.8), while others showed lower densities (e.g., the IRZ and ORZ sampling at RM 42.1-42.6). USFWS staff, in collaboration with FFWCC, plan to continue data collection, analysis, and to compare the mesohabitats.

Table 9.4 Composition of the March 2012 map of mesohabitats along with average depth and substrate observed within habitats during the mussel survey.

Mesohabitat Class*	Total # of polygons	Average area per polygon (ha)	Total area (ha)	% of Total habitat	Average depth (m)	Mean substrate score
Point Bar	49	1.03	50.6	7.3	0.6	3.3
Inner Recirculation Zone	49	0.55	27.1	3.9	1.2	1.7
Outer Recirculation Zone	49	0.34	15.7	2.3	1.2	2.3
Mid-Channel	50	10.0	498.6	71.6	2.3	3.6
Pool/Outer Bend	50	2.1	104.3	15.0	4.3	2.8

*Area values are reported in hectares (ha), and depth in meters (m). The mean substrate score represents the average of all substrate scores associated with samples obtained within a habitat where a score of 1= fines, 2= mix of mud, silt, and fine sand, 3= fine sand, and 4= coarse sand. (Smit 2014)

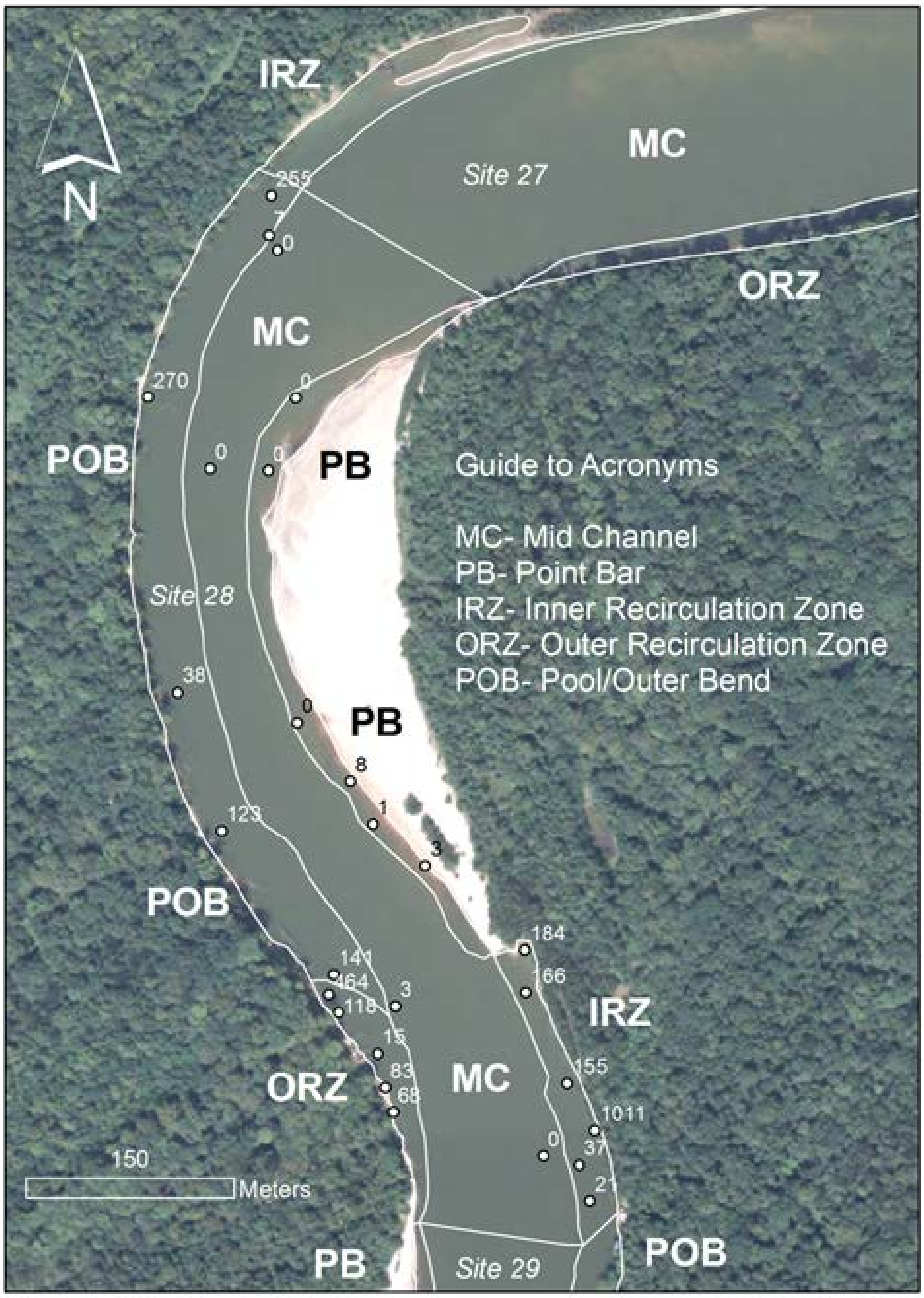


Figure 9.1 Map of sampling site 28 from Smit (2014) and USFWS (unpublished data) showing habitat classes.

9.1.1.2 Population Status and Trends in the Action Area

In the 2012 BO, we provided an estimate of fat threeridge in near-bank habitats, those areas most affected by the operations at Jim Woodruff Dam only. Recent survey techniques using SCUBA and habitat mapping using side-scan sonar throughout the known range in the ACF Basin have increased our knowledge of the population size of fat threeridge (Smit 2014, Smit and Kaeser *in press*). The sonar mapping approach identified twice as many patches and ten times the quantity of suitable habitat than identified using traditional approaches and SCUBA sampling identified high densities of mussels. Fat threeridge was the most abundant mussel in terms of frequency collected of the 18 mussel species detected during surveys (Smit 2014, Smit and Kaeser *in press*). During these 2012-2015 surveys, 7,454 individuals were collected from the lower Chipola River and lower and middle Apalachicola River (Table 9.1, 9.2, 9.3). Recent surveys all reported evidence of fat threeridge recruitment in the Apalachicola River based on size class information (Gangloff 2011, Smit 2014, Smit and Kaeser *in press*).

The highest densities of fat threeridge occur in the lower Chipola River and between RM 27-50 of middle Apalachicola River with mean densities ranging from 2.1 to 11.2 individuals/sq. m, but densities ranged up to 19.5 individuals/sq. m in optimal habitat in the lower Chipola River. Densities varied with habitat class and IRZ, ORZ, and POB generally having the highest densities (Table 9.5). Based on these densities and the area of habitat mapped in each river reach, current estimates of the population size of fat threeridge in the action area range from about 6,009,000 to 18,650,000 individuals, with a mean of approximately 12,167,000. According to the 2015 Annual Report for USACE, incidental take monitoring began under the current RIOP conditions, there has been a cumulative take estimate of 8,374 fat threeridge. For the fat threeridge this represents a total of approximately 0.07% of the population.

Table 9.5 Population estimates based on densities sampled in each habitat (Smit 2014, Smit and Kaeser *in press*).

River	Habitat Class	Mapped area (m^2)	Mean Density	lower 95% CI	upper 95% CI	Population Estimate	lower 95% CI	upper 95% CI
Middle Apalachicola River	IRZ	270,698	4.6	2.0	6.9	1,239,797	527,861	1,867,816
	ORZ	157,183	4.8	3.0	6.4	754,478	474,693	1,007,543
	POB	1,043,241	2.1	1.0	3.0	2,169,941	1,084,971	3,077,561
	PB	505,010	0.1	0.0	1.3	30,301	0	656,513
	MC	4,985,217	0.0	0.0	0.0	0	0	0
	River Total	6,961,349				4,194,517	2,087,524	6,609,433
Lower Apalachicola River	SBA	681,500	0.9			599,720		
Lower Chipola River	SBA	381,803	11.2	6.9	15.6	4,276,195	2,618,406	5,953,074
	POB	281,579	11.0	2.5	19.5	3,097,370	703,948	5,488,539
	MC	1,265,849	0.2	0.0	0.5	202,536	0	632,925
	River Total	1,929,231				7,373,564	3,322,353	11,441,613
Total		9,572,080				12,167,801	6,009,598	18,650,766

As found by Kaeser and Herrington (USFWS 2011), higher exposure rates of fat threeridge mussels occur at flows less than 5,000 cfs. Fat threeridge may move up to 100 cm per day, with a maximum of 2.9 meters to avoid exposure, but shorter distances are typical. Seventy percent of exposed mussels may survive up to 6 days following exposure. Around 8% of fat threeridge may bury completely to avoid exposure and thereby survive up to 27 days. 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, burrowed or became exposed (8%). The majority (70%) of exposed mussels survived between 1 and 6 days following exposure. Mussel mortality occurs at fall rates less than 0.25 ft/day, and slower fall rates will facilitate movement and likely reduce mortality (USFWS 2011). Because the ability to respond to 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 low slope mussel habitat is a relatively flat plane, a small decline in river stage exposes a broad area of habitat. We found that mussels at 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. The mortality due to low flows observed from 2006-2015 may also depend 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).

Fritts and Bringolf (2014) found that while fat threeridge is a host generalist, capable of metamorphosis on many fish, including 27 fish species in 14 families, consistently high success was found only on darters. Fat threeridge has approximately a 25-80% metamorphic success across all species. This work emphasizes the importance of the floodplain habitat for the recruitment of these fish populations and fat threeridge (Dutterer et al. 2012, Burgess et al. 2013). Striped bass (*Morone saxatilis*) were also found to be a host fish for fat threeridge. The ability of fat threeridge to metamorphose robustly on the migratory suggests that population structure may be influenced by long distance dispersal to a greater extent than mussel species that are specialists on more sedentary fish species. Studies of the suitability of other migratory species such as sturgeons, Skipjack Herring (*Alosa chrysochloris*), and Alabama Shad (*Alosa alabamae*) as hosts are needed (Fritts and Bringolf 2014).

Considering the recent information, the fat threeridge population in the action area appears stable and may be increasing in size. Fat threeridge are abundant in the middle Apalachicola and the lower Chipola rivers. Additional work in the lower Apalachicola River is ongoing and needed to refine population estimates.

9.1.2 Purple bankclimber

9.1.2.1 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 8.3). 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 USFWS, 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 status of purple bankclimber is scheduled to be fully reviewed and evaluated in 2019.

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 dive surveys in the deeper portions of the Apalachicola and Chipola main channels. This study found purple bankclimbers in depths ranging from 0.5 to 5 meters (1.6 to16 ft) relative to the water surface (Gangloff 2011). 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 unpublished 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.

9.1.2.2 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 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, Smit 2014, USFWS unpublished 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 during these surveys. Only 31 individuals were collected during 2012-2015 surveys of the middle and lower Apalachicola and lower Chipola River (Table 9.1, 9.2, and 9.3). According to the 2015 Annual Report submitted to the USFWS, since incidental take monitoring began under the current RIOP conditions, there has been a cumulative take estimate of 40 purple bankclimbers.

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), and based on known-age individuals, 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.

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 USACE 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 USACE estimated that no purple bankclimber take resulted from the reduction in flow. After the USACE's surveys, the FFWCC found that at least three had died at the shoal in December of 2007.

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. 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.

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. 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 bankclimbers were exposed and mortalities occurred in 2011 when Woodruff releases were below 5,000 cfs at the Chattahoochee gage. On three visits to the Race Shoals area during the period of June 6-16, five freshly dead purple bankclimbers were discovered. Three of these were as a direct result of exposure, and were found very near the water margin. The other two had apparently been harvested for bait, either that day or the day before. The USACE 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.

9.1.3 Chipola slabshell

9.1.3.1 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 three locations on the Apalachicola main channel (Figure 8.4). Since 2010, live individuals and one shell (fresh dead) have been collected in the Apalachicola River main channel. The status of Chipola slabshell is scheduled to be fully reviewed and evaluated in 2019.

9.1.3.2 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 survey conducted by Gangloff provided a population estimate of 2,645 slabshell in bank margin habitats <2 m deep (USFWS 2012). 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.

A survey conducted in 2011 in a small boat ramp basin on the Chipola River prior to dredging the basin yielded a total of 21 Chipola slabshell. It is possible that this species (and/or its fish hosts) utilizes slow-flowing habitats more than previously understood.

Both studies found variation in sizes. In the quantitative survey by Gangloff, lengths ranged from 22.1 to 56.4 mm; and individuals from the boat ramp basin 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.

Only 65 individuals were collected during 2012-2015 surveys of the lower Chipola River and middle Apalachicola River (Table 9.1 and 9.2). According to the 2015 Annual Report submitted to the USFWS, since incidental take monitoring began under the RIOP conditions, there has been a cumulative take estimate of 24 Chipola slabshell.

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 USACE 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% in the Chipola River. As explained in Appendix A, 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 much in the lower Chipola River as flow declines from Woodruff are attenuated by tributary discharges from the Chipola main channel.

9.2 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.

9.2.1 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.

We summarized channel morphology changes in the Apalachicola River previously and have no indication that channel morphology has changed in general (USFWS 2012). USACE agreed to provide access to cross-sectional data as it was available from USGS (USACE, Mobile District, Brian Zettle, pers. comm., 6/21/16). 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 (Layzer and Scott 2006). 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 USACE's dredging records show that since 1992, 84.1 miles of the 105.4 miles between Woodruff Dam and RM 1.0 were not dredged, suggesting that these portions of the river transport the sediment they receive without substantial aggradation, though remain slightly entrenched from past navigation dredging spoil along the banks.

The overall amount of stable riverine habitat available for the listed mussels may vary 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 depositional habitat downstream of large point bars has shifted downstream since 2007, which is consistent with patterns of actively meandering rivers. As a meander bend of the channel migrates downstream, the point bar upstream of the bend moves with it. The bar migrates downstream with aggradation of sediments at the downstream end of the bar. It appears that the redistribution of habitat is not changing the overall quantity of habitats, but geomorphic monitoring should quantify the relative rates of aggradation and degradation at micro-, meso-, and reach-scales along the Apalachicola River.

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 deep-water habitat (Gangloff 2011, Smit 2014, Smit and Kaeser *in press*) suggests that mussels are capable of finding or seeking refuge within this habitat during high flow conditions, perhaps by burrowing or by occupying microhabitat refugia created by submerged woody debris. 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 could 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 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, though limited in the upper reach nearest Woodruff Dam. 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, since this stream is not regulated and the past effects of the Dead River sediment discharge have stabilized.

9.2.2 Substrate

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

We describe the substrate and habitat preference for all three mussel species in previous sections. As described above, mussels need stable substrates. Because substrate stability and channel stability are interrelated, the substrate in the critical habitat units is affected in the same manner as described above. 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 showing occupation of pool/outer bend habitats by mussels (Gangloff 2011, Smit 2014, Smit and Kaeser *in press*), 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.

9.2.3 Permanently flowing water

Permanently flowing water.

Although highly regulated, 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 Appendix A), 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 subsequent sections for additional analysis regarding abundance of host fish.

Mussels will survive and reproduce best 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 (USFWS 2012). 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.

Because mussels inhabit the river margins 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. The elevations where mussels are found along the river margin in any particular year may be influenced by hydrological conditions prior to the survey (USFWS 2012). 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 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.

9.2.4 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 et al. 2001, Sparks and Strayer 1998, Augspurger et al. 2003). The 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 and somewhat dated, 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 et al. 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 USFWS 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 et al. 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 unpublished data). Swift Slough is relatively shaded and receives ground water input. In shallow backwater 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 unpublished data; USFWS unpublished 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 groundwater 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 unpublished 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 $\pm$ 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.

Low DO and high temperatures occur in the action area during periods of low flows. While these temporary changes in water quality do not permanently limit the designated critical habitat, they are modification that could negatively affect the conservation of the species in Unit 8 or Unit 2.

9.2.5 Fish hosts

> *Fish hosts* (*such as native basses, sunfishes, minnows, darters, and sturgeon*) *that support obligate parasitic 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 (Fritts and Bringloff 2014). 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, potentially resulting from frequent contact with host fish delayed by lack of passage at Woodruff.

Although mussels are not generally found in seasonally dry floodplain habitats, their host fish species are likely to use floodplain habitats during flood events, 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 6 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. 2012).

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.

9.3 Factors Affecting Species Environment within the Action Area

Section 2 describes factors affecting the physical environment of the species and 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. Over time and to some degree, these actions have influenced 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 as the baseline for this consultation.

10 MUSSELS - EFFECTS OF THE ACTION

10.1 Factors to be Considered

We describe our analytical approach using the STELLA and ResSim models and the general changes to the flow regime due to the action in detail in Appendix A. In general, we used both models to look for greatest negative effect on the mussel species and their critical habitat. Here, we summarize the key factors we considered in our analysis.

Proximity of the action: 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 their critical habitat. The proposed action is implemented through releases from Woodruff Dam, which affect species and habitat features from immediately below the dam to as far as 100 miles downstream.

Distribution: The proposed action could alter flows in the Apalachicola River and its distributaries downstream of Woodruff Dam. The action area includes most of the current 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 WCM 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 late spring through fall. We examine how the WCM 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 primarily be affected by the actions: permanently flowing water, water quality, and host fish. We examine how the WCM 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 applicable until the WCM is modified. According to USACE policy, Water Control Manuals are intended to be updated every five years; however, the Master WCM for the ACF Basin has not been updated since the attempt to update it in 1989. This attempt resulted in legal action and the subsequent IOP and RIOPs that have guided operations since that time. Although the duration of the WCM is indefinite, the nature of its effects is such that none are permanent. The USACE may conceivably alter its reservoir operations at any time; therefore, flow alterations that may result from the proposed action will probably not result in permanent impacts to the habitat of any of the listed species. However, we examine how the proposed WCM 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 WCM is applicable year round; therefore, changes to the flow regime and relevant water quality parameters may occur within the scope of the WCM at any time and/or continuously until such time as the WCM is revised or a new plan is adopted. However, we examine how the proposed WCM 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 WCM may variously affect the flow regime depending on time of year, basin inflow conditions, and composite storage levels as defined in Table 1.4, but maintains a minimum flow of 5,000 cfs during most times and 4,500 cfs at all times. We examine how the WCM affects the magnitude of flow events relative to the baseline.

10.2 Analyses for Effects of the Action

We calculated a series of performance metrics based on changes in flows or other PCEs for critical habitat. We calculated nine metrics based on changes in daily flow across the 74-year record (1939-2012) as described in Appendix A. We also describe two qualitative metrics by summarizing available information on temperature and sub-daily flows.

10.2.1 Freshwater Mussel Hydroecological Metrics

This section focuses on direct and indirect effects to listed mussels by potential exposure during low-flow conditions. During the summer of 2006 and fall of 2010 by USFWS and 2013-2015 during USACE take monitoring, listed mussels were found exposed and stranded at elevations up to approximately 10,000 cfs. The analysis in previous BOs for operations at Jim Woodruff Dam (USFWS 2006, 2008, 2012) assessed impacts to listed mussel species by analyzing the differences between the flow regimes in the range of flow less than 10,000 cfs using seven metrics based on annual flows. In this BO, we developed nine metrics to assess the effects of flow at targeted times during the annual cycle that correspond to five different phases of the mussel life cycle. For several flow effects, we calculated flows with different time windows (e.g., March 1-November 24 and March 1-August 15) or at different flow thresholds that were thought to be important (e.g., <10,000 cfs, <7,500 cfs) resulting in nine rather than 5 metrics. We first present the conceptual foundation for each metric in the context of the mussel life cycle and then present the analysis, results and interpretation for each metric.

Mussel Life Cycle: Freshwater mussels have a complex life-cycle that involves infection of fish hosts by a larval stage called glochidia (Figure 10.1). The fish host provides a mechanism for dispersal (short and long-range depending on host behavior) within the aquatic system. Without susceptible fish hosts, mussels cannot complete their life cycle. The infection of a fish host is an important, contact-related phenomenon. Following transformation on the fish host, the settlement of juvenile mussels in suitable riverine habitat may be an important determinant of year class strength. Both infection and settlement success may be influenced by discharge, or rates of change in discharge, in the Apalachicola River, but more data are necessary to inform our understanding of the mechanics.

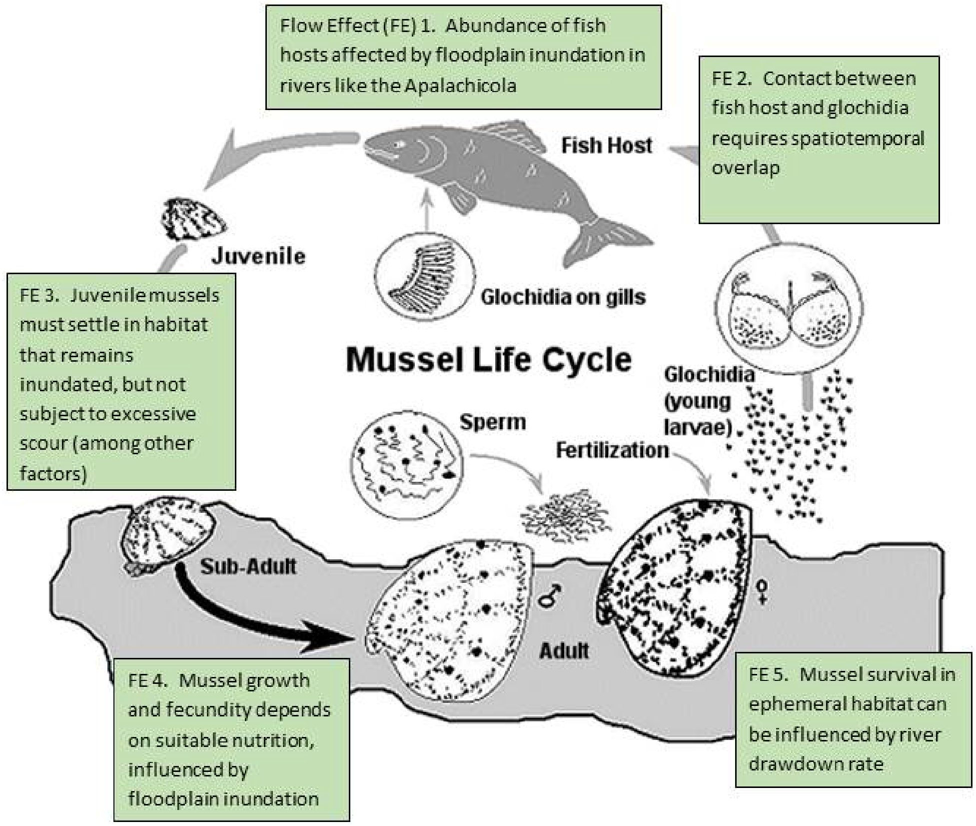


Figure 10.1 Conceptual links between changes in river flow and key points in mussel life history (diagram modified from IMT 2002)

Distribution and Abundance of Freshwater Mussels: Unlike fish, adult mussels do not disperse rapidly into higher elevation habitats with rising water levels. Rather, their distribution and abundance is largely influenced by the annual, or semi-annual recurrence of low flows (i.e., flows <~7,000 cfs) during dry periods. Low flow events physically define the portion of the channel that remains permanently inundated; low flow events thereby define the extent of suitable mussel habitat. In this sense, habitats existing above the seasonally recurring low flow threshold of ~5,000 cfs can be considered ephemeral.

In a 2012 study of mussel distribution and abundance in the middle reach of the Apalachicola (river miles 35 to 65), Smit (2014) documented the occurrence of mussels in 3 primary mesohabitats in the main river channel: Inner Recirculation Zone (IRZ), Outer Recirculation Zone (ORZ), and Pool/Outer Bend (POB). Two of these habitats, the IRZ and ORZ, are associated with relatively shallower depths, and lower bank slopes. Although mussels were documented to occur throughout these habitats, the abundance of mussels was positively correlated with distance to the 5,000 cfs bank boundary (elevation). The increased density of mussels in proximity to this boundary may be a function of enhanced growth and survival, settlement rates, and/or dynamics associated with retreat into this zone by mussels previously settled at higher elevations, under periods of elevated discharge. The resulting high density "band" of mussels often found adjacent to the low flow river margin has been frequently targeted during mussel surveys (Gangloff 2012). Until recently, the prevailing paradigm associated with mussel distribution in the river identified this band of shallow, near bank habitat as the primary mussel habitat throughout the main river channel.

We now know that mussels are also distributed in deep, outer bend (pool) habitats of the river (Smit 2014). These habitats are characterized by the presence of submerged timber (large woody debris). Smit (2014) observed that mussel occurrence was identical to that of inner and outer recirculation zones; mean density was similar but slightly lower than density in the IRZ and ORZ.

Flow Effect 1 - Flows for Host Fish Production: The abundance of a variety of fish (i.e., susceptible hosts) in large, low gradient, floodplain river systems like the Apalachicola is strongly related to connectivity and inundation of the floodplain (Burgess et al. 2013, Dutterer et al. 2012). Indeed, seasonal access to inundated floodplain habitats is a critical link in the ecology of many fish species inhabiting large river-floodplain systems including the Apalachicola (Junk et al. 1989, Burgess et al. 2013, Reckendorfer et al. 2013).

The fat threeridge is a host generalist, and has been shown to transform on a variety of fishes that inhabit the Apalachicola, including Centrarchids such as bluegill, redbreast sunfish, and largemouth bass. Additionally, several species of darters, minnows, and striped bass support the transformation of some species of mussel glochidia into juveniles (Fritts and Bringolf 2014). Fritts and Bringolf (2014) discussed the potential importance of darters as hosts for fat threeridge in terms of the consistently high metamorphosis success, and benthic habitat use associated with darters. The Weed shiner (*Notropis texanus*) was identified as a suitable host (O'Brien and Williams 2002) although transformation success was quite low; however, Fritts and Bringolf (2014) did not observe transformation occurring on this fish host. During light trap studies of larval fish in the Apalachicola River and floodplain, the Weed shiner was the most abundant larval fish captured during both 2003 and 2007 (59% and 39% composition of catch, respectively; Walsh et al. 2009).

Less is known about the fish hosts of the other two mussel species. The Chipola slabshell has been documented to transform on bluegill and redbreast sunfish (Preister 2008). The purple bankclimber is considered to be a host specialist, and has been documented to transform only on Sturgeons, and Blackbanded and Halloween darters (Fritts et al. 2012).

Many of these host fish species utilize inundated floodplain habitats of the Apalachicola River system for spawning, rearing, foraging, and sheltering (Walsh et al. 2009). However, the susceptibility of fish hosts to infection by mussel glochidia is also a function of the exposure history (i.e., age) and size of the host fish, with younger (i.e., naïve) and smaller fish being more susceptible (references provided in Strayer 2008). These fish host population characteristics have been shown to be influenced by flows and floodplain connectivity. For example, the abundance of Age 0 (young-of-the-year) largemouth bass and redear sunfish as observed during fall sampling was positively correlated with the proportion of days between March 1 and September 30 exhibiting flows >460 m^3/s (16,400 cfs) at Chattahoochee, FL (Dutterer et al. 2012).

Thus, strong cohorts of young, naive fish hosts may be expected to occur in years with above average floodplain inundation and connectivity during the growing season, and conversely, years with below average floodplain inundation are associated with smaller cohorts of susceptible Age 0 fish hosts. Three hydroecological metrics were used to measure the effects of WCM flows on fish host production.

Flows Effect 2 - Glochidial Infection of Susceptible Fish Hosts: Some of the freshwater mussels inhabiting the Apalachicola and lower Chipola River, including fat threeridge and Chipola slabshell, indiscriminately release or broadcast their glochidia to the water column. Infection is suspected to occur when a susceptible fish host passively contacts a waterborne glochidial mass. This broadcast strategy differs fundamentally from one that involves display mechanisms that attract or lure a host fish into contact with glochidia, thereby enhancing infection rates above what might be expected based upon random contact alone. However, it is worth noting, the glochidial mass of Chipola slabshell resembles a small insect larva (Preister 2008), and this resemblance may enhance contact with fish hosts over species with a broadcast strategy alone. Further, infection of fish hosts by broadcasting glochidia is likely to be influenced by the spatiotemporal overlap of glochidia-releasing female mussels and susceptible fish hosts.

For Flow Effect 2, our key assumption is that infection rates will be maximized when the greatest number of susceptible fish are in close proximity to the greatest number of glochidia-releasing mussels under conditions of low, stable flow. The spatial location of susceptible fish hosts, and the timing of habitat use, is likely to vary as a function of discharge (Burgess et al. 2013). Fish hosts may follow or track the inshore edge of the aquatic environment, or “moving littoral” (*sensu* Junk et al. 1989), as rising water levels permit access to food and cover in adjacent, higher elevation riparian and floodplain habitats. The density of glochidia-releasing mussels, regardless of river stage, will be greatest within main channel habitats were mussels are located. Whether the appropriate host fish are present in the “infection zone” (i.e., in close proximity to glochidia-releasing mussels), will thus depend on river discharge.

Infection of suitable fish hosts may be conceptualized and modeled as a contact phenomenon. Other contact-infection processes have been modeled (in 2D and 3D) for various parasites and communicable diseases of wildlife, providing support and inspiration for this conceptual hypothesis (Hassell 2000, Mundt et al. 2009). The following parameters are key to modeling the host infection process:

- Density of susceptible fish hosts within the “infection zone” as a function of the density of each fish species and age and/or infection history of the hosts;
- Concentration of glochidial web-masses in the water column as a function of the density of female mussels releasing glochidia, duration of glochidial viability, and water temperature and other factors influencing species specific timing; and
- Discharge within the “infection zone” as it influences the overlap, and rate of contact between fish and glochidia.

The release of glochidia to the water column would be closely associated with this period of gravidity, and the viability of glochidia once released to the water column is limited to 2 days (O’Brien and Williams 2002). Fat threeridge have been observed as gravid and supporting mature glochidia during field collections between late May and late June (USFWS observations 2014-2015, O'Brien and Williams 2002). Chipola slabshell are presumed to be short-term brooders (Williams et al. 2008) and have been found to be gravid in June-early July (Brim Box and Williams 2000, Preister 2008). Purple bankclimber were found to be gravid from late February through mid-April (O'Brien and Williams 2002), a period that coincides with spawning of Gulf sturgeon and darter host species.

Higher rates of host infection will lead to greater reproductive success and higher production of juvenile mussels, although empirical evidence on this topic is lacking. From 3-13% of fish can be infected by mussels (Braun et al. 2014), and fat threeridge has approximately a 25-80% metamorphic success after infection (Fritts and Bringolf 2014).

Flows Effect 3 - Settlement Success - Survival of Juvenile Mussels after Release from Fish Hosts: After a period of encystment and transformation, juvenile mussels drop off the fish host and settle on the river bottom. In laboratory settings, transformation of fat threeridge glochidia on fish hosts required 10 to 14 days at 23 $\pm$ 1.5 C (73.4 $\pm$ 2.7 F) (O'Brien and Williams 2002). In a study of 24 fish hosts, transformation of fat threeridge required 10 to 18 days at water temperatures of 22-23 C (71.6-73.4 F) (Fritts and Bringolf 2014).

Although relatively little is known about factors affecting dispersal and settlement of juvenile mussels in large rivers, insights into the role of velocity, velocity gradients, and distance of the fish host above the river bottom during juvenile mussel drop have been provided by hydrologic modeling (Daraio et al. 2012). Habitat preferences of host fish are likely to influence where juvenile mussels settle in the river bed. The role of settling velocity in a turbulent river was examined by Schwalb et al. (2012a,b) using controlled field experiments.

Survival of juvenile mussels may depend on the physical location of settlement and associated factors such as: substrate type, porosity, water quality conditions of the microhabitat, food availability in the substrate, and the potential for physical scour or displacement by shear forces of the river current acting upon the area of settlement (Strayer 2008, French and Ackerman 2014).

Using a 2D model of hydrologic variables in a reach of the Upper Mississippi River, Morales et al. (2006) identified areas of the channel associated with low shear stress as places where small particles (like juvenile mussels) would settle and collect. These areas corresponded to documented locations of mussel beds. Alternatively, these locations might represent areas of flow refuge where juvenile mussels settled, and subsequently survived because they were not displaced by river currents during their descent, or dislodged from the habitat.

After settling, juvenile mussels burrow into the sediment. Juvenile mussels may lack the capacity to migrate in response to follow water levels, and thus would be subject to desiccation and mortality if settlement occurred at higher elevations, in ephemeral habitat. Ephemeral habitats, or river margin and floodplain areas that are only seasonally inundated, may represent sinks for juvenile mussels (Singer and Gangloff 2011, Gates et al. 2015).

Given the relationship between fish host habitat use and river discharge, low stable flows during the period of juvenile mussel drop (~2 weeks post-infection) should favor the successful establishment and recruitment of juveniles to the mussel population. We used two hydroecological metrics to measure the effect of the WCM on the infection and settlement process (Flow Effects 2 & 3).

Flows Effect 4 - Mussel Growth and Fecundity with respect to Floodplain Inundation: Mussels filter feed to obtain nutrition in the form of phytoplankton (algae) and suspended, bacterial rich, fine particulate organic matter (McMahon and Bogan 2001, Strayer et al. 2004, Vaughn et al. 2008). Mussels also obtain nutrition by deposit feeding, or extraction of food from the river sediments they inhabit (discussed in Haag 2012). Pulsed inundation of the floodplain during the growing season may stimulate primary production within backwater areas, and contribute phytoplankton, fine particulate organic matter, and bacteria to the water column (Junk et al. 1989), thereby enhancing the food resources available to mussels, and in turn, enhancing growth and survival of mussels. Although more research is needed to investigate the coupling of floodplain inundated and mussel growth in the Apalachicola River system, mussel fecundity may be a function of size of the female mussel, and therefore, conditions that support increased mussel growth likewise enhance fecundity (Strayer 2008). Floodplain inundation may have both individual and population level effects via the supply of mussel food to the system. We used one hydroecological metric to test the effect of the WCM on the floodplain process during the growing season.

Flows Effect 5 - River Drawdown and Mussel Survival in Ephemeral Habitats: Field studies have documented the ability of mussels like fat threeridge to relocate to lower elevations as water level declines in the Apalachicola River (USFWS 2011). Since mussels are relatively slow moving, their ability to retreat during water level declines is a function of site slope and the rate of water surface elevation decline (USFWS 2011, Newton et al. 2015). Mussels inhabiting deeper areas of the IRZ, ORZ, and POB are not at-risk of exposure and mortality during these episodes because these habitats are continuously inundated throughout the year. Maintaining slow drawdown rates when river discharge is falling from 10,000 to 5,000 cfs provides the greatest opportunity for successful escapement of ephemeral habitat by mussels that inhabit the “moving littoral” zone of the river.

At the average drawdown rate from 2006-present of 0.13 ft/day (USACE 2016), the sites that are most at risk of experiencing some exposure and mortality of freshwater mussels are those with the lowest bank slopes, slopes of <20%, as observed across a multitude of sites in the Apalachicola River and lower Chipola River (USFWS 2011). We used three hydroecological metrics to test the effect of the WCM on the river drawdown process.

The following section evaluates the effects of the WCM to these hydroecological metrics (Table 10.1). Appendix A details the effects of the WCM to the critical habitat in the action area of which a summary is incorporated in the below sections.

Table 10.1 Summary of the hydroecological metrics and the effect of the WCM on mussels.

Metric ID	Hydroecological Metric Title	Species Ecology	Interpretation	WCM effect
M1	Floodplain Access for Spawning- % days inundated (Mar 1-Nov 24)	Host Fish Production	higher % days of floodplain inundation better for host fish	negative
M2	Floodplain Access for Spawning- % days inundated (Mar 1-Aug 15)	Host Fish Production	higher % days of floodplain inundation better for host fish	negative
M3	Floodplain Access for Spawning, 30-day inundation acres (Mar 1-Aug 15)	Host Fish Production	more acres inundated better for host fish	negative
M4	Low Flow during Infection and Settlement (Jun 1-Jul 15)	Host Fish Infection	greater # of low flow days = higher infection/survival of juveniles	negative
M5	Stable Flows during Infection and Settlement, max days <7.5 k cfs (Jun 1-Jul 15)	Host Fish Infection	greater # consecutive days of low flow better	slight negative
M6	Pulsed Inundation during late growing season, 30 days and 15 days (Jul 15-Nov 24)	Mussel Growth	more pulses is better for mussel growth	very slight negative
M7	Mussel Survival during Extreme Low Flow, annual 1 day minimum flow	Mussel Survival	fewer days of flow <5kcfs better for survival	negative
M8	Mussel Survival during Extreme Low Flow, annual total # days <5kcfs and <5.1 kcfs	Mussel Survival	fewer days of flow <5.0 kcfs better for survival	negative
M9	Mussel Survival during Drawdown, freq of stage changes all flows and flows <10kcfs	Mussel Survival	fewer stage changes >0.25 foot/day better for survival	slight negative
MQ1	Temperature changes downstream of Woodruff	Habitat Availability & Quality	temps below lethal limits good	inconclusive
MQ2	Hydropeaking at Woodruff	Habitat Availability & Quality	more stability in daily flows better for survival, recruitment, growth	neutral (FTR, CS only)

10.2.1.1 Flows for Host Fish Production (FE1)

Freshwater Mussel Hydroecological Metric 1 - Access to Floodplain for Spawning and Rearing of Host Fish

Metric Description: To evaluate the potential effects of the proposed action on the ability of adult host fish to access the floodplain for spawning and juvenile host fish to hatch and mature in the floodplain, we calculated the number of days between March 1 and November 24 exhibiting flows ≥16,200 cfs.

This metric was used by Dutterer et al. (2012) in a study of fish recruitment and floodplain inundation in the Apalachicola River. March represents the onset of spawning for stream fish in the Apalachicola River (Pine et al. 2006, Walsh et al. 2009, Burgess et al. 2013). At 16,200 cfs, approximately 10% of the available floodplain is inundated (Light et al. 1998). Light et al. (2006) defined the growing season for floodplain vegetation (Mar 1-Nov 24) based on historic records of first and last freeze observed at Quincy, FL. This 268-day time frame includes most of the growing season that includes spawning, rearing, growth, and survival of fishes utilizing the inundated floodplain. At least 30 days of inundation are required to provide adequate duration of time for spawning to occur for many of the host fishes for fat threeridge and Chipola slabshell. This metric emphasizes the general precept that a greater number of days of floodplain inundation equates to improved host fish recruitment.

Results: The total number of days of floodplain inundation at ≥16,200 cfs between March 1 and November 24 occurring under the 2 flow regimens (baseline, WCM) is presented as a probability of exceedance plot in Figure 10.2. Both models showed the same pattern (i.e., that the WCM decreased the days of floodplain inundation), but the STELLA model showed the greater effect. Compared to the baseline, the WCM results in 819 days less of floodplain inundation for the 74 year record (i.e., a 10 day reduction annually) and an overall 4% reduction in inundation from 8267 under baseline to 7448 of 19832 days based on the STELLA model. During years characterized by an intermediate range of days of floodplain inundation (i.e., range of 60-40% exceedance probability), we observed the most discernable difference in the number of days of inundation between the WCM and baseline management plans with 42 days less of inundation during this range and a maximum of 15 days less of inundation under the WCM at 40% probability of exceedance. To get at least 30 days of inundation which is needed for host fish to spawn successfully, the WCM reduces the probability of getting at least 30 days of inundation from 96% under the baseline to 85%. In other words, host fish may not reproduce in the floodplain 11 years under the WCM compared to 3 years of a 74 year record under the baseline (i.e., an 11% chance that host fish won’t spawn during the WCM).

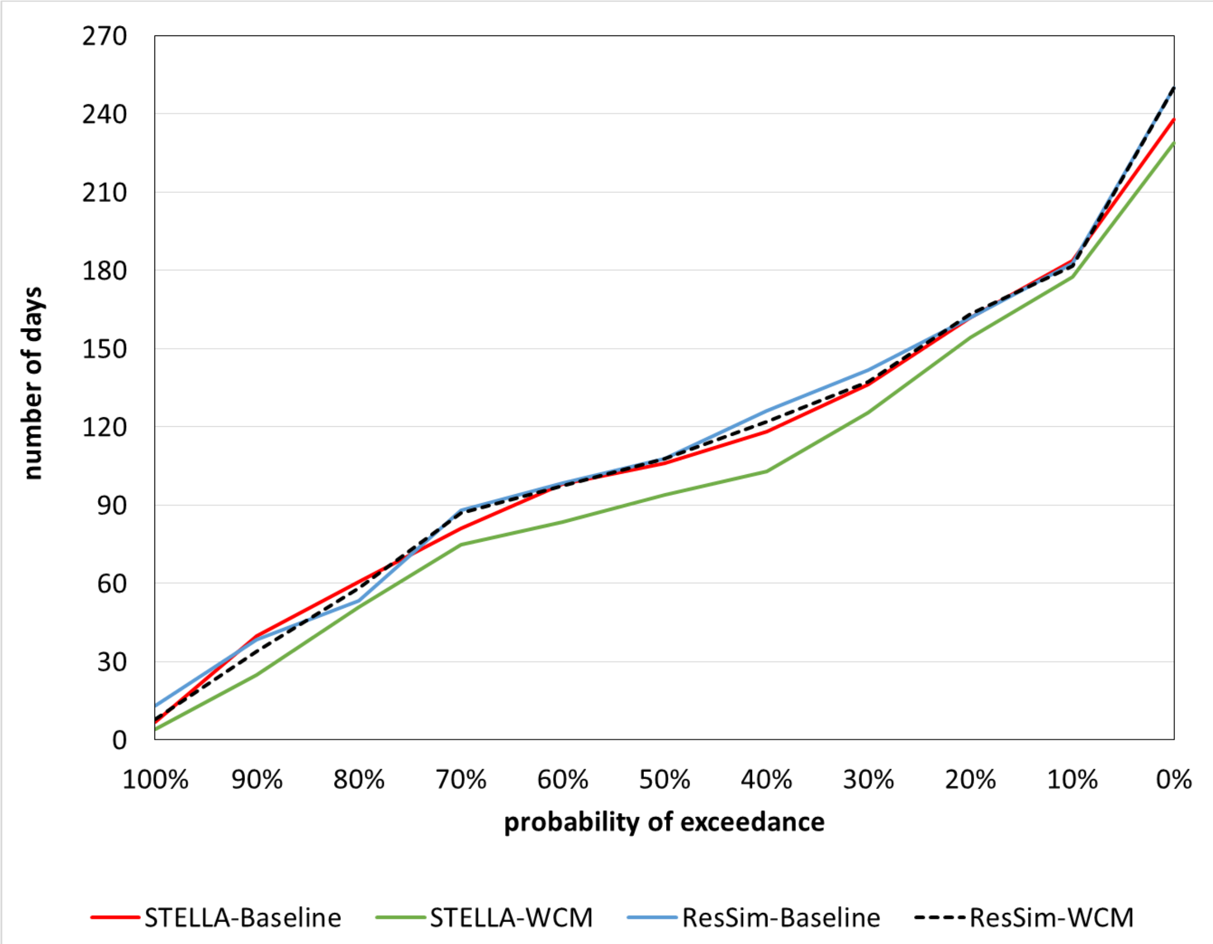


Figure 10.2 Probability of exceedance plot showing the number of days between March 1 and November 24 with flows ≥16,200 cfs under the baseline and WCM flow regimes

Interpretation: The results of this analysis indicated that the WCM exhibited an adverse effect relative to the baseline by reducing the total number of days of floodplain inundation by 15% and result in 11% fewer years with adequate number of days for host fish to spawn. Fewer days of floodplain inundation is expected to result in a reduction of access to the floodplain by adult host fish, lower fish host populations, and a subsequent reduction in recruitment of mussels.

Freshwater Mussel Hydroecological Metric 2 - Access to Floodplain for Spawning of Host Fish

Metric Description: To evaluate the potential effects of the proposed action on the ability of adult host fish to access the floodplain for spawning, we calculated the number of days between March 1 and August 15 exhibiting flows ≥16,200 cfs.

This metric was used by Dutterer et al. (2012) in a study of fish recruitment and floodplain inundation in the Apalachicola River. March represents the onset of spawning for stream fish in the Apalachicola River (Pine et al. 2006, Walsh et al. 2009, Burgess et al. 2013). August 15 represents the approximate end of the spawning season for most of the host fish species, and this this 167-day time frame includes most of the early growing season that includes spawning of fishes utilizing the inundated floodplain. Similar to Freshwater Mussel Hydroecological Metric 1, this metric emphasizes the general precept that a greater number of days of floodplain inundation equates to improved host fish recruitment, but focuses on access for spawning alone.

Results: The total number of days of floodplain inundation at $\geq$16,200 cfs between March 1 and August 15 occurring under the 2 flow regimens (baseline, WCM) is presented as a probability of exceedance plot in Figure 10.3. Both models showed the same pattern (i.e., that the WCM decreased the days of floodplain inundation), but the STELLA model showed the greater effect. Compared to the baseline, the WCM results in 848 days less of floodplain inundation (i.e., an average of 11 days or 18% reduction annually for the 74 year record) and overall reduces floodplain inundation by 6% (6244 of 12358 days). During years characterized by higher and intermediate range of days of floodplain inundation (i.e., range of 90-40% exceedance probability, drier to intermediate years), we observed the most discernable difference in the number of days of inundation between the WCM and baseline management plans with 89 days less of inundation during this range and a maximum of 19 days less of inundation under the WCM at 90% and 50% probability of exceedance (i.e., in drier and average years). To achieve at least 30 days of inundation which is needed for host fish to spawn successfully, the WCM reduces the probability of getting at least 30 days of inundation from 93% under the baseline to 84%. In other words, host fish may not reproduce in the floodplain 14 years under the WCM compared to 5 years of the 74 year record under the baseline (i.e., a 9% chance that fish host won’t spawn in the floodplain during the WCM). However, this is an estimate of the minimum number of days required because this metric did not calculate the number of continuous days required by host fish to successfully spawn.

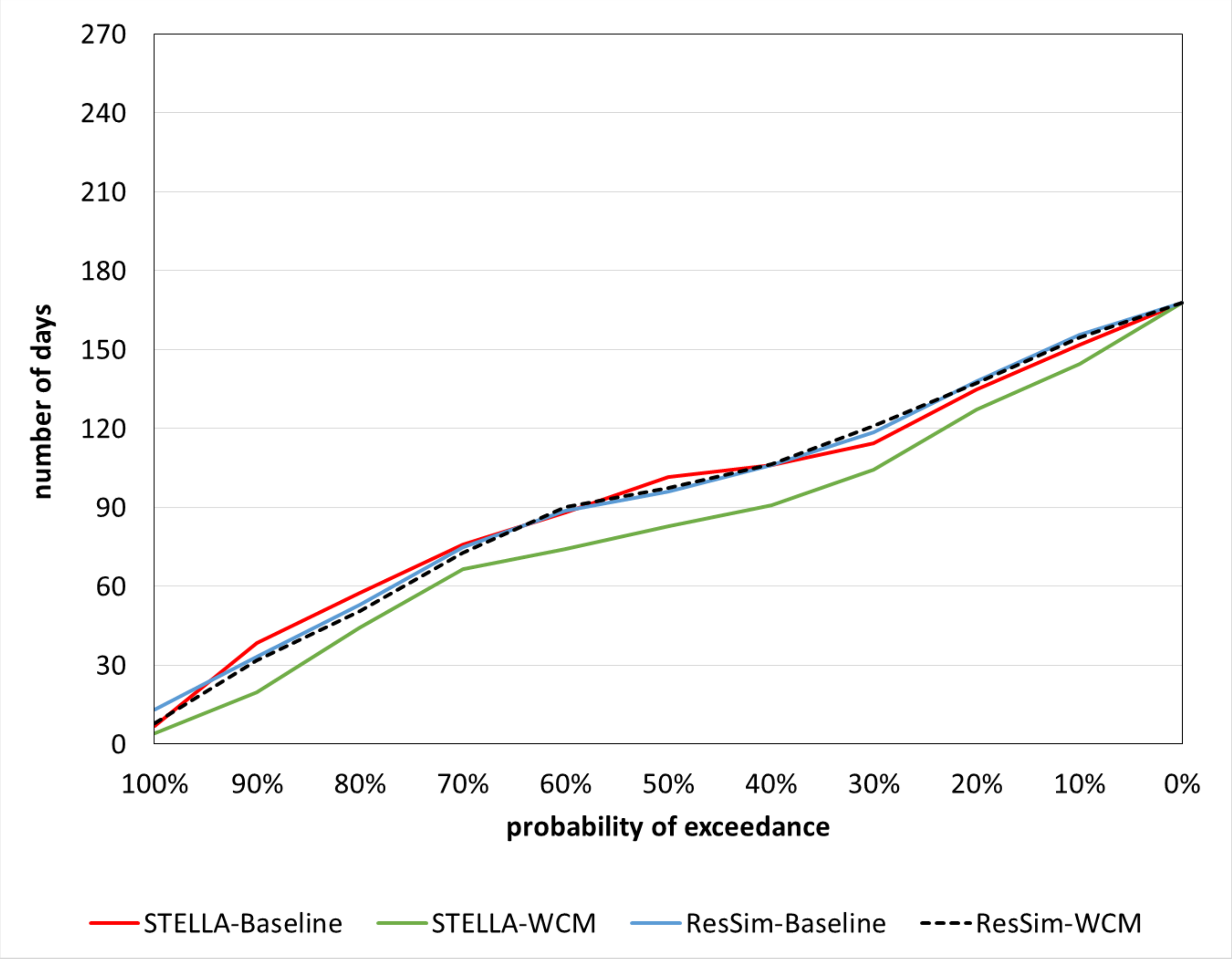


Figure 10.3 Probability of exceedance plot showing the number of days between March 1 and August 15 with flows ≥16,200 cfs under the baseline and WCM flow regimes

Interpretation: The results of this analysis indicated that the WCM exhibited an adverse effect relative to the baseline by reducing the total number of days of floodplain inundation by 17% and reduce the chance of host fish having adequate time to spawn in the floodplain by 12%. Fewer days of floodplain inundation is expected to result in a reduction of access to the floodplain by adult host fish, lower fish host populations, and ultimately a reduction in recruitment of mussels.

Freshwater Mussel Hydroecological Metric 3 - Access to Floodplain for Spawning of Host Fish

Metric Description: To evaluate the potential effects of the proposed action on the ability of adult host fish to access the floodplain for spawning, we calculated the maximum continuous 30-day inundation of the floodplain by flows ≥16,200 cfs between March 1 and August 15.

This metric measures large pulses of water during growing season and represents a measure of the maximum number of acres continuously inundated by a single floodplain inundation episode (i.e., a pulse). Continuous inundation is likely to be maximized by the largest runoff pulse occurring within the specified temporal window. This metric emphasizes the spatial aspect of the area of floodplain inundated and the temporal aspect of duration (30-days) to provide continuous inundation for completion of spawning activities (as with the previous two metrics in this set). This metric has been used previously (USFWS 2012) and was presented in BA by USACE, but as with Freshwater Mussel Hydroecological Metric 2, we have reduced the window of time to focus on the critical time for spawning host fishes to access the floodplain. The maximum amount of floodplain acres that can be inundated is approximately 80,000 acres; an inundation of this magnitude occurs at flows of ~125,000 cfs (Light et al. 2006; Figure 2.7).

Results: The maximum number of continuous days of floodplain inundation at ≥16,200 cfs between March 1 and August 15 occurring under the 2 flow regimens (baseline, WCM) is presented as a probability of exceedance plot in Figure 10.4. Both models showed the same pattern (i.e., that the WCM decreased the ac-days of floodplain inundation), but the STELLA model showed the greater effect. Compared to the baseline, the WCM results in 32,788 ac less of floodplain inundation (of app. 5.92 mil ac, 0.55% reduction) for the 74 year record total, but an average of a 433 ac/year (i.e., 6% reduction annually). Further, this overall pattern, masks more nuanced shifts (i.e., lower and intermediate acres of floodplain inundation). During years characterized by lower acres of floodplain inundation (i.e., range of 97-73% exceedance probability, the 19 years with lower inundation), the WCM reduces floodplain inundation by an average of 2,794 ac/yr (38% decrease), but conversely increases inundation by 1,169 ac/yr in intermediate years (i.e., 72-34% exceedance probability, the 28 years with intermediate inundation). We observed the most discernable difference in the number of acres of inundation between the WCM and baseline management plans with a maximum of 4,174 ac less of inundation under the WCM at 90% probability of exceedance. The WCM will reduce the amount of pulsed floodplain inundation by 2,215 ac on average in 5 years.

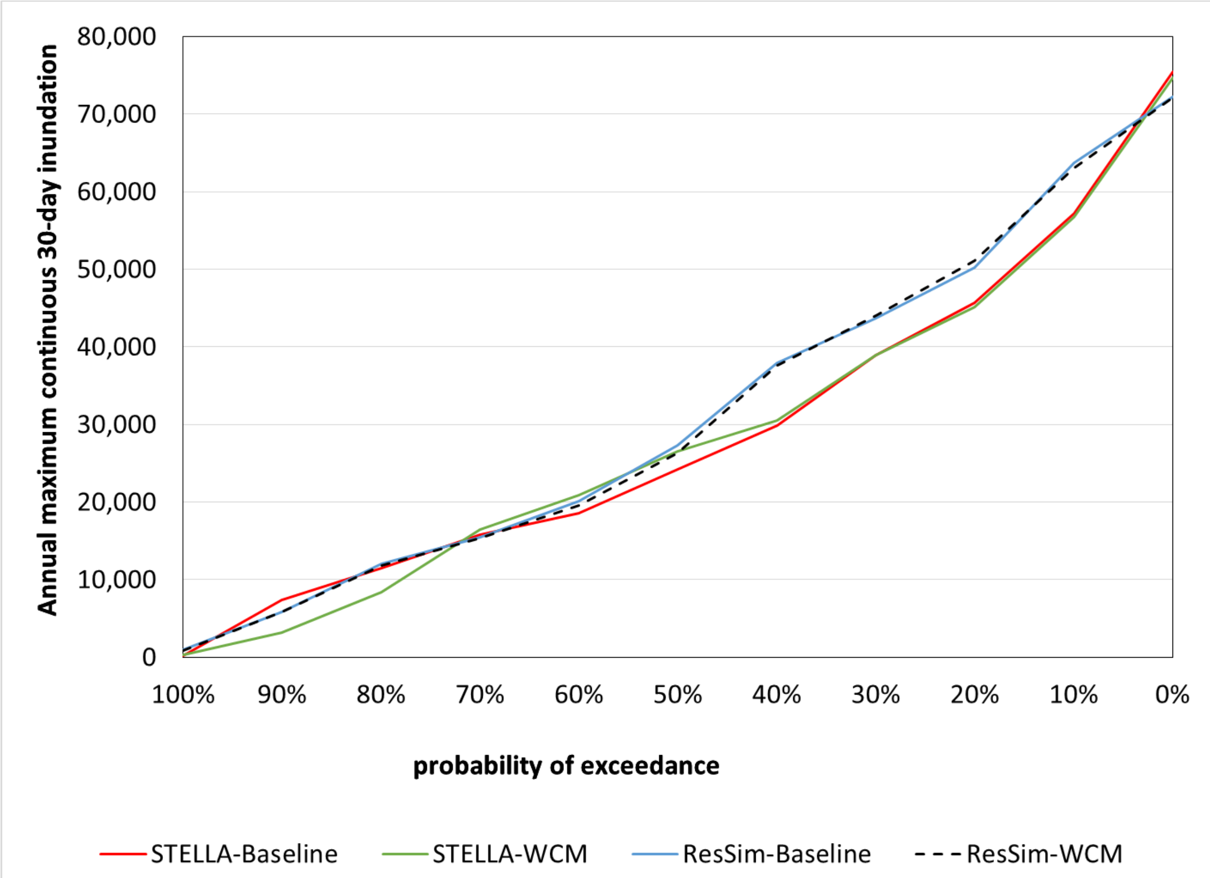


Figure 10.4 Probability of exceedance plot showing the maximum acres inundated continuously for 30 days between March 1 and August 15 with flows ≥16,200 cfs under the baseline and WCM flow regimes

Interpretation: The results of this analysis indicated that the WCM exhibited a slight adverse effect relative to the baseline by reducing the total acres of floodplain inundated during pulsed flows by 6% or 433 ac/yr on average, but by 38% or 2,794 ac/yr in the 19 years with the lowest inundation. The WCM will reduce the amount of pulsed floodplain inundation by 2,215 ac on average in 5 years. This reduction in acres of floodplain inundation is expected to result in a reduction of spawning habitat for adult host fish, reduced recruitment in fish host populations, and consequently a reduction in fish hosts available for mussel infection. Lower fish host populations will subsequently reduce recruitment of mussels.

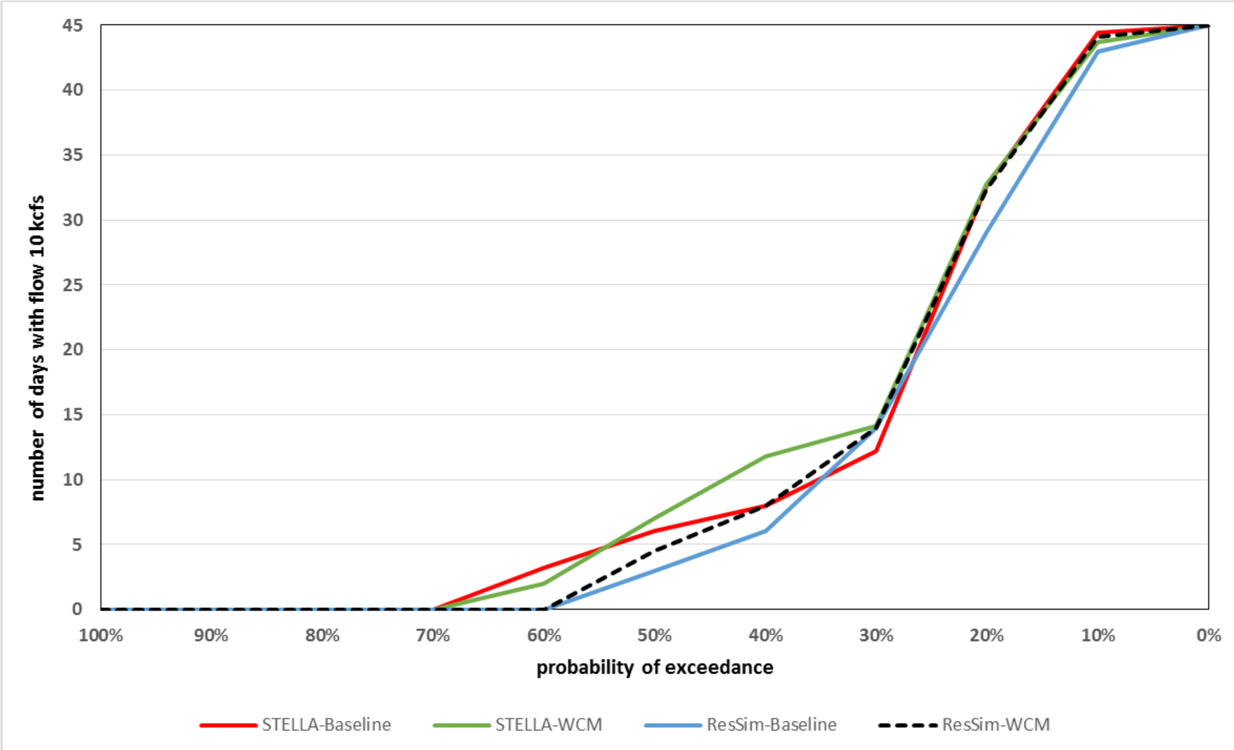
10.2.1.2 Flows for Host Fish Infection (FE2) and Juvenile Mussel Recruitment (FE3)

Freshwater Mussel Hydroecological Metric 4 - Low Flows during Host Infection and Juvenile Settlement

Metric Description: To evaluate the potential effects of the proposed action on the ability of adult host fish to be infected and juvenile mussels to drop in appropriate locations for high survival, we calculated the number of days between June 1 and July 15 exhibiting low and very low flows (<5, 5-6, 6-7.5, and 7.5-10 kcfs).

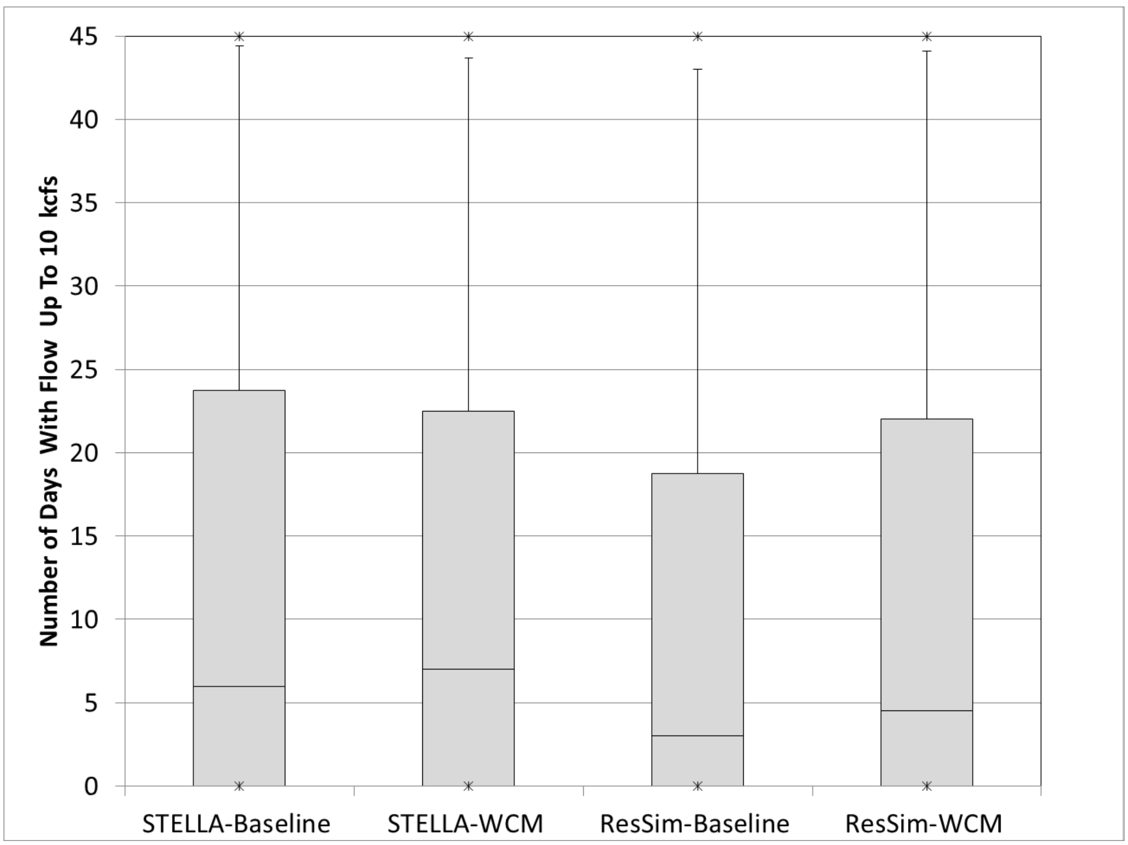
This metric reflects the number of days during the infection and juvenile drop cycle that flows are low or very low and almost entirely contained within the main channel of the river. Note, this metric only apply to species that are gravid, releasing glochidia, and experiencing juvenile drop in June through early July, such as *A. neislerii, E. chipolaensis,* and other non-listed species. This metric assumes that low flows during this 45-day time period will consolidate host fishes in the main river channel during the time of glochidial release and juvenile drop and that juvenile drop in the main river channel will lead to higher survival of juvenile mussels and higher recruitment to the adult mussel population. We have adopted the definition of very low flows of <5,000 cfs in the Apalachicola River used by Light et al. (1998). This metric assumes that the zone of stability and highest survival for mussels is near the 5,000 cfs waterline and flows below that will harm the mussel population. Further, mussel drop near this 5,000 cfs waterline will result in the highest survival of juvenile mussels and settlement further from this 5,000 cfs waterline will result in lower survival. To further focus on effects occurring within a range of flows identified as thresholds for ephemeral habitat between 5,000 and 10,000 cfs, we conducted a series of analyses that summarized total number of days during the period June 1 and July 15 when flows were: <5,000, 5,000-5,999, 6,000-7,499, and 7,500-10,000 cfs. The 74 year record has 3,330 days between June 1 and July 15. These flows quantify the ephemeral habitat available to mussels within the Apalachicola River.

Results: We compared the total number of days overall when flows are ≤10,000 cfs between June 1 and July 15 occurring under the 2 flow regimens (baseline, WCM), presented as a probability of exceedance plot in Figure 10.5A. Both models showed the same pattern (i.e., that the WCM increased the days of flows <10,000 cfs), but the STELLA model showed the greater effect. Overall, the WCM provides an additional 5 days compared to the baseline when flows are <10,000 cfs. However, the median is only one day higher on the box plot Figure 10.5B and the 50% box and the 90% whiskers both are slightly reduced compared to the baseline. Although the differences among alternatives are only visible in the years with more days of flow <10,000 cfs (i.e., the drier years), a more detailed look at this change in management shows both these beneficial and adverse effects of the WCM compared to the baseline.



number of days with flow 10 kcfs
45
40
35
30
25
20
15
10
5
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
probability of exceedance
STELLA-Baseline
STELLA-WCM
ResSim-Baseline
ResSim-WCM

A



Number of Days With Flow Up To 10 kcfs
45
40
35
30
25
20
15
10
5
0
STELLA-Baseline
STELLA-WCM
ResSim-Baseline
ResSim-WCM

B

Figure 10.5 Probability of exceedance plot (A) and box plot (B) showing total number of days overall when flows are ≤10,000 cfs between June 1 and July 15 occurring under the baseline and WCM flow regimes

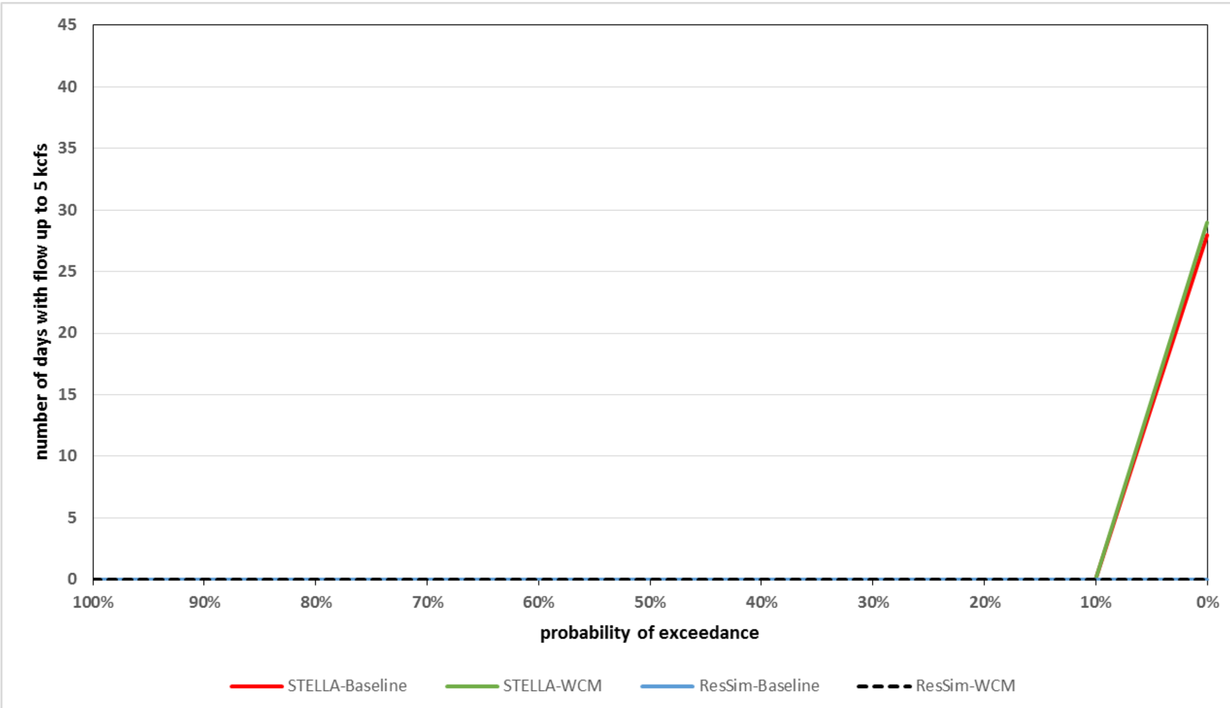


Figure 10.5C Probability of exceedance plot showing total number of days overall when flows are <5,000 cfs between June 1 and July 15 occurring under the baseline and WCM flow regimes

The total number of days at flows <5,000 cfs between June 1 and July 15 occurring under the 2 flow regimens (baseline, WCM) is presented as a probability of exceedance plot in Figure 10.5C. Because the WCM and baseline have nearly identical rules for when to drop below 5,000 cfs, the 29 days below 5,000 cfs is a one day increase in the number of days below 5,000 cfs across the 74 year record compared to the baseline (1/3,330 days = 0.03% change). The WCM would on average increase the days < 5,000 cfs by 0.2% in 5 years. This would be an adverse effect on the mussel population by dropping flows below the normal zone of stability dictated by the 5,000 cfs management threshold.

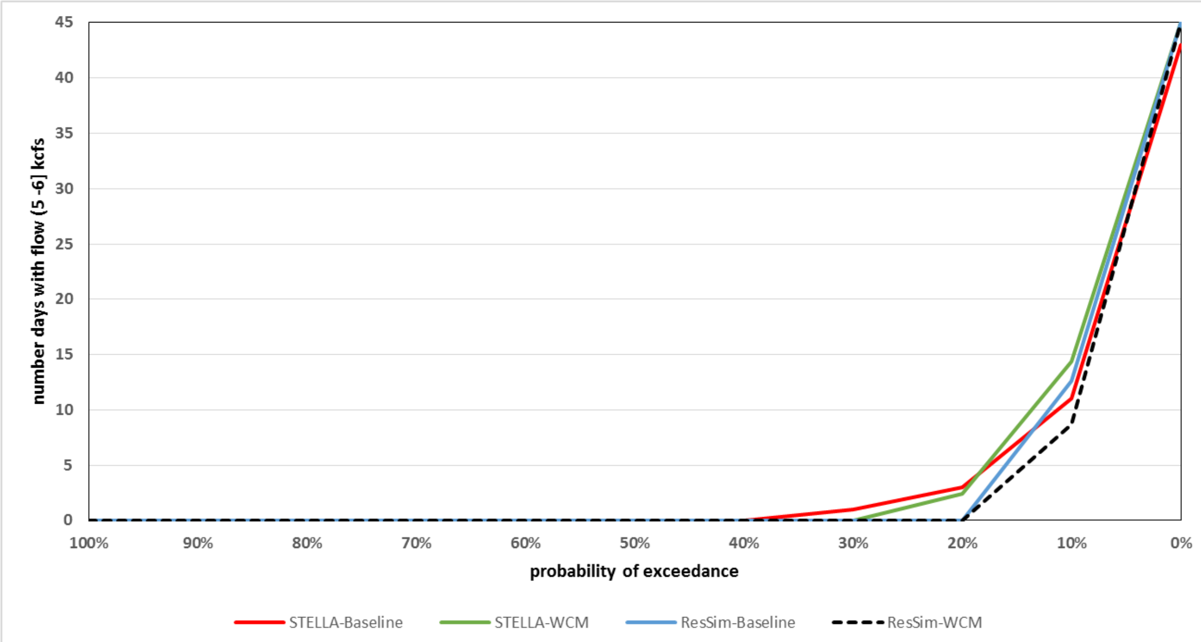


Figure 10.5D Probability of exceedance plot showing total number of days overall when flows are 5,000-5,999 cfs between June 1 and July 15 occurring under the baseline and WCM flow regimes

The total number of days at flows 5,000-5,999 cfs between June 1 and July 15 occurring under the 2 flow regimens (baseline, WCM) is presented as a probability of exceedance plot in Figure 10.5D. The WCM provides an additional 30 days over the 74 year record compared to the baseline during this range of flows (30/3,330 days = 0.9% change). The WCM would on average increase the days at 5,000-5,999 cfs by 4.5% in 5 years. This may be a slight benefit for the mussel population by increasing the time for juvenile mussels to drop and settle in this more stable habitat near 5,000 cfs.

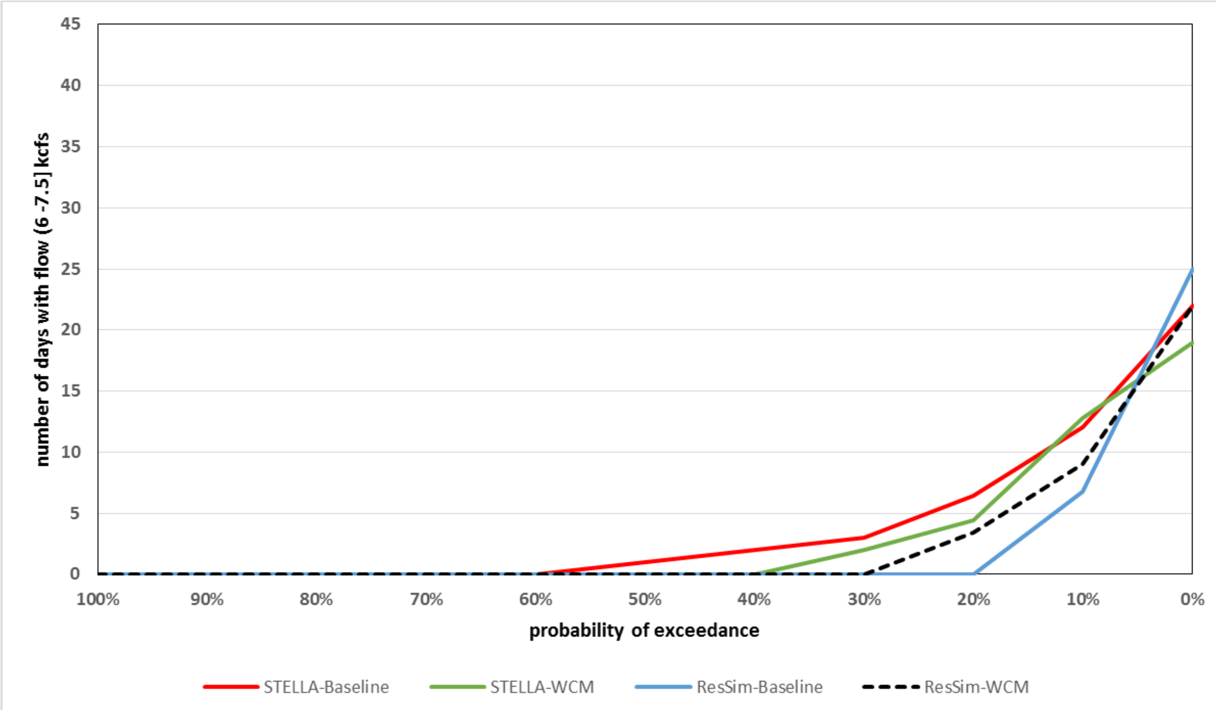


Figure 10.5E Probability of exceedance plot showing total number of days overall when flows are 6,000-7,499 cfs between June 1 and July 15 occurring under the baseline and WCM flow regimes

The total number of days at flows 6,000-7,499 cfs between June 1 and July 15 occurring under the 2 flow regimens (baseline, WCM) is presented as a probability of exceedance plot in Figure 10.5E. The WCM provides 51 days less over the 74 year record compared to the baseline during this range of flows (51/3,330 days = 1.5% change). The WCM would on average change the days at 6,000-7,499 cfs by 7.6% in 5 years. This may be a slight adverse effect for the mussel population by decreasing the time for juvenile mussels to drop and settle in this better ephemeral habitat closer to the more stable 5,000 cfs stable zone.

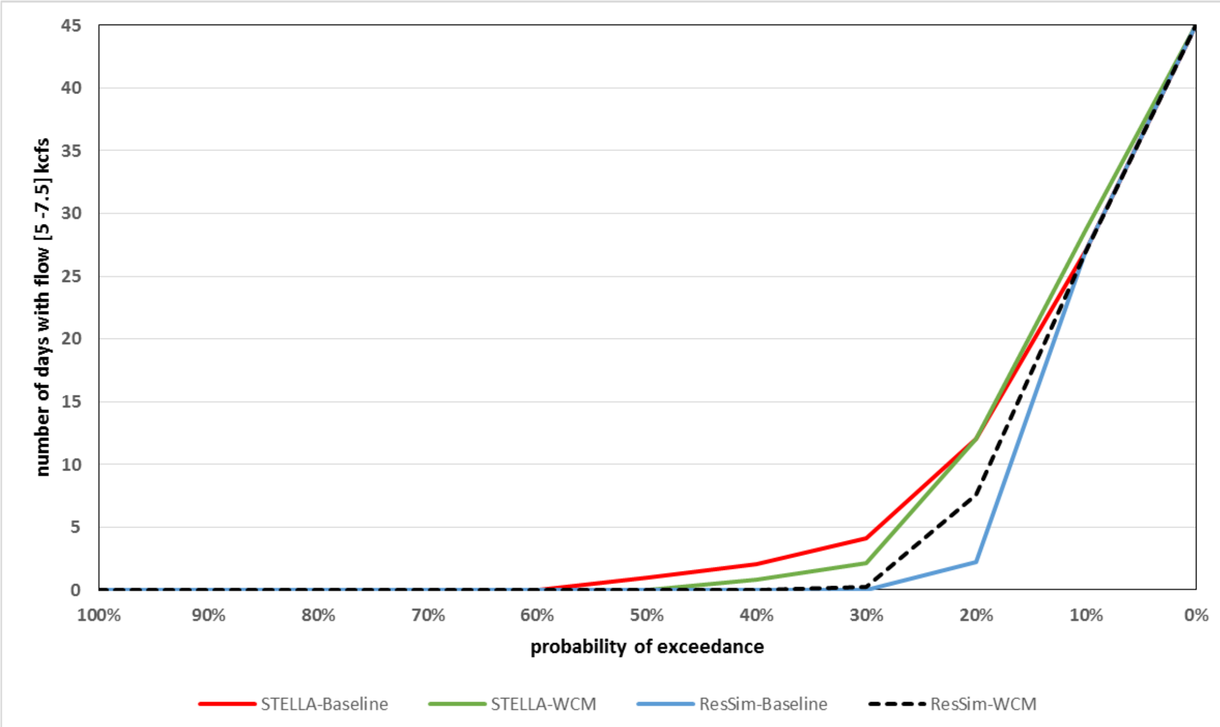


Figure 10.5F Probability of exceedance plot showing total number of days overall when flows are 5,000-7,499 cfs between June 1 and July 15 occurring under the baseline and WCM flow regimes

For flows 5,000-7,499 cfs, the total number of days at flows between June 1 and July 15 occurring under the 2 flow regimens (baseline, WCM) is presented as a probability of exceedance plot in Figure 10.5F. The WCM provides 21 days less over the 74 year record compared to the baseline during this range of flows (21/3,330 days = 0.6% change). The WCM would on average change the days at 5,000-7,499 cfs by 3.1% in 5 years. This may be a slight adverse effect for the mussel population by decreasing the time for juvenile mussels to drop and settle in this better ephemeral habitat closer to the more stable 5,000 cfs stable zone.

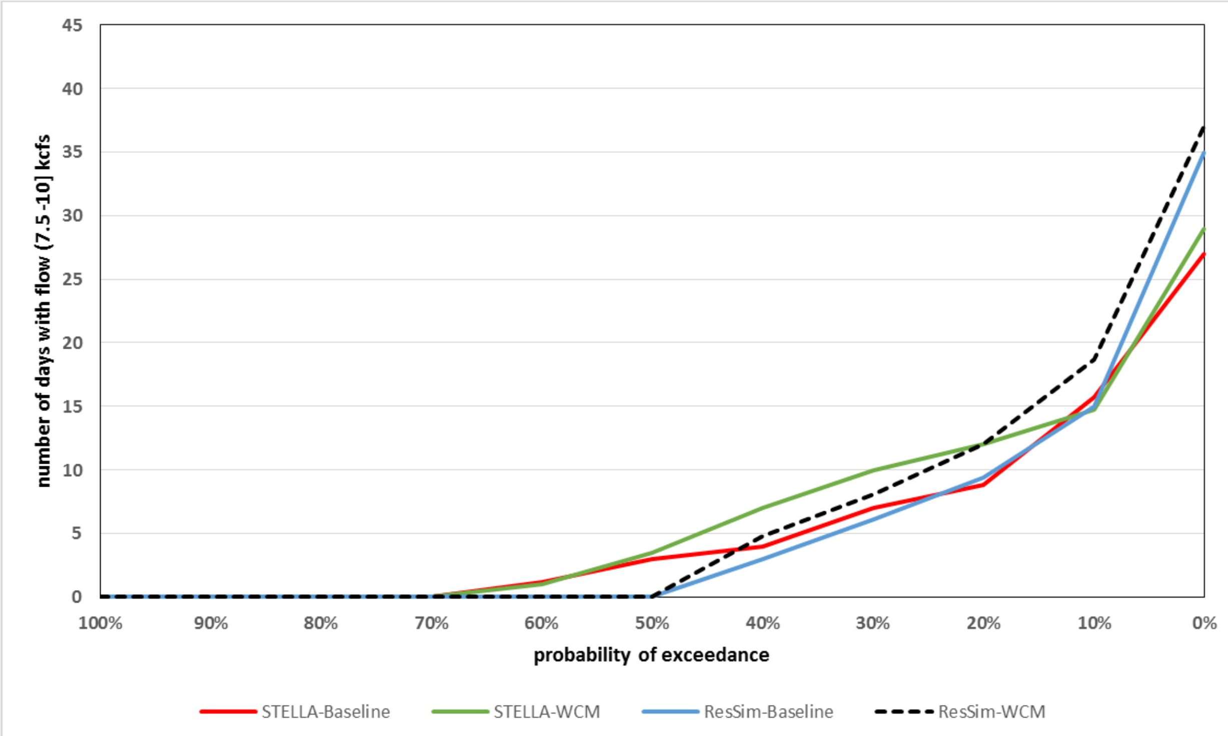


Figure 10.5G Probability of exceedance plot showing total number of days overall when flows are 7,500-10,000 cfs between June 1 and July 15 occurring under the baseline and WCM flow regimes

The total number of days at flows 7,500-10,000 cfs between June 1 and July 15 occurring under the 2 flow regimens (baseline, WCM) is presented as a probability of exceedance plot in Figure 10.5G. The WCM provides 48 days more across the 74 years compared to the baseline during this range of flows (48/3,330 days = 1.4% change). The WCM would on average change the days at 7,500-10,000 cfs by 7.2% in 5 years. This may be an adverse effect for the mussel population by increasing the time for juvenile mussels to drop and settle in this ephemeral habitat further from the more stable 5,000 cfs stable zone.

These basic patterns of very slight differences between the baseline and WCM can also been seen on the flow duration curve. The flow between June 1 and July 15 when flows are between 4,500 and 10,000 cfs occurring under the 2 flow regimens (baseline, WCM) is presented as a probability of exceedance plot in Figure 10.5H. The WCM has a slightly lower probability of a flow <6,500 cfs and slightly higher probability of flows >7,000 cfs than the baseline.

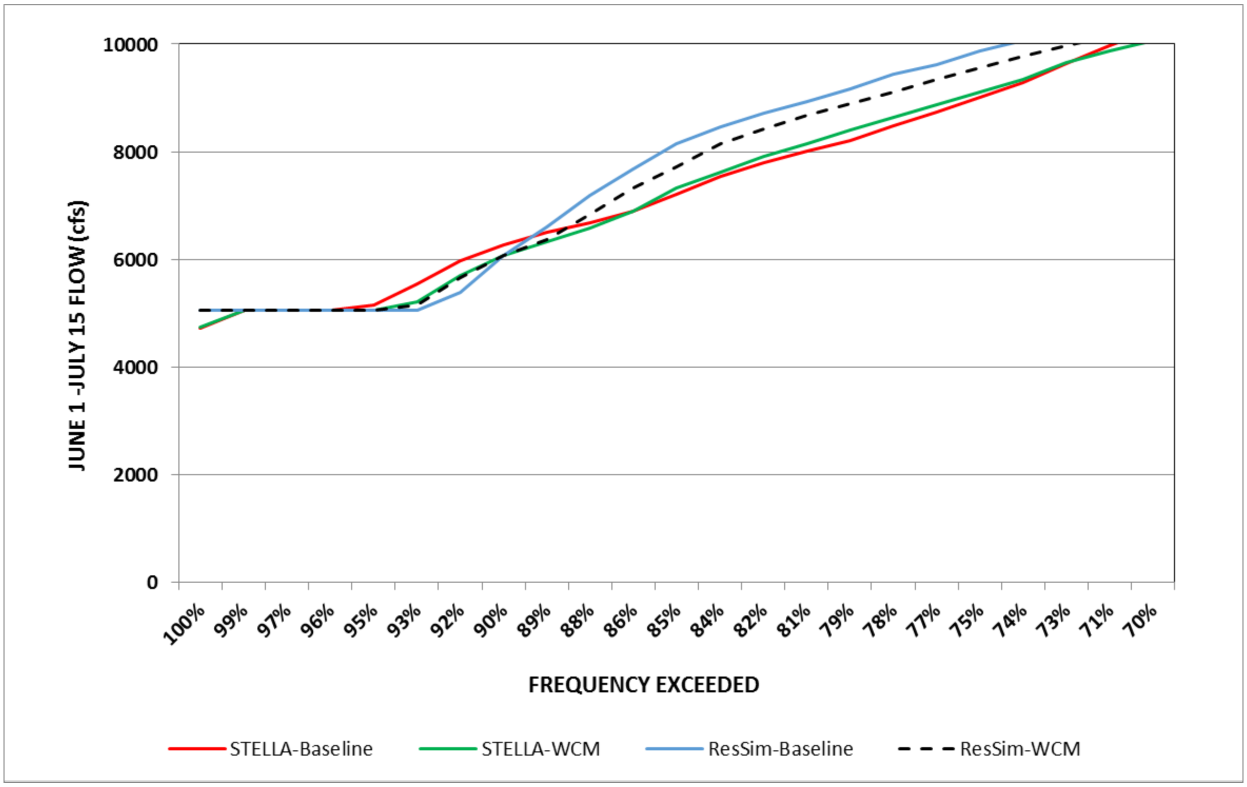


Figure 10.5H Probability of exceedance plot showing flows (cfs) <10,000 cfs between June 1 and July 15 occurring under the baseline and WCM flow regimes

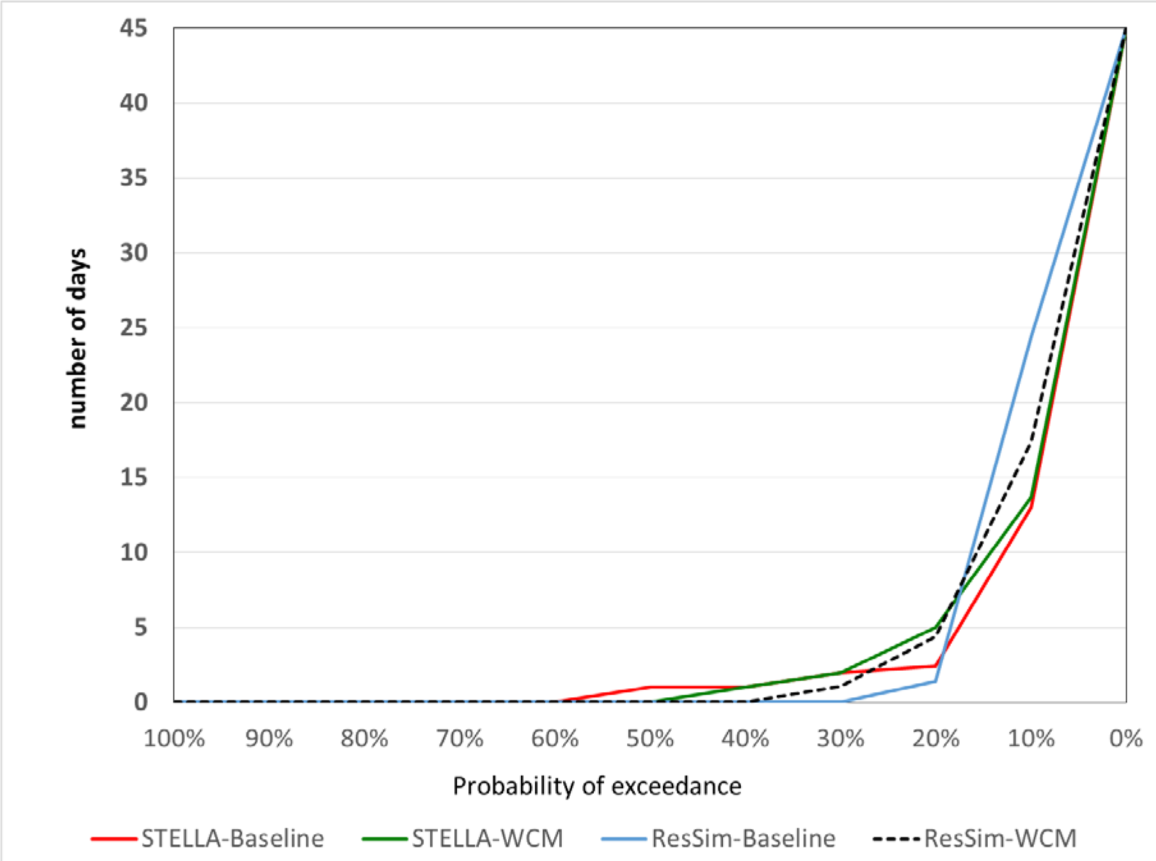
Interpretation: The WCM provides a mix of beneficial and adverse effects compared to the baseline. Overall, the greater number of low flow days during the infection and drop cycle may correspond to higher infection rates and survival of juvenile mussels following release from the fish host. The WCM's slight benefit of a 30-day increase (0.9%) in the number of days in the 5,000-5,999 cfs range during June 1-July 15 infection and drop cycle may correspond to slightly higher infection rates, settlement of juvenile mussels in this zone near the 5,000 cfs management threshold, and increased survival of juvenile mussels following settlement in this relatively stable zone. However, these slight benefits may be outweighed by the 1-day increase (0.03%) in the number of days below 5,000 cfs, the 51-day drop (1.5%) in number of days in the 6,000-7,499 cfs range, and the 48 additional days (1.4%) in the 7,500-10,000 cfs range.

Freshwater Mussel Hydroecological Metric 5 - Stable Low Flows during Host Infection and Juvenile Settlement

Metric Description: To evaluate the potential effects of the proposed action on the ability of adult host fish to be infected and juvenile mussels to drop in appropriate locations for high survival, we calculated the maximum number of consecutive days between June 1 and July 15 exhibiting flows <7,500 cfs.

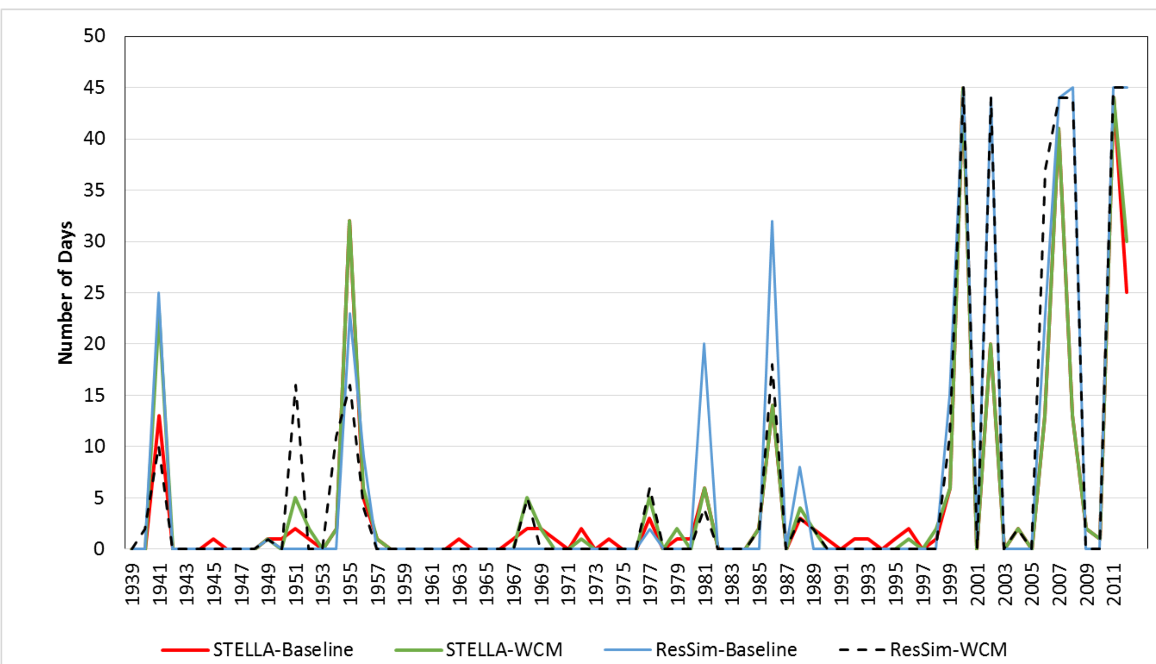
Designed to complement Freshwater Mussel Hydroecological Metric 4, this metric reflects the number of days during the infection and juvenile drop cycle that flows are low or very low and almost entirely contained within the main channel of the river. However, this metric emphasizes the consistency, or stability of low flows occurring during the infection and drop cycle. Low, stable flows during this 45-day time period, rather than intermittent, short-term increases in discharge due to natural or anthropogenic effects, are considered beneficial for the infection of host fish and for settlement of juvenile mussels in areas of the channel most likely to remain inundated year-round. This metric assumes that the zone of stability and highest survival for mussels is near the 5,000 cfs waterline, and mussel drop closer to this 5,000 cfs waterline will result in the highest survival of juvenile mussels and settlement farther from this 5,000 cfs waterline will result in lower survival. We use <7,500 cfs to represent this higher survival, better ephemeral habitat. Note, this metric only apply to species that are gravid, releasing glochidia, and experiencing juvenile drop in June through early July, such as *A. neislerii, E. chipolaensis,* and other non-listed species.

Results: The total number of days at flows <7,500 cfs between June 1 and July 15 occurring under the 2 flow regimens (baseline, WCM) is presented as a probability of exceedance plot in Figure 10.6A and a summary of the days per year (Figure 10.6B). Both models showed different patterns, and the ResSim model showed a negative effect. Based on the ResSim models, the WCM provides 10 days less of consecutive flows <7,500 cfs compared to the baseline across the 74 years (i.e., 0.3 days on average), and this effect is mostly visible in the years with more days of flow <7,500 cfs (i.e., the drier years). Again, this pattern can be seen in the flow duration curve where the WCM has a slightly lower probability of flows between 5,000 and 7,000 than the baseline Figure 10.5H. This may be slightly negative effect for the mussel population by decreasing the time for juvenile mussels to drop and settle in this ephemeral habitat closer to the more stable 5,000 cfs stable zone.



45
40
35
30
25
20
15
10
5
0
number of days
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Probability of exceedance
STELLA-Baseline
STELLA-WCM
ResSim-Baseline
ResSim-WCM

A



50
45
40
35
30
25
20
15
10
5
0
Number of Days
1939
1941
1943
1945
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
STELLA-Baseline
STELLA-WCM
ResSim-Baseline
ResSim-WCM

B

Figure 10.6 Probability of exceedance plot (A) and an annual summary (B) showing total number of days when flows are continuously <7,500 cfs between June 1 and July 15 occurring under the baseline and WCM flow regimes

Interpretation: The WCM provides a slight negative effect compared to the baseline. Higher number of consecutive low flow days during the infection and drop cycle may correspond to higher infection rates and higher survival of juvenile mussels following release from the fish host. The WCM's slightly negative effect of a 0.3 day average decrease in the number of consecutive days <7,500 cfs during June 1-July 15 infection and drop cycle may correspond to slightly lower infection rates, settlement of juvenile mussels in this zone near the 5,000 cfs management threshold, and decreased survival of juvenile mussels following settlement in this relatively stable zone.

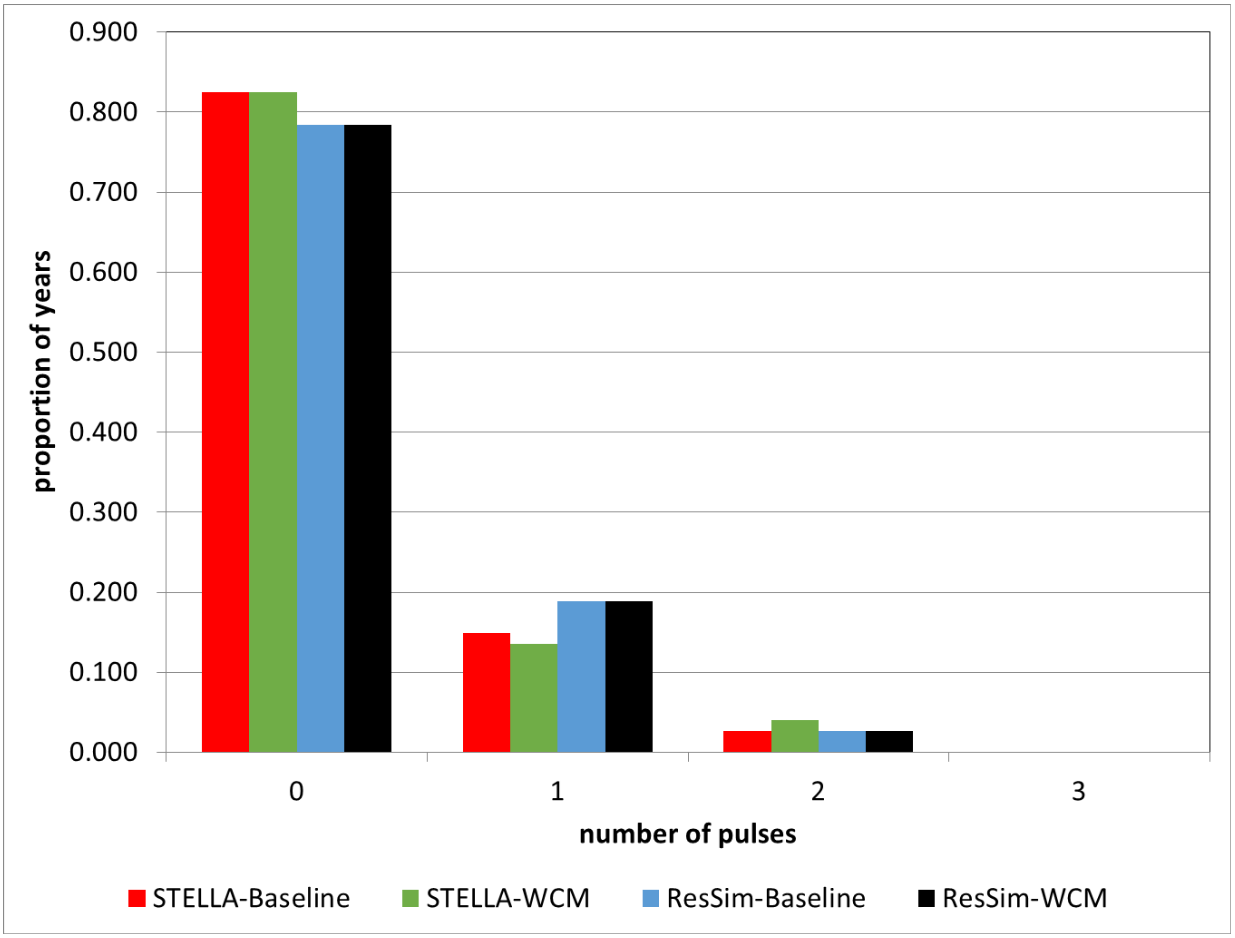
10.2.1.3 Flows for Mussel Growth and Fecundity with respect to Floodplain Inundation (FE4)

Freshwater Mussel Hydroecological Metric 6 - Pulsed Floodplain Inundation during Summer-Fall

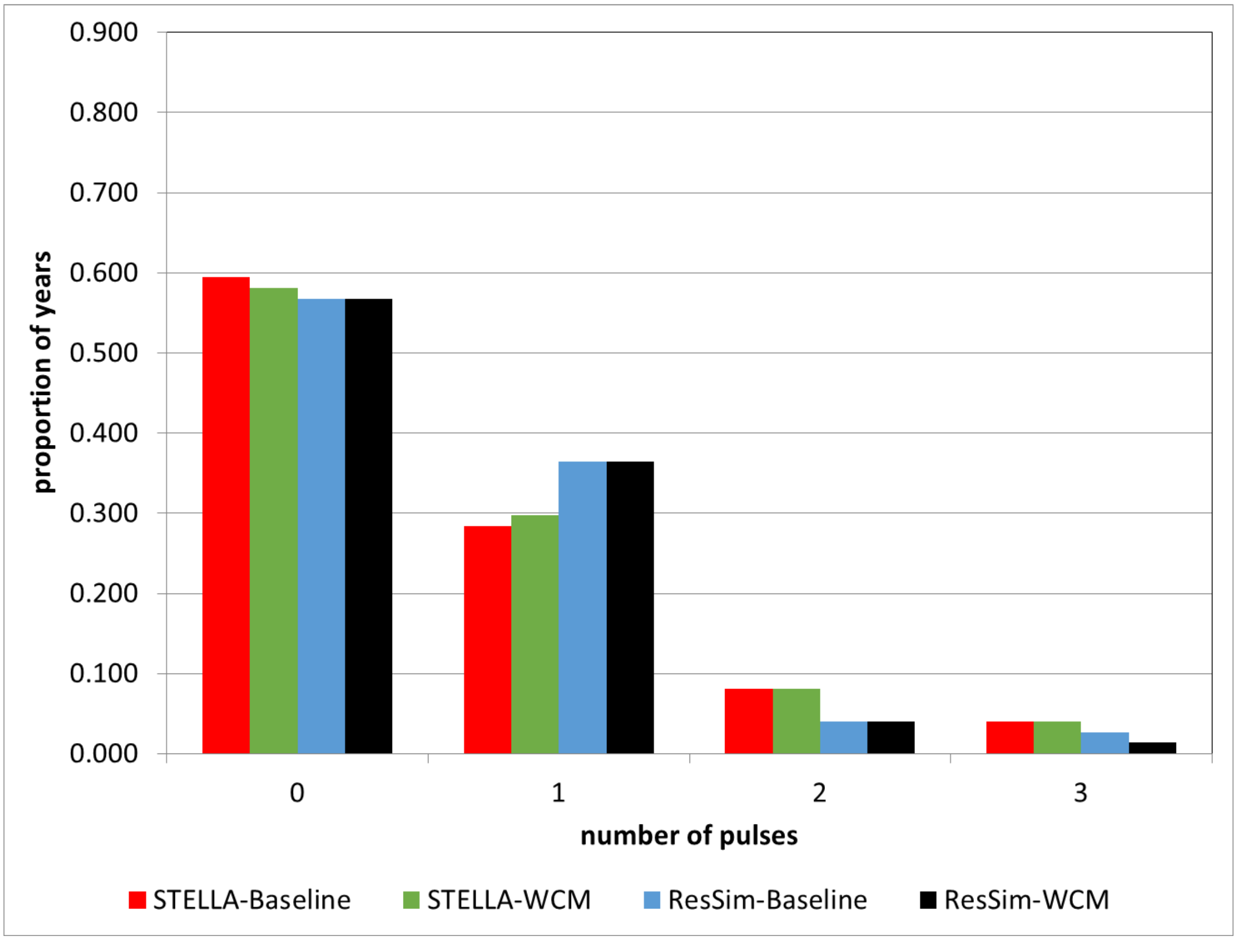
Metric Description: To evaluate the potential effects of the proposed action on the contribution of the floodplain to nutrients for food production for mussel growth and fecundity, we calculated the total number of floodplain pulse episodes between July 15 and November 24.

This metric emphasizes the role of floodplain inundation pulses during the mid- to late- growing season after mussel drop, rather than focus singularly on the amount of time the floodplain is inundated. A flood pulse is a discrete discharge episode with flows continuously ≥16,200 cfs for a period of at least 15 or 30 of days, followed by a period of flows <16,200 cfs for a period of at least 7 days. As with other hydroecological metrics, we used 16,200 cfs as an approximate flow threshold where substantial floodplain inundation occurs, although the maximum inundation of the floodplain occurs at approximately 125,000 cfs. Cycles of inundation followed by drying may stimulate productivity, and recruitment of carbon to the main channel (Junk et al. 1989) where mussels are filter feeding. This time period is important for growth of juvenile mussels and growth and fecundity of adult female mussels (Strayer 2008). The inundation period must be sufficient to allow for primary production to occur. Because there is uncertainty surrounding the duration of time the floodplain needs to be inundated to stimulate this primary productivity and carbon recruitment to the main channel of the river where most of the mussel population will survive and reproduce, we calculated both a 15-day and a 30-day pulse to bracket the potential durations of time. This metric calculates the proportion of years in the 74 year record with 0, 1, 2, and 3 floodplain pulses.

Results: The proportion of years with 30-day (A) and 15-day (B) floodplain pulses between July 15 and November 24 occurring under the 2 flow regimens (baseline, WCM) is presented in Figure 10.7. The models showed differing results, and the ResSim model showed a negative effect. The WCM and baseline provided the same number of years with at least one 30-day pulse across the 74 year record (16 years or 22% of the time), but the WCM provided one less year with a 15-day pulse compared to the baseline (31 years or 42% of the time). Across the 74-year record, the WCM provided one less year with three 15-day pulses (1.4% of the time) 15-day pulses than the baseline.



A



B

Figure 10.7 The proportion of years in the 74 year period of record with 30-day (A) and 15-day (B) floodplain pulses between July 15 and November 24 occurring under the baseline and WCM flow regimes

Interpretation: Although these are rare events in the record, providing one less year with three 15-day pulses once every 74 years (1.4% decrease) are slightly negative effects of the WCM. Under the WCM (as well as the baseline), we expect 1 year with at least a 30-day pulse and 2 years with a 15-day pulse in 5 years. This reduction in pulses of nutrients may provide less carbon and consequently primary productivity to the main channel of the river where the majority of the mussel population resides. This may reduce food resources for the mussel population may decrease juvenile mussel growth and female mussel fecundity in these rare years.

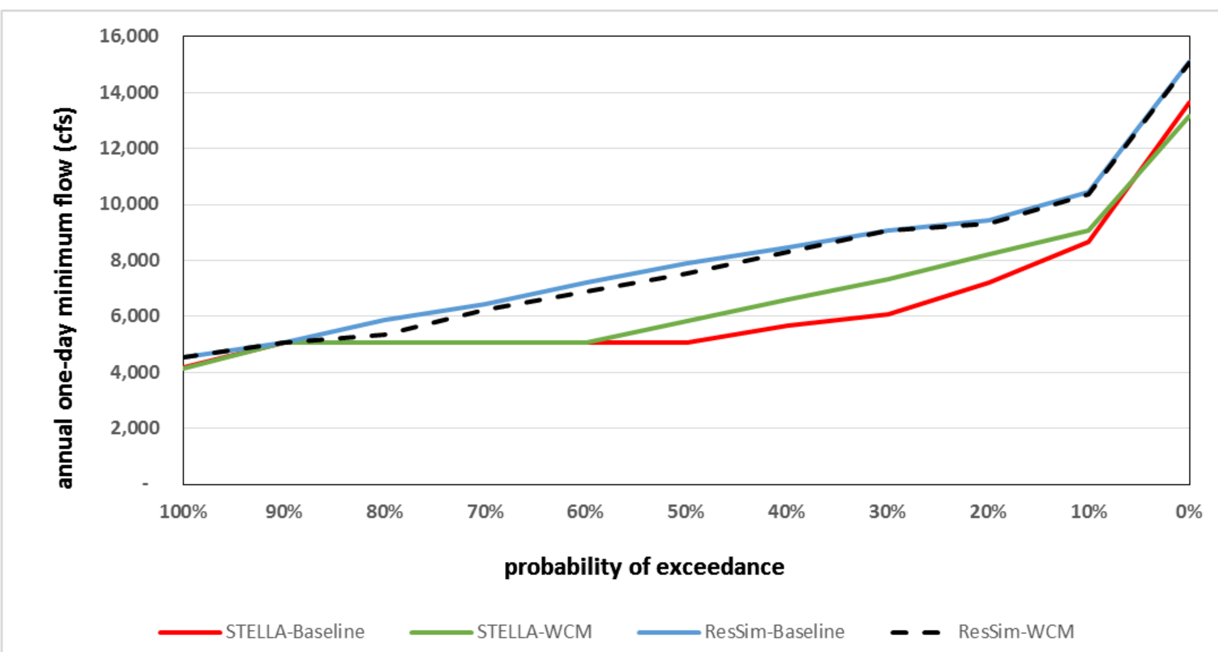
10.2.1.4 Flows for River Drawdown and Mussel Survival in Ephemeral Habitats (FE5)

Freshwater Mussel Hydroecological Metric 7 - Mussel Exposure and Survival during Extreme Low Flows

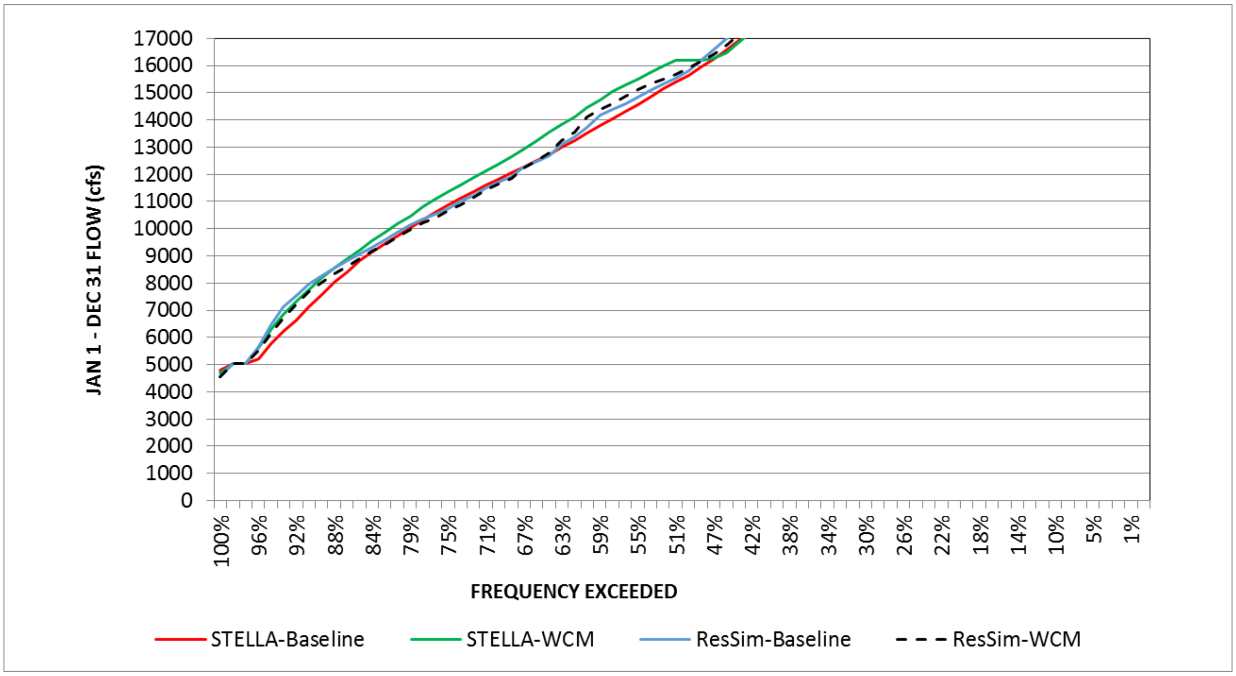
Metric Description: To evaluate the potential effects of the proposed action on mussel exposure and survival during extreme low flows, we calculated the annual 1-day minimum flow for the Apalachicola River across the 74 years of record.

This metric emphasizes the importance of the low flow experienced by the mussel population each year and the probability of experiencing very low flows (i.e., <5,000 cfs). Since mussels are relatively slow moving, their ability to retreat during water level declines is a function of site slope and the rate of water surface elevation decline (USFWS 2011, Newton et al. 2015). However, field studies have documented the ability of mussels like *A. neislerii* to relocate to lower elevations as water level declines in the Apalachicola River (USFWS 2011). Minimum flows and how the rules in the baseline and WCM management plans are implemented are important, especially as the flows reach and drop below the relatively stable 5,000 cfs minimum in the rule sets that govern each management plan. In both plans, the drought operations allow flows to drop to 4,500 cfs in drought situations. These thresholds are important because they provide the habitat stability during low flows that mussels require (Strayer 2008). Note that a version of this metric is presented in tabular form for the 1975-2011 time period in the BA (Table 10 in 6/30 BA).

Results: The annual minimum flow occurring under the 2 flow regimens (baseline, WCM) is presented as a probability of exceedance plot in Figure 10.8A. The models showed the different patterns, but the ResSim model showed a negative effect (i.e., that the WCM increased the chance of flows ≤5,000 cfs). The WCM increased the chance of minimum flows below 5,000 cfs to approximately 3%. The WCM provides an additional 1% of years that the annual minimum flow is ≤5,000 cfs compared to the baseline. During the WCM, we would expect to have a 3% chance to reach ≤5000 cfs. This effect can also be seen in the annual flow duration curve in which the WCM provides lower flows in the approximately 96% to 50% exceedance range Figure 10.8B.



A



B

Figure 10.8 Probability of exceedance plots showing the annual one-day minimum flow (A) and annual flows (cfs) ≤17,000 cfs (B) occurring under the baseline and WCM flow regimes

Interpretation: Fewer years with flows less than 5,000 cfs should benefit mussel populations since this commonly recurring low flow or inundation elevation (wetted perimeter) is associated with the minimum flow rules in each management plan. When viewed in conjunction with the stable flows for settlement of mussels in early summer, flows at or above the 5,000 cfs threshold should allow mussel populations to grow in the relatively stable environment created by this threshold. Consequently, increasing the probability of time at or below this threshold by 1% under the WCM should adversely affect mussel populations. During the WCM, we would expect a 3% chance to reach flows ≤5,000 cfs.

Freshwater Mussel Hydroecological Metric 8 - Mussel Exposure and Survival during Extreme Low Flows

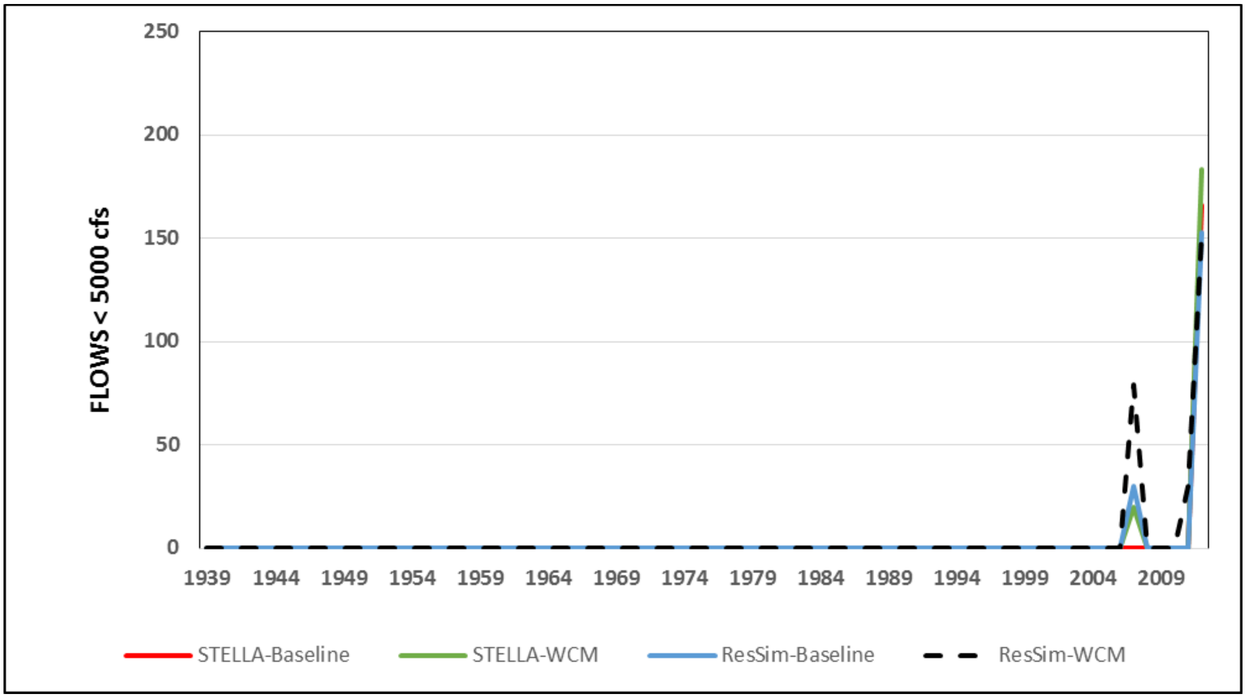
Metric Description: To evaluate the potential effects of the proposed action on mussel exposure and survival during extreme low flows, we calculated the annual 1-day minimum flow at two thresholds (<5,000 cfs and <5,100 cfs) for the Apalachicola River by year of record.

This metric emphasizes response to drought and the importance of the low flows near (<5,100 cfs) and less than the minimum management threshold of 5,000 cfs. It was designed to complement mussel metric 7. Since mussels are relatively slow moving, their ability to retreat during water level declines is a function of site slope and the rate of water surface elevation decline (USFWS 2011, Newton et al. 2015). However, field studies have documented the ability of mussels like fat threeridge to relocate to lower elevations as water level declines in the Apalachicola River (USFWS 2011). Minimum flows and how the rules in the baseline and WCM management plans are implemented are important, especially as the flows reach and drop below the relatively stable 5,000 cfs minimum in the rule sets that govern each management plan. In both plans, the drought operations allow flows to drop to 4,500 cfs in drought situations. These thresholds are important because they provide the habitat stability during low flows that mussels require (Strayer 2008).

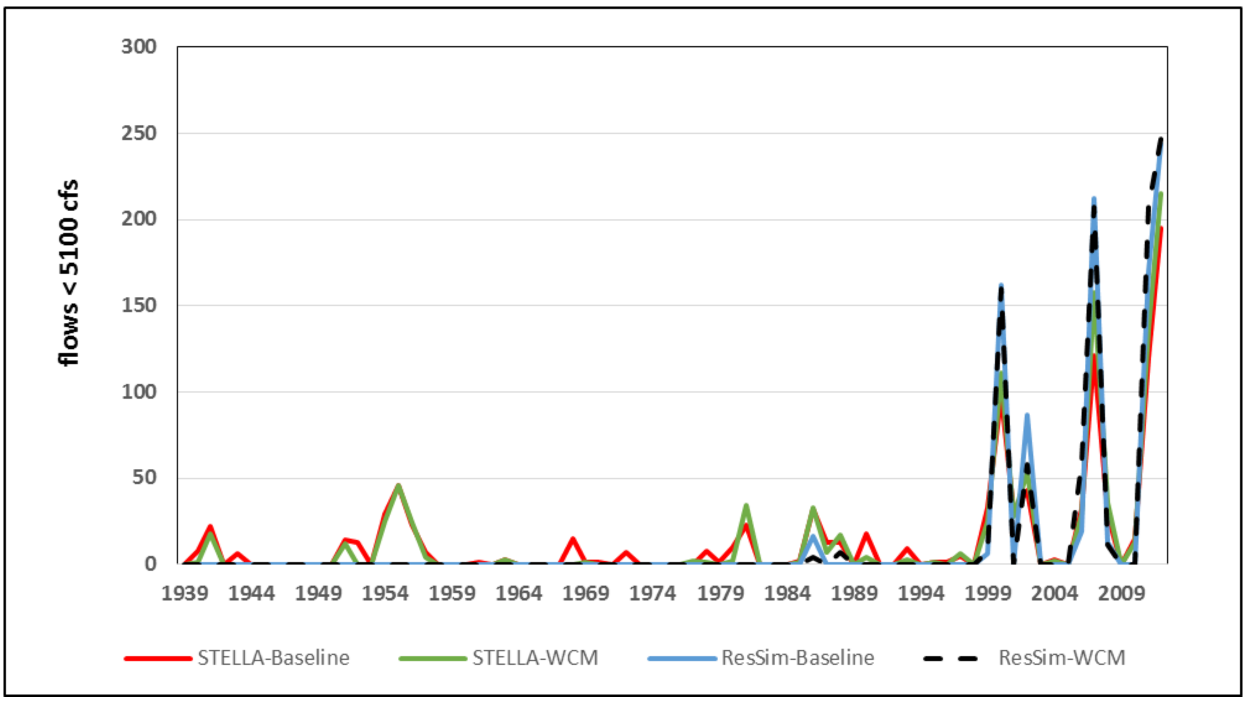
Results: The total number of days when flows are <5,000 cfs occurring under the 2 flow regimens (baseline, WCM) is by year of record in Figure 10.9A. Both models showed similar patterns. However, the ResSim model showed a stronger negative effect when flows are <5,000. The WCM and baseline provide essentially identical management with flows not dropping below 5,000 cfs across the period of record with the exception of the response to the recent droughts in which the WCM spent 79 days <5,000 cfs and the baseline 30 days in 2007 and the WCM spent 29 days more (182 vs 153) than the baseline < 5,000 cfs in 2011-2012 (1.4% increase in number of years). Under the WCM, we would expect flows < 5000 cfs in 4.1% of years or an 8.1% chance in one of five years.

When we calculate the total number of days when flows are <5,100 cfs occurring under the 2 flow regimens (baseline, WCM) by year of record (Figure 10.9B), we see more discrimination between the WCM and baseline management plans. The WCM increased the number of days <5,100 cfs by 39 days across the 74 years with flows below 5,100 cfs, but the WCM had 10 years (13.5%) where flows dropped below 5,100 cfs while the baseline had 9 years (12.2%). Under the WCM, we would expect flows < 5,100 cfs in one of five years.

It is worth noting that the recent hydrographic record has been drier and resulted in a pattern of increasing prevalence of low flows. This potential challenge to management is evident in the recent record from 1999 to 2012 and is especially visible in Figure 10.9B. Flows never went below 5000 cfs from 1939-2006, but did three times in the last 6 years of the record. Similarly, flows never went below 5100 cfs from 1939-1985, but did 10 times in the last 27 years of the record.



A



B

Figure 10.9 An annual summary of the total number of days when flows are continuously <5,000 cfs (A) and <5,100 (B) occurring under the baseline and WCM flow

Interpretation: Fewer years experiencing flows less than or near 5,000 cfs should benefit mussel populations since this commonly recurring low flow is associated with the minimum flow rules in each management plan. When viewed in conjunction with the stable flows for settlement of mussels in early summer, flows at or above the 5,000 cfs threshold should allow mussel populations to grow in the relatively stable environment created by this threshold. The increased year in which time was spent below 5,000 cfs and increased 78 days during these two droughts may have highly detrimental effects to the mussel population because it disrupts the otherwise stable habitat maintained by the 5,000 cfs threshold. Under the WCM, we would expect flows < 5,100 cfs in one year and an 8.1% chance to drop < 5000 cfs in one of five years.

Freshwater Mussel Hydroecological Metric 9 - Mussel Exposure and Survival during Drawdown

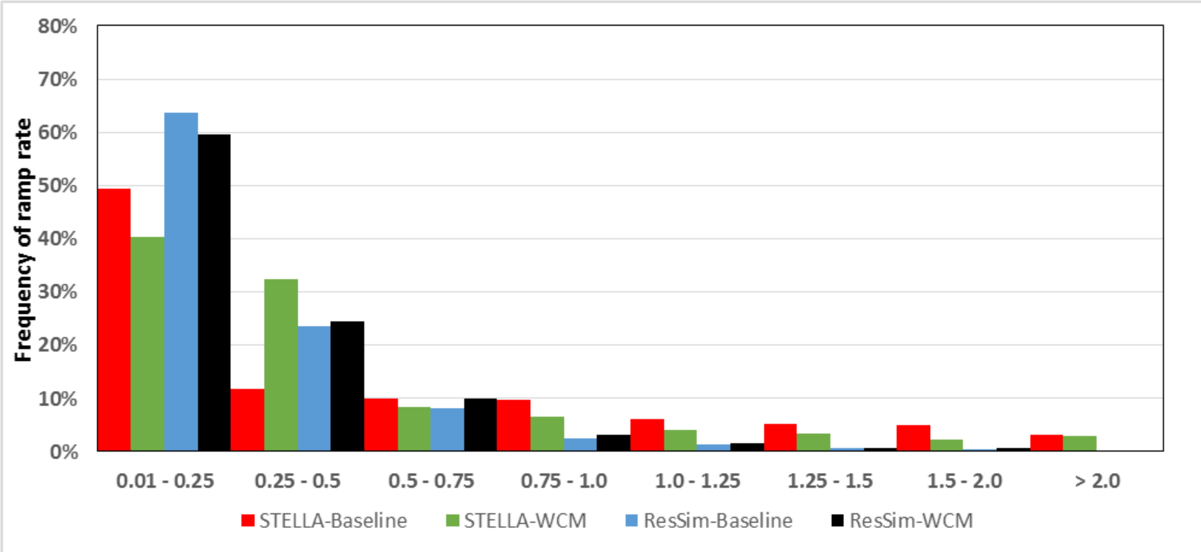
*Metric Descriptio*n: To evaluate the potential effects of the proposed action on mussel exposure and survival during drawdown, we calculated the frequency (in percent of days) of daily stage changes (ft/day) for all flows and when releases from Jim Woodruff Dam are less than 10,000 cfs.

This metric emphasizes response to drought and the importance of the ramp rate (i.e., change in flow while flows are decreasing) when moving toward low flows and especially the ramp rate as water is drawn down from 10,000 to 5,000 cfs. It was designed to complement mussel metrics 7 & 8. Since mussels are relatively slow moving, their ability to retreat during water level declines is a function of site slope and the rate of water surface elevation decline (USFWS 2011, Newton et al. 2015). However, field studies have documented the ability of mussels like *A. neislerii* to relocate to lower elevations as water level declines in the Apalachicola River (USFWS 2011).

At the daily drawdown rate of 0.25 feet/day (app. 220-500 cfs/day) included in the conservation measures (Table 1.4), the sites that are most at risk of experiencing some exposure and mortality of freshwater mussels are those with the lowest bank slopes- slopes of <0.2 (i.e., 20%), as observed across a multitude of sites in the Apalachicola River and lower Chipola River (USFWS 2011). Maintaining slow drawdown rates when river discharge is falling from 10,000 to 5,000 cfs provides the greatest opportunity for successful escapement of ephemeral habitat by mussels that inhabit the "moving littoral" zone of the river. How the maximum ramp rates rules in the baseline and WCM management plans are implemented is important, especially as the flows reach and drop toward and below the relatively stable 5,000 cfs minimum.

This metric is essentially a check of the rules in the management plans and is presented for continuity with previous BOs for Jim Woodruff Dam operations (USFWS 2008, 2012). Note that a version of this metric is presented in Figure 34 & 35 for the 1975-2011 time period in the BA (6/30 version).

Results: The frequency (in percent of days) of daily stage changes (ft/day) for all flows occurring under the 2 flow regimens (baseline, WCM) is presented in Figure 10.10A. Both models showed the same pattern (i.e., that the WCM and baseline showed little change in daily ramp rates), but the ResSim model showed the greater effect. The WCM has 4% fewer days with ramp rates ≤0.25 ft/day than the baseline when looking at all flows. When flows are <10,000 cfs, the frequency (in percent of days) of daily stage changes (ft/day) occurring under the 2 flow regimens (baseline, WCM) is presented in Figure 10.10B. In this case, the WCM has 11% fewer days with ramp rates ≤0.25 ft/day than the baseline.



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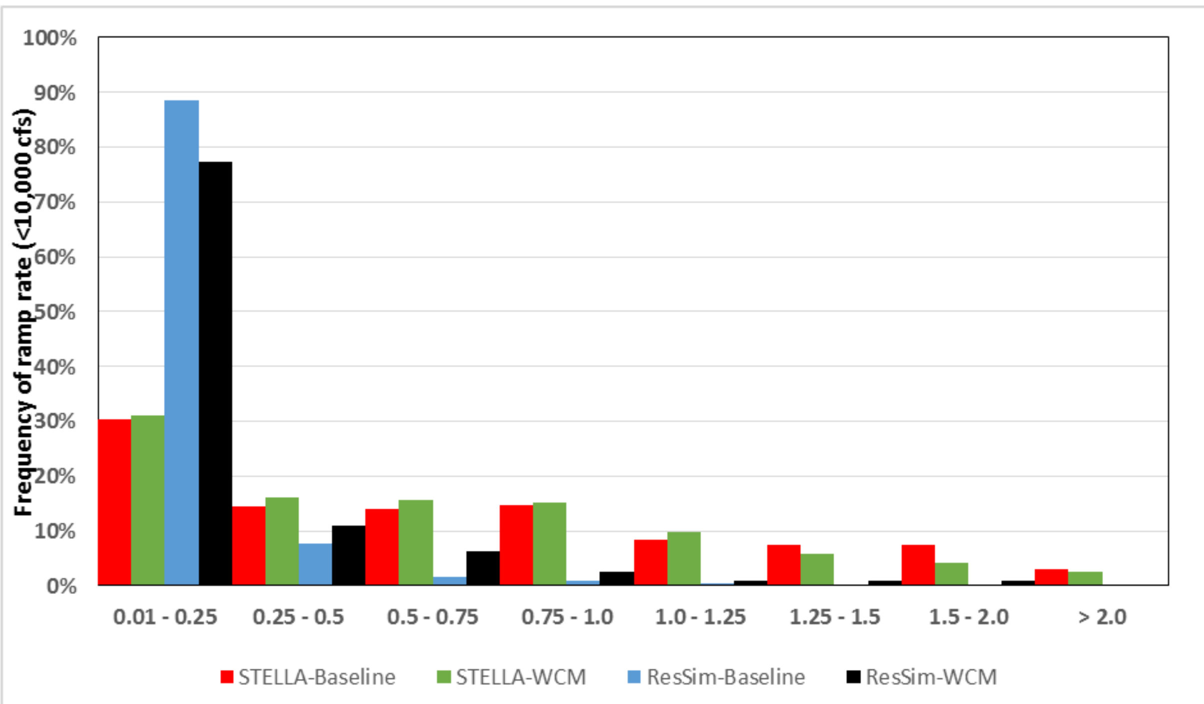


B

Figure 10.10 The frequency of days across the 74-year record with decreasing flow ramp rates < 0.25 ft/day and in categories >0,25 ft/day at all flows (A) and when flows are <10,000 (B) occurring under the baseline and WCM flow regimes

Interpretation: Lower ramp rates should result in less stranding and lower mortality of mussels especially when dropping from 10,000 to 5,000 cfs. Thus, the WCM provides a slight negative effect with the 11% decrease in days with daily ramp rates $\leq$0.25 ft/day. However, these figures must be interpreted with caution because the data is based on daily averages. The Jim Woodruff Dam hydrogeneration schedule does result in stage changes *within* each day, not obvious from the "average daily flow" reported, but certainly extreme within each day. These within day stage changes could result in stranding of aquatic organisms, including mussels, fish hosts, and Gulf sturgeon (as discussed in the previous section). These effects on mussels are discussed in the next section.

10.2.1.5 Other Effects of the WCM on Mussel Life History and Critical Habitat

The hydroecological metrics calculated to assess effects on daily flow do not cover other effects of the action. Two other effects that are worthy of discussion and qualitative analysis are changes in temperature and sub-daily flows for hydropower generation (hydropeaking).

Freshwater Mussel Qualitative Metric 1 - Mussel Growth and Survival at Increased Temperatures

As described earlier, mussels are very sensitive to changes in temperature and rely on temperature cues to initiate spawning. In addition, temperature is correlated with DO levels and die offs of other mussels have been documented in the ACF downstream of the dam.

The USACE in its BA developed a HEC-5Q model to analyze WCM effects to water temperature. Figure 2.5 provide a representation of WCM effects on stream temperature when compared to the baseline in March - May and September through December time frames, respectively. Examining the area of interest downstream of Jim Woodruff Dam, the upper limits of the temperature experienced by the mussels are near levels at which they experience thermal stress. However, WCM operations would result in no discernable change to temperatures based on this model (Figure 5.7).

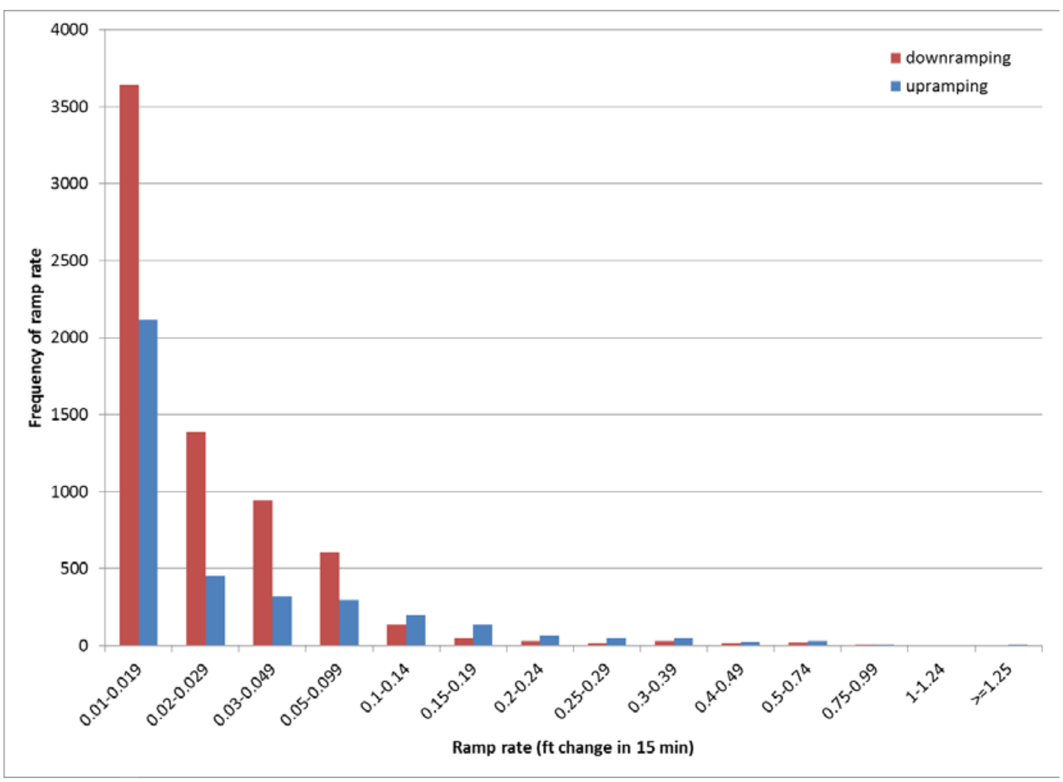
Empirical data on temperature are limited. Only 270 records of temperature ranging from October 1960 to July 2011 are available from the Chattahoochee gage from the USGS website (accessed July 15, 2016). These temperatures average 20.5 C (min 7 degrees C, max 31 degrees C). Additional data are needed to better assess changes in temperature, validate the USACE HEC-5Q model, and assess the effects of these temperature changes on mussels.

Freshwater Mussel Qualitative Metric 2 - Mussel Exposure, Survival, and Habitat Loss during Hydropeaking

*Metric Descriptio*n: In order to evaluate the potential effects of the proposed action on glochidial infection and juvenile drop during hydropeaking, we calculated the frequency (in percent of days) of 15-minute stage changes (ft/15-min) for all flows during the glochidial infection and drop season (June 1-July 15) and when releases from Jim Woodruff Dam are 6,700-18,300 cfs based on 15-minute gage height data from 2008-2015 at the Chattahoochee gage. In order to evaluate how often conditions for hydropeaking occur during the infection and drop season, we calculated the annual number of days between two thresholds (6,700 cfs and 18,300 cfs) for the Apalachicola River by year of record using the ACF STELLA model and 74-year record.

As discussed in section 1, peaking operations at Jim Woodruff Dam occur between 6,700 cfs and 18,300 cfs. We used 15-minute data from USGS gage 02358000 to analyze the effect of peaking activity on stage and discharge each afternoon (i.e., short durations of increases and decreases in flows lasting 2-6 hrs) from approximately 4:00 p.m. to 10:00 p.m. The large, rapid changes in volume of water from hydropeaking may affect the success of glochidial infection and juvenile drop.

Results: Sub-daily, 15-minute discharge and gage height data from the Chattahoochee gage for 8 years (2008-2015) are summarized in Figure 10.11. These data show down ramping up to 0.92 ft/15 min and up to 0.97 ft/15 min up ramping when flows are between 6,700 cfs and 18,300 cfs during the infection and drop season (Figure 10.11A), although the vast majority (95%) of flows are below the 0.25 ft/day ramp rate threshold. To quantify the prevalence and magnitude of peaking activity for hydropower production, we summarized the data by 6 hour intervals each afternoon between 4 pm and 10 pm (Figure 10.11B). This analysis showed down ramp rates up to 1.6 ft/6 hrs and up ramping rates of up to 1.8 ft/6 hrs while hydropeaking activities are occurring, and 91% of down ramps and 77% of up ramps are above 0.25 ft/day, which is the daily average ramp rate conservation measure. Further, some change of flow occurred during the peaking window of time each afternoon approximately 63% of the time when flows are 6,700-18,300 cfs.



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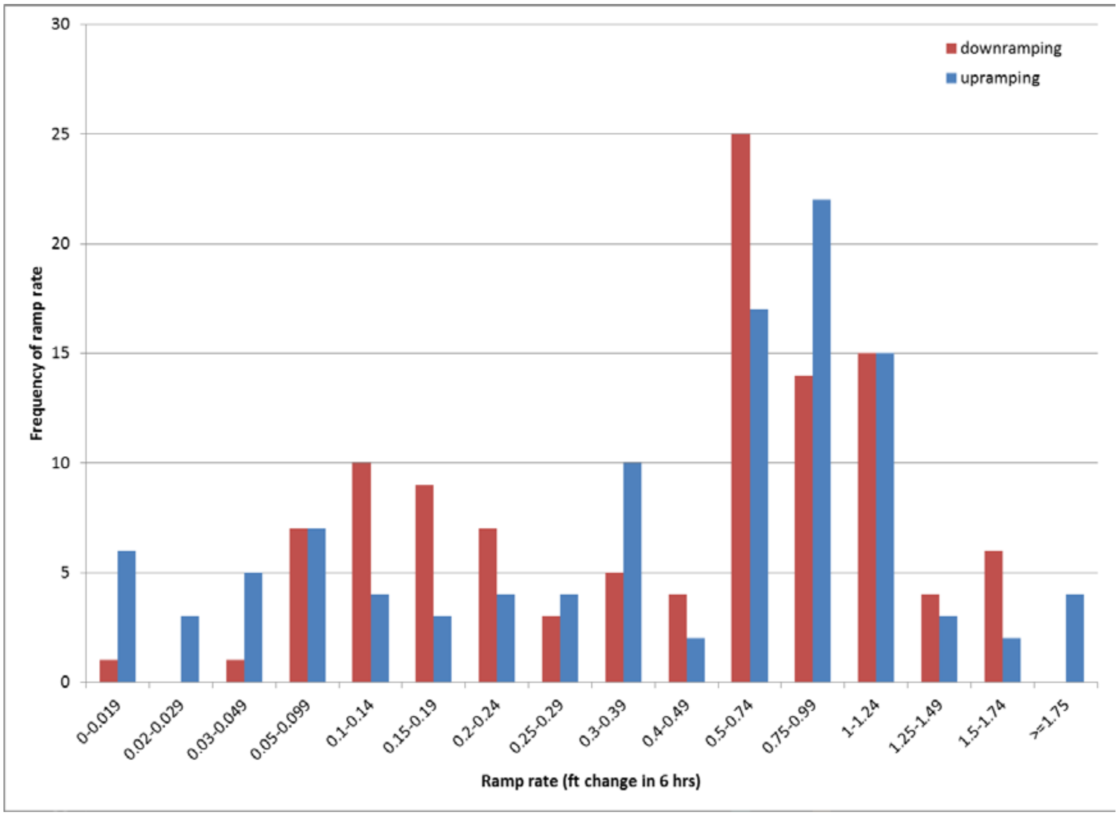
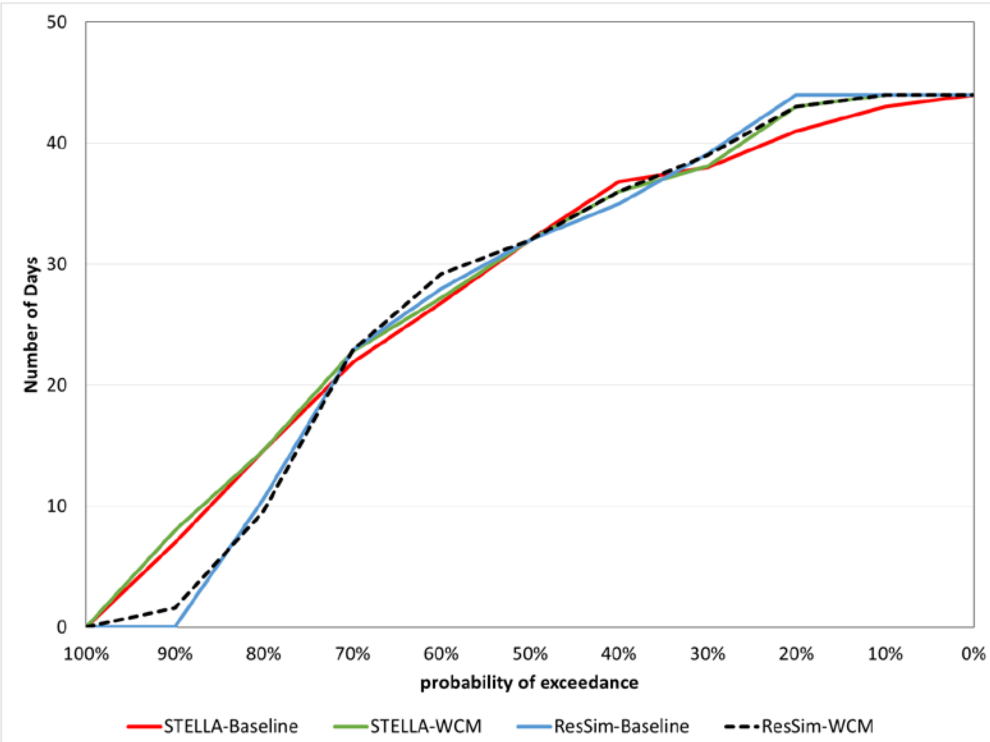


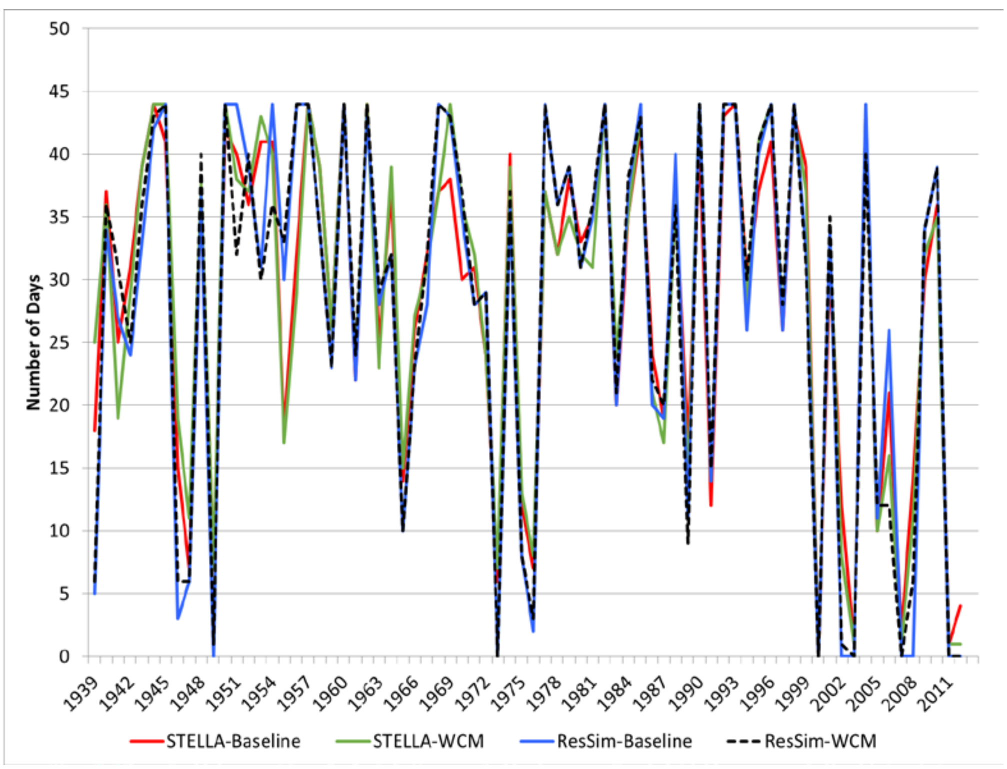
B

Figure 10.11 The frequency of observed 15-minute ramp rates during the mussel infection and drop season (June 1-July 15) (A) and 6-hr ramp rates when flows are (B) from 2008-2015.



50
40
30
20
10
0
Number of Days
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
probability of exceedance
STELLA-Baseline
STELLA-WCM
ResSim-Baseline
ResSim-WCM

A



50
45
40
35
30
25
20
15
10
5
0
Number of Days
1939
1942
1945
1948
1951
1954
1957
1960
1963
1966
1969
1972
1975
1978
1981
1984
1987
1990
1993
1996
1999
2002
2005
2008
2011
STELLA-Baseline
STELLA-WCM
ResSim-Baseline
ResSim-WCM

B

Figure 10.12 Number of days when conditions are correct to allow peaking operations at Jim Woodruff Dam during the 44-day mussel infection and drop season presented as a probability of exceedance plot (A) and count of days (B).

The total number of days at flows between 6,700 and 18,300 cfs between June 1 and July 15 occurring under the 2 flow regimens (baseline, WCM from both models) is presented as a probability of exceedance plot (Figure 10.12A) and a summary of the days per year (Figure 10.12B). Both models showed the same pattern (i.e., that the WCM increased the amount of time appropriate for hydropeaking), but the STELLA model showed the greater effect. According to this model, the WCM provides 11 days more of appropriate conditions for hydropeaking compared to the baseline across the 74 years (i.e., 0.4 days on average or 2 day increase during the WCM). Based on 8 years of 15-minute data, peaking occurs 65% of the time under both regimes. Essentially, the WCM represents no change or, perhaps, a very slight increase (<1%) the probability of conditions when hydropeaking may occur, and therefore, we expect no change from the baseline under the WCM for mussel infection and drop for fat threeridge and Chipola slabshell.

Interpretation: In other rivers, peaking hydropower operations cause fluctuations in water levels that results in erosion of the riverbanks and sedimentation of the river, increases habitat instability, and results in thermal changes. This effect can be seen for miles downstream in other rivers and likely results in mortality due to exposure as well as thermal shock to the aquatic fauna in the river including mussels during the juvenile drop and settlement season (USFWS 2011). In addition, glochidia masses may be washed downriver into unsuitable habitat during late spring and early summer peaking releases. However, many of the changes in the ACF Basin may have already occurred, and there is little information to connect these expectations to fat threeridge and Chipola slabshell ecology. Additionally, there is little change in the conditions appropriate for hydropeaking under the WCM, so we expect no change from the baseline.

10.2.2 Climate Change Considerations

As described in Appendix B, we used climate model projections, downscaled and validated for the ACF basin, in order to estimate (using the STELLA model) results of WCM for period 2020-2069. This time frame begins during the period of the proposed WCM operation, and provides a horizon that should include a full range of climate effects to evaluate. Our estimated climate change factors were based on the overall changes in median flow volume for each calendar month, and did not account for changes in the distribution of flows (i.e., for the possibility that, for example, increased median flows may be accompanied by lower low flows and higher high flows). The results from applying these climate change factors to the UIF represent a conservative estimate of the likely range of responses that can be expected during the foreseeable future. The results from climate projections for mussel metrics show a large spread of outcomes associated with the range of climate projections. However, the general patterns between WCM and baseline were similar to that of the observed hydrology for the 1939-2012 period of record and both management actions typically fell near the median predicted flows from the 97 climate models (Appendix B).

10.3 Species' Response to the Action

The previous section on Analysis of the Effects of the Action discussed the effects of flow regime alteration on the listed mussels at several life history stages including juvenile and adult survival, and juvenile recruitment as well as habitat effects including host fish production, and water quality. The following sections interpret these effects on the listed mussels in light of studies on the spatial distribution and biology of the mussels and their host fishes. We summarize the effects on each of these PCEs and each mussel species below (see also Table 10.1).

10.3.1 Critical Habitat

As described above, the PCEs that may primarily be affected by the WCM include permanently flowing water, water quality, and host fish.

Permanently flowing water: Low flows are dictated by rules in the WCM at 5,000 cfs with a minimum of 4,500 cfs under drought operations. For river drawdown and low flows, the three hydroecological metrics indicate the WCM is expected to have adverse effects for mussel exposure and survival during drawdown and low flows compared to the baseline. The WCM provides slight negative effects by increasing the probability of spending time ≤ 5,000 cfs by 1% resulting in 3 - 8.1% chance that the flows will drop below this threshold (M7 and M8). These changes may have highly detrimental effects to the mussel population because it disrupts the otherwise stable habitat maintained by the 5,000 cfs threshold. Additionally, the WCM provides an 11% decrease in days with daily ramp rates ≤0.25 ft/day (M9B) when flows are <10,000 cfs, which may result in slightly more stranding and higher mortality of mussels during drawdown. However, mussels persist in the areas below 4,500 cfs, and the dewatered habitat is not permanently lost. Accordingly, 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.

For higher flows inundating the floodplain, the WCM is expected to have slightly negative effects for mussel growth and fecundity during the late growing season compared to the baseline. Although these are rare events in the record, providing one less 15-day pulse once every 74 years (1.4% decrease) (M6B) is slightly negative effects of the WCM. Under the WCM, we expect 1 year with at least a 30-day pulse and 2 years with a 15-day pulse in 5 years. This slight reduction in pulses of nutrients may provide less carbon and consequently primary productivity to the main channel of the river where it may reduce food resources for the mussel population.

Hydropeaking occurs about 63% of time when conditions are appropriate and results in fluctuations in flow of up to about 1.8 ft/6 hrs (MQ2). This action in other rivers has resulted in erosion of the riverbanks and sedimentation of the river changing the dynamics of the two other PCEs (geomorphically stable stream channel; predominantly sand, gravel or cobble substrate). These effects may be more permanent and increase habitat instability for mussels. WCM operations essentially did not change the conditions when hydropeaking can occur and changes to the channel habitat are part of the baseline, so we expect no permanent change to the flow regime PCE.

Water quality: We expect localized water quality impacts (low DO and high temperatures) to continue to occur in the action area especially during periods of low flows. Water quality modeling (Figure 2.5) indicates the WCM operations would result in little to no change in temperatures. However, the upper limits of the temperature experienced by the mussels are near that at which they experience thermal stress. Data on water temperature and DO are needed to further assess these modeled results, but these temporary changes in water quality are not anticipated to permanently limit the ability of the critical habitat to function for the conservation of the species.

Host fish: Fish hosts may also be affected by the WCM operations. As described earlier, 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. Fish are affected by low-flow events due to constriction of habitat, elevated temperature, reduced dissolved oxygen in backwaters, etc.

The three hydroecological metrics for fish hosts for fat threeridge and Chipola slabshell indicate these hosts will be adversely affected by reduction in floodplain inundation during their spawning season. Overall, the WCM is expected to have an adverse effect on host fish populations compared to the baseline by reducing access to the floodplain during critical times in the growing season for host fish spawning and rearing for fat threeridge and Chipola slabshell. The WCM reduced the total number of days of floodplain inundation by 11% between March 1 and November 24 each year resulting in 11% fewer years with adequate number of days for host fish to spawn (M1), and 13% between March 1 and August 15 each year resulting in 12% fewer years with adequate number of days for host fish to spawn (M2). These reduction equate to approximately a 50% chance that host fish will not reproduce in one year of 5-yr WCM. In addition, the WCM also reduced the total acres of floodplain inundated during 30-day pulsed flows between March 1 and August 15 by 6% or 433 ac/yr on average but by 38% or 2794 ac/yr in the 19 years with the lowest inundation (M3). The WCM will reduce the amount of pulsed floodplain inundation by 2,215 ac on average in 5 years. Fewer days of floodplain inundation combined with the reduction in acres of floodplain inundation is expected to result in a reduction of spawning habitat for adult host fish, reduced growth and recruitment in fish host populations, and consequently a reduction in fish hosts available for mussel infection (Burgess et al. 2013). For example, a 30% reduction in flows during the spawning period resulted in a reduction in recruitment of 19-62% in redbreast sunfish (Sammons and Maceina 2009).

The two hydroecological metrics for infection of fish hosts for fat threeridge and Chipola slabshell indicate there will be a mix of adverse and slightly beneficial effects on infection of these hosts during the late spring and early summer infection and drop period. The WCM provided one slight benefits with a 30-day increase (0.9%) in the number of days in the 5,000-5,999 cfs range during June 1-July 15 infection and drop window (M4B). However, there is an adverse effect of the 1-day (0.03%) increase in the number of days below 5,000 cfs (M4C) and the 51-day (1.5%) drop in number of days in the 6,000-7,499 cfs range (M4E) as well as the 0.3 day average decrease (i.e., 1.3 day decrease during the WCM) in the number of consecutive days

<7,500 cfs (M5). These slightly lower number of low flow days (5000-7500 cfs) and consecutive low flow days during the infection and drop cycle may correspond to slightly lower infection rates, settlement of juvenile mussels in this zone near the 5,000 cfs management threshold, and decreased survival of juvenile mussels following release from the fish host in this relatively stable zone. Additionally, the 1-day increase in time below 5,000 cfs will have a destabilizing effect on the majority of the mussel population near the stable habitat zone defined by 5,000 cfs.

For purple bankclimber, the Gulf sturgeon is the key fish host and, as discussed earlier, the five hydroecological metrics indicate this species is not likely to be affected by the small changes in most of these metrics. There may be a slight negative affect because the WCM provides 10 days (0.3%) and on average 23,093 ac-days (4.7%) less floodplain inundation (GS 1, GS 4). However, the magnitude of this measurable effect of these changes on Gulf sturgeon populations is difficult to quantify. Increasing the time when conditions are appropriate to hydropeak by an average of 5.3 days (or 26 days for the WCM over 5 years) as well as the probability that conditions will be appropriate to hydropeak at least once during the spawning season by 12% and overall by 6% are all adverse effects of the WCM on Gulf sturgeon (GS Q1). These may also be adverse effects to purple bankclimber because Gulf sturgeon is a key host fish for this mussel species.

10.3.2 Fat threeridge

The current range of the fat threeridge is about 75% of its historical range, 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 8.1.1, the fat threeridge population in the action area appears stable. Recent survey techniques using SCUBA and habitat mapping using side-scan sonar have resulted in better sampling of populations and higher population estimates, as well as a better mapping of the habitat for and assessment of the vertical distribution of fat threeridge (Smit 2014). The sonar mapping approach identified twice as many patches and ten times the quantity of suitable habitat than identified using traditional approaches.

Current estimates of the population size of fat threeridge in the action area range from about 6,009,000 to 18,650,000 animals with a mean of approximately 12,167,000. Fat threeridge is the most abundant mussel in terms of frequency collected of the 18 mussel species detected during surveys (Smit 2014; Smit and Kaeser *in press*). During 2012-2015 surveys, 7,454 individuals were collected from the lower Chipola River and lower and middle Apalachicola River (Table 8.1, 8.2, 8.3; Smit 2014, Smit and Kaeser *in press*). The highest densities of fat threeridge occur between RM 27-50 of middle Apalachicola River and lower Chipola River with densities ranging from 3.7 to 7.0 individuals/sq. m, but densities ranged up to 11.2 individuals/sq. m in optimal habitat in the lower Chipola River. The largest portion of the population (61%) occurs in the Chipola Cutoff and lower Chipola River downstream of Dead Lake. This portion of the Chipola River receives about 34% of the flow from the Apalachicola River (Biendenharn 2007); therefore, flows in the Apalachicola River affect flows in the Chipola River and fat threeridge populations in this area. The remaining population occurs in the middle (34%), lower (5%), and upper (<1%) Apalachicola River.

Our analyses indicate fat threeridge may be negatively affected by low flows and effects on fish host populations. The effects of the mussel metrics are summarized by life stage below:
Glochidia production = slight negative, year round

- Very slight negative (M6)
    - 1.4% decrease in 15-day pulses
    - During the WCM, we expect 1 year with a 30-day pulse and 1 year with a 15-day pulse in 5 years

Fish host infection and drop = negative

- Negative (M1-4) Mar - Nov
    - M1-3 = app 50% chance that host fish won't reproduce in the floodplain in one year of 5-yr WCM and floodplain inundation reduced by 2,215 ac.
    - M4 = 1-day increase (0.03%) in the number of days below 5,000 cfs, the 51-day drop (1.5%) in number of days in the 6,000-7,499 cfs range
- Slight negative (M5) Jun - Jul
    - 0.3 day average decrease in the number of consecutive days <7,500 cfs during June 1-July 15

Juvenile growth and survival = mixed effects, mostly negative

- Slightly negative (M6) year round
    - 1.4% decrease in 15-day pulses
    - During the WCM, we expect 1 year with a 30-day pulse and 1 year with a 15-day pulse in 5 years
- Slight negative (M7) year round but mostly in summer
    - Increase probability of spending time ≤5,000 threshold by 1%
    - During the WCM, we expect a 3% chance to reach ≤5,000 cfs
- Negative (M8) year round but mostly in summer
    - 8.1% chance to drop < 5,000 cfs in one of the years of WCM
- Neutral near dam (MQ2) year round, mostly in summer
    - peaking occurs about 63% of days and results in fluctuations in flow of up to app 1.6 ft / 6hrs
    - No change in occurrence of conditions appropriate for peaking from baseline

Adult survival, growth and fecundity = mixed effects, mostly negative

- Slightly negative (M6) year round
    - 1.4% decrease in 15-day pulses
    - During the WCM, we expect 1 year with a 30-day pulse and 1 year with a 15-day pulse in 5 years
- Slight negative (M7) year round but mostly in summer
    - Increase probability of spending time ≤5,000 threshold by 1%
    - During the WCM, we expect a 3% chance to reach ≤5,000 cfs
- Negative (M8) year round but mostly in summer
    - 8.1% chance to drop < 5000 cfs in one of the years of WCM
- Neutral near dam (MQ2) year round, June 1-July 15
    - peaking occurs about 63% of days and results in fluctuations in flow of up to app 1.6 ft / 6hrs
    - No change in occurrence of conditions appropriate for peaking from baseline

The fat threeridge population was affected by low flows between 5,000 to 10,000 cfs in 2006-2007 and 2010-2011 as well as by flows less than 5,000 cfs during 2007 and 2011-2012. Since then, there has been a cumulative take estimate of 8,374 fat threeridge. These low flows affect adult survival, growth and fecundity and juvenile growth and survival.

Fat threeridge move in response to declines in river stage, but mussels need time to move with declining flows and these led to the fall rates conservation measures in the WCM. 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, burrowed or became exposed (8%). The majority (70%) of exposed mussels survived between 1 and 6 days following exposure. Mussel mortality occurs at fall rates less than 0.25 ft/day, and slower fall rates will facilitate movement and likely reduce mortality (USFWS 2011). 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. Updating our earlier work (USFWS 2012) with increased understanding of occupied habitats, we found that sites with a mean slope of <20% were at a much higher risk of experiencing mortality 0.02% of the local population. Mussel sites in the Chipola River generally have slopes >20%; therefore, mortality appears to be limited in the Chipola River. The mortality due to low flows observed from 2006-2015 may also depend on preceding hydrologic conditions: if flows are high for long periods (2002-2006), then mortality tends to be higher (0.03% in 2006-2007) and if the high water periods are shorter, then mortality is lower (2008-2010, 2010 mortality <0.01% of the population). 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 2006-2015 have captured the range of variability in mortality rates, and we assume mortality that occurs at flows less than 5,000 cfs would occur in addition to natural mortality. It is probable longer durations of higher flows facilitate the movement of more mussels into higher habitats, and based on previous work (USFWS 2012), we conservatively attribute these mortality events to the USACE's discretionary actions.

Previously, we used a 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 (USFWS 2012, Miller 2011a,b). Although the results from the PVA for low-flow events between 5,000 - 10,000 cfs is outdated due to our current understanding of the distribution of fat threeridge and its habitat, the PVA results remain robust that an isolated extreme low-flow event (< 5,000 cfs) with a low probability of occurrence and a high severity does not appear to pose a major threat to fat threeridge in the Apalachicola River or Chipola River. As discussed earlier, we believe the fat threeridge population in the action area is stable and probably increasing.

Loss of host fish affects the ability of fat threeridge to reproduce. There is approximately a 50% chance that fish will fail to reproduce successfully in portions of the floodplain in one year of 5-yr WCM and floodplain inundation reduced by 2,165 ac. Fewer days of floodplain inundation combined with the reduction in acres of floodplain inundation is expected to result in a reduction of spawning habitat for adult fish, reduced growth and recruitment in fish populations, and consequently a reduction in fish hosts available for mussel infection (Dutterer et al. 2012, Burgess et al. 2013). We assume this effect will be very small (<0.02% of the population). However, we provide an example below to show the data needs for calculating this effect.

For example, a 30% reduction in flows during the spawning period resulted in a reduction in recruitment of 19-62% in redbreast sunfish (Sammons and Maceina 2009). We assume this combined effect will reduce host fish populations by 20% during 1 year of the WCM. The frequency of female mussel gravidity during the reproductive season ranges from 3-56% in other mussels (Price and Eads 2011), and from 3-13% of fish can be infected by mussels (Braun et al. 2014). However, the presence of glochidia on a fish does not necessarily indicate that the fish is a host because glochidia will attach to non-hosts. Fat threeridge has approximately a 25-80% metamorphic success (Fritts and Bringolf 2014), but success on wild fish will be lower due to predation and other stressors that may lead to mortality in infected fish. If we assume an equal sex ratio, only 25% of the population of 12,000,000 are reproductive females, 25% of reproductive females are gravid, a 8% infection rate, and a 50% metamorphic success rate, then approximately 2,600 juvenile mussels may be lost due to this effect in at most 1 year of the WCM. However, these calculations are based on information from other mussel species and genera and should be interpreted with caution. More data to validate these many assumptions are required to refine this estimate.

We estimate that there are currently about 6,009,000 to 18,650,000 fat threeridge (a mean of approximately 12,167,000) in the middle and lower Apalachicola River and lower Chipola River and our understanding of fat threeridge populations in this area has improved greatly in the last 4 years. We anticipate incidental take of fat threeridge if flows are reduced to 4,500 cfs. Take estimates of 0.17%, 1.2%, 0.09% fat threeridge population have been documented in the middle and lower Apalachicola and lower Chipola, respectively, when flows were reduced below 5,000 cfs in the past. If we conservatively assume that 0.09-1.2% of the population would again recolonize that area of habitat between 4,500 and 5,000, a reduction in flow to 4,500 cfs could potentially affect approximately 22,000 individuals. The USACE cumulative take estimate of 8,374 fat threeridge since take monitoring began for the RIOP when flows were reduced to 5,000 cfs is approximately 0.07% of the population. Based on these take estimate, we conservatively expect that no more than 0.1% of the population would recolonize the elevations above 5,000 cfs during the 5-year timeframe of this action, so we also anticipate that 12,000 individuals may be affected if fat threeridge recolonize area above elevations of 5,000 cfs and subsequent mortality occurs at low flows.

10.3.3 Purple bankclimber

Although purple bankclimber is currently known from about 35 locations, the only known location where the purple bankclimber is locally abundant is the limestone shoal at RM 105 (Race Shoals), where we estimated in 2011 that about 30,000 individuals occur. Very few individuals have been collected from the remainder of the river, and only 31 individuals were collected during 2012-2015 surveys by USFWS staff of the lower Chipola River and middle Apalachicola River (Table 8.1, 8.2, 8.3). We were unable to quantify the amount of mortality at elevations above 5,000 cfs in 2006-2007, and we did not observe any dead purple bankclimbers at elevations above 5,000 cfs during our surveys in 2010-2011. However, limited purple bankclimber mortality occurred in 2007 and 2011 when flows were less than 5,000 cfs (three individuals in 2007 and 6 to 39 individuals in 2011). No mortality due to exposure from low flows was recorded in 2006-2008 or 2010-2011, but there has been a cumulative take estimate of 40 purple bankclimber since incidental take monitoring began.

The effects of the mussel metrics are summarized by life stage below for purple bankclimber:
Glochidia production = slight negative, year round

- Very slight negative (M6)
  - 1.4% decrease in 15-day pulses
  - During the WCM, we expect 1 year with a 30-day pulse and 1 year with a 15-day pulse in 5 years

Fish host infection and drop = negative

- Negative (GS1 – floodplain inundation) winter and spring
  - Negative effect in 10% of the years
  - During times of high flow (10-20% probability of exceedance range)
  - Up to 10 days reduction for the 190 day period
- Slightly negative (M6) year round
  - 1.4% decrease in 15-day pulses
  - During the WCM, we expect 1 year with a 30-day pulse and 1 year with a 15-day pulse in 5 years

Juvenile growth and survival = negative

- Slightly negative (M6) year round
  - 1.4% decrease in 15-day pulses
  - During the WCM, we expect 1 year with a 30-day pulse and 1 year with a 15-day pulse in 5 years
- Slight negative (M7) year round but mostly in summer
  - Increase probability of spending time ≤5,000 threshold by 1%
  - During the WCM, we expect a 3% chance to reach ≤5,000 cfs
- Negative (M8) year round but mostly in summer
  - 8.1% chance to drop < 5000 cfs in one of the years of WCM
- Neutral near dam (MQ2) year round, mostly in summer
  - peaking occurs about 63% of days and results in fluctuations in flow of up to app 1.6 ft / 6hrs
  - No change in occurrence of conditions appropriate for peaking from baseline

Adult survival, growth and fecundity = negative

- Slightly negative (M6) year round
  - 1.4% decrease in 15-day pulses
  - During the WCM, we expect 1 year with a 30-day pulse and 1 year with a 15-day pulse in 5 years
- Slight negative (M7) year round but mostly in summer
  - Increase probability of spending time ≤5,000 threshold by 1%
  - During the WCM, we expect a 3% chance to reach ≤5,000 cfs
- Negative (M8) year round but mostly in summer
  - 8.1% chance to drop < 5000 cfs in one of the years of WCM

- Negative near dam (GSQ1) during spawning season for sturgeon March 1-May 31
    - Under WCM operations, changes in river stage of up to three feet have been observed within a six hour time period and peaking conditions increased to about 35% of the spawning season.

Changes in the flow regime due to the WCM that affect the frequency and duration of flows greater than 4,500 cfs are unlikely to affect the purple bankclimber. Unlike the fat threeridge, it does not appear that purple bankclimber recolonized elevations above 5,000 cfs between 2008-2011 or after the recent drought in 2011-2012. Movement at Race Shoals 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 surveys of the Race Shoals, it is unlikely that there are currently any live purple bankclimbers at elevations above 4,500 cfs. 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, and mean density in these areas was $0.17/m^2$ vs. $0.48/m^2$ in water deeper than 1.5 m. Purple bankclimbers located in shallow water may be at higher risk of collection. It is evident that they are being harvested by fishermen and used for bait at Race Shoals. 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 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.

Unlike for fat threeridge and Chipola slabshell, the Gulf sturgeon is a key fish host for purple bankclimber and the five hydroecological metrics indicate this species is not likely to be affected by the small changes in these metrics. There may be a slight negative affect during the years with the lowest and highest inundation (i.e., dry years), but the biological effect of these changes on Gulf sturgeon is unknown.

We do not have a good recent population estimate for the purple bankclimber in the whole Apalachicola River and Chipola River, but we estimated that about 30,000 individuals may occur at Race Shoals, although the distribution of this estimate is limited and perhaps has low reliability. The species is more detectable, and probably much more abundant, in other parts of its range, such as the Flint River and the Ochlockonee River. If bankclimbers recolonize the habitats >5,000 cfs, 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 remains difficult to quantify how many individuals might recolonize bank elevations above 4,500 cfs. We anticipate incidental take of a small number of purple bankclimbers if flows are reduced to 4,500 cfs, primarily at Race Shoals. This is based on the USACE's estimate of incidental take of 39 individuals in 2011 when flows were inadvertently reduced below 5,000 cfs and the 40 individuals detected during take monitoring, which is together approximately 0.2% of the population. If we conservatively assume that 0.2% of the population again recolonize the area of habitat, reducing flows to 4,500 cfs could potentially result in incidental take of 60 individuals. Similarly, we expect that approximately 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.

10.3.4 Chipola slabshell

The surveys 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. Only 65 individuals were collected during 2012-2015 surveys by USFWS staff of the lower Chipola River and middle Apalachicola River (Table 8.1 and 8.3). No mortality due to exposure from low flows was recorded in 2006-2008 or 2010-2011, but there has been a cumulative take estimate of 24 Chipola slabshell since take monitoring began. 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 (Appendix A). 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.

The effects of the mussel metrics are summarized by life stage below:
Glochidia production = slight negative, year round

- Very slight negative (M6)
    - 1.4% decrease in 15-day pulses
    - During the WCM, we expect 1 year with a 30-day pulse and 1 year with a 15-day pulse in 5 years

Fish host infection and drop = negative

- Negative (M1-4) Mar - Nov
    - M1-3 = app 50% chance that host fish won't reproduce in the floodplain in one year of 5-yr WCM and floodplain inundation reduced by 2,215 ac.
    - M4 = 1-day increase (0.03%) in the number of days below 5,000 cfs, the 51-day drop (1.5%) in number of days in the 6,000-7,499 cfs range
- Slight negative (M5) Jun - Jul
    - 0.3 day average decrease in the number of consecutive days <7,500 cfs during June 1-July 15

Juvenile growth and survival = mixed effects, mostly negative

- Slightly negative (M6) year round
    - 1.4% decrease in 15-day pulses
    - During the WCM, we expect 1 year with a 30-day pulse and 1 year with a 15-day pulse in 5 years
- Slight negative (M7) year round but mostly in summer
    - Increase probability of spending time ≤5,000 threshold by 1%
    - During the WCM, we expect a 3% chance to reach ≤5,000 cfs
- Negative (M8) year round but mostly in summer
    - 8.1% chance to drop < 5,000 cfs in one of five years of the WCM
- Neutral near dam (MQ2) year round, mostly in summer

    - peaking occurs about 63% of days and results in fluctuations in flow of up to app 1.6 ft / 6hrs
    - No change in occurrence of conditions appropriate for peaking from baseline

Adult survival, growth and fecundity = mixed effects, mostly negative

- Slightly negative (M6) year round
    - 1.4% decrease in 15-day pulses
    - During the WCM, we expect 1 year with a 30-day pulse and 1 year with a 15-day pulse in 5 years
- Slight negative (M7) year round but mostly in summer
    - Increase probability of spending time ≤5,000 threshold by 1%
    - During the WCM, we expect a 3% chance to reach ≤5,000 cfs
- Negative (M8) year round but mostly in summer
    - 8.1% chance to drop < 5000 cfs in one of five years of the WCM
- Neutral near dam (MQ2) year round, June 1-July 15
    - peaking occurs about 63% of days and results in fluctuations in flow of up to app 1.6 ft / 6hrs
    - No change in occurrence of conditions appropriate for peaking from baseline

Changes in the flow regime due to the WCM that affect the frequency and duration of flows greater than 4,500 cfs are unlikely to affect the Chipola slabshell, except through effects to host fish. However, it is possible that the species went undetected due to undersampling or that individuals may have been stranded and overlooked during surveys. If so, undetected mortality may be occurring at an undefined rate. Support for this came from USACE monitoring and discovery of additional Chipola slabshell mortality in July 2014 and subsequent revision of take coverage. Being a more mobile species, we expect some recolonization of areas >5,000 cfs and subsequent mortality when flows are again reduced to this level. We still 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 9.1).

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. Low-flow Chipola slabshell mortality was observed in 2014, and we assume that some low-flow mortality may be occurring. Based on limited survey data and take monitoring, we assume that flow reductions to 4,500 cfs could affect less than 1% of the Chipola slabshell population. Because of the 10 Chipola slabshell that recolonized and were exposed in 2014, we also estimate a take rate of 0.4%. However, given the mobility of the species, these likely underestimate low-flow-related mortality. Further, our current population estimate of about 2,650 is likely an under-estimate in the action area. In combination, these assumptions provide a basis for a conservative, not-likely-to-exceed, take estimate of 2% of the population that recognizes the data uncertainties. Additionally, Chipola slabshell may experience harm through reduced recruitment. However, the magnitude of this effect is currently unknown and expected not to be appreciable.

10.4 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). By definition, 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 USFWS is aware of only one action that satisfy the definitions of interrelated and interdependent actions that will not themselves undergo section 7 consultation in the future, or that are not already included in the Baseline or our representations of flows under the WCM. This action will undergo section 7 consultation in the future, but is worthy of mention because they address possible reasonable and prudent measures and terms and conditions for addressing effects of hydropeaking. The USACE contract with Southeast Power Administration and Duke Energy will undergo section 7 in the future. This contract controls hydropower production and hydropeaking.

11 MUSSELS - CUMULATIVE EFFECTS

Cumulative effects for mussels are anticipated to be similar to those for Gulf sturgeon.

12 MUSSELS - CONCLUSION

The proposed action provides both beneficial and adverse effects to the species and their designated critical habitats. To the extent that the consumptive use assumptions are accurate, differences between the Baseline and the simulated flows of the WCM 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 WCM simulated flow regime to the USACE's discretionary operations. Differences between the Baseline and WCM are summarized for each of the species below (for more details, see section 10).

Most of these effects, both beneficial and adverse, derive from relatively minor differences between the WCM and Baseline. Generally, it appears that USACE would store water more often and augment flows less often under the WCM than has occurred under current management. The WCM 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 and less than 7,500 cfs is increased. Additionally, floodplain inundation during spring and summer is reduced. 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.

12.1 Fat threeridge

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 8, Mussels -

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 WCM 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 WCM supports a minimum flow of 5,000 cfs, which benefits the fat threeridge, except when drought operations are triggered that provide for minimum-flow support of 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 WCM more frequently. The results of an earlier PVA indicated that the population can sustain reductions of 1-2%, and this magnitude of population reduction occurred in the past at a probability less than expected in the WCM. However, the PVA also indicates that increasing the frequency of such events results in a greater impact to long-term population viability, and the WCM increases the probability from once to twice in 74 years. 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 WCM 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. Further, the WCM would have a negative, but not appreciable, impact on the survival and recovery of the fat threeridge due to reduced recruitment if flows inundate the floodplain for less than 30 consecutive days between March and August.

12.2 Purple bankclimber

The core of the known population of purple bankclimbers in the action area is at the Race Shoals (the limestone shoal at RM 105), but the species is apparently rare in the rest of the river and may be experiencing poor recruitment. Little recent information in the action area is available on the species with only 31 individuals collected during 2012-2015 surveys and 40 detected during take monitoring, 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. A whole river population estimate is not available, but the population at Race Shoals was estimated to be 30,000. The principal effects to the purple bankclimber in the action area are those we described in section 8, Mussels - 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 for the fat threeridge apply also to purple bankclimber with the exception that purple bankclimbers are rarely found at stages greater than 4,500 cfs in the Apalachicola River. We have observed limited mortality of the population during low flows from 2008-2015 with 39 individuals in 2011 when flows were inadvertently reduced below 5,000 cfs and 40 individuals detected during USACE take monitoring.

Therefore, our analysis indicates that the WCM would have a negative, but not appreciable, impact on the survival and recovery of the purple bankclimber. This impact is 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.

12.3 Chipola slabshell

Surveys from 1990 to present have documented many occurrences but found that 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 8, Mussels - Environmental Baseline do not apply to the Chipola slabshell, as its known range within the action area is almost entirely 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 for the fat threeridge apply also to the Chipola slabshell, but probably to a lesser extent in the narrower channel and higher bank slopes of the Chipola River. No Chipola slabshell mortality was documented during the low flows of 2006-2008 and 2010-2011, but there has been a cumulative take estimate of 24 Chipola slabshell under USACE take monitoring. 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 WCM 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. Further, the WCM would have a negative, but not appreciable, impact on the survival and recovery of the Chipola slabshell due to reduced recruitment if flows inundate the floodplain for less than 30 consecutive days between March and August.

12.4 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 WCM 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 WCM increased the probability of reducing flows <5,000 cfs, although this is still a very infrequent event (3 of 74 years in the record). This would occur under drought operations, and droughts substantially change the nature of all of these PCEs compared to normal flows. At higher flows inundating the floodplain, the WCM is expected to have slightly negative effects for mussel growth and fecundity during the late growing season compared to the baseline. Although these are also rare events in the record (1 of 74 years in the record), one less pulse of nutrients may provide less carbon and consequently primary productivity to the main channel of the river to the majority of the mussel population. Additional data on the effects of up to 1.8 ft sub-daily fluctuations in flows, but these changes are not anticipated to permanently limit the ability of the critical habitat to function for the conservation of the three species.

The temporary changes in water quality (temperature and DO) are not anticipated to permanently limit the ability of the critical habitat to function for the conservation of the three species. Data on water quality are needed to further assess the USACE's modeled results in the future.

The WCM reduces the amount of floodplain habitat available to fish hosts for fat threeridge and Chipola slabshell, which likely rely upon floodplain habitats for spawning and rearing habitat. Fewer days of floodplain inundation combined with the reduction in acres of floodplain inundation is expected to result in a reduction of spawning habitat for adult host fish, reduced growth and recruitment in fish host populations, and consequently a reduction in fish hosts available for fat threeridge and Chipola slabshell infection. For purple bankclimber, the Gulf sturgeon is the key fish host and our analysis indicates this species also likely to be affected by the additional conditions available for hydropeaking under the WCM.

The WCM is not expected to 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.

12.5 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 USFWS' 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 WCM is intended to apply until a new WCM is adopted. Given the USACE's current timeline, the findings of this BO shall apply for five years until September 14, 2021, or until amended through a reinitiation of consultation or superseded with a new opinion for a new proposed action.

13 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 USFWS 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 USFWS 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 USACE 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 USACE has a continuing duty to regulate the action covered by this incidental take statement. If the USACE: (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 USACE must report the progress of the action and its impact on the species to the USFWS as specified in the ITS [50 CFR §402.14(I)(3)].

13.1 AMOUNT OR EXTENT OF TAKE ANTICIPATED

The extent of the take is described below based on the effects analyses presented in sections 5 for Gulf sturgeon and 10 for mussels. Two forms of take are expected for Gulf sturgeon and two for the three mussel species.

13.1.1 Gulf sturgeon

Take of Gulf sturgeon eggs and larvae may occur due to rapid increases and decreases in stage and discharge associated with hydropeaking operations at Jim Woodruff Dam during the spawning season (March 1-May 31). The form of this take is injury or mortality of fertilized eggs and larvae caused by sudden alteration of water depth and velocity, which disrupts normal hatching and dispersal patterns and reduces food resources for larval sturgeon. The take will occur during and shortly after spawning and hatching, as spawning habitats potentially become temporarily unsuitable during the months of March, April, and May. Our analysis in section 5.2.2 indicates that hydropeaking events causing this form of take will occur on average 32 days per spawning season or up to 160 days in the next five spawning seasons; however, we are unable to estimate the number of individual eggs and larvae affected.

The second form of take of Gulf sturgeon is caused by WCM operations reducing the estuarine invertebrate production, which is critical to juvenile sturgeon growth and survival in the first winter of life. The take will occur in in the late summer and fall (July 15-November 24) as well as winter and spring periods (November 24-June1). Our analysis in section 5.2.1 indicates that the floodplain inundation critical to developing these food resources will be reduced on average from 674,000 ac-days per year to 655,000 ac-day per year in the late summer and fall period (i.e., by 19,000 ac-day per year or up to 95,000 ac-day per year in the next five years) and on average by 2.4 days or (i.e., 12.1 days over five years) during the winter and spring periods; however, we are unable to estimate the number of individual juveniles affected.

The USFWS anticipates the incidental taking of Gulf sturgeon associated with WCM operations will be difficult to detect for the following reasons:

- Gulf sturgeon are wide-ranging;
- they occur in habitats and at low densities that make finding a dead or impaired specimen unlikely, and
- changes to fitness parameters (e.g., decreased growth or recruitment) are difficult to assess in the small population in the ACF Basin.

Therefore, USACE will monitor the extent of Gulf sturgeon take using 1) the aggregate number of days in which hydropeaking occurs (i.e., number of days with flows between 6,700 and 18,300 cfs between March 1 and May 31) not to exceed an average 32 days per spawning season or up to 160 days in the next five spawning seasons; and 2) the floodplain inundation will not be reduced below 655,000 ac-day per summer and fall period on average (or a reduction of up to 95,000 ac-days over the next five summer and fall periods) or below 135 days during the winter and spring period on average (or a reduction of up to 12 days over the next five winter and spring periods). These are surrogate measures that indicate the frequency of conditions created by WCM operations that cause the anticipated taking. Exceeding these surrogate measures of the levels of incidental take for Gulf sturgeon shall prompt a reinitiation of this consultation.

13.1.2 Mussels

Take of listed mussels due to the WCM may occur when conditions are such that USACE 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. Take of fat threeridge and Chipola slabshell due to the WCM may also occur when conditions are such that USACE reduces the floodplain inundation to less than 30 consecutive days between March 1 and August 15. The form of this take is harm through reduction in host fish populations and mortality of glochidia. These conditions may result in reduced recruitment of fat threeridge and Chipola slabshell in the subsequent year. Our analysis in section 10.2.1.1 indicates that the 30-day floodplain inundation critical to host fish production will be reduced on average by 12.3% per year. The magnitude of this effect is currently unknown, but we believe it to be very small (i.e., <0.02% of the population).

Our analysis in section 10.2.1.4 indicate a 3-8.1% chance of implementing a reduction in flows less than 5,000 cfs, because the 1939-2012 simulations trigger the 4,500 minimum flow of the WCM three times (in 2007, 2011, and 2012). Therefore, we expect that incidental take of listed mussels attributable to the reduction in flow to 4,500 cfs could at most consist of one event in the next five years. We also anticipate that mussels could recolonize habitats greater than 5,000 cfs and be incidentally taken during subsequent low flows. Our model results indicate that incidental take of listed mussels attributable to the reduction flows greater than 5,000 cfs occur with a 13.5% chance, and one event of this nature is likely to occur at flows above 5,000 cfs in the next five years.

We expect a maximum of 34,000 fat threeridge 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 (22,000 individuals) and when individuals recolonize habitats greater than 5,000 cfs followed by stranding during subsequent low flows (12,000 individuals). We expect a maximum of 90 purple bankclimbers (60 if flows are reduced to 4,500 cfs; 30 in habitats greater than 5,000 cfs) 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. We expect a maximum of 106 Chipola slabshell (53 if flows are reduced to 4,500 cfs; 53 in habitats greater than 5,000 cfs) may be exposed in the Chipola River downstream of the Chipola Cutoff and middle Apalachicola during this event. USACE will monitor the extent of this form of take based on observed mortality. Additionally, fat threeridge and Chipola slabshell may experience harm through reduced recruitment. USACE will monitor the extent of this form of take using a surrogate measure that indicates the frequency of conditions created by WCM operations that cause the anticipated taking; a year with less than 30 consecutive days of at least 31,000 ac of floodplain inundation between March 1 and August 15 will not occur more than once in the next five years. Exceeding this level of incidental take for these three mussel species shall prompt a reinitiation of this consultation.

13.2 EFFECT OF THE TAKE

In the accompanying BO, the USFWS 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 no more than reduction in flow to 4,500 cfs and no more than one reduction in flow to 5,000 cfs occur within the duration of the BO.

13.3 REASONABLE AND PRUDENT MEASURES

The USFWS believes the following reasonable and prudent measures are necessary and appropriate to minimize the impacts of incidental take of Gulf sturgeon, 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 2016-1. Adaptive Management. Identify ways to avoid and minimize take and implement alternative management strategies within the scope of the authorities of WCM as new information is collected.

Rationale: Additional information will be collected to address uncertainties about the listed species and their critical habitat PCEs 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 USACE's water management operations are effective or could be improved within the scope of the WCM. Appendix C and Appendix D present possible uncertainties about USACE actions and a preliminary assessment of actions to be assessed through adaptive management identified by USFWS. Putting this information in the proper decision context of USACE's operations is the fundamental basis for adaptive management according to policy and guidance under both USACE and USFWS (PARMS 2004, Williams et al. 2007, Williams and Brown 2012, USACE 2013, USACE 2015b). Formalizing the adaptive management process will provide a framework for assessing management options that are within the authority of USACE Mobile District under the WCM as well as setting the appropriate decision context for future updates to the WCM as appropriate.

RPM 2016-2. Water Quantity and Water Quality Stations. Develop and implement a monitoring program associated with USGS, NOAA or other similar monitoring stations within the ACF Basin for water quantity and water quality parameters.

Rationale: Gaging of water quantity and quality within the ACF Basin will be used to inform estimates of take and management options to be assessed through adaptive management (RPM 2016-1). Improved water quality information is also essential to understanding the influences of USACE management on key water quality parameters associated with PCEs for critical habitat of listed mussels and sturgeon.

RPM 2016-3. Species Monitoring. Monitor the level of take associated with the WCM and evaluate ways to avoid and minimize take by monitoring the distribution and abundance of the listed species in the action area.

Rationale: Monitoring populations and relevant habitat conditions associated with take of listed species within the ACF Basin will serve the USACE's information needs for future consultations on updates to the WCM and associated activities. 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 will inform the adaptive management framework developed for RPM 2016-1.

13.4 TERMS AND CONDITIONS

In order to be exempt from the prohibitions of section 9 of the Act, the USACE must comply with the following terms and conditions, which implement the reasonable and prudent measures described above. These terms and conditions are mandatory. Adaptive management, monitoring, and other conditions in the RPMs and conservation measures are subject to the availability of funds by Congress, or revenue from the project operations. The USACE 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 USACE will reinitiate consultation with USFWS. Upon the signing of a Record of Decision, these terms and conditions supersede those of the previous BO and its amendments. These terms and conditions are effective until replaced by a BO or amended BO in the ACF basin.

13.4.1 Adaptive Management (RPM 2016-1)

a) **Develop an Adaptive Management Framework.** The USACE and USFWS will develop an adaptive management framework for identifying ways to minimize take as new information is collected. Implementation of these adaptive management strategies will begin by March 14, 2017 or within 60 days of the Record of Decision being signed, whichever comes later. The framework will:
   i) Outline the adverse effects identified in the BO.
   ii) Specify objectives to assess those effects and identify possible alternative actions to minimize those effects. Appendix C and D provide examples of uncertainties and a preliminary assessment of actions that identified providing more floodplain inundation, reducing opportunities for hydropeaking, and reducing frequency of low flows as general outcomes of actions that would address the adverse effects.
   iii) Identify specific, measureable attributes to monitor progress toward the objectives, the sampling design(s) for measuring those attributes, and the period over which monitoring will be conducted.
   iv) Describe process for evaluating the adverse effects and developing, implementing, and assessing the recommended actions to further avoid and minimize take of listed species included in this consultation.

b) **Establish an Adaptive Management Technical Team.** In order to accomplish a), USACE will establish an informal, multi-agency technical team. This team will consist of technical staff from USACE and USFWS. Technical representatives from other Federal agencies (e.g., National Marine Fisheries Service, USGS) may be asked to participate as mutually agreed upon by USACE and USFWS. This team will develop and implement the adaptive management framework.

   This adaptive management technical team will meet as needed, but at least annually during the next five years, or until a new BO is issued, to review and discuss the monitoring efforts established in the adaptive management plan. As appropriate and based on the data collected and analyses done pursuant to the management/work plans described in a), the technical advisory team will identify potential conservation measures, within the scope of the WCM, to further avoid and minimize take of listed species in the river reaches included as part of this consultation.

c) **Minimize Foraging Effects on Juvenile Gulf Sturgeon:** To minimize the negative effects of the WCM on food production for juvenile Gulf sturgeon and adverse modification to critical habitat, USACE will inundate the floodplain with a magnitude of at least 100,000 ac in pulses of at least 15 consecutive days in July 15-November 24 over 5 years (based on metrics GS4 and GS5 in section 5.2.1). Additional water will be added to the floodplain during the November 24-June 1 for an average of 12 days (based on GS1). USACE will monitor the biological effect of these proposed actions (e.g., starting by monitoring primary productivity in the Apalachicola River), and the details of how and when in these time periods the floodplain is inundated will be explored within the authority of the WCM through adaptive management. Through an incremental approach over 5 years, the result of adaptive management will be a set of management rules and targeted monitoring to meet these criteria. For example, if a 30-day pulse in July-August is provided, this may also benefit mussel host fish populations (based on M2, M3 in section 10.2.1.1). The adaptive management technical team will begin analyzing food production in the lower Apalachicola River as measured at the Sumatra gage. Use of chlorophyll a and turbidity monitoring will be reviewed by the adaptive management team to determine if it would capture the effects of the action on the food production or to determine if another monitoring regime in the vicinity of the Sumatra gage is more efficient and effective than chlorophyll a and turbidity monitoring at the gage.

d) **Implement Adaptive Management Recommendations.** The USACE shall assume responsibility for implementing the monitoring actions that the adaptive management technical team recommends and that the USFWS agrees are reasonable and necessary to understand, avoid, and minimize take resulting from the actions taken under USACE's WCM.

e) **Review WCM Implementation.** The USACE shall organize semi-annual meetings with USFWS to review implementation of the WCM and adaptive management framework including new data and results, information needs and methods to address those needs, evaluations and monitoring specified in this ITS, formulate actions that minimize take of listed species, and monitor the effectiveness of those actions.

f) **Provide Annual Report.** The USACE shall provide an annual report to USFWS on or before January 31 each year documenting (1) compliance with the terms and conditions of this ITS during the previous year, (2) any conservation measures implemented for listed species in the action area; and (3) recommendations for actions in the coming year to minimize take of listed species.

g) **Provide Monthly Status Update.** The USACE shall provide by email or other timely electronic means to USFWS on a monthly basis the status of WCM implementation including the hydrology of the system, composite system storage, and any data related to any other adopted criteria.

13.4.2 Water Quantity and Water Quality Stations (RPM 2016-2)

a) **Monitor Water Quantity and Water Quality.** USACE and USFWS will work with USGS to develop and implement a monitoring program that supplements current monitoring stations within the ACF Basin. USACE, in collaboration with USGS, will begin implementation of additional gaging by March 14, 2017 or within 60 days of the Record of Decision being signed, whichever comes later. The supplemental information to be collected will include additional water quantity and/or water quality parameters related to PCEs for critical habitat of the listed species, including flow, water temperature, salinity, and dissolved oxygen. The USACE will be responsible for funding the annual maintenance costs associated with the supplemental data collected at these existing gage locations for the duration of the BO to aid in monitoring abiotic conditions tied to the baseline and potential changes in take. Through the adaptive management approach the USFWS and USACE will assess the need to increase, reduce, or change the monitoring locations set forth in these terms and conditions. Additional to the species monitoring described in RMP 2016-3, the following gages will be monitored for discharge, stage, water temperature, dissolved oxygen at a minimum, with other water quality parameters as needed (pH, conductivity, turbidity, salinity) to assess the status and possible adverse modification of PCEs for critical habitat and associated take for listed mussels and sturgeon. Each gage shall monitor river conditions at 15-minute or other appropriate intervals and seasons as agreed by USFWS with data transmitted via satellite to the USGS office, for display on the USGS web page in real-time, and available in regular reports. The Chattahoochee and Sumatra gages will be monitored at least monthly. If the latest measurement suggests that the Chattahoochee 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 USFWS and USGS indicates that a discharge measurement is unnecessary. All data will be shared with the USFWS at least annually in the report described for RPM 2016-1. Parameters currently missing from gage stations or additional parameters required (if any) are indicated next to the gage name:

a. Chattahoochee River
    i. MI 46 near Columbia (USGS 02343805) - water temperature, dissolved oxygen
b. Tributaries to Lake Seminole
    i. Spring Creek near Reynoldsville (USGS 02357150) - dissolved oxygen
    ii. Flint River at Bainbridge (USGS 02356000) - dissolved oxygen
c. Apalachicola River
    i. Apalachicola River at Chattahoochee (USGS 02358000) - water temperature, dissolved oxygen
    ii. Apalachicola River at Sumatra (USGS 02359170) - water temperature, dissolved oxygen, salinity (and possibly chlorophyll a and turbidity as assessed by the adaptive management technical team)

b) **Establish New Gage Stations.** Additional gages (Figure 13.1 and section 14) may be established if the scientific information obtained from monitoring leads the adaptive management technical team to determine additional gages downstream are necessary to capture the effect of the action on food production or foraging access for Gulf sturgeon.

13.4.3 Species Monitoring (RPM 2016-3)

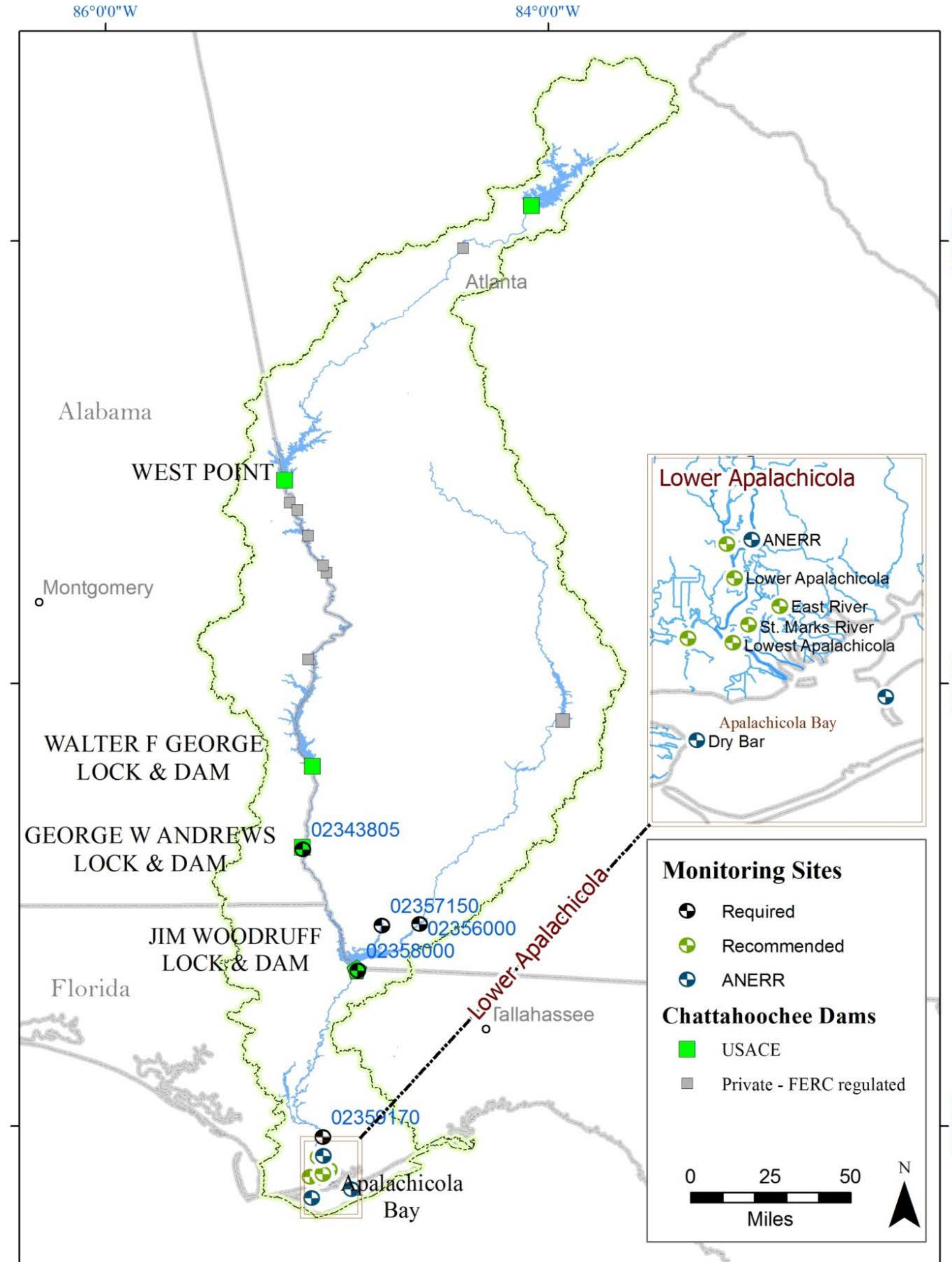
In consultation with the USFWS, the USACE shall plan and implement the following monitoring efforts relative to the endangered and threatened species, their habitats, designated critical habitat that will develop information necessary to understand the impact of incidental take and to ensure that the anticipated levels of incidental take are not exceeded.

a) **Monitoring and Reporting Take**

a. USACE will, in coordination with USFWS and the adaptive management technical team, develop and implement monitoring programs to establish baselines and track changes in abundance, density, and frequency of occurrence of fat threeridge, Chipola slabshell and purple bankclimber within the aquatic habitats downstream of Woodruff Dam. This species monitoring is additional to and complements the water quality monitoring as part of RPM 2016-2. Reports and data will be provided to the USFWS at least annually and will be shared with the adaptive management technical team as needed. These monitoring plans will be completed and implemented by March 14, 2017 or within 60 days of the Record of Decision being signed, whichever comes later.
    i. Take of mussels due to exposure from declining minimum releases shall be monitored in accordance with the monitoring plan developed by USACE and approved by USFWS to ensure that the anticipated level of take (section 13.1) is not exceeded.
    ii. Take of mussels due to a reduction in floodplain inundation during the host fish spawning/rearing season shall be monitored in accordance with the monitoring plan developed by USACE and approved by USFWS to ensure the anticipated level of take (section 13.1) is not exceeded. Possible monitoring parameters include, but are not limited to, host fish availability and glochidial infection rates.

b. In coordination and collaboration with USFWS and the adaptive management technical team, USACE will develop and implement a plan to create opportunities within existing operations to monitor the outcome of actions to minimize potential effects of hydropeaking at Jim Woodruff Dam and reduction in floodplain inundation on Gulf sturgeon. This species monitoring is additional to and complements the water quality monitoring as part of RPM 2016-2. USACE will submit a draft plan for USFWS review and approval by January 1, 2017 or 60 days before the first Gulf sturgeon spawning season after the Record of Decision is signed, whichever comes later. Reports and data will be provided to the USFWS at least annually. Monitoring objectives and design will be linked to assessment of take and to assessment of the success of the adaptive management actions (i.e., targeted monitoring for adaptive management).
    i. Based on 13.4.1 c), possible monitoring parameters for floodplain inundation include, but are not limited to, young of year and juvenile Gulf sturgeon survival and growth.
    ii. Possible monitoring parameters for hydropeaking include, but are not limited to, available spawning habitat, spawning behavior, egg viability, larval survival and growth.

b) **Adapt Monitoring:** Coordinate monitoring results with the adaptive management technical team and, if needed, adapt the monitoring according to the adaptive management technical team recommendations and the formal adaptive management framework developed for RPM 2016-1.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JIM WOODRUFF LOCK & DAM
Florida
Lower Apalachicola
Tallahassee
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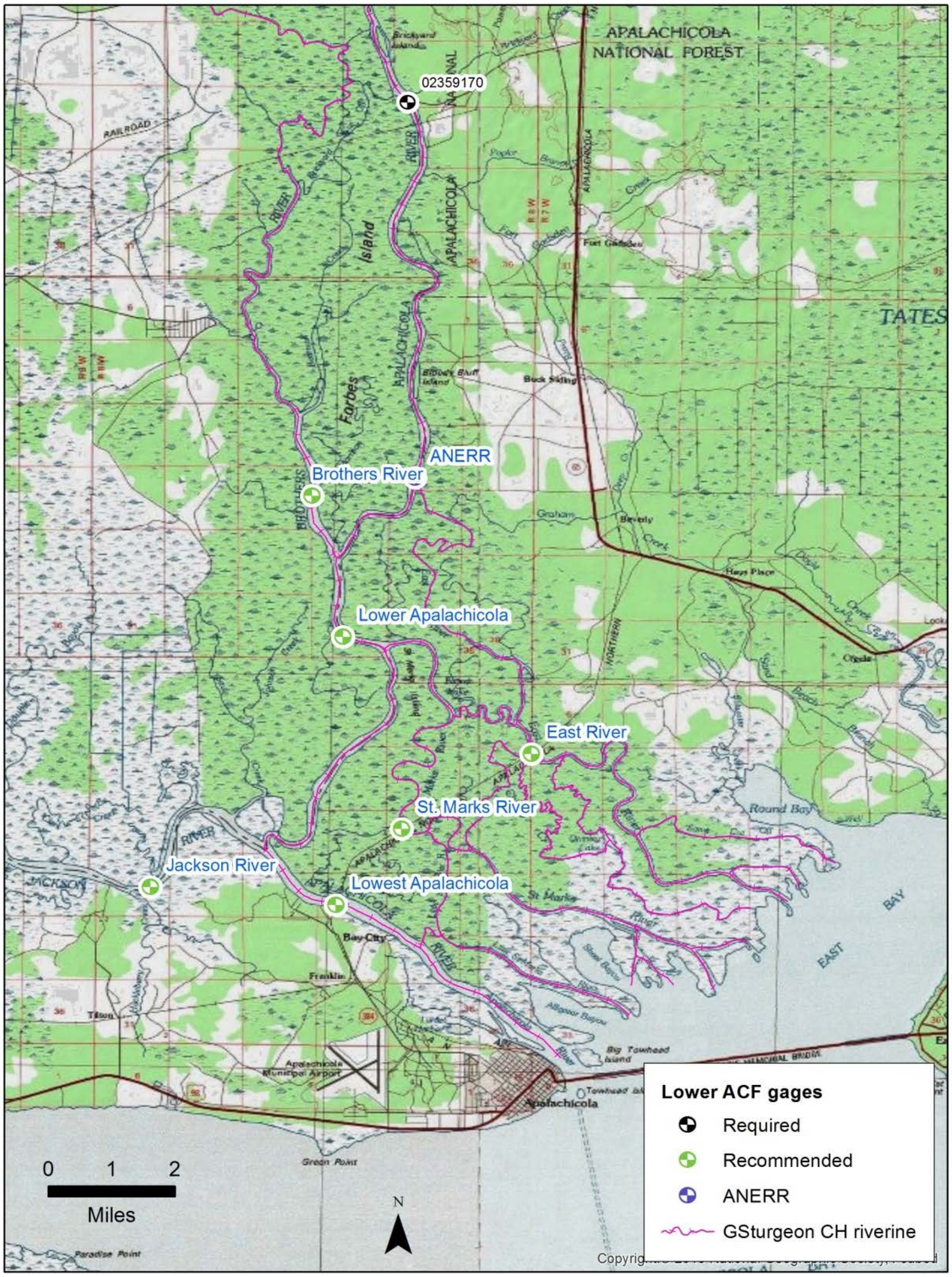


B

Figure 13.1 Apalachicola - Chattahoochee - Flint River Basin (A) and estuary rivers (B) showing a potential water quantity and water quality monitoring design for RPM 2016-2 and Conservation Recommendation 2 in reference to the five USACE projects included in this consultation and other federally regulated projects in the basin.

14 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 are within an action agency's authority 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 USFWS recommends that the Mobile District of the USACE:

1. Work with the USFWS to formalize a 7a(1) agreement that works towards recovery of listed, candidate, and at risk species in the basin. The species in the ACF are recoverable, but cannot be recovered without key partners. USACE controls water operations in the system and this has implications for the aquatic species. Effort spent on conservation actions now should result in a greater return on conservation investment and allow for more operational flexibility in the future. In addition, an appropriately designed 7a(1) program will promote recovery and facilitate future interagency 7a(2) interactions.
2. In collaboration with the USFWS, implement Gulf sturgeon monitoring with emphasis on WCM operations whose effect to Gulf sturgeon is highly uncertain. Monitoring includes but is not limited to the following:
    a. An evaluation of WCM effects to stream temperature during the spawning season that could include: 1) varying inflows to Lake Seminole; 2) Jim Woodruff Dam release alternatives; or 3) changes to the local environment that could reduce stream temperatures during the spawning season.
    b. Support of USFWS research on young-of-year telemetry and habitat use.
    c. Young-of-year and juvenile invertebrate forage studies and/or models that: 1) describe the taxonomy of food items consumed by both life stages; 2) evaluate the availability of food items; and 3) relate food resource availability to condition of each respective life stage.
    d. Quantitatively assess invertebrate production in the floodplain resulting from high magnitude peak flow events.
    e. Estuarine salinity models that spatially assesses the effects of Apalachicola River inflows on estuary salinity with a focus on East Bay.
    f. An evaluation of spawning substrate enhancement at known spawning location(s).
    g. Water quality monitoring at (Figure 13.1):
        i. Chattahoochee River
            1. Buford Dam (USGS 02334430) - dissolved oxygen
            2. Atlanta (USGS 02336000) - dissolved oxygen
            3. GA 280 near Atlanta (USGS 02336490) - water temperature, dissolved oxygen
            4. Fairburn (USGS 02337170)

        5. West Point (USGS 02339500) - water temperature, dissolved oxygen
        6. Ft Gaines (USGS 0234332415)
    ii. Apalachicola River
        1. Apalachicola River at Blountstown (USGS 02358700) - water temperature, dissolved oxygen
        2. Wewahitchka (USGS 02358754) - water temperature, dissolved oxygen
    iii. Chipola River
        1. Marianna (USGS 02358789) - water temperature, dissolved oxygen
        2. Altha (USGS 02359000) - water temperature, dissolved oxygen
    iv. Jackson River / Gulf Intracoastal Waterway (new gage vicinity of StM 345)
    v. Lower Apalachicola River and its distributary rivers (new gages)
        1. Lower Apalachicola River (vicinity of RM 4.5, USGS tidal gage 02359230)
        2. Lower Apalachicola River (vicinity of RM 11.0, -84.031, 29.827)
        3. St. Marks River (vicinity of old trestle, -85.017, 29.783)
        4. East River (vicinity of old trestle, -84.988, 29.80)

3. In collaboration with the USFWS, continue to develop and assess potential adjustments to water management decisions under the WCM in response to increased knowledge of listed species effects and develop additional conservation measures and management options for the ACF Basin to promote recovery of listed species. In particular, the USFWS has already identified potential management adjustments in an operating alternative portrayed in Appendix D; this operational alternative represents another option to manage the basin in consideration of fish and wildlife resources.
4. In collaboration with the USFWS, improve measures of success in reaching explicit objectives for both fish and wildlife resources and other project purposes prior to the next update of the WCM.
5. Develop a report using the best available science that describes how predicted changes in climate could affect WCM operations. The USFWS suggests that the report be updated once every five years.
6. Implement Gulf sturgeon and freshwater mussel recovery actions, including but not limited to, developing habitat suitability indices, conducting life history and population studies, restoring reaches to provide suitable habitat, and assessing sediment quality. From mussel recovery plan (USFWS 2003):
    a. Secure extant subpopulations and currently occupied habitats and ensure subpopulation viability.
    b. Search for additional subpopulations of the species and suitable habitat.
    c. Determine through research and propagation technology the feasibility of augmenting extant subpopulations and reintroducing or reestablishing the species into historical habitat.
    d. Develop and implement a program to evaluate efforts and monitor subpopulation levels and habitat conditions of existing subpopulations, as well as newly discovered, reintroduced, or expanding subpopulations.
    e. Develop and utilize a public outreach and environmental education program.
    f. Assess the overall success of the recovery program and recommend actions.

From Gulf sturgeon recovery plan (USFWS 1995)

a. Determine essential ecosystems, identify essential habitats, assess population status, and refine life history investigations in management unit rivers.
b. Identify essential habitats important to each life stage in river basin and contiguous estuarine and neritic waters.
c. Conduct and refine field investigations to locate important spawning, feeding, and developmental habitats.
d. Characterize riverine, estuarine, and neritic areas that provide essential habitat.
e. Conduct life history studies on the biological and ecological requirements of little known or inadequately sampled life stages.
f. Assess the relationship between groundwater pumping and reduction of groundwater flows into management units, and quantify loss of riverine habitat related to reduced groundwater in-flows.
g. Restore, enhance, and provide access to essential habitats: Identify dam and lock sites that offer the greatest feasibility for successful restoration of and to essential habitats (i.e., up-river spawning areas). Evaluate, design, and provide means for Gulf sturgeon to bypass migration restrictions within essential habitats. Operate and/or modify dams to restore the benefits of historical flow patterns and processes of sedimentation. Identify potential modifications to specific navigation projects to minimize impacts which alter riverine habitats or modify thermal or substrate characteristics of those habitats.
h. Restore the benefits of natural riverine habitats.
i. Seek optimum consistency between the purposes of federal and state authorized reservoirs, flood control projects, navigation projects, hydropower projects, and federal and state mandated restorations of fish populations.

7. 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.
8. Identify and implement water conservation measures in the basin to avoid impacts to fish and wildlife resources by working with municipal, agricultural, and industrial water users to reduce consumptive uses to develop additional drought response strategies.
9. Assist stakeholders to plan future water management to minimize water consumption thus minimizing detrimental effects to species.
10. 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 USFWS to be kept informed of actions minimizing or avoiding adverse effects or benefiting listed species or their habitats, the USFWS requests notification of the implementation of any conservation recommendations in the annual report required in section 9.

15 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.

16 FISH AND WILDLIFE COORDINATION ACT PLANNING ASSISTANCE

In accordance with the planning aid provisions of the FWCA, the USFWS has been coordinating with you and the States on the development of updated WCM for the ACF River Basin. The USFWS's fish and wildlife concerns, planning objectives, recommendations and requested analyses have been previously described in detail to the USACE in our August 29, 2013 PAL. We also submitted a final FWCA report on September 9, 2016. Our recommendations in this letter and report still apply, and we encourage the USACE to follow the recommendations and conservation measures included in these documents. We encourage the USACE to work closely with USFWS to develop alternatives that are protective of fish and wildlife resources in the ACF Basin, and we stand by ready to assist.

17 APPENDIX A. EFFECTS OF THE ACTION - PHYSICAL ENVIRONMENT

17.1 Factors Considered

The WCM 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 WCM. 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. In the Environmental Baseline – Physical Environment section, we outlined two principal components of the species' environment in the action area: channel morphology and 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 (USFWS 2012). USACE will continue to evaluate this rate of change as discussed in the Environmental Baseline – Physical Conditions section. We have no ability at this time to predict specific effects on channel morphology that may result from the influence of the WCM. We considered water quality parameters but do not have enough information to determine whether WCM 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.

17.2 Analyses for Effects of the Action

To determine the future effect of continued project operations as prescribed by the WCM, we must compare the environmental conditions expected under the WCM 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. In the 2008 and 2012 BOs environmental baseline (a.k.a. baseline) was defined as the observed flows of the river since the full complement of the USACE's reservoirs were completed and for which an unimpaired data set was available, so that the proposed action could be modeled (calendar years 1975 to 2012). In this BO, an alternative strategy is being employed as discussed in the Environmental Baseline section. Under this approach, the modeled effects of the WCM are compared to the modeled effects of the USACE's no action alternative (NAA) for 1939-2012. The NAA (and baseline for this consultation) is the RIOP management implemented from 2012-present.

In analyzing the effects of the proposed action, the fact that the storage capacity of the ACF basin reservoirs is small relative to flow in the Apalachicola River was taken into account. The ACF basin has about 1,640,000 acre-feet of conservation storage at full summer pool (USACE, 2015 p2-24). The majority of the basin's storage capacity (65%) is at Lake Lanier which only impounds 6% of the basin. Lake Lanier is therefore managed conservatively because in being a headwater reservoir it is difficult to refill and because the reservoir plays an integral role in supplying water to Metro Atlanta. Consequently, since the completion of Lake Lanier in 1955, the minimum elevation ever experienced at the reservoir is about 1050.79 msl in December 2007 (USACE 2016), which is about 15 feet above the bottom of the conservation pool.

To account for this limitation of the reservoir system in the ACF basin to either store or release water, when analyzing the effects of the proposed action the USFWS focuses on lower portion of the flow regime. Analysis of modeling results suggests that under operations called for in both the WCM and baseline, the reservoir system has the greatest capacity to effect on discharge in the Apalachicola River in the flow range below 30,000 cfs discharge from Jim Woodruff Dam and the capacity of the reservoir system to influence flow declines as flows approach 30,000 cfs. Because of the importance of floodplain inundation to the aquatic ecosystem and the fact that at flows above 15,000 cfs the area of inundation increases more rapidly, the analysis of effects will focus on the flow range of 15,000 to 30,000 cfs.

17.2.1 Model Descriptions

The USACE used “HEC-ResSim Version 3.2, Build 3.2.1.19” (USACE, 2013) to simulate flow operations in the ACF Basin. HEC-ResSim is a tool for simulating flow operations in managed systems developed by the USACE's 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. HEC-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 a rule-based description of the operational goals and constraints that reservoir operators must consider when making release decisions. HEC-ResSim for the ACF is described in detail by USACE (2014, 2015 Appendix E).

For purposes of this BO, the USFWS choose to use an additional river-reach model to simulate the flow operations in the ACF basin, the ACF STELLA model. The ACF-STELLA model was an existing model first developed during the ACF Comprehensive Study and was used for this analysis because: 1) the ACF-STELLA model has been shown to calibrate well with previous versions of the HEC ResSim model (Leitman and Kiker 2015), 2) the ACF-STELLA model has a much shorter run-time than the HEC ResSim model (< 5 minutes versus ~25 minutes) (Leitman and Kiker 2015), and 3) the modeling demand of this analysis, including the climate change analyses found later in the BO required over three hundred model runs. The USFWS previously used a version of this model to develop an alternative which was submitted to the USACE as an alternative to be considered in developing the Water Control Manual (USFWS 2013).

Other system-wide water models of the ACF have been developed to explore management alternatives for different agencies, municipalities and stakeholders (Sheer et al. 2013, Sauchyn et al. 2016, USACE-HEC 2016, Kistenmacher and Georgakakos 2011, Kistenmacher and Georgakakos 2015). The ACF-STELLA was first developed in the ACF Basin Comprehensive Study as part of a shared-vision stakeholder process (Palmer 1998). The ACF-STELLA model used for the BO was tested by comparing predictions with the HEC-ResSim model used by the USACE to formally evaluate ACF basin management alternatives. The two models were compared using 70 years of daily output (1939–2008; n = 25,668) for eight different ACF gage sites (five flow stations and three reservoir elevations) using the 2012 RIOP management inputs (Leitman and Kiker 2015). The comparison between the two models showed a strong match ($p<0.01$ rejection significance) between the daily outputs for six of the eight sites, with median Nash–Sutcliffe coefficient of efficiencies (Ritter and Carpena 2013) ranging from 0.732 to 0.979 (Note: a Nash-Sutcliffe value > 0.65 indicates acceptable, > 0.8 good and > 0.9 very good). The one gage site matched 7 day moving average flows with a Nash-Sutcliffe coefficient of efficiency of 0.788 ($p<0.01$ rejection significance) and the one reservoir elevation (W.F. George) matched with a Nash-Sutcliffe coefficient of 0.833 ($p<0.01$ rejection significance) when anomalous maximum elevations were filtered from the HEC-ResSim output (Leitman and Kiker 2015). In the model simulations which were done for the Water Control Manual, the anomalous elevations at WF George were removed from the HEC-ResSim analysis.

To provide a potential range of flows that might be experienced while the proposed action scenarios are in effect, the ACF-STELLA 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 current, official unimpaired flow data set represents the years 1939 to 2011. Unimpaired flow computations require actual water use data from the three States. USACE provided provisional UIF for 2012, but with the acknowledgment that 2011 is the most recent year of this data provided to the USACE from all three of the States. Georgia has supplied water use data for 2012, but Florida and Alabama do not have complete water use data (James Hathorn, USACE, personal communication, 6/21/16). This situation created a dilemma for the USFWS in preparing the BO since 2012 was the most severe drought in the period-of-record for the ACF basin and therefore would provide the most severe test of the WCM in regard to both impacts upon designated species and reservoir storage, yet the unimpaired flow 2012 was not completed. Since the major driver of the 2012 drought having such low flows in the Apalachicola River was the extreme low flows in the Flint basin whose withdrawals are completely within Georgia, and that the consumptive demands in Alabama and Florida are quite small relative to the flow in the Apalachicola River (Leitman et al. 2016), a decision was made to include the partially complete 2012 unimpaired flow data in the analyses done with the ACF-STELLA and ResSim models for the BO.

As described above, the consumptive demands used in the models are summarized in Table 17.1. A 74-year unimpaired flow hydrologic period of record (1939 through 2012) was used to run the simulations. The data in these tables was taken from the USACE's HEC-ResSim database and it the identical data used in the ResSim modeling and represents both net municipal and industrial demands and agricultural demands effects on streamflow. The baseline data represents current demands and the WCM represents forecasted future demands for Metro Atlanta and current demands for the balance of the basin. The average annual demands for the ACF basin under the baseline is 958 mgd and for the WCM 1,102 mgd.

Table 17.1 Consumptive demands used in the ACF-STELLA model for the WCM (A) and baseline (B).

A

	BUFORD	ATLANTA	WHITESBURG	WEST POINT	COLUMBUS	WF GEORGE	ANDREWS	MONTEZUMA	ALBANY	NEWTON	BAINBRIDGE	WOODRUFF	BLOUNTSTOWN	SUMATRA
JAN	175.21	401.81	-427.72	68.18	70.31	1.36	-8.69	21.33	68.18	-11.97	1.36	-9.28	1.6	0.01
FEB	186.25	391.76	-377.81	71.69	65.4	8.6	-8.2	14.65	71.69	-13.2	8.6	-0.48	1.6	0.02
MAR	195.77	398.24	-409.99	80.69	65.63	27.56	-5.66	21.82	80.69	5.38	27.56	58.42	1.5	-11.76
APR	234.62	476.33	-369.63	85.52	74.27	68.45	-4.99	31.93	85.52	13.61	68.45	52.61	1.7	-28.17
MAY	256.56	505.77	-354.31	87.43	87.69	223.17	0.84	53.41	87.43	53.33	223.17	191.97	2	-1
JUN	275.75	508.69	-348.94	100.01	98.7	328.4	2.51	63.1	100.01	68.05	328.4	260.22	1.7	0.05
JUL	272.43	541.66	-372.85	100.4	101.93	348.79	4.99	79.59	100.4	65.92	348.79	263.55	1.7	1.55
AUG	236.9	516.66	-360.67	101.69	101.64	372.53	1.48	85.87	101.69	66.76	372.53	255.43	1.8	0.68
SEP	226.97	492.51	-348.1	95.64	89.89	377.57	-1.78	45.55	95.64	70.81	377.57	188.68	1.8	0
OCT	207.03	447.27	-373.5	80.21	89.36	160.36	-4.11	21.14	80.21	40.19	160.36	71.98	1.7	0.18
NOV	199.67	430.81	-366.96	72.32	79.79	121.06	-5.26	23.59	72.32	31.28	121.06	47.76	1.5	3.78
DEC	181.52	404.5	-388.97	75.11	73.14	88.86	-7.33	31.76	75.11	21.18	88.86	29.09	1.5	3.44
ANNUAL AV.	220.72	459.67	-374.95	84.91	83.15	177.23	-3.02	41.15	84.91	34.28	177.23	117.50	1.68	-2.60

B

	BUFORD	ATLANTA	WHITESBURG	WEST POINT	COLUMBUS	WF GEORGE	ANDREWS	MONTEZUMA	ALBANY	NEWTON	BAINBRIDGE	WOODRUFF	BLOUNTSTOWN	SUMATRA
JAN	72.26	215.08	-200.48	68.18	70.31	1.36	-8.69	21.33	68.18	-11.97	1.36	-9.28	1.6	0.01
FEB	77.37	209.71	-177.95	71.69	65.4	8.6	-8.2	14.65	71.69	-13.2	8.6	-0.48	1.6	0.02
MAR	81.19	213.17	-192.28	80.69	65.63	27.56	-5.66	21.82	80.69	5.38	27.56	58.42	1.5	-11.76
APR	98.06	254.97	-174.39	85.52	74.27	68.45	-4.99	31.93	85.52	13.61	68.45	52.61	1.7	-28.17
MAY	107.54	270.73	-168.9	87.43	87.69	223.17	0.84	53.41	87.43	53.33	223.17	191.97	2	-1
JUN	116.28	272.3	-165.45	100.01	98.7	328.4	2.51	63.1	100.01	68.05	328.4	260.22	1.7	0.05
JUL	114.93	289.95	-175.35	100.4	101.93	348.79	4.99	79.59	100.4	65.92	348.79	263.55	1.7	1.55
AUG	99.03	276.55	-170.6	101.69	101.64	372.53	1.48	85.87	101.69	66.76	372.53	255.43	1.8	0.68
SEP	95.26	263.63	-164.3	95.64	89.89	377.57	-1.78	45.55	95.64	70.81	377.57	188.68	1.8	0
OCT	85.68	239.42	-173.86	80.21	89.36	160.36	-4.11	21.14	80.21	40.19	160.36	71.98	1.7	0.18
NOV	83.93	230.59	-170.56	72.32	79.79	121.06	-5.26	23.59	72.32	31.28	121.06	47.76	1.5	3.78
DEC	75.63	216.52	-180.03	75.11	73.14	88.86	-7.33	31.76	75.11	21.18	88.86	29.09	1.5	3.44
ANNUAL AV.	92.26	246.05	-176.18	84.91	83.15	177.23	-3.02	41.15	84.91	34.28	177.23	117.50	1.68	-2.60

The fall rates used in the ResSim model for the BO and the 2016 BA followed the maximum fall rate schedule. However, the USACE believes that when flows are less than 10,000 cfs, the observed fall rates are more conservative than those reflected in the BA 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. During the 2012 BO, the ResSim model was modified to reflect the actual down ramping operation which is more conservative than the maximum fall rate schedule. The ACF-STELLA model simulated the baseline (NAA) and WCM (PAA) using a standard 0.13 ft/day fall rate (see section 1), which is the average fall rate in this range of flows since the USACE implemented the maximum fall rate schedule in September 2006. This is consistent with previous simulations for the 2012 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.

In sections 5 and 10 of this BO, we draw inference from both ACF STELLA model and the HEC-ResSim ACF model. The remainder of section 17.2 draws inference from the STELLA model only. Similar analyses are presented using the HEC-ResSim model in the DEIS (USACE 2015). We further compare the two models in section 17.3.

17.2.2 General Effects on the Flow Regime

The USACE alters the flow regime of the Apalachicola River by storing and releasing water from its reservoirs. Figure 17.1 shows a frequency-duration curve for the WCM (PAA) and baseline (NAA) for Jim Woodruff outflow for 1939 – 2012 modeled in ACF-STELLA. In comparing these two model runs it should be noted that in the baseline current levels of demands are used in the model run whereas in the WCM future demands are used. This figure shows that under the WCM operations, when the entire spectrum of flow is considered there appears to be minimal differences between the two operation approaches. Figure 17.1B shows that if the range of flows is reduced to the range that can be affected by reservoir operations in the ACF basin (roughly 30,000 cfs) that differences between the two operational approaches are apparent at flows in the 16,000 to 20,000 cfs range.

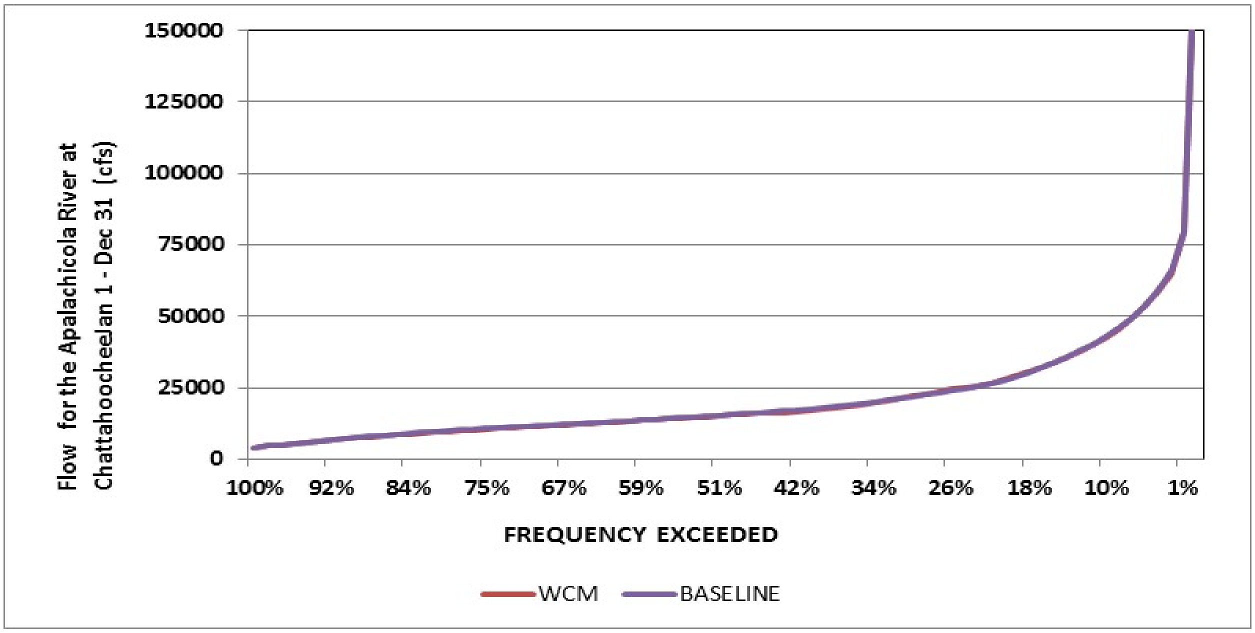


Figure 17.1A. Flow duration curve comparing baseline and WCM.

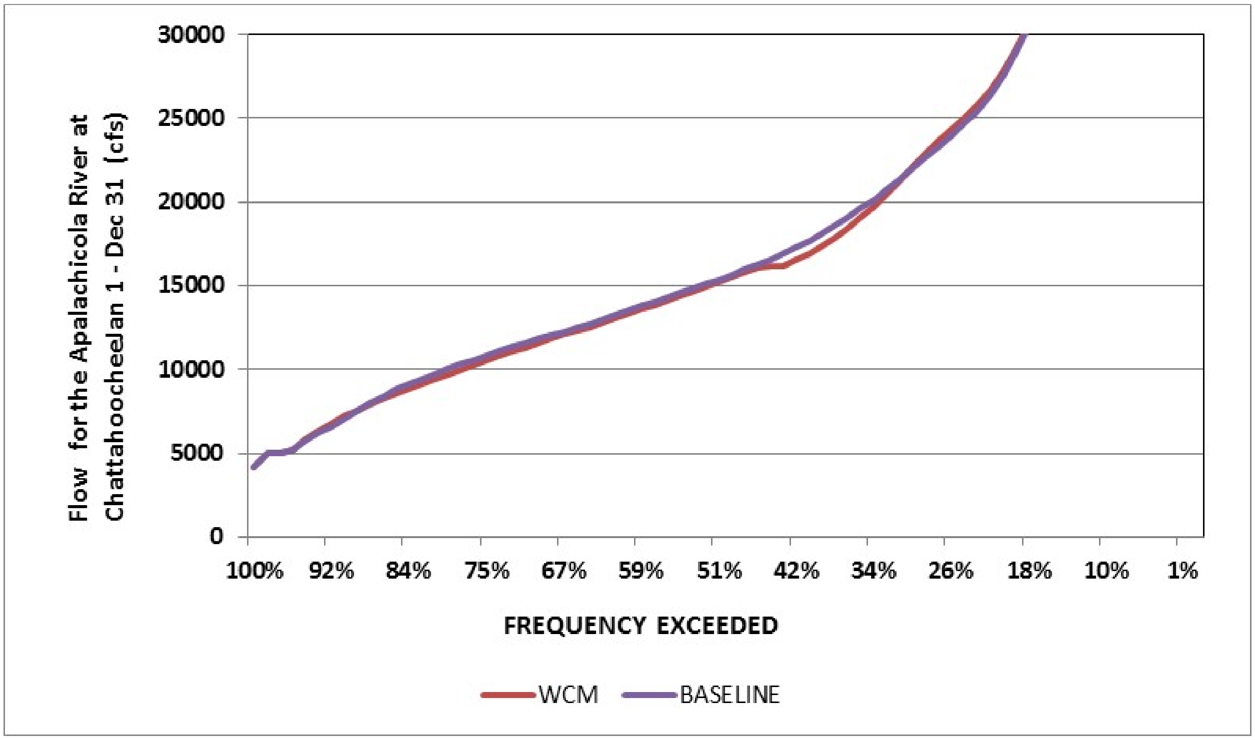


Figure 17.1B. Flow duration curve comparing baseline and WCM when flows are <30,000 cfs.

The composite storage of water in three largest ACF basin (Lanier, West Point, and W.F. George) plays an integral role in defining releases both under the WCM and baseline. The composite storage 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 17.2 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 the baseline and WCM. Figures 17.3A, B, C and D show the median, 75% exceeded, 90% exceeded and 100% exceeded storage volume for each of the year for values for the years 1939 to 2012. These figures show that for the WCM the median volume of water in storage decreases relative to the baseline in the winter and increases in the Spring. For the 75% exceeded volumes the WCM decreases in the winter into the Spring, but stores more water in the Summer. For the 90% exceeded volumes the WCM operations result in less storage in the winter and for the 100% exceeded volumes the WCM generally resulted in less storage throughout the year.

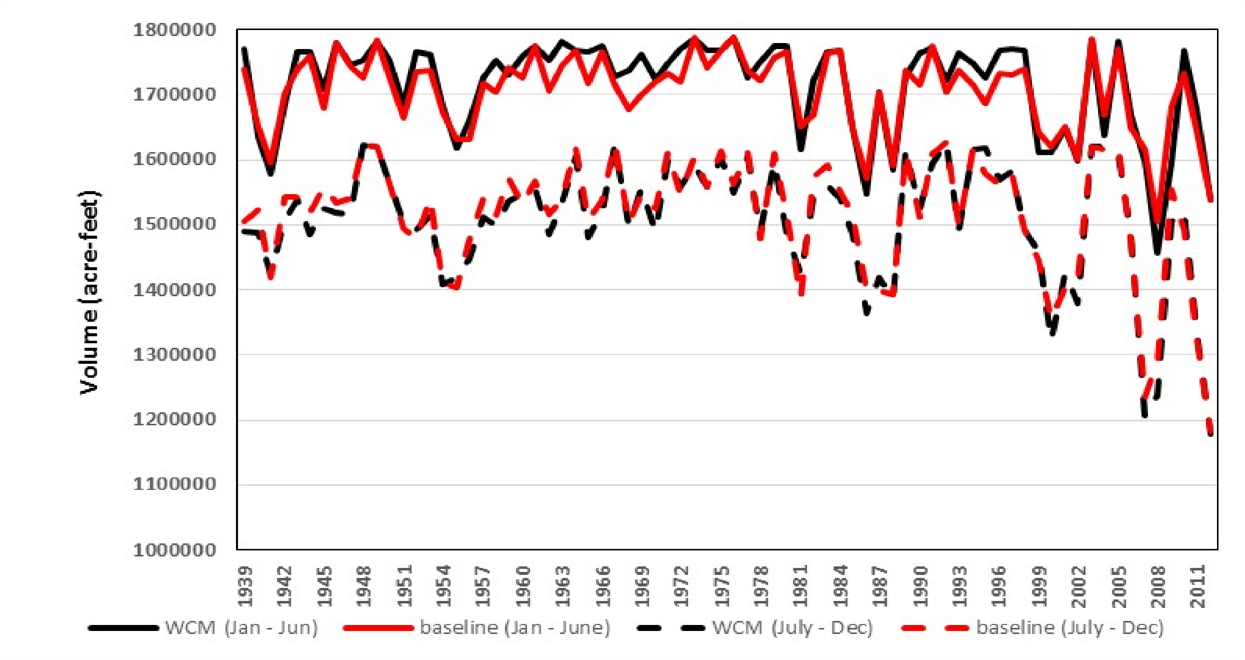


Figure 17.2. Annual range of reservoir composite storage (excluding inactive storage) as measured by the January-to-June maximum storage versus the July-to-December minimum storage level comparing the baseline and WCM.

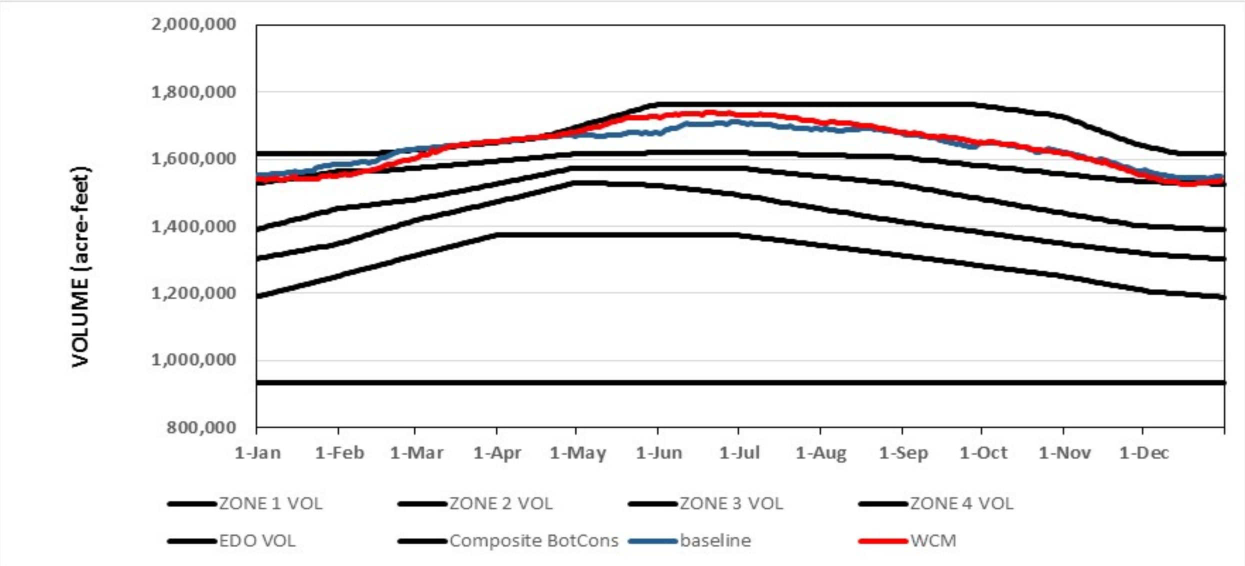


Figure 17.3A. The median conservation storage volume under the baseline and WCM for each of the year for values for the years 1939 to 2012.

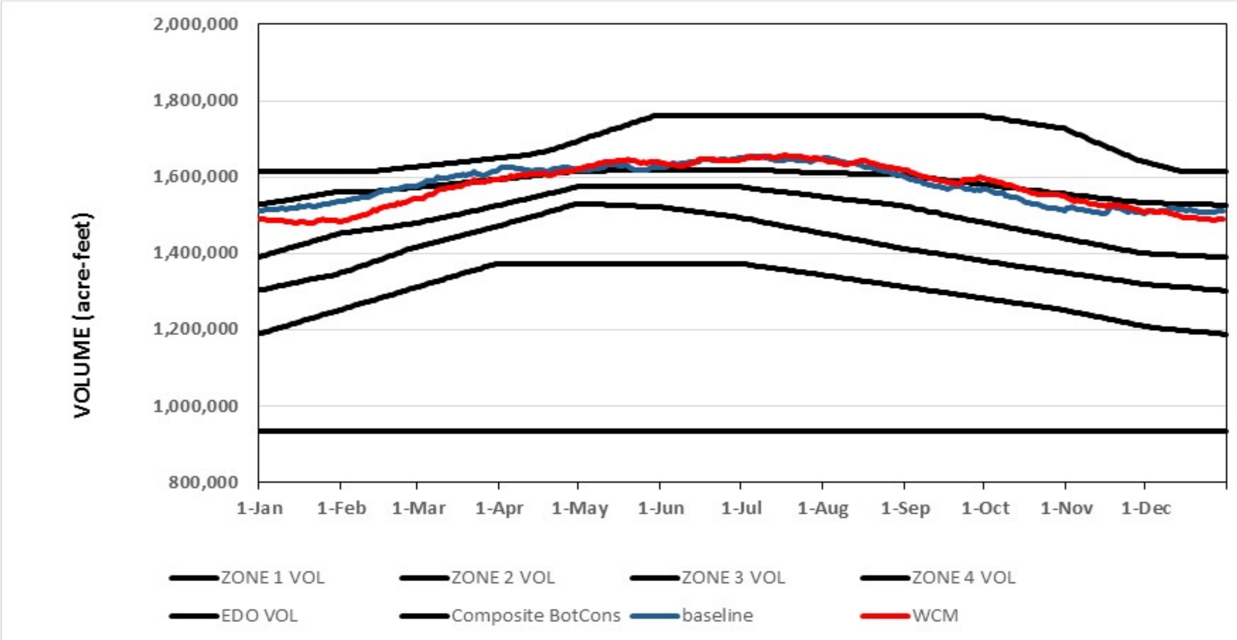


Figure 17.3B. The 75% exceeded conservation volume under the baseline and WCM for each of the year for values for the years 1939 to 2012

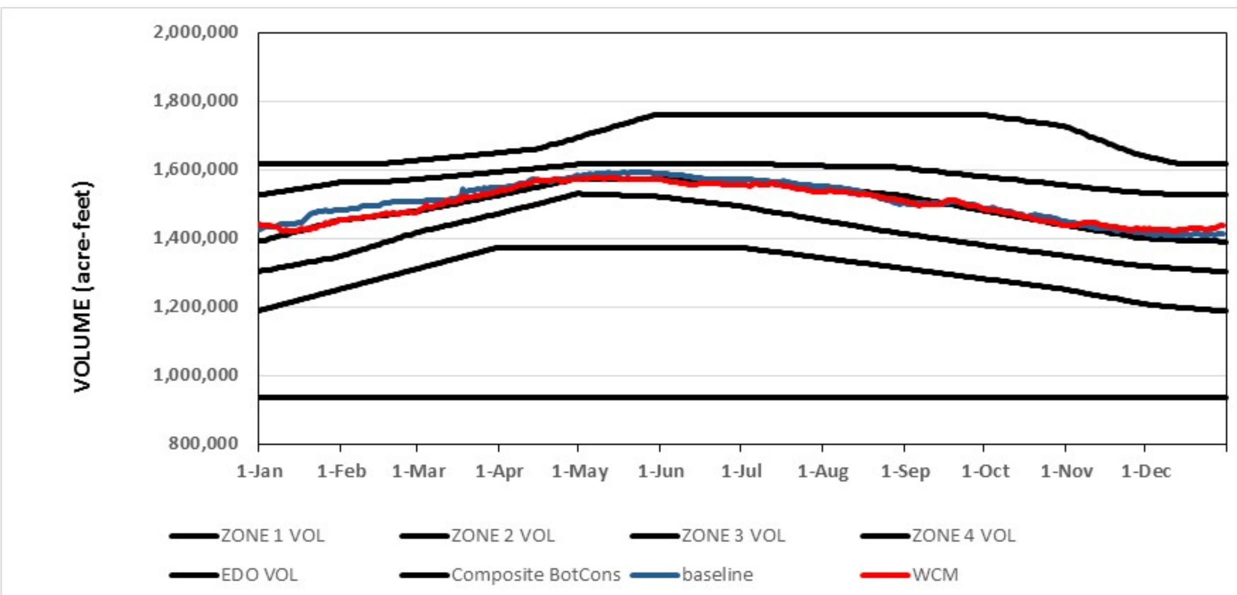


Figure 17.3C. The 90% exceeded conservation volume under the baseline and WCM for each of the year for values for the years 1939 to 2012

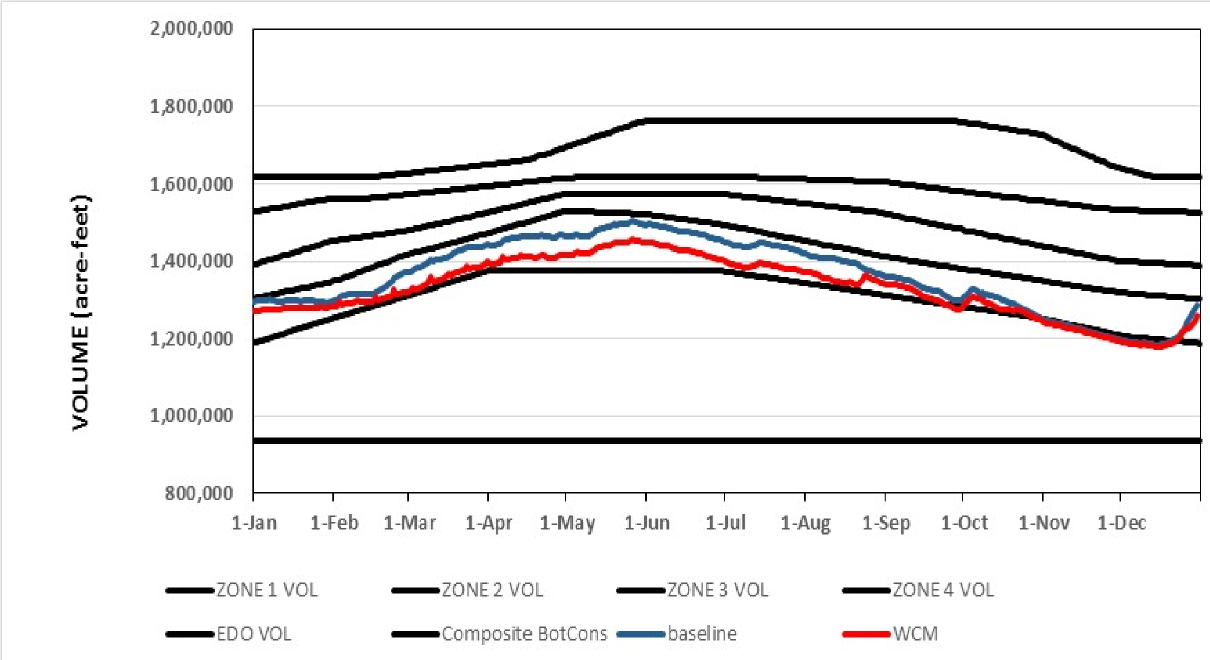
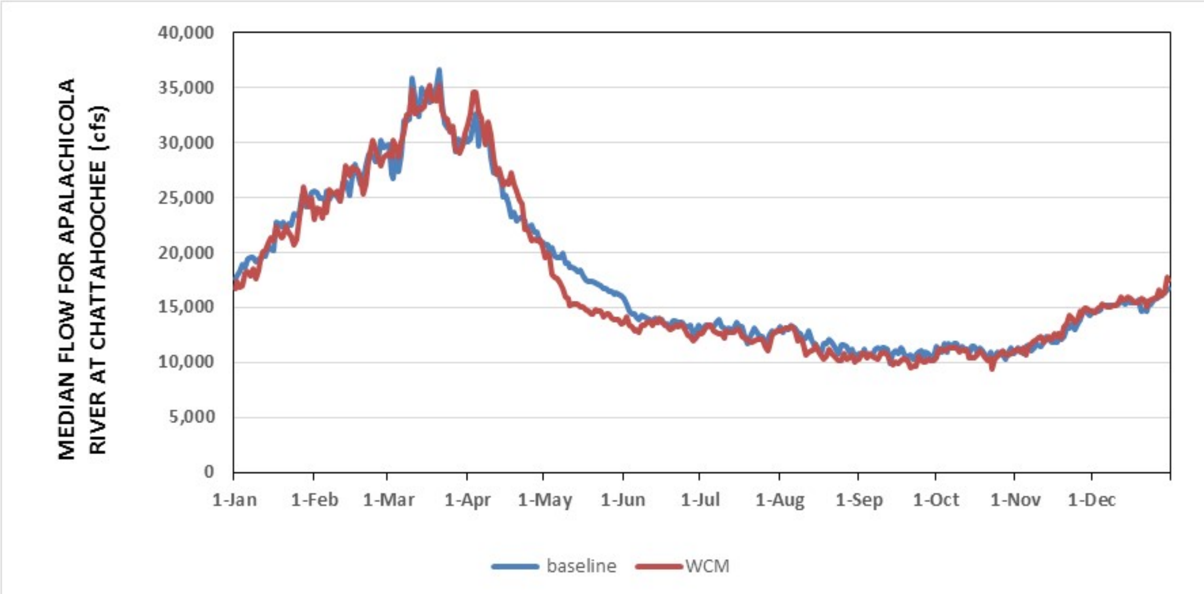
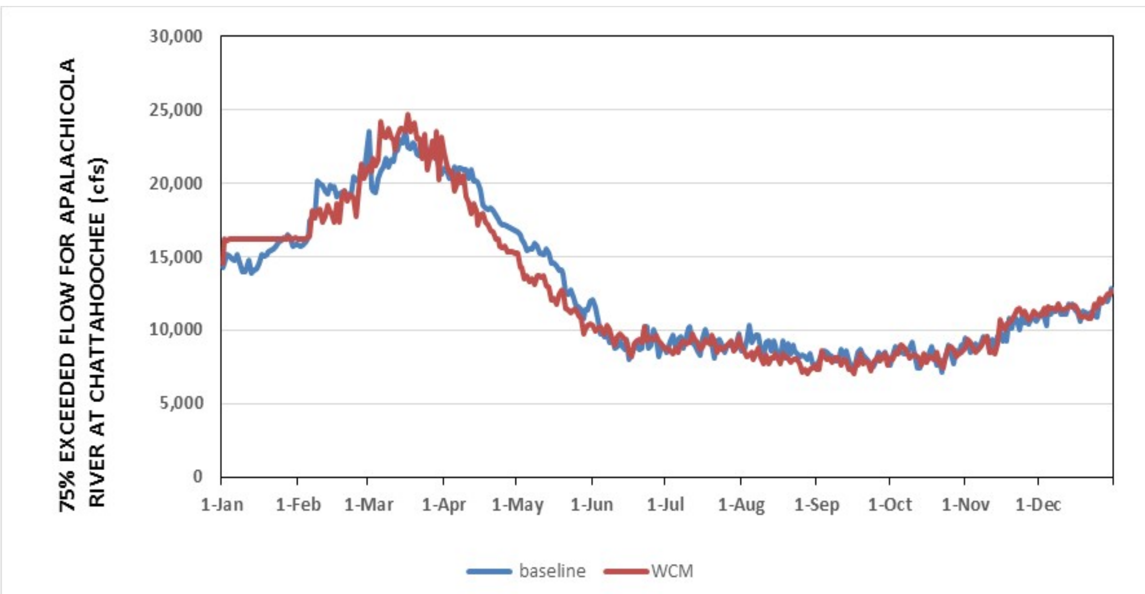


Figure 17.3D. The minimum conservation volume under the baseline and WCM for each of the year for values for the years 1939 to 2012

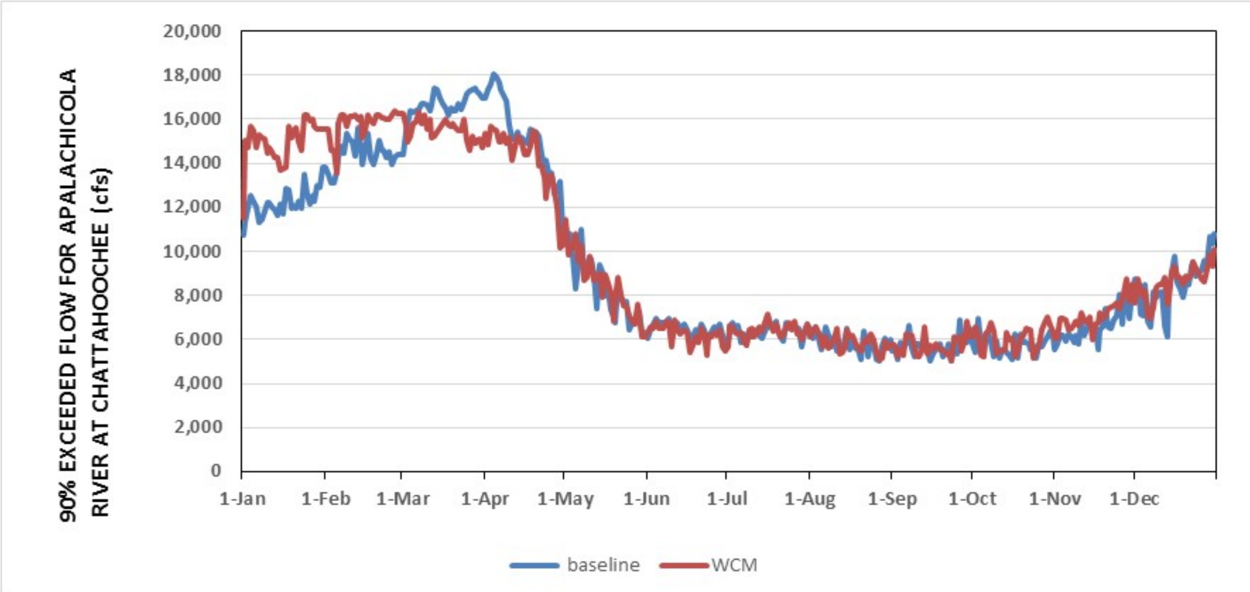
Figures 17.4A-D compare the flow for the Apalachicola River at Chattahoochee (i.e., Jim Woodruff outflow) for WCM and baseline for median, 75% exceeded, 90% exceeded and 100% exceeded values for 1939 - 2012 using the ACF-STELLA model and therefore show the seasonal timing and magnitude frequency of the modeled flow of the Apalachicola River for the baseline and WCM. These figures show for median and 75% exceeded flows the volume of water at this gage was greater in late Spring under the baseline and for the 90% exceeded flows the baseline provided a greater volume of water in late winter-early spring period. Under 100% exceeded flows (minimum flows) there were only minor differences between the baseline and WCM.



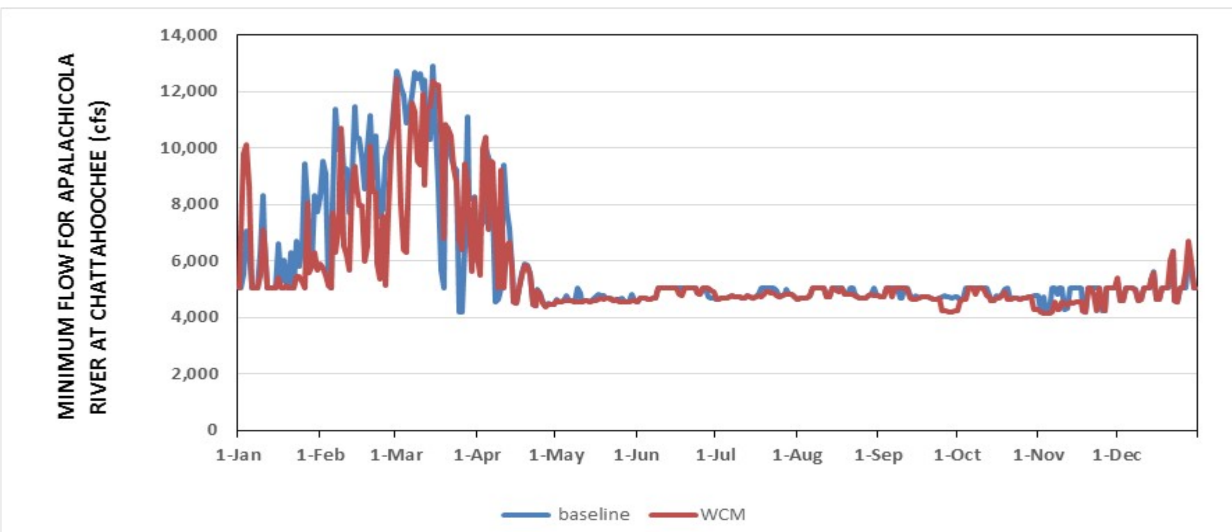
Figures 17.4A. The median exceeded flow in the Apalachicola River under the baseline and WCM for each day of the year for 1939 to 2012



Figures 17.4B. The 75% exceeded flow in the Apalachicola River under the baseline and WCM for each day of the year for 1939 to 2012



Figures 17.4C. The 90% exceeded flow in the Apalachicola River under the baseline and WCM for each day of the year for 1939 to 2012



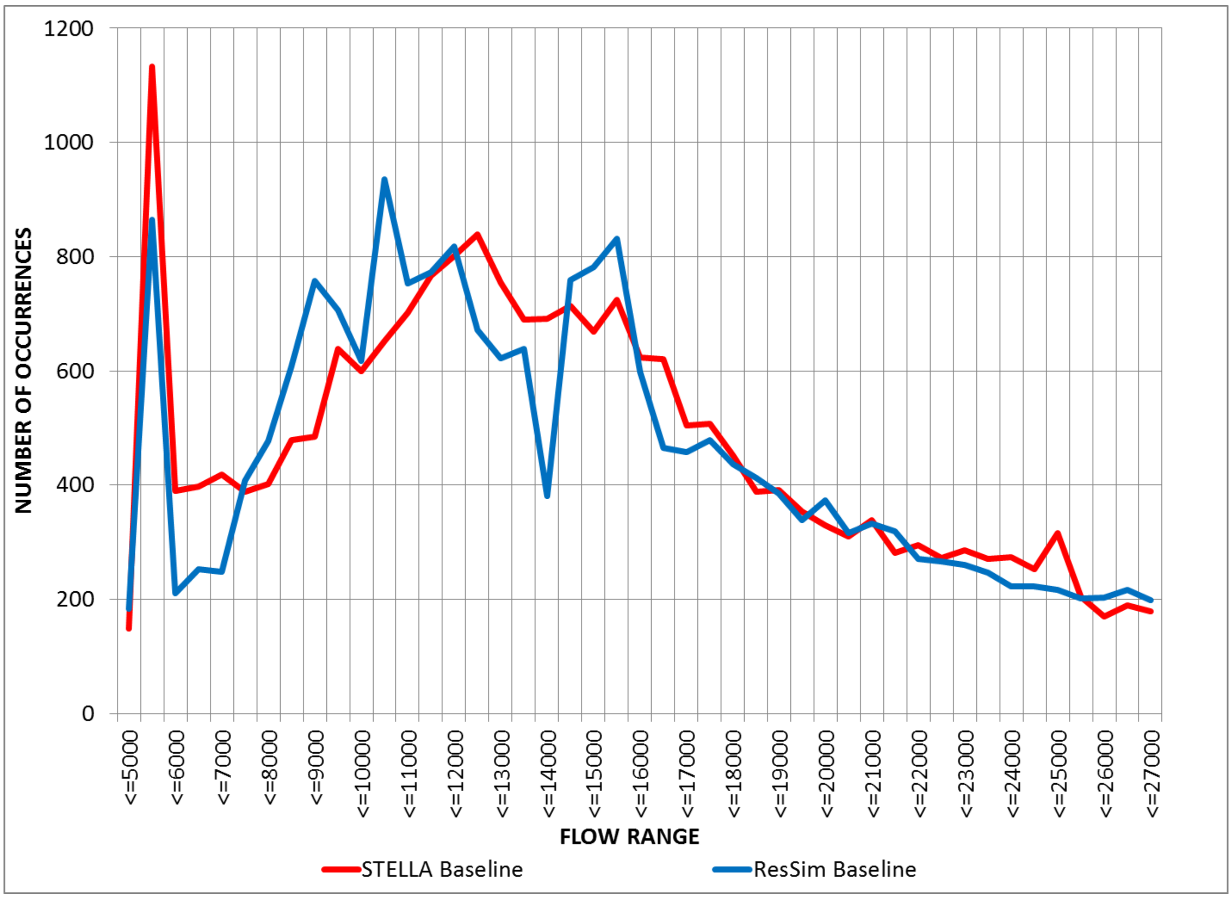
Figures 17.4D. The minimum flow in the Apalachicola River under the baseline and WCM for each day of the year for 1939 to 2012

The WCM model maintains a minimum release from Woodruff Dam of between 4,550 and 5,050 cfs, a flow range which occurs about 3.5% of the time (950 days) in the years 1939-2012 under the WCM and 3.6% of the time under the baseline (966 days). The WCM is intended to support the minimum flow 5,000 cfs until composite storage falls into the “drought zone” of Zone 4, which occurred 86 days under the WCM (25 days in 2007 and 61 days in 2012) and 50 days under the baseline (50 days in 2012).

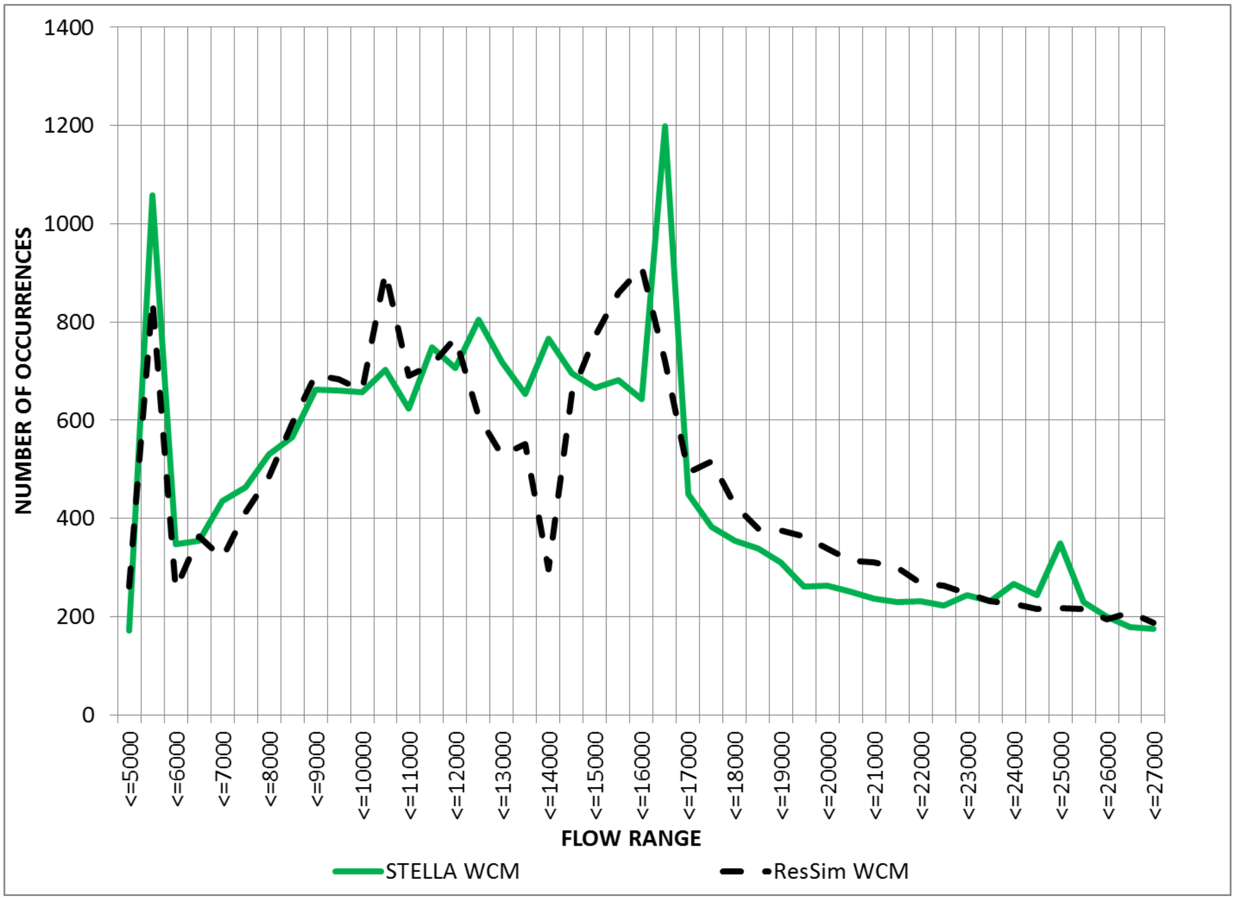
We examine the possible effects of these various changes to the flow regime to the listed species and their habitats in sections 5 and 10.

17.3 Comparison of HEC-ResSim and STELLA modeling approaches

The HEC-ResSim and STELLA models were developed independently to mirror USACE operations within the ACF Basin independently as described above and in the BA (USACE 2016; see also USACE 2015, Appendix E; USACE 2014). Using a simple comparison of counts of occurrence of flows in 500 cfs flow ranges (Figure 17.5), two differences between the models were identified and allowed to remain in the models are described below. 1) The way each model addresses balancing pool and tailwater elevations to ensure maintenance of the head limit of Woodruff Dam differed (i.e., the difference in the peaks between 5,000-6,000 cfs on Figure 17.5A & B). 2) The way each model incorporated the flows to maintain the 7-foot navigation channel differed (i.e., the difference in the peaks at about 10,000 and 16,000 cfs on Figure 17.5B). Here, we provide a summary of those differences.



A



B

Figures 17.5 Predicted frequency of flows in 500 cfs categories under the baseline (A) and WCM (B) from the HEC-ResSim and STELLA models for 1939 to 2012

17.3.1 Head limit

ResSim: The following is an excerpt from USACE 2015 (p. E-1, E-21). "The Jim Woodruff lock and spillway have a maximum head limit due to structural stability. In addition, the Jim Woodruff project complies with a number of very significant and complex environmental requirements, including actions contained in the Revised Interim Operations Plan (RIOP) at Jim Woodruff Dam, Gulf Sturgeon Spawning Operational Consideration, and Fish Spawning Operational Consideration for Lake Seminole and the Apalachicola River. These operational requirements often trigger system operations to use storages on a basin-wide basis.

This rule (see [Figure 17.3.1]) represents the physical operation constraint of the maximum head limit at Jim Woodruff Dam. A head limit curve, which was provided by the Mobile District, defines the minimum tailwater elevation necessary to adequately limit the head difference for a given reservoir pool elevation. A state variable, "Woodruff_MinTailwater", is created to determine the minimum tailwater elevation based on the head limit curve. Using the pool elevation at the previous time step, the state variable script computes the minimum tailwater elevation for the current time step. In the ResSim model, the minimum tailwater elevation is converted to a discharge value based on the tailwater stage-discharge rating curve at the downstream USGS Chattahoochee gage and is used as a minimum release from Jim Woodruff. This head limit rule is placed at the top of each zone indicating the highest rule priority for each zone. The state variable that determines the minimum tailwater is explained in detail Appendix H, page H-34-35."

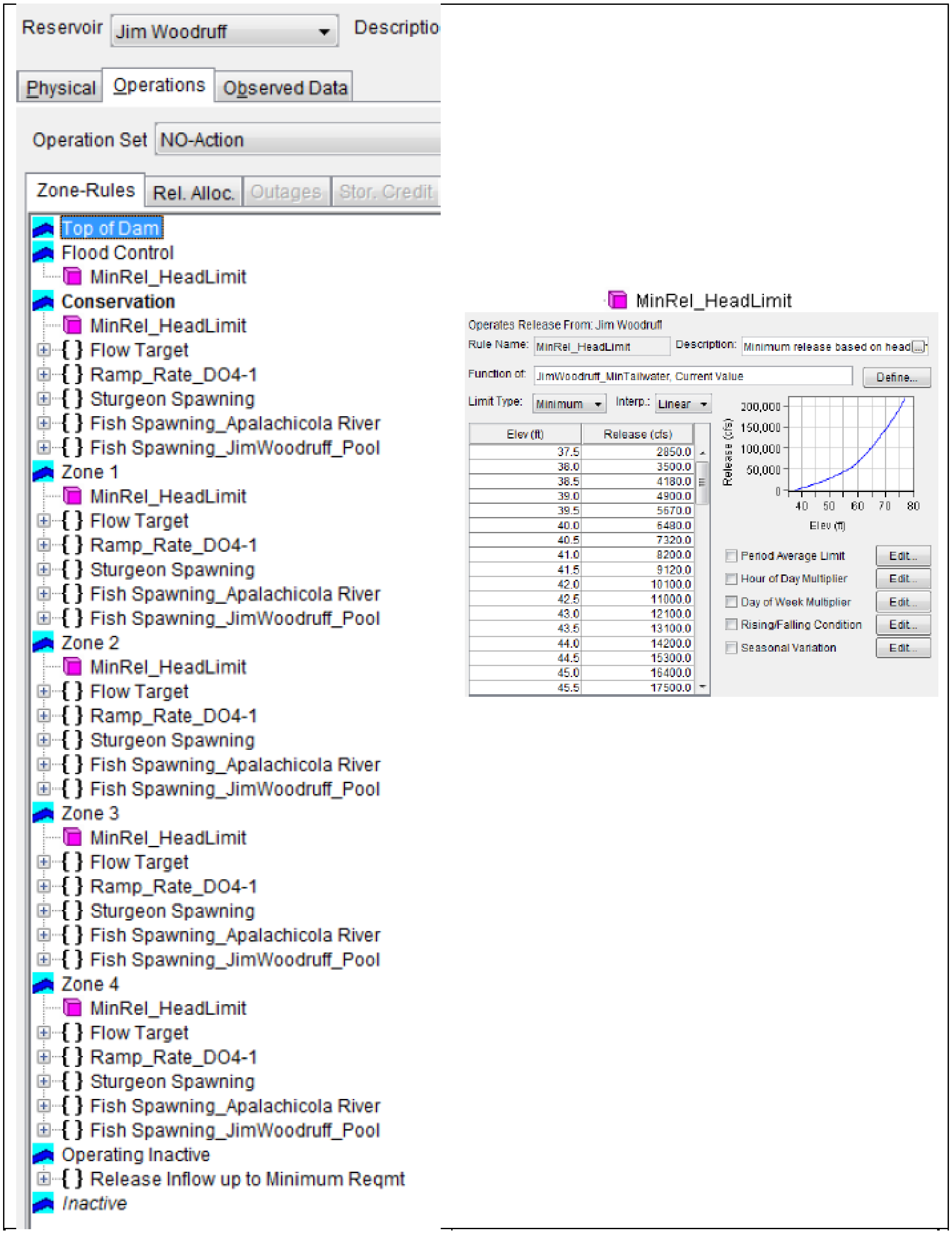


Figure 17.3.1 Reservoir Editor- Network 2014: Operations Tab – NO-Action OpSet – Zones and Rules

STELLA: For dam safety purposes, limitations are placed on the head limit at Jim Woodruff Dam (i.e., the elevation difference between the pool elevation in Lake Seminole and the elevation in the tailwater). In the ACF STELLA model head limitation requirements are implemented by lowering the rule curve or rule elevation in Lake Seminole (i.e., the elevation which marks the top of a reservoir's conservation pool) as releases from Jim Woodruff Dam decrease. The resultant lowering of the rule curve reduces the volume of water in the conservation pool at Lake Seminole which in turn requires greater releases from W.F. George reservoir to allow the required minimum release from Woodruff to be met. The relationship between elevations at Lake Seminole and releases from Jim Woodruff (which would define the elevation of the tailwater) was supplied by the USACE. The STELLA rules are as follows:
JW RULE REQ = IF (LakeSeminole_cfsd>JWRuleVol_cfsd) THEN
MAX((LakeSeminole_cfsd-JWRuleVol_cfsd)/5+JWInActual-NetWithWFGJW,
JW_OUTFLOW_DELAY - JW_RAMPING_LIMIT, 0) ELSE
Max(LakeSeminole_cfsd+(JWInActual)-NetWithWFGJW-JWRuleVol_cfsd,0)
WHERE:
JWRuleVol_cfsd = 6.86186255E2*JWRuleElev^2 -8.65850908E4*JWRuleElev+2.78378753E6
(Volume corresponding to the rule curve in the units of cfs-days)
WHERE:
JWRuleElev = The flow from JW in the previous time step is converted to an elevation based on the following relationship. Units cfs. The resultant elevation becomes the rule elevation for the reservoir.

flow	elevation
5000	76
7600	76.25
10200	76.5
12800	76.75
15400	77
18000	77.25
20600	77.5
23200	77.75
25800	78
28400	78
31000	78

17.3.2 Navigation flows

ResSim: The following is an excerpt from USACE 2014 (p. 57-58). "The provision of reliable navigation has always been a challenging task in the ACF System. A navigation measure considered was the concept of a definite navigation season (January through May). In developing this measure, USACE balanced use of storage for navigation versus the use of storage for other authorized project purposes and considered the effects on other needs and requirements in the system such as hydroelectric power generation and recreation. Assessment of the frequency of channel availability and the number of drought operations triggered by the implementation of navigation showed that navigation options are only feasible when the composite system storage is in Zones 1 or 2. [Figure 1.7] shows the conservation storage in a navigation season. The goal of the navigation operation rules is to maintain a flow rate of 16,200 cfs at the Blountstown gage as much as possible, which represents 7 ft of minimum navigation depth.

Nested conditional statements use existing RIOP state variables as well as one named *NavigationSeason*, which indicates whether the release decision occurs during January-May. If true, and if the system composite storage zone is 1 or 2 and not under drought operations then the minimum release rule *MinRel_Navigation* specifies release. The settings are shown in [Figure 17.3.2] and [Figure 17.3.3]. Description of the state variables can be found in Appendix H."

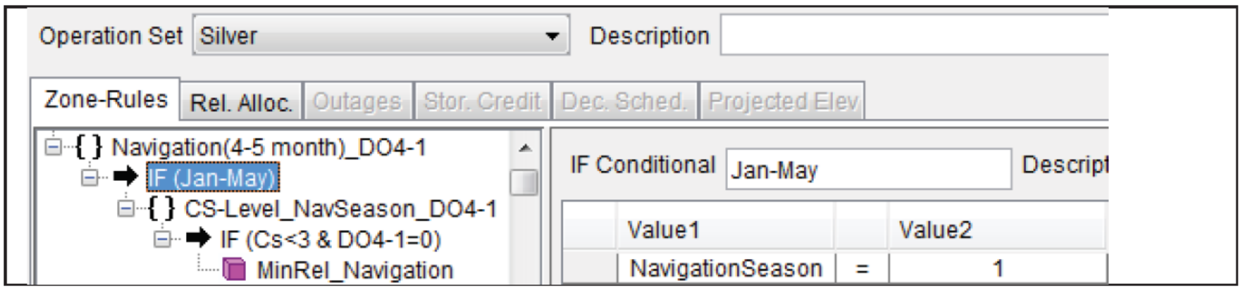


Figure 17.3.2 Conditional Blocks for Navigation (4-5 month)_DO4-1 Rule

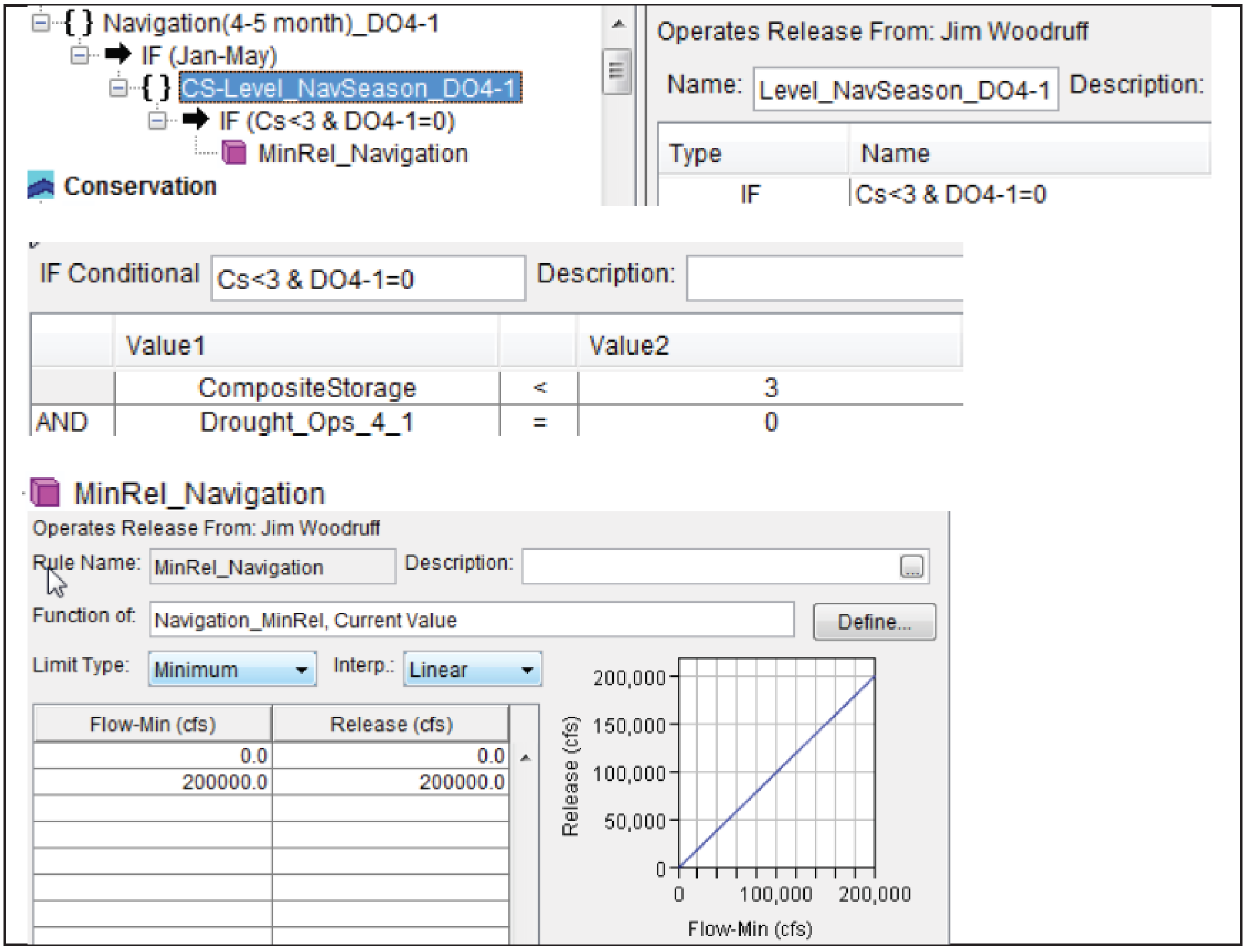


Figure 17.3.3 Release Rules for Navigation(4-5month)_DO4-1 Rule

STELLA: The approach to modeling the navigation release in the ACF-STELLA model is based on providing a 16,200 cfs release from Jim Woodruff Dam to support providing a 7-foot navigation channel in January through May provided that: 1) the composite storage for the ACF basin is either in Zone 1 or 2 and 2) drought relief is not in effect. The STELLA rules are as follows:

JW PAA PRELIM = IF month >=3 AND month <= 5 THEN PAA_MARCH_TO_MAY
ELSE IF month >= 6 AND month <=11 THEN PAA_JUNE_TO_NOV
ELSE PAA_DEC_TO_FEB
WHERE:
PAA_DEC_TO_FEB = IF drought trigger = 1 THEN 5050 ELSE IF MONTH < 3 AND Composite Zone < 3 THEN 16200 ELSE 5050
PAA_MARCH_TO_MAY = IF drought trigger = 1 THEN 5050 ELSE IF Composite_Zone <= 2 THEN
IF JW_Basin_inflow_7_day >= 34000 THEN 25000
ELSE IF JW_Basin_inflow_7_day >= 16000 THEN MIN (16,200, (16000 + 0.5 * (JW_Basin_inflow_7_day - 16000)))
ELSE IF JW_Basin_inflow_7_day >=5050 THEN JW_Basin_inflow_7_day

ELSE IF JW_Basin_inflow_7_day < 5050 THEN 5050
ELSE IF Composite Zone = 3
THEN IF JW_Basin_inflow_7_day >= 39000 THEN 25000
ELSE IF JW_Basin_inflow_7_day >= 11000 THEN 11000 + 0.5 * (JW_Basin_inflow_7_day - 11000)
ELSE MAX (JW_Basin_inflow_7_day, 5050)
ELSE 5050
ELSE 5050

18 APPENDIX B. CLIMATE MODEL PROJECTIONS: IMPLEMENTATION AND MODELING RESULTS

18.1 Climate model projections

The most recent set of climate projections for the globe come from the Coupled Model Intercomparison Project (CMIP5), an international, multi-institutional, coordinated Global Climate Model (GCM) project that developed simulations of the long-term atmospheric response under a set of pre-defined scenarios of evolving greenhouse gas concentrations (representative concentration pathways (RCPs). The GCM output is available at a relatively coarse resolution (on the order of 100km) over the entire globe, and consists of meteorological variables (e.g., temperature and precipitation), typically with a daily time step. The suite of GCM model output provides an estimate of the uncertainty in climate response that stems from incomplete knowledge and numerical representation of atmospheric and oceanic processes that shape the climate response to changes in greenhouse gas concentrations. Simulations are made both for a historical period (e.g., 1950-2000) under prescribed historical greenhouse gas concentrations, and for a future period (e.g., out to 2100) in which the greenhouse gas concentrations are prescribed to evolve according to a pre-defined scenario. The simulations for temperature, precipitation, and other variables for the historical period are compared to observed values for these variables, in order to estimate the systematic errors of each model, i.e., the model bias. This bias can then be removed from the future period projections, resulting in a bias-corrected set of projected fields.

Modeling the impacts of climate change on the ACF flow under different management options requires an estimate of the projected changes in unimpaired flows at local scales. The environmental input to the STELLA model for the ACF consists of unimpaired flow (UIF) contributed at several reaches. To construct the projected changes in the UIF at these reaches under climate change, we used the results from 97 Bias-corrected, spatially disaggregated (BCSD) climate projections representing 31 CMIP5 climate models and 4 RCPs, that had been further fed into a Variable Infiltration Capacity (VIC) hydrologic model to simulate future hydrology (Brekke et al. 2014). The resulting downscaled hydrologic simulations for runoff were available as monthly time series for 1950-2099 on a grid over the contiguous US with 0.125-degree (approximately 12.5km) latitude and longitude resolution.

18.2 Validation of model-simulated runoff as a proxy for unimpaired flow

Before proceeding to implementation of the runoff projections to modeling, we needed to evaluate how well the historical (1950-1999) downscaled runoff projections compared to the historical UIF for that period. This evaluation has to be done in a statistical sense, rather than as time series, because by their nature, climate runs do not represent specific years, but rather the statistical behavior of the atmospheric system within a given period. For each reach (Figure 18.1) we constructed the median annual cycle for runoff for each model, and for historical UIF. Similarly, we constructed the annual cycles for standard deviations of runoff for each model and for the UIF. Figure 18.2 shows an example of this comparison for one of the reaches (Middle Flint). The annual cycles of median runoff and UIF are generally very strongly correlated

(Figure 18.2C and Table 18.1) proving that annual cycles of median monthly simulated runoff are in very good agreement with the annual cycle of median monthly UIF for all reaches with the exception of Sumatra. The annual cycles of standard deviations are strongly correlated, although the strength of the relationship is slightly lower, especially in reaches that contained an outlier caused by tropical storm Alberto in July of 1994; if the outlier month is excluded from consideration, correlations significantly increase.

This validation step showed that simulated runoff tends to be an overestimate of the UIF, but that the shape of the seasonal cycle for runoff is very similar to that of UIF, suggesting that despite the differences between simulated runoff and historical UIF, a proportionality between the two exists. To evaluate whether this is the case, we next calculated the regression fit between UIF and simulated runoff and in ranked pairs of monthly means. For the median model projection within a given calendar month (e.g., January) and a given reach, the monthly runoff values for 1950-1999 were arranged from smallest to largest; similarly, the UIF values for that calendar month and reach were arranged from smallest to largest. A regression fit between UIF and runoff was calculated assuming (a) linear relationship of the form UIF=A*runoff+B and (b) linear relationship of the form UIF=C*runoff. An example is shown in Figure 18.3 for the Middle Flint reach in July. A comparison between the R^2 coefficients of the two fits (Table 18.2) shows strong support for the assumption that within a given calendar month UIF can be considered proportional to runoff.

18.3 Incorporating climate change projections of runoff into STELLA

The findings described in the preceding section support the viability of the assumption that projected UIFs for each month can be constructed on the basis of Future UIF=Historical UIF * (Projected Future Runoff):(Simulated Historical Runoff). There are a number of ways to implement Future UIF=Historical UIF * (Projected Future Runoff):(Simulated Historical Runoff).

One option, which was followed by ACF Draft EIS (USACE 2015) is the following:

- For every calendar month, rank the monthly mean UIFs, the projected runoff, and the historical runoff; Calculate the ratio of projected to historical runoff from the values in the N-ranked position, and multiply the N-ranked past UIF value by this ratio
- This approach has the benefit of allowing for the possibility that minimum monthly flows become lower, and at the same time maximum flows become larger (or vice versa), but the downside of basing the ratios on single data points which would show undue influence of chance, especially at the lower and higher ends.

As a more robust alternative, we have chosen the following approach:

- Multiply each past UIF value by a change factor = the ratio of the median projected runoff to the median historical runoff value for that calendar month
- This has the downside of not allowing for the lowest and highest monthly flows to change in opposite directions, but the benefit of not being unduly influenced by chance realizations

A further necessary decision is which model projections to use for developing of the climate change scenarios for unimpaired flows. The ACF Draft EIS approach was to use a subset of three models, representing a dry, median and wet scenario, selected on the basis of ranking of the projected changes of total annual volume of runoff for the basin. This does not account for the possibility that (a) different models may rank differently in terms of projected change for different months and (b) that this ranking may vary along the basin. In our approach we make use of the information contained in each projection separately (since we are not limited by model run time to just three scenarios). With this we would expect to see a more accurate range of the possible outcomes implied by the downscaled model projections. In addition to individual models, we consider the overall 0^{th} (minimum) through 100^{th} (maximum) percentile of projected changes for each month, in increments of 10 percentiles.

The time frame chosen for the projections was 2020-2079. An examination of the climate projections indicated no clear separation between the four greenhouse gas concentration scenarios (RCPs), consistent with the ACF Draft EIS. This is likely due to the fact that both temperature and precipitation tend to increase with higher RCPs so that the contribution to projected runoff by increase in precipitation is likely partially offset by increased evaporation due to increased projected temperatures. As a result, we have chosen to consider the model projections stemming from different RCPs as part of the same envelope.

Change factors for each reach were developed as described above were calculated for each month, and for each individual climate model projection as well as for the climate model projections' envelope at 11 levels: 0^{th} (Minimum), 10^{th}, 20^{th}, 30^{th}, 40^{th}, 50^{th} (Median), 60^{th}, 70^{th}, 80^{th}, 90^{th} and 100^{th} (Maximum) percentiles of change, based on the models' 2020-2069 climatology relative to their 1950-1999 climatology.

Amongst the climate model projections it is often the case that increased median flows can be accompanied with lower low flows and higher high flows. It should be underscored that the climate change factors calculated here are based on the overall changes in flow volume for a given calendar month, and not for changes in the distribution of flows. The results from applying these climate change factors to the UIF will result in a conservative estimate of the likely range of responses that can be expected in reality.

The change factors for the 9 reaches (Figure 18.1) for the envelope percentiles are shown in Figure 18.3. The UIF climate change envelope is narrower during January-June and broader during July-December. For all reaches and all months, the median of all models' projections is greater than one. This means that more than half of the climate model projections produce higher median runoff for the future period than in the historical period. The minimum of the climate envelopes (the driest edge of the climate envelope) is an over 25% reduction of the median flows; the maximum (wettest edge of the climate envelope) is more variable across reaches and calendar months, ranging from an approximately 25%-50% increase of median flows in January-March for the upper reaches, to over 75% for the lower reaches in July and October.

These climate change factors were used to proportionally modify the daily UIF time series from 1939-2012, resulting in a set of projections for the basin. Results presented in the Section 18.4 discuss changes in flow and reservoir elevations for the 11 levels of the climate change envelope under three operation rules (baseline, WCM, and USFWS). USFWS alternative is provided to inform adaptive management alternative actions that may be possible within the authority of the WCM. Results presented in Sections 18.5 and 18.6 compare select mussel and sturgeon metrics, respectively, for the 11 levels of the climate change envelope under two of the operation rules (baseline, WCM).

18.4 Results for flow and reservoir elevations

Figure 18.4 illustrates the spread of the projected climate change envelope for 90% exceeded flows at Jim Woodruff Dam for the three sets of operation rules. The spread of the envelopes for any given calendar day is on the order of 5,000 cfs, which underscores the large range of uncertainty in the projected future, and the need for flexibility in developing suitable operation rules for the future. Similar results occurred for the 10% exceeded, 25% exceeded, median, 75% exceeded and 100% exceeded flows.

Figure 18.5 compares the 90% exceeded flows at Jim Woodruff Dam under the baseline, WCM, and USFWS, for five levels of the climate change envelope: envelope minimum, 10%, median, 90% and maximum. During the low flow period (roughly May to December) the WCM tends to provide higher low flows than the baseline, and the USFWS tends to provide higher low flows than both WCM and baseline, except at the maximum level of the climate envelope when the operating rules perform similarly.

Figure 18.6 illustrates the spread of the projected climate change envelope for 90% exceeded elevations at Lake Lanier for the three sets of operation rules. The spread of the envelopes for any given calendar day is on the order of 15 ft. Results are similar in nature for other exceedance levels, and for the reservoirs at W.F. George and West Point.

Figure 18.7 compares the 90% exceeded elevations at Lake Lanier under the baseline, WCM, and USFWS, for five levels of the climate change envelope: envelope minimum, 10%, median, 90% and maximum. Elevations are highest under the baseline, followed by WCM, followed by USFWS operations. The difference between elevations under baseline, WCM and USFWS is largest for the lower (drier) end of the climate envelope.

18.5 Results for Mussel Metrics

Four mussel metrics were selected for examining the impact of projected climate change under baseline and WCM. Below is a list of these metrics' abbreviated names and their description:

- M2: Annual number of days between March 1 and August 15 with flows ≥16,200 cfs (measure of the access to floodplain for spawning and rearing)
- M3: Annual maximum continuous inundation (measure of access to floodplain during spawning and rearing)

- M4: Annual number of days between June 1 and July 15 with flows greater than 5,000 cfs and less-than-or-equal-to 7,500 cfs (measure of low flows during host infection and juvenile settlement) Note that this metric excludes flows ≤ 5,000 cfs so some low flows are not counted.
- M7: Annual 1-day minimum flow (measure of exposure during extreme low flows)

The remaining metrics are shown in Figures 18.M1, 18.M5, 18.M6, 18.M8, and 18.M9.

Figure 18.8 illustrates the response of M2 to the minimum, 10%, median, 90%, and maximum levels of the climate envelope under baseline and WCM. Also shown for comparison are the values of the metric for the 1939-2012 period. The median metric values for baseline range from 75 (minimum of the climate change envelope) to 149 days (maximum of the climate change envelope); for WCM this range is 60 to 136 days.

Figure 18.9 compares the response of M2 to the minimum, 10%, median, 90%, and maximum levels of the climate envelope under baseline and WCM. It shows that while the probability distribution of the number of days between March 1 and August 15 exhibiting flows ≥16,200 cfs is dependent on the climate envelope level, for any given level of the climate envelope baseline provides better access to the floodplain for spawning and rearing than the WCM. An additional/alternative way to describe this can be that any given value of the metric is more frequently exceeded under baseline than under WCM.

Figure 18.10 illustrates the response of M3 to the minimum, 10%, median, 90%, and maximum levels of the climate envelope under baseline and WCM. The median metric values for baseline range from about 17,700 to 39,300 acres; for WCM this range is very similar, from about 15,600 to 40,600 acres.

Figure 18.11 compares the response of M3 to the minimum, 10%, median, 90%, and maximum levels of the climate envelope under baseline and WCM. For all levels of the climate envelope, the 100% exceedance values for WCM are greater than or equal to those for baseline. The 90% exceedance values for WCM are smaller than those for baseline for all but the minimum levels of the climate envelope. Results are mixed at other exceedance levels.

Figure 18.12 illustrates the response of M4 to the minimum, 10%, median, 90%, and maximum levels of the climate envelope under baseline and WCM. Since this metric represents fairly low flows, its median values are fairly small, ranging from 0 days (maximum level of the climate envelope) to 3 days (minimum level of the climate envelope) for baseline, and 0 to 2 days in the WCM. At the 10% exceeded level, the metric values range from 4 to 31 days for the baseline, and from 14 to 35 days for the WCM.

Figure 18.13 compares the response of M4 to the minimum, 10%, median, 90%, and maximum levels of the climate envelope under baseline and WCM. Largest differences are seen for the 90% and maximum levels of the climate envelope, at the 20%, 10% and 0% exceedance levels, where the WCM provides significantly larger values of this metric than does baseline.

Figure 18.14 illustrates the response of M7 to the minimum, 10%, median, 90%, and maximum levels of the climate envelope under baseline and WCM. Median values for M11 for baseline range between 5,050 (minimum level of the climate envelope) and about 8,000 cfs (maximum level of the climate envelope; for WCM this range is 5,050 to about 8,400 cfs.

Figure 18.15 compares the response of M7 to the minimum, 10%, median, 90%, and maximum levels of the climate envelope under baseline and WCM. The annual minimum flows under WCM tend to be similar to or higher than those under baseline at most exceedance levels and for most levels of the climate envelope. Annual minimum flow of 6,000 cfs is systematically more frequently exceeded under WCM than under baseline for any given level of the climate envelope.

18.6 Results for Sturgeon Metrics

Three sturgeon metrics were selected for examining the impact of projected climate change under baseline and WCM. Below is a list of these metrics' abbreviated names and their description:

- S1: Annual number of days between November 24 and June 1 exhibiting flows ≥16,200 cfs (measure of general floodplain forest inundation and nutrient supply)
- S4: Annual cumulative acre-days inundated during the period July 15 through November 24 (measure of general floodplain forest inundation and nutrient supply)
- S6a: Annual number of days during the period November 1 through March 15 exhibiting flows ≥16,700 cfs (measure of general low salinity conditions for sturgeon access to foraging habitat)
- SQ1: Annual number of days during the period March 1 through May 31 exhibiting flows between 5,000 cfs and 16,700 cfs (measure of how frequently sturgeon spawning may be affected by hydropeaking)

The remaining metrics are shown in Figures 18.S2, 18.S3, and 18.S5 - 18.S8.

Figure 18.16 illustrates the response of S1 to the minimum, 10%, median, 90%, and maximum levels of the climate envelope under baseline and WCM. The median annual number of days for S1 under baseline ranges between 112 (minimum level of the climate envelope) to 169 (maximum level of the climate envelope); under WCM this range is 107 to 168 days.

Figure 18.17 compares the response of S1 to the minimum, 10%, median, 90%, and maximum levels of the climate envelope under baseline and WCM. At the highest levels of exceedance (corresponding to the driest years) for most levels of the climate envelope WCM tends to provide higher values of S1 than does baseline. For the lower levels of exceedance (wetter years) the opposite is true: WCM tends to provide lower values of S1 than does baseline.

Figure 18.18 illustrates the response of S4 to the minimum, 10%, median, 90%, and maximum levels of the climate envelope under baseline and WCM. Median S4 values for baseline range between approximately 151,500 (minimum level of the climate envelope) to 1,053,000 acre-days (maximum level of the climate envelope); for WCM this range is approximately 137,200 to 1,044,000 acre-days.

Figure 18.19 compares the response of S4 to the minimum, 10%, median, 90%, and maximum levels of the climate envelope under baseline and WCM. The S4 metric values are generally lower under WCM than under baseline, with a few exceptions.

Figure 18.20 illustrates the response of S6a to the minimum, 10%, median, 90%, and maximum levels of the climate envelope under baseline and WCM. The median annual number of days for S6a under baseline ranges between 56 (minimum level of the climate envelope) and 109 (maximum level of the climate envelope); under WCM this range is 57 to 109 days.

Figure 18.21 compares the response of S6a to the minimum, 10%, median, 90%, and maximum levels of the climate envelope under baseline and WCM. For highest levels of exceedance (corresponding to dryer years) WCM tends to provide lower S6a values than does baseline at most levels of the climate envelope; results are mixed for lower levels of exceedance (wetter years).

Figure 18.22 illustrates the response of SQ1 to the minimum, 10%, median, 90%, and maximum levels of the climate envelope under baseline and WCM. The median annual number of days for SQ1 under baseline ranges between 22 (minimum level of the climate envelope) and 0 (maximum level of the climate envelope); under WCM this range is 36 to 10 days.

Figure 18.23 compares the response of SQ1 to the minimum, 10%, median, 90%, and maximum levels of the climate envelope under baseline and WCM. The WCM tends to provide higher SQ1 values than does baseline at nearly all levels of the climate envelope.

18.7 Figures and Tables for Appendix B

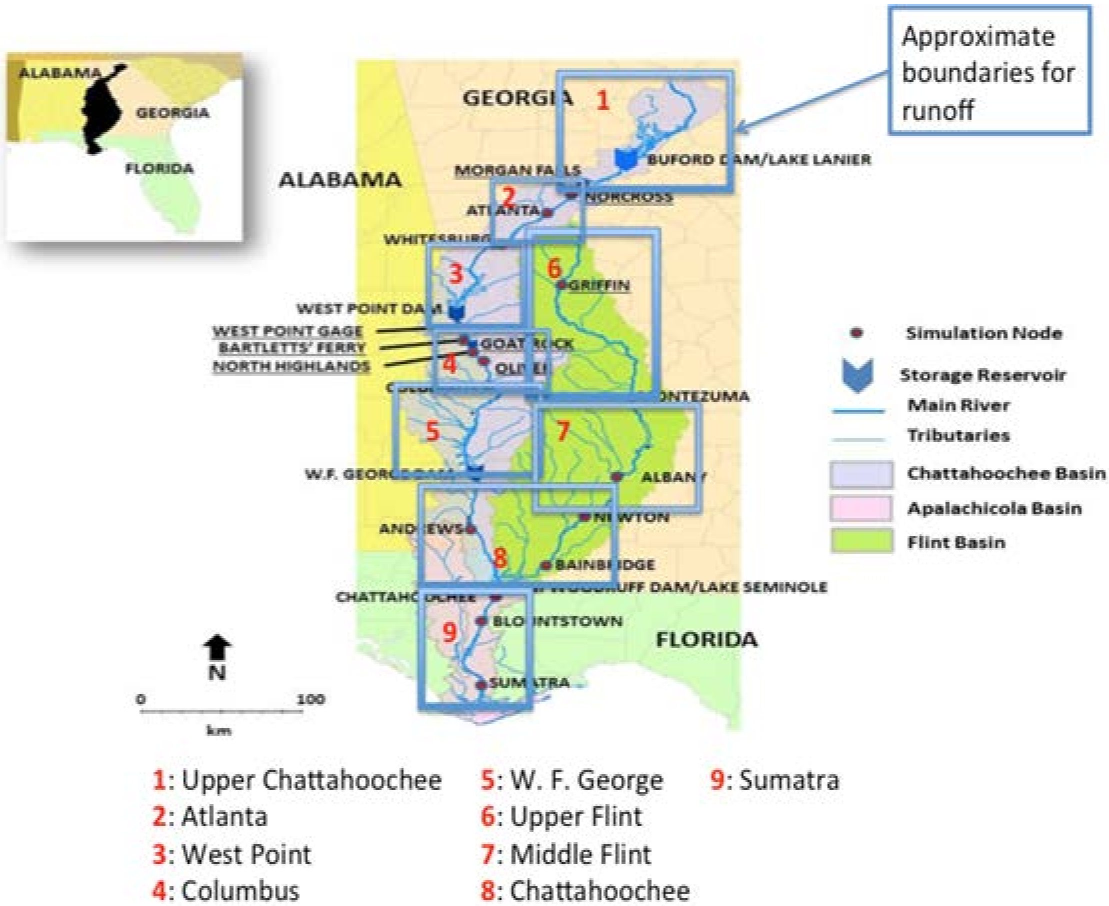


Figure 18.1: Delineation of reaches and approximate boundaries for runoff

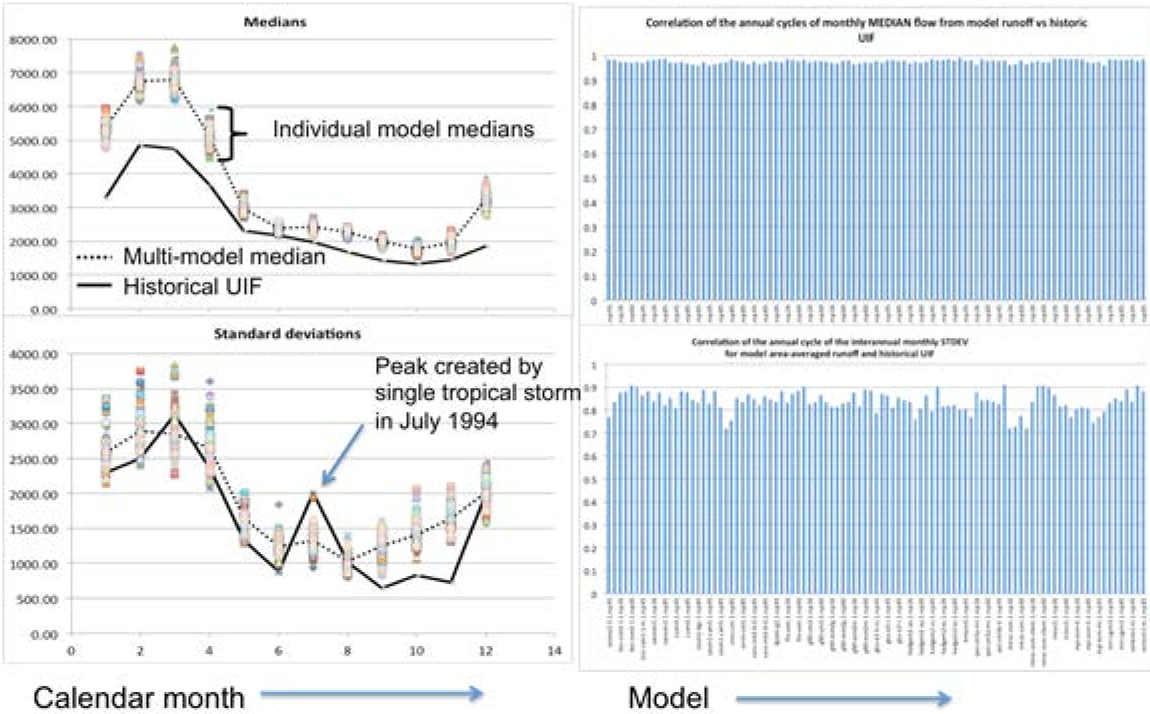


Figure 18.2: Comparison of annual cycles of median runoff/median UIF and standard deviation of runoff/UIF for the Middle Flint reach

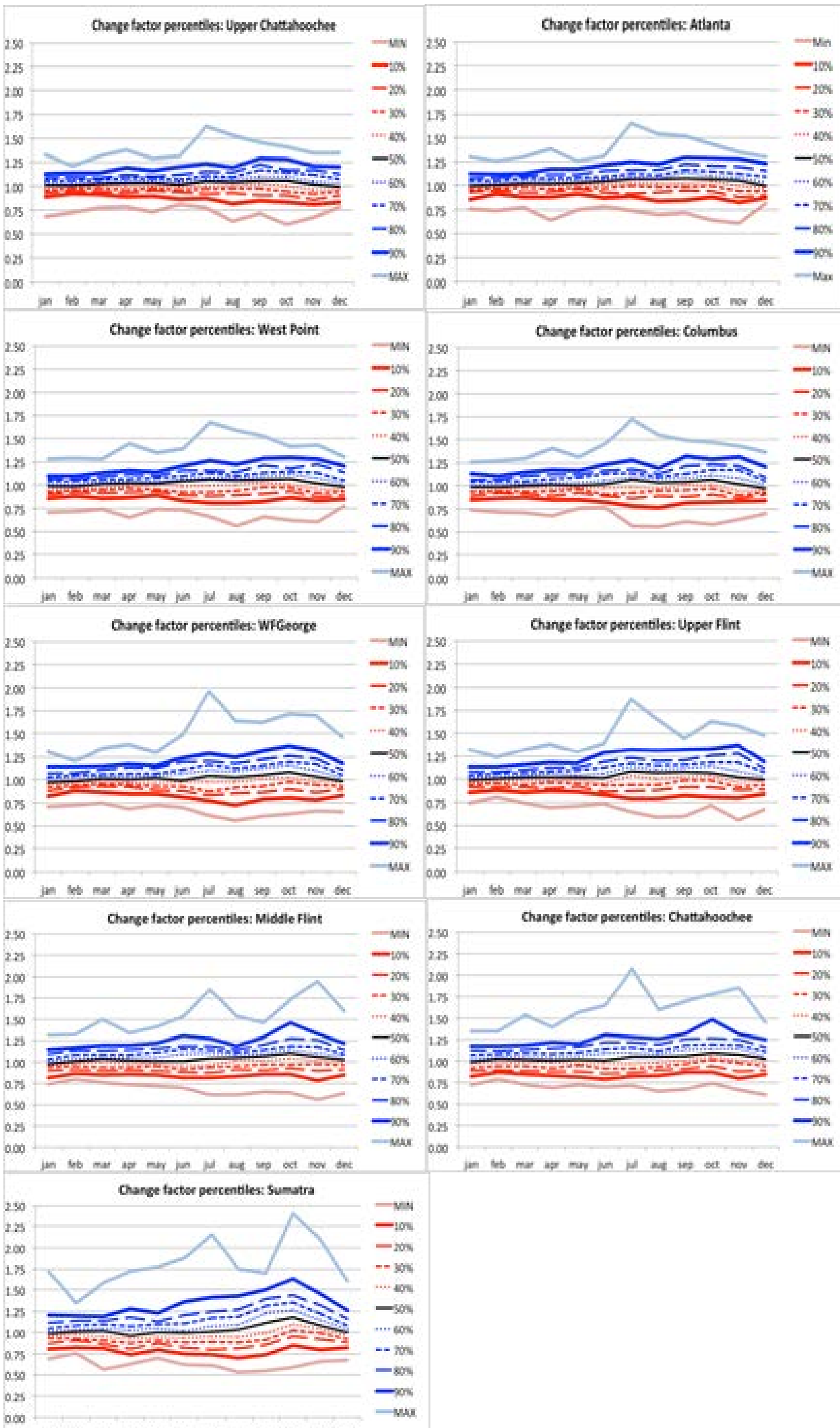


Figure 18.3: Change factors for UIF, January through December, for all reaches, at various levels of the climate change models' envelope

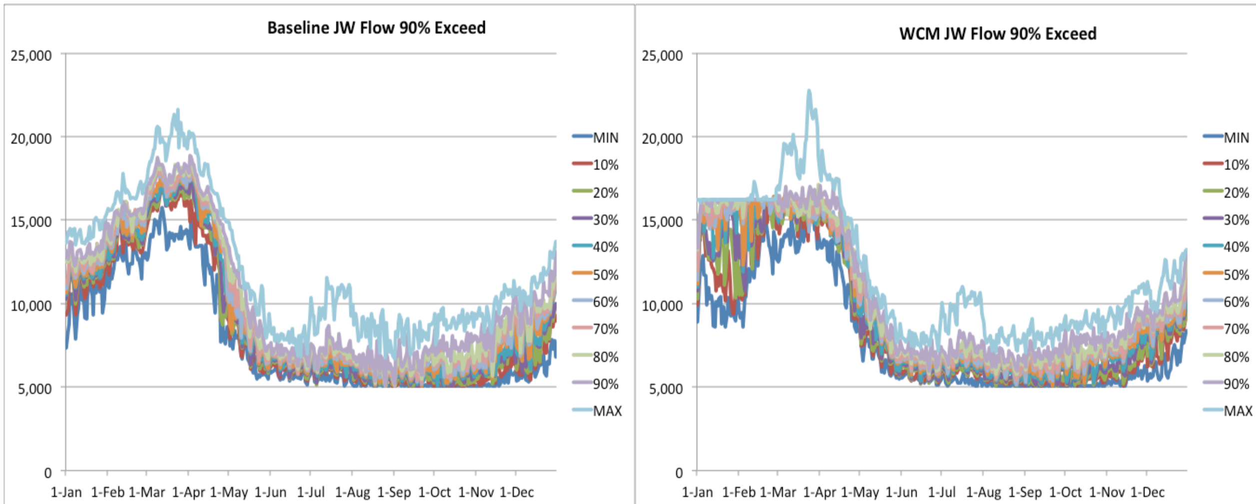


Figure 18.4: Comparison of the climate change envelopes for the 90% exceeded flows at Jim Woodruff Dam for a) baseline, b)WCM, and c) USFWS operation rules.

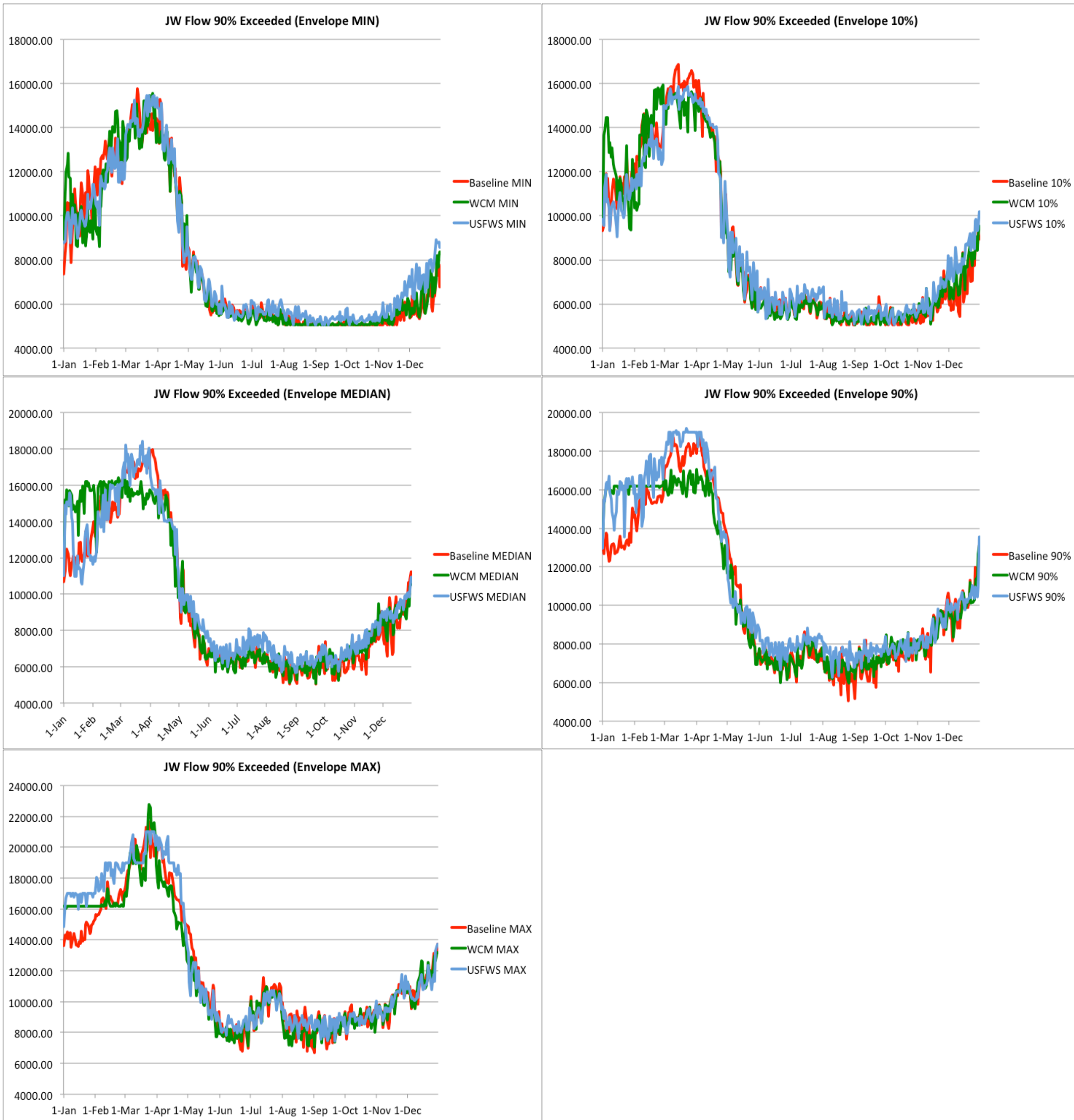


Figure 18.5: Comparison of the 90% exceeded flows at Jim Woodruff Dam under baseline, WCM and USFWS operating rules for the a) Minimum, b) 10%, c) Median, d) 90% and e) Maximum of the climate change envelope

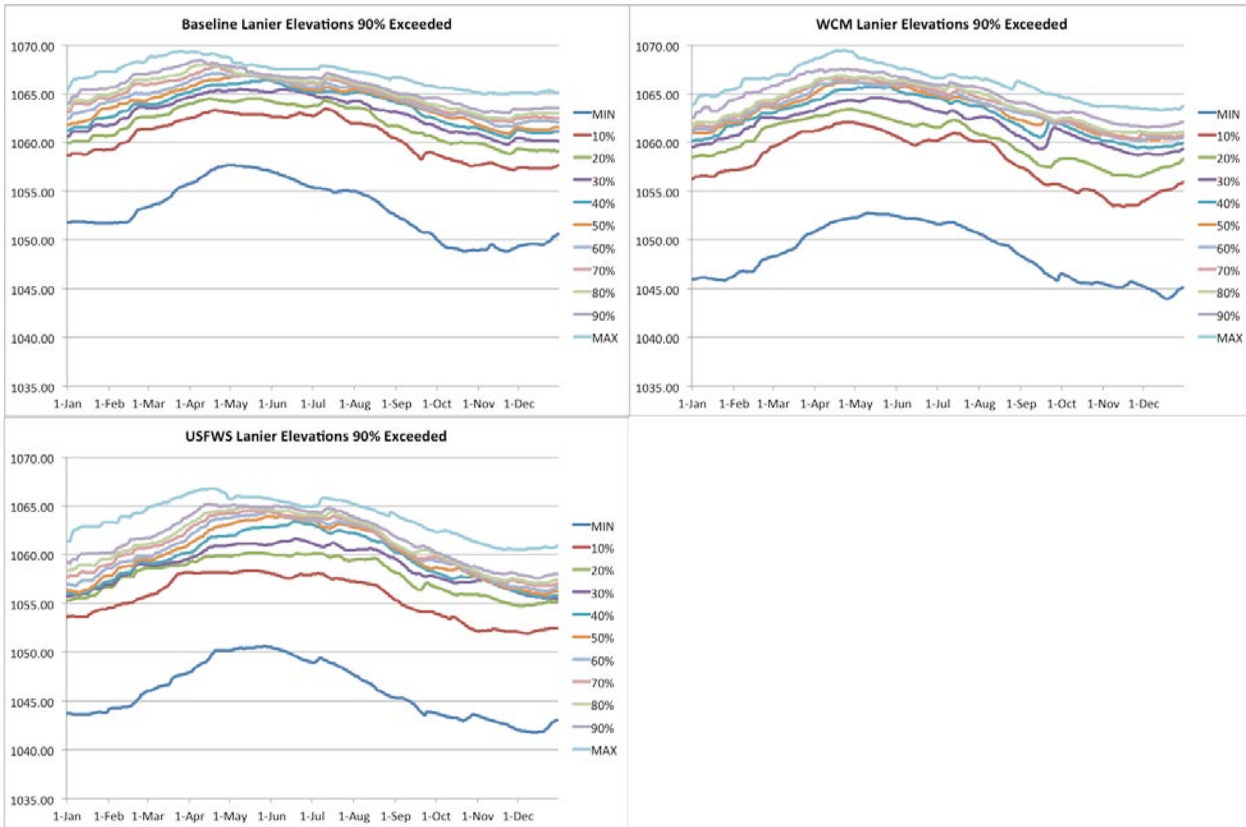


Figure 18.6: Comparison of the climate change envelopes for the 90% exceeded elevations at Lake Lanier for a) baseline, b) WCM, and c) USFWS operation rules.

Figure 18.7: Comparison of the 90% exceeded elevations at Lake Lanier under baseline, WCM and USFWS operating rules for the a) Minimum, b) 10%, c) Median, d) 90% and e) Maximum of the climate change envelope

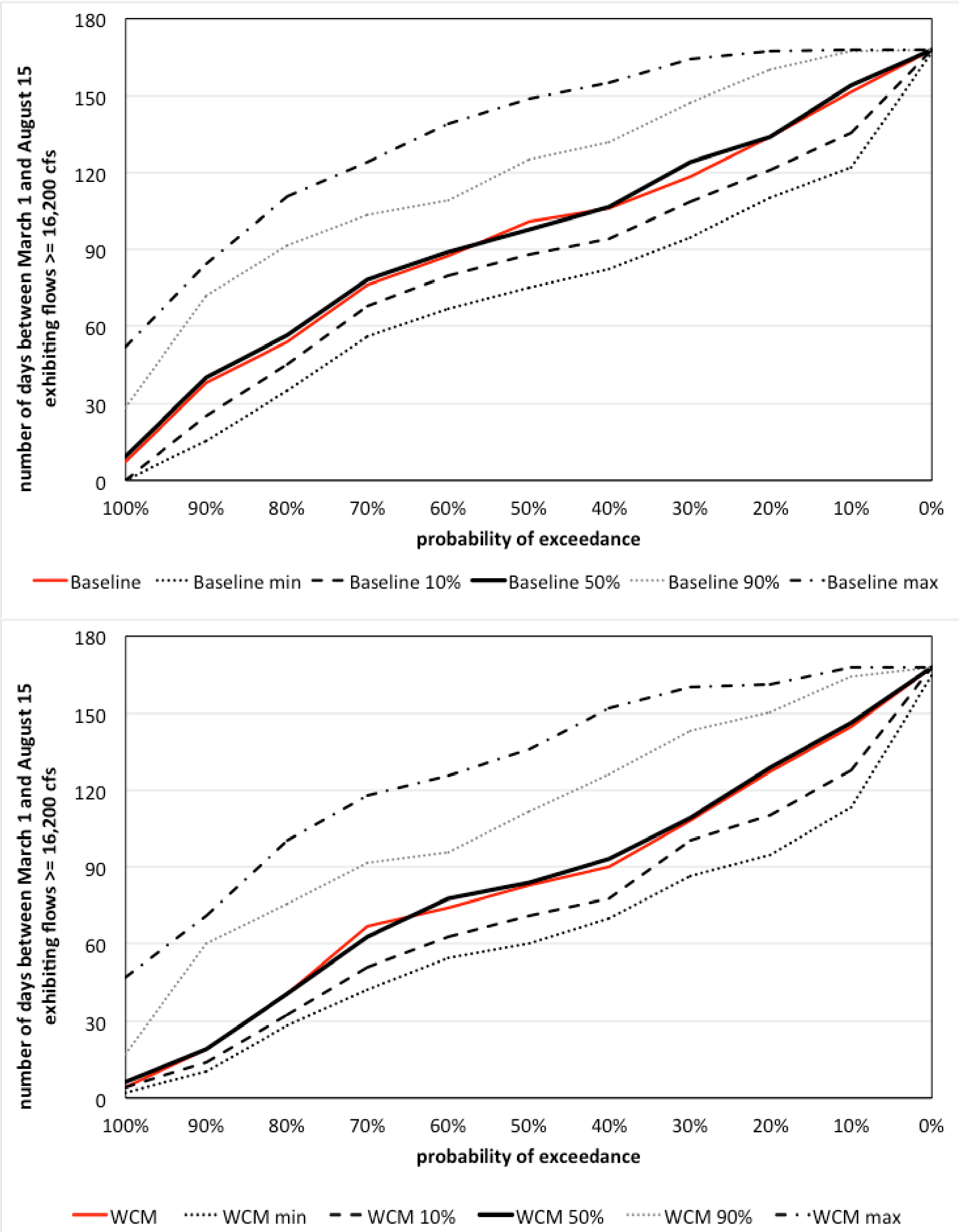


Figure 18.8: Response of metric M2 to the minimum, 10%, median, 90%, and maximum of the climate change envelope for a) baseline, and b) WCM. The metric values for 1939-2012 (no climate change) are provided for comparison (red line).

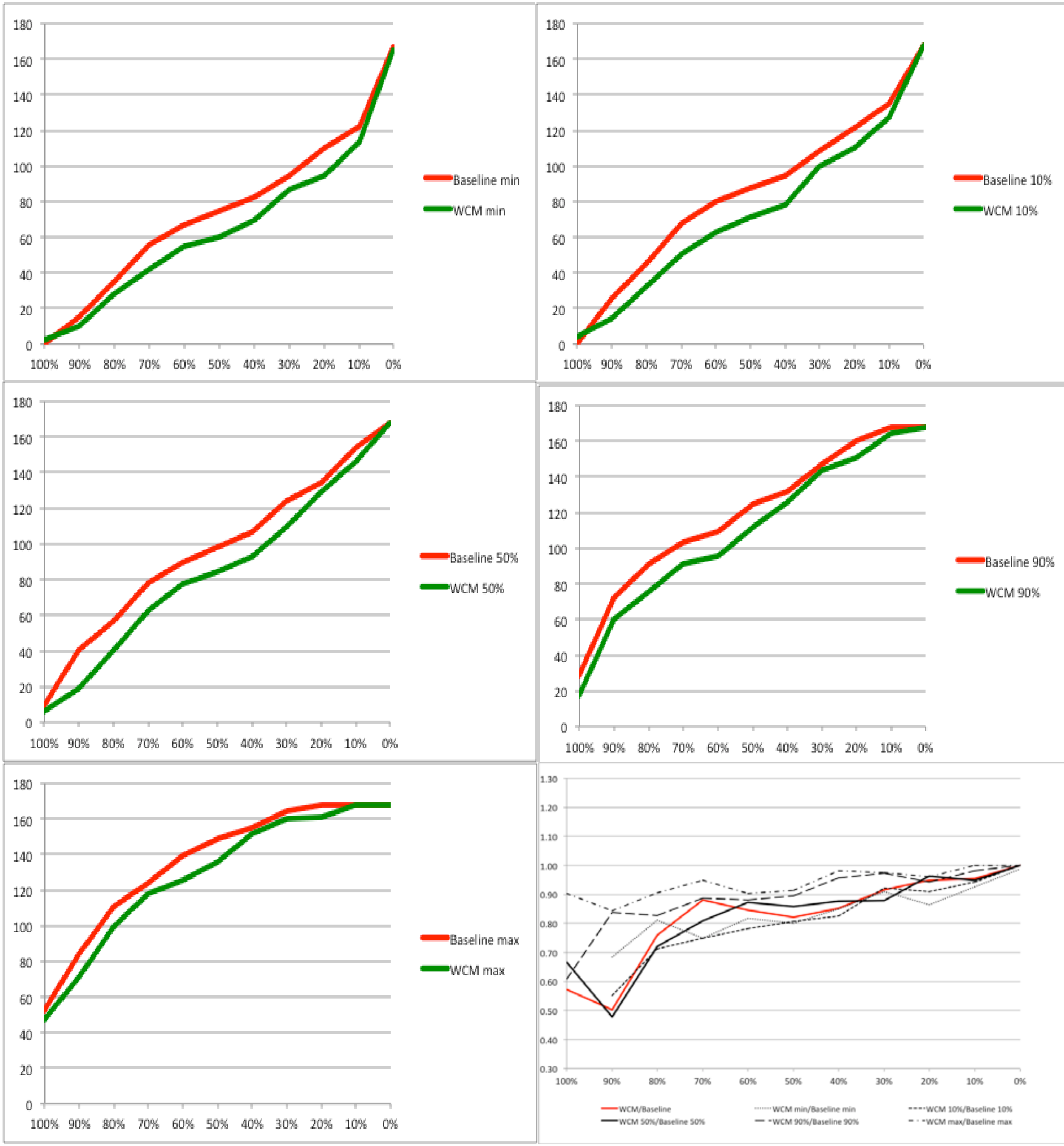


Figure 18.9 Comparison of M2 metric performance of baseline and WCM for the a) minimum, b) 10%, c) median, d) 90%, and e) maximum levels of the climate change envelope. Panel f) is the ratio (WCM/baseline) of the metric values at a given exceedance level for the minimum, 10%, median, 90% and maximum levels of the climate envelope (black lines) along with the ratio (WCM/baseline) with no climate change (red line).

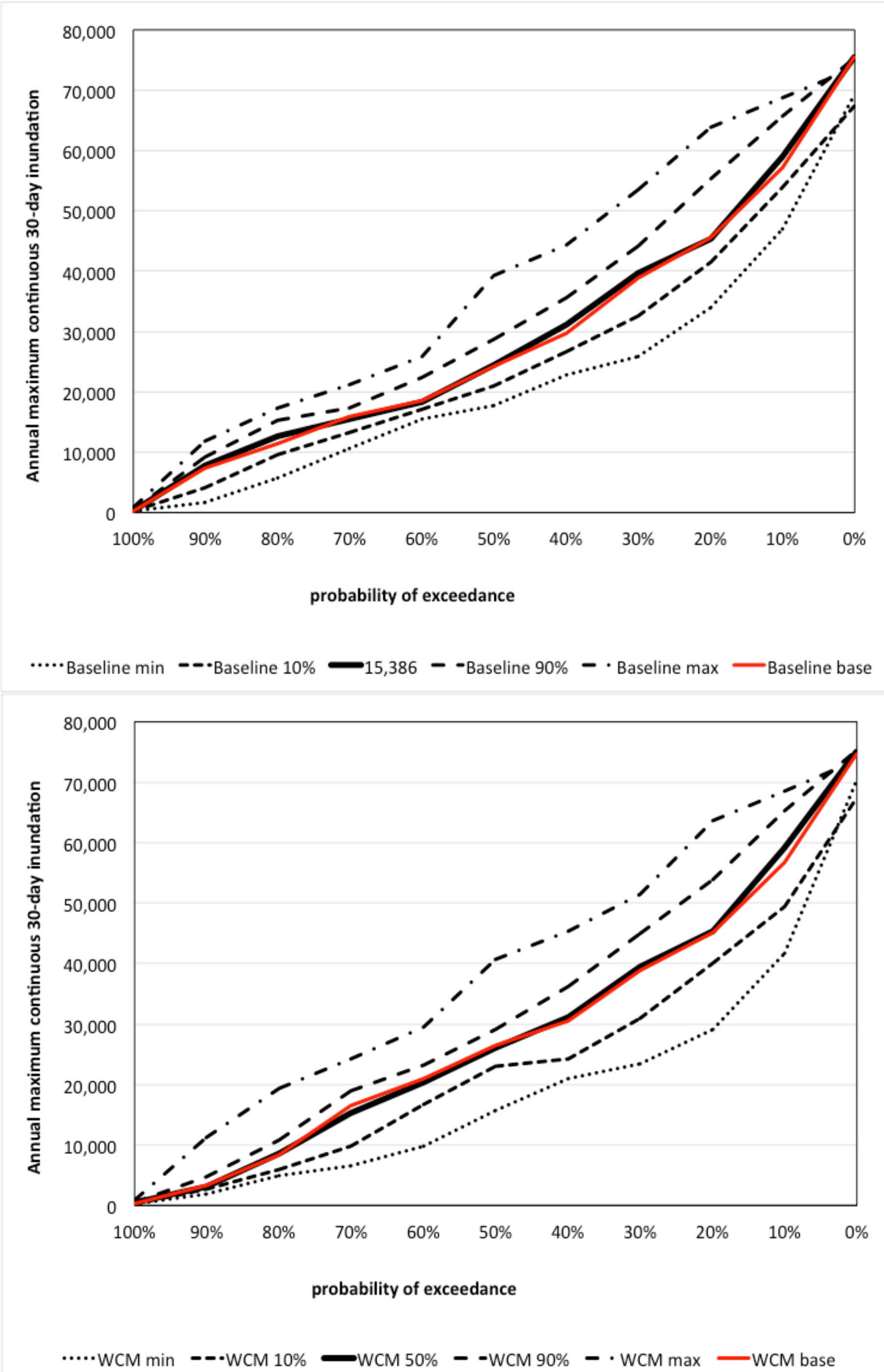


Figure 18.10: Response of metric M3 to the minimum, 10%, median, 90%, and maximum of the climate change envelope for a) baseline, and b) WCM. The metric values for 1939-2012 (no climate change) are provided for comparison (red line).

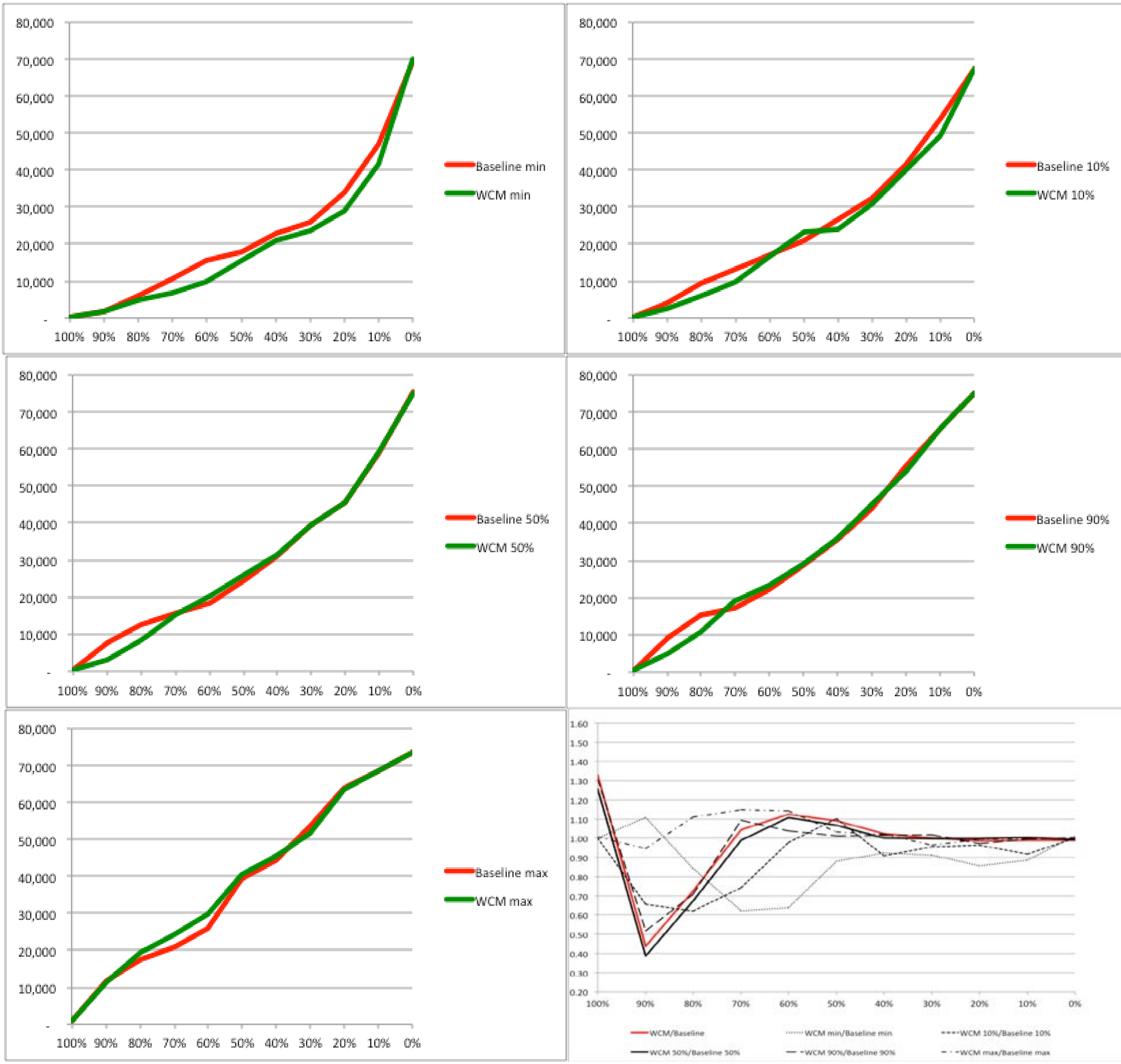


Figure 18.11 Comparison of M3 metric performance of baseline and WCM for the a) minimum, b) 10%, c) median, d) 90%, and e) maximum levels of the climate change envelope. Panel f) is the ratio (WCM/baseline) of the metric values at a given exceedance level for the minimum, 10%, median, 90% and maximum levels of the climate envelope (black lines) along with the ratio (WCM/baseline) with no climate change (red line).

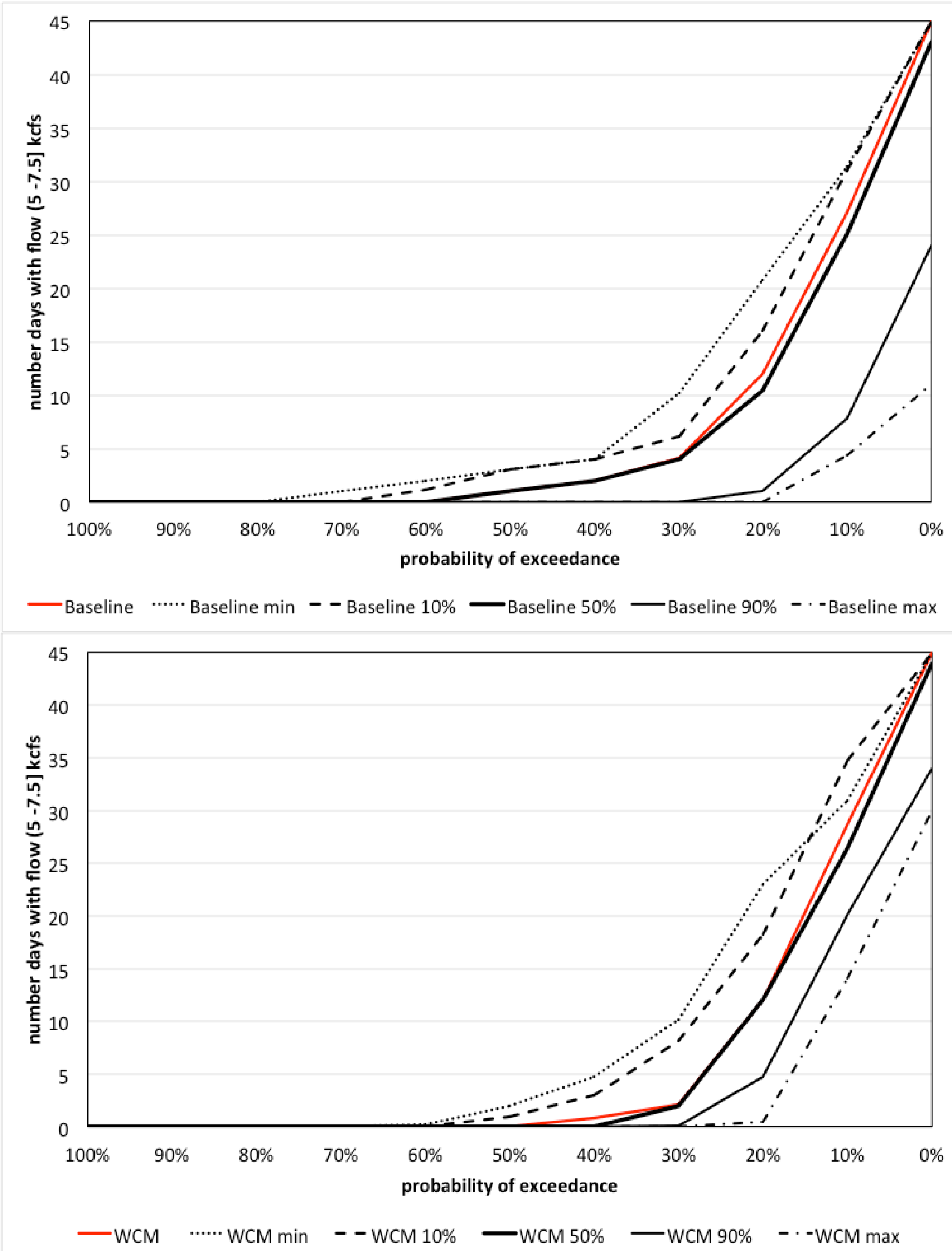


Figure 18.12: Response of metric M4 to the minimum, 10%, median, 90%, and maximum of the climate change envelope for a) baseline, and b) WCM. The metric values for 1939-2012 (no climate change) are provided for comparison (red line).

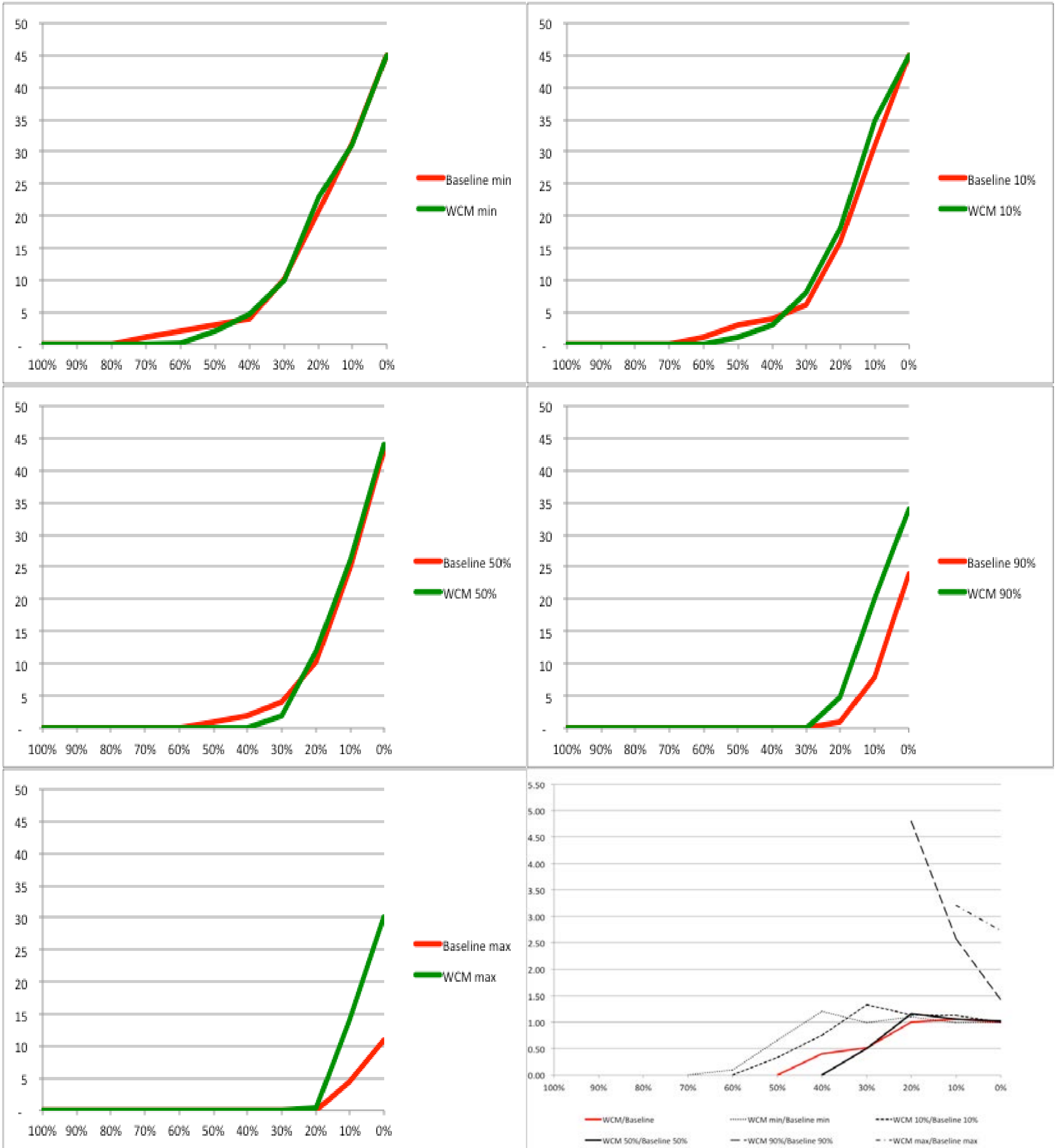


Figure 18.13 Comparison of M4 metric performance of baseline and WCM for the a) minimum, b) 10%, c) median, d) 90%, and e) maximum levels of the climate change envelope. Panel f) is the ratio (WCM/baseline) of the metric values at a given exceedance level for the minimum, 10%, median, 90% and maximum levels of the climate envelope (black lines) along with the ratio (WCM/baseline) with no climate change (red line). Note that due to the small number of days and large number of 0 values in some parts of the curves, panel f) is to be interpreted with caution; for the 90% and maximum levels of the climate envelope, exceedances for levels above 10% involve division by 0, hence no values are shown.

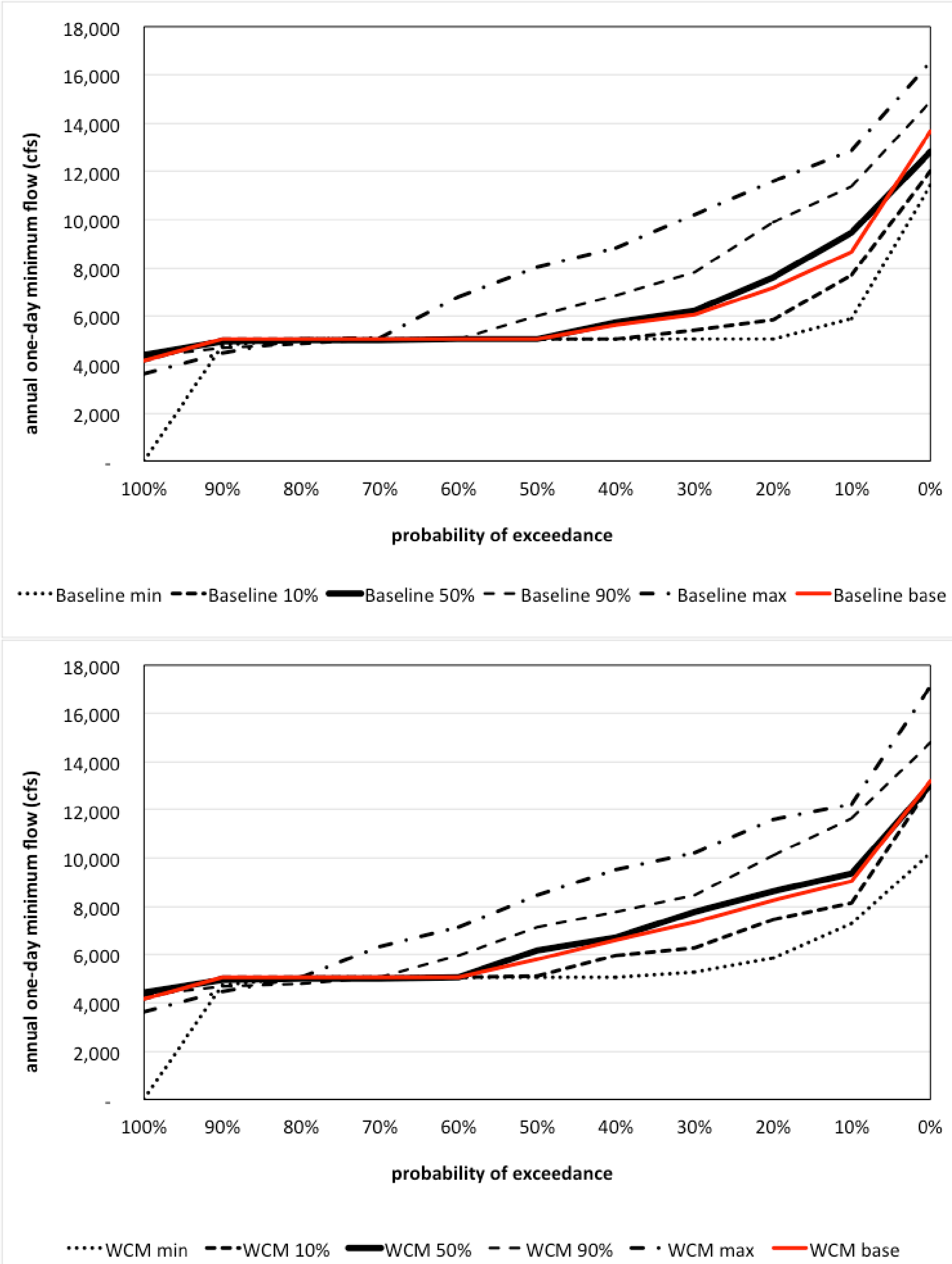


Figure 18.14 Response of metric M7 to the minimum, 10%, median, 90%, and maximum of the climate change envelope for a) baseline, and b) WCM. The metric values for 1939-2012 (no climate change) are provided for comparison (red line).

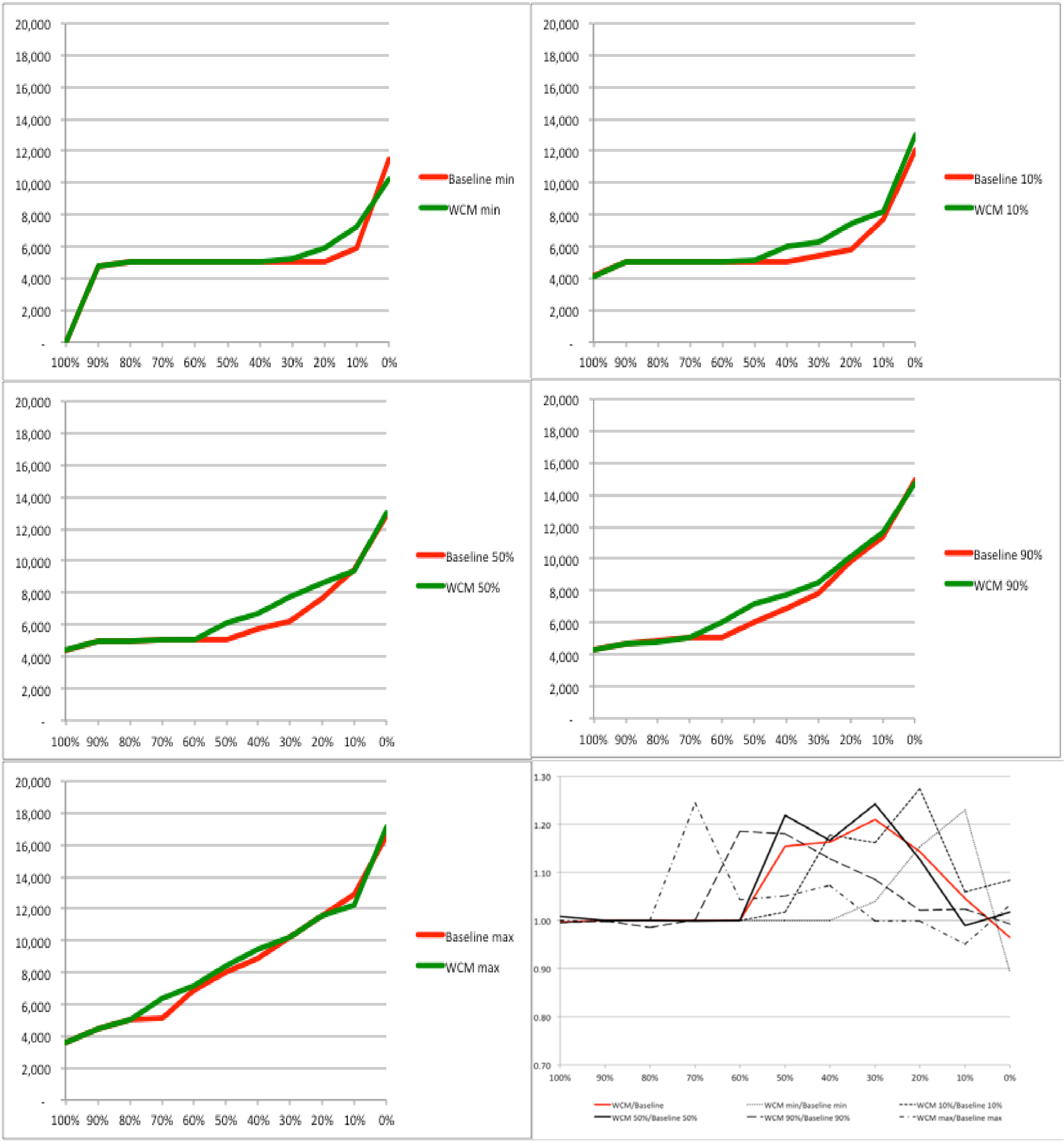


Figure 18.15 Comparison of M7 metric performance of baseline and WCM for the a) minimum, b) 10%, c) median, d) 90%, and e) maximum levels of the climate change envelope. Panel f) is the ratio (WCM/baseline) of the metric values at a given exceedance level for the minimum, 10%, median, 90% and maximum levels of the climate envelope (black lines) along with the ratio (WCM/baseline) with no climate change (red line).

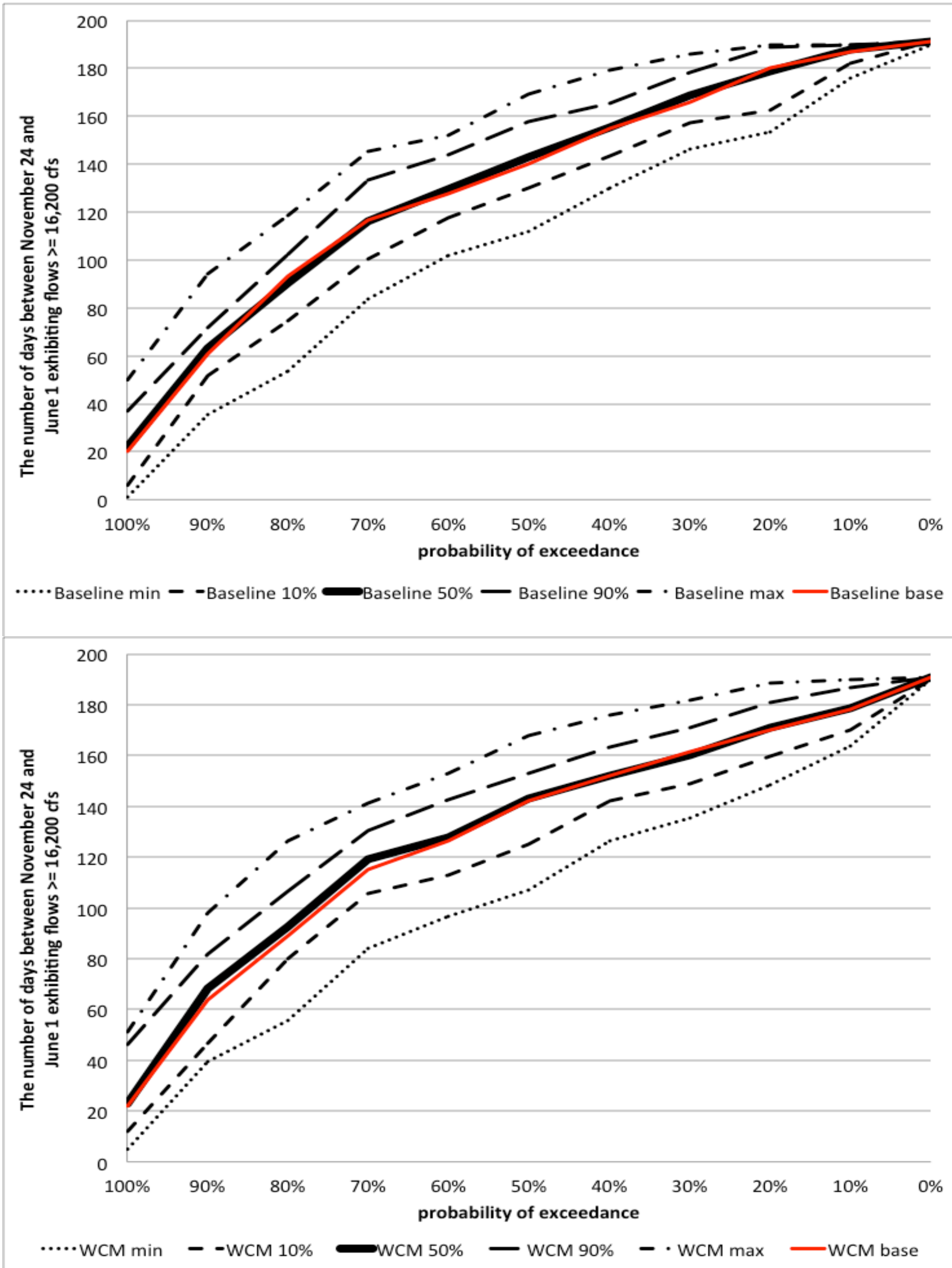


Figure 18.16 Response of metric S1 to the minimum, 10%, median, 90%, and maximum of the climate change envelope for a) baseline, and b) WCM. The metric values for 1939-2012 (no climate change) are provided for comparison (red line).

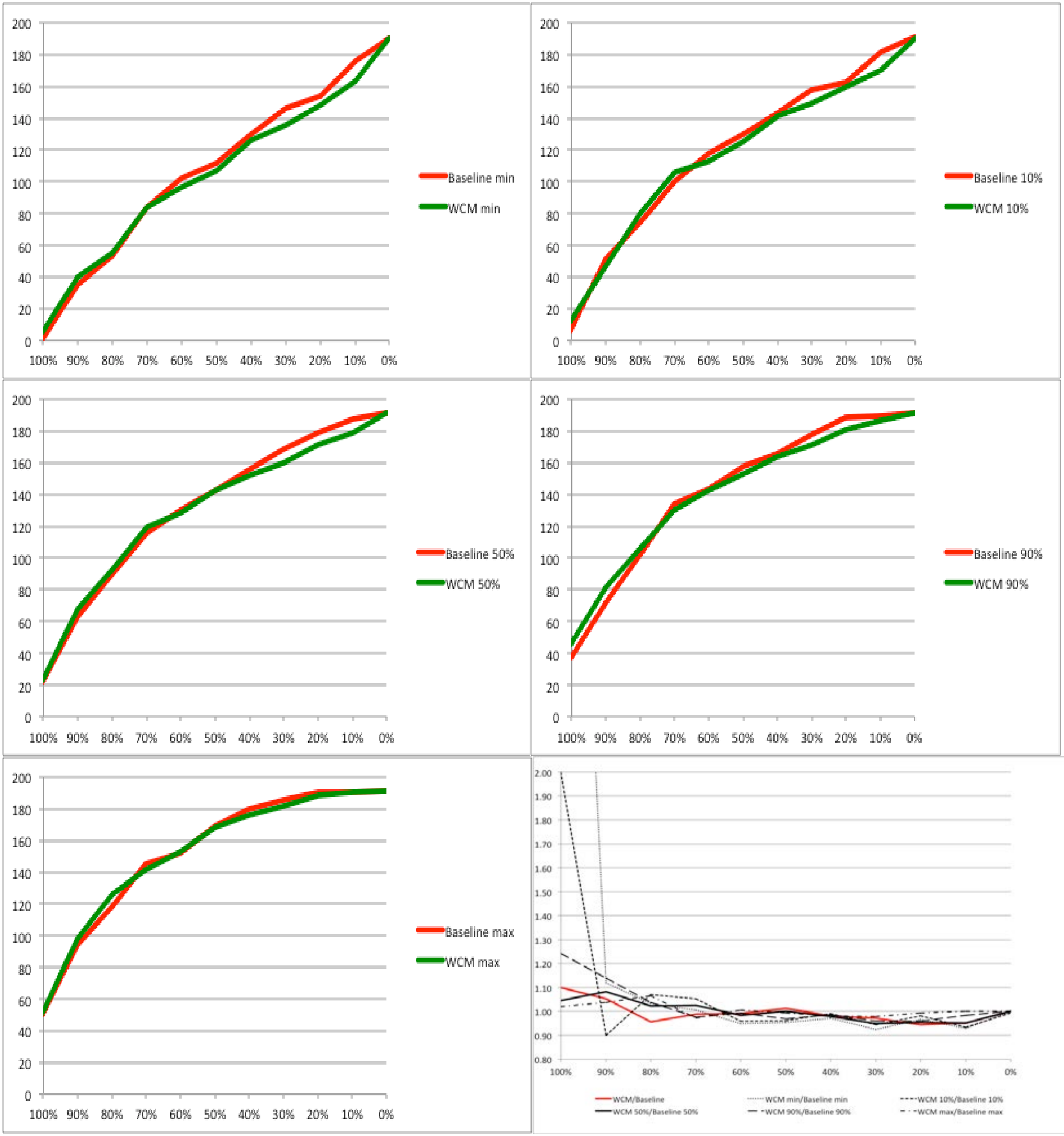


Figure 18.17 Comparison of S1 metric performance of baseline and WCM for the a) minimum, b) 10%, c) median, d) 90%, and e) maximum levels of the climate change envelope. Panel f) is the ratio (WCM/baseline) of the metric values at a given exceedance level for the minimum, 10%, median, 90% and maximum levels of the climate envelope (black lines) along with the ratio (WCM/baseline) with no climate change (red line).

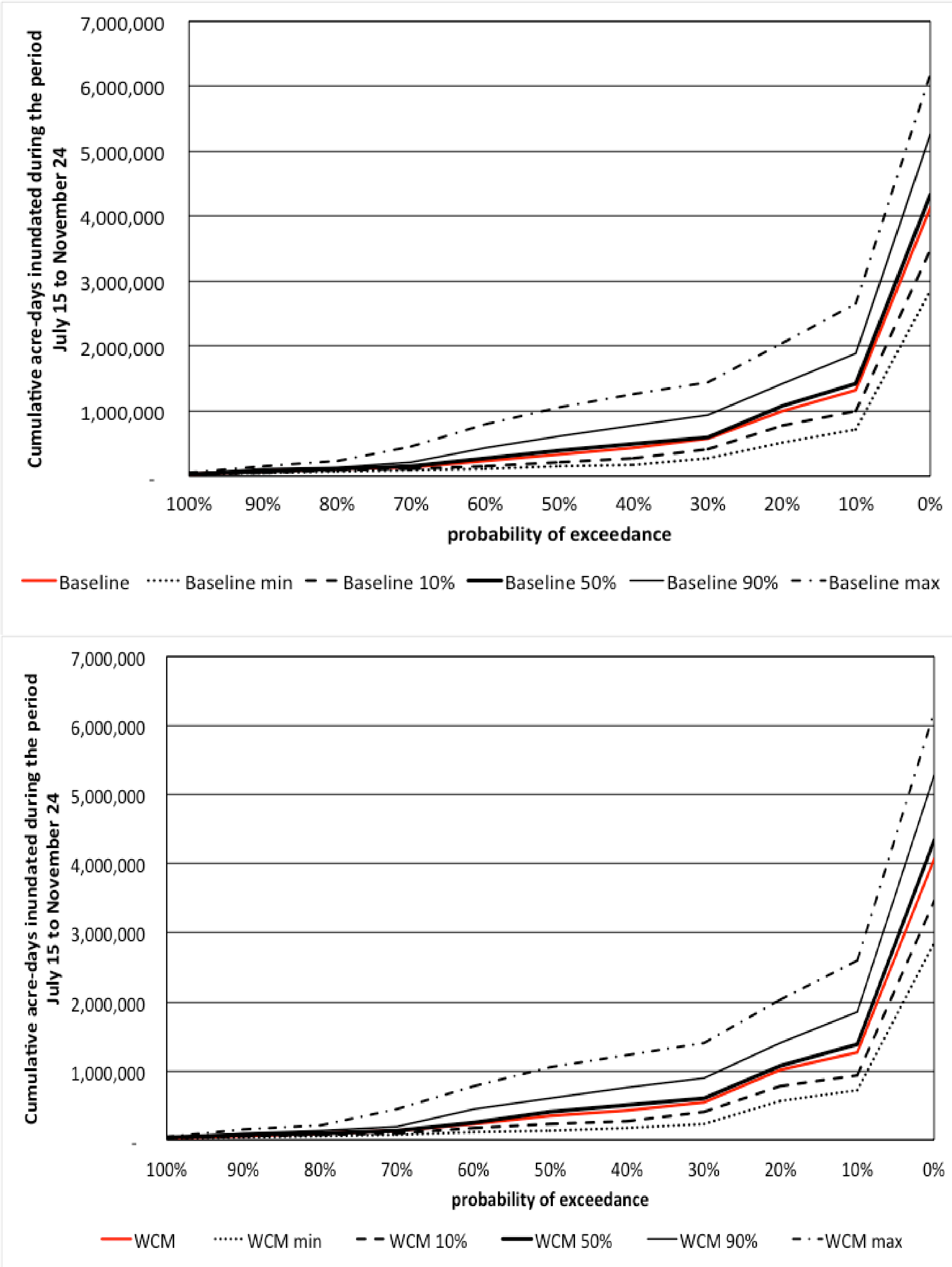


Figure 18.18 Response of metric S4 to the minimum, 10%, median, 90%, and maximum of the climate change envelope for a) baseline, and b) WCM. The metric values for 1939-2012 (no climate change) are provided for comparison (red line).

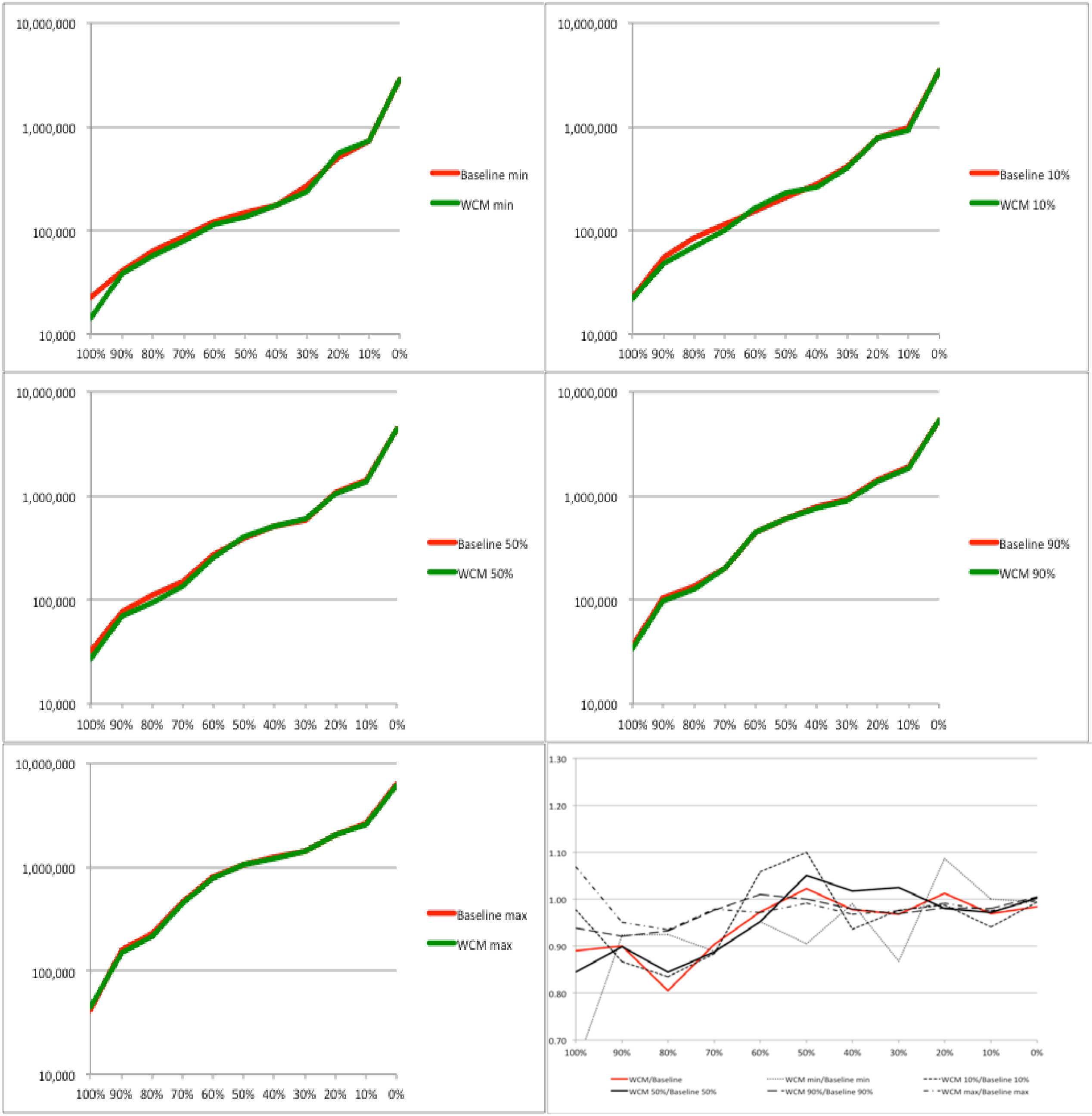


Figure 18.19 Comparison of S4 metric performance of baseline and WCM for the a) minimum, b) 10%, c) median, d) 90%, and e) maximum levels of the climate change envelope (note logarithmic scale). Panel f) is the ratio (WCM/baseline) of the metric values at a given exceedance level for the minimum, 10%, median, 90% and maximum levels of the climate envelope (black lines) along with the ratio (WCM/baseline) with no climate change (red line).

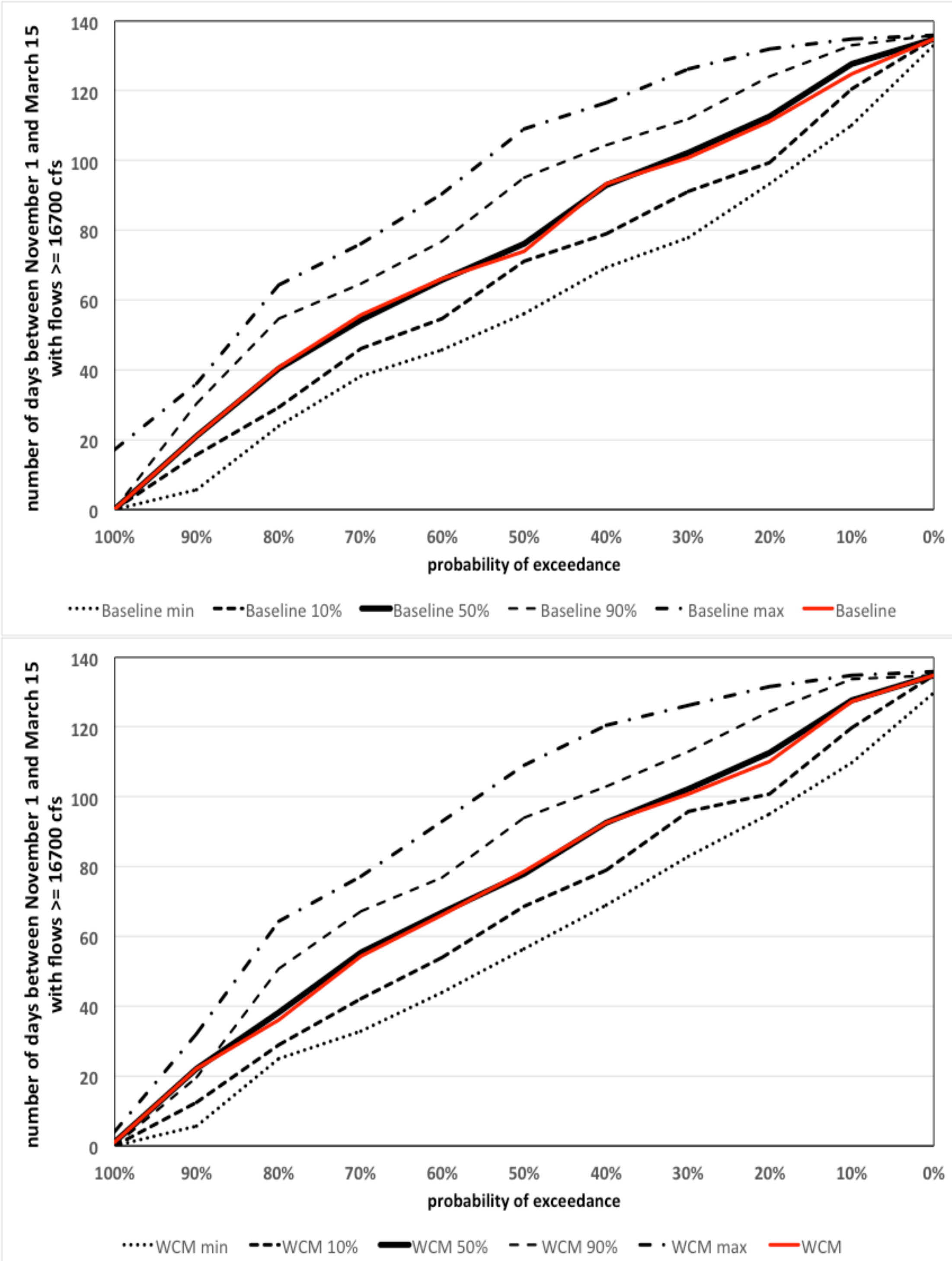


Figure 18.20 Response of metric S6a to the minimum, 10%, median, 90%, and maximum of the climate change envelope for a) baseline, and b) WCM. The metric values for 1939-2012 (no climate change) are provided for comparison (red line).

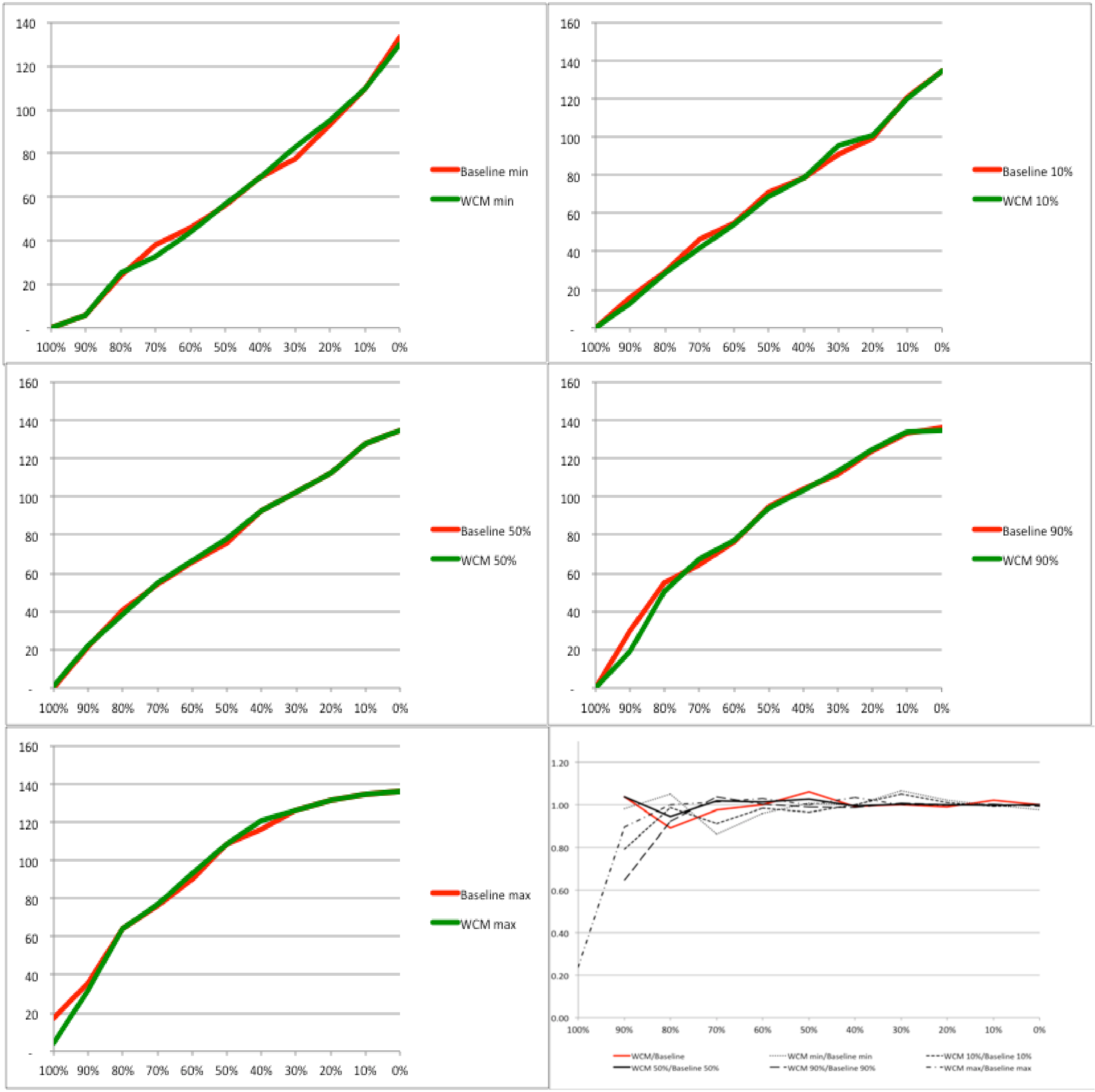


Figure 18.21 Comparison of S6a metric performance of baseline and WCM for the a) minimum, b) 10%, c) median, d) 90%, and e) maximum levels of the climate change envelope. Panel f) is the ratio (WCM/baseline) of the metric values at a given exceedance level for the minimum, 10%, median, 90% and maximum levels of the climate envelope (black lines) along with the ratio (WCM/baseline) with no climate change (red line).

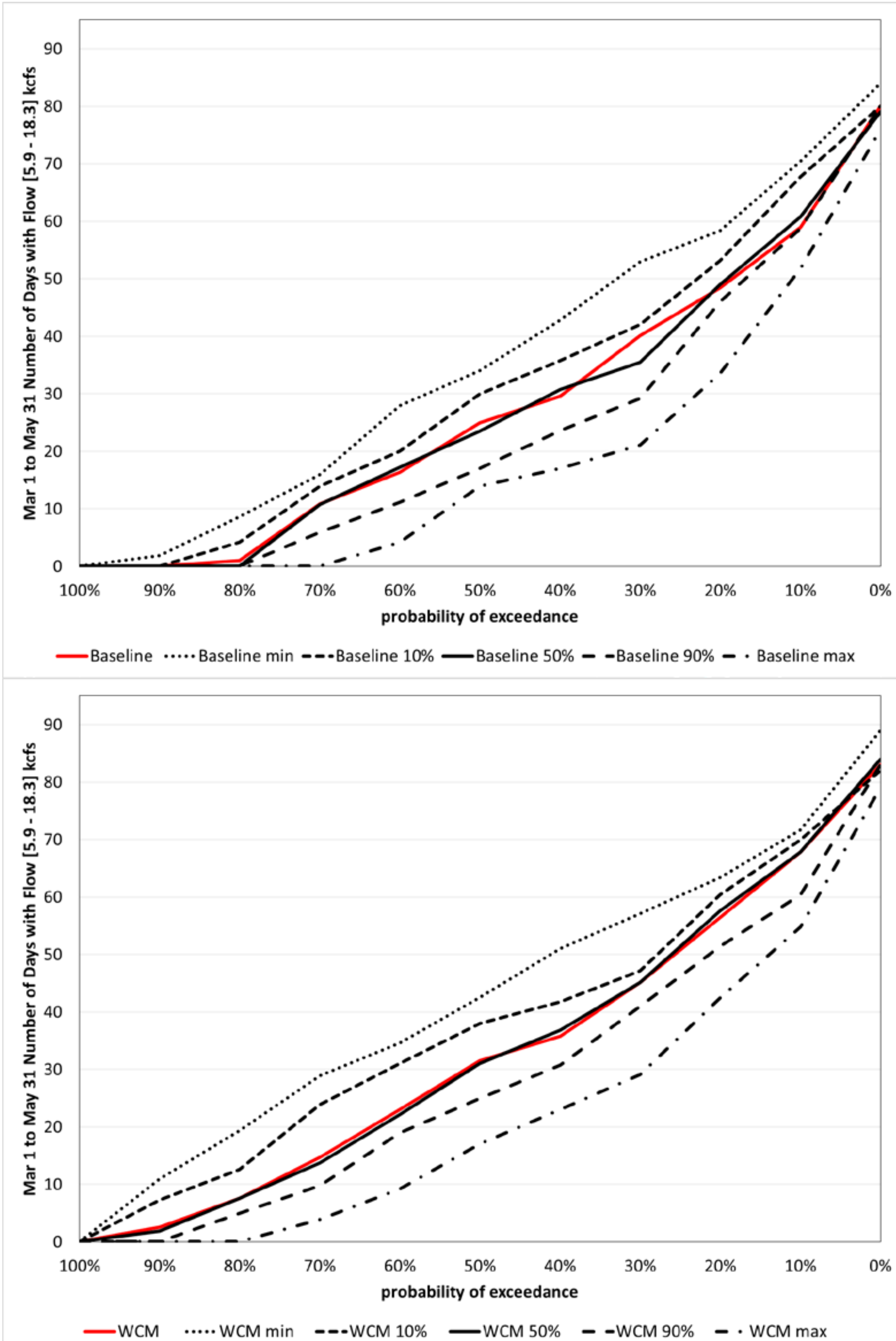


Figure 18.22 Response of metric SQ1 to the minimum, 10%, median, 90%, and maximum of the climate change envelope for a) baseline, and b) WCM. The metric values for 1939-2012 (no climate change) are provided for comparison (red line).

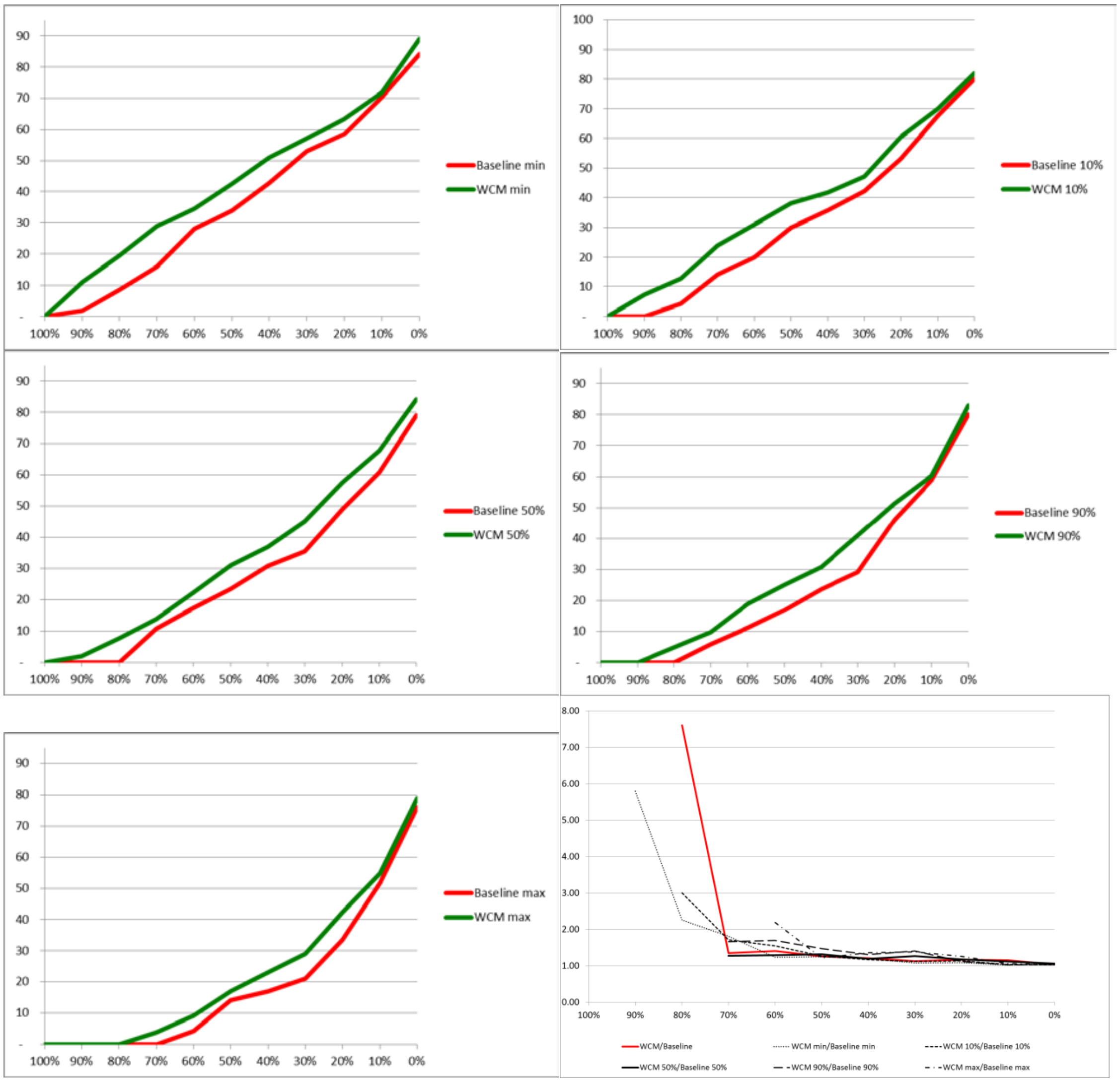


Figure 18.23 Comparison of SQ1 metric performance of baseline and WCM for the a) minimum, b) 10%, c) median, d) 90%, and e) maximum levels of the climate change envelope. Panel f) is the ratio (WCM/baseline) of the metric values at a given exceedance level for the minimum, 10%, median, 90% and maximum levels of the climate envelope (black lines) along with the ratio (WCM/baseline) with no climate change (red line).

Table 18.1: Median (across all available models) correlation of annual cycles for reaches 1-9 delineated in Figure 18.1

a) Median runoff vs. median UIF

region	1	2	3	4	5	6	7	8	9
value	0.92	0.98	0.96	0.96	0.98	0.99	0.98	0.93	0.56

b) Standard deviation of runoff vs. standard deviation of UIF

region	1	2	3	4	5	6	7	8	9
value	0.88	0.91	0.88	0.92	0.78	0.62	0.83	0.81	0.12

Table 18.2: R^2 values for regression fit between monthly unimpaired flow and runoff for reaches 1-9 delineated in Figure 18.1

a) R^2 values for a regression fit UIF = A*runoff+B

region	1	2	3	4	5	6	7	8	9
Jan	0.98	0.99	0.98	0.99	0.96	0.98	0.95	0.88	0.96
Apr	0.97	0.97	0.97	0.98	0.99	0.98	0.97	0.99	0.85
Jul	0.99	0.97	0.98	0.96	0.98	0.93	0.96	0.98	0.96
Oct	0.98	0.95	0.89	0.96	0.97	0.91	0.89	0.93	0.95

b) R^2 values for a regression fit UIF = C*runoff

region	1	2	3	4	5	6	7	8	9
Jan	0.91	0.90	0.89	0.97	0.91	0.98	0.91	0.88	0.94
Apr	0.96	0.95	0.94	0.97	0.88	0.96	0.96	0.99	0.84
Jul	0.98	0.87	0.91	0.73	0.91	0.93	0.96	0.93	0.96
Oct	0.98	0.86	0.78	0.92	0.88	0.91	0.85	0.88	0.95

The figures showing the sensitivity to climate changes for the remaining mussel and sturgeon metrics are show in the following figures.

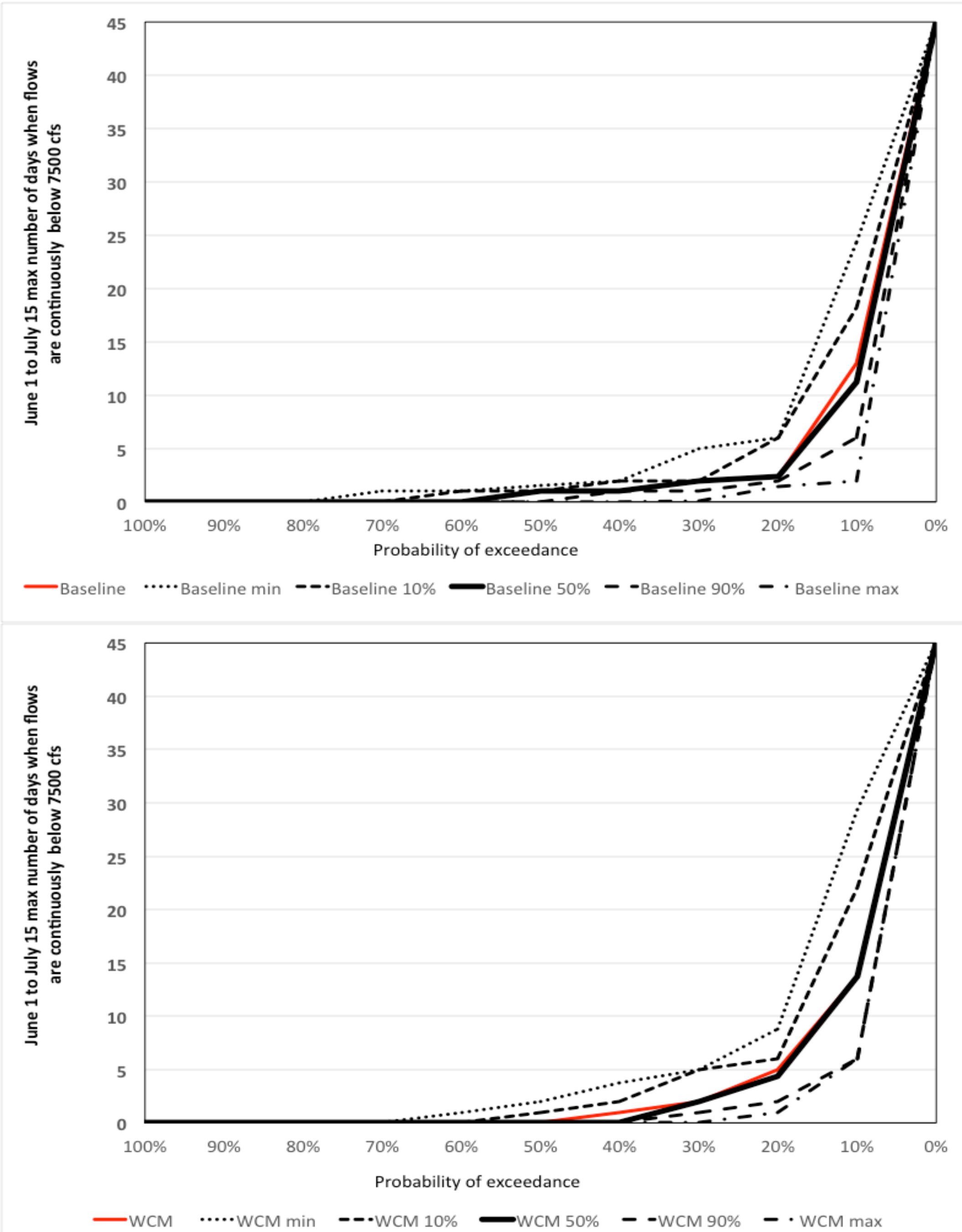


Figure 18.M9. Response of metric M9 to the minimum, 10%, median, 90%, and maximum of the climate change envelope for a) baseline, and b) WCM. The metric values for 1939-2012 (no climate change) are provided for comparison (red line).

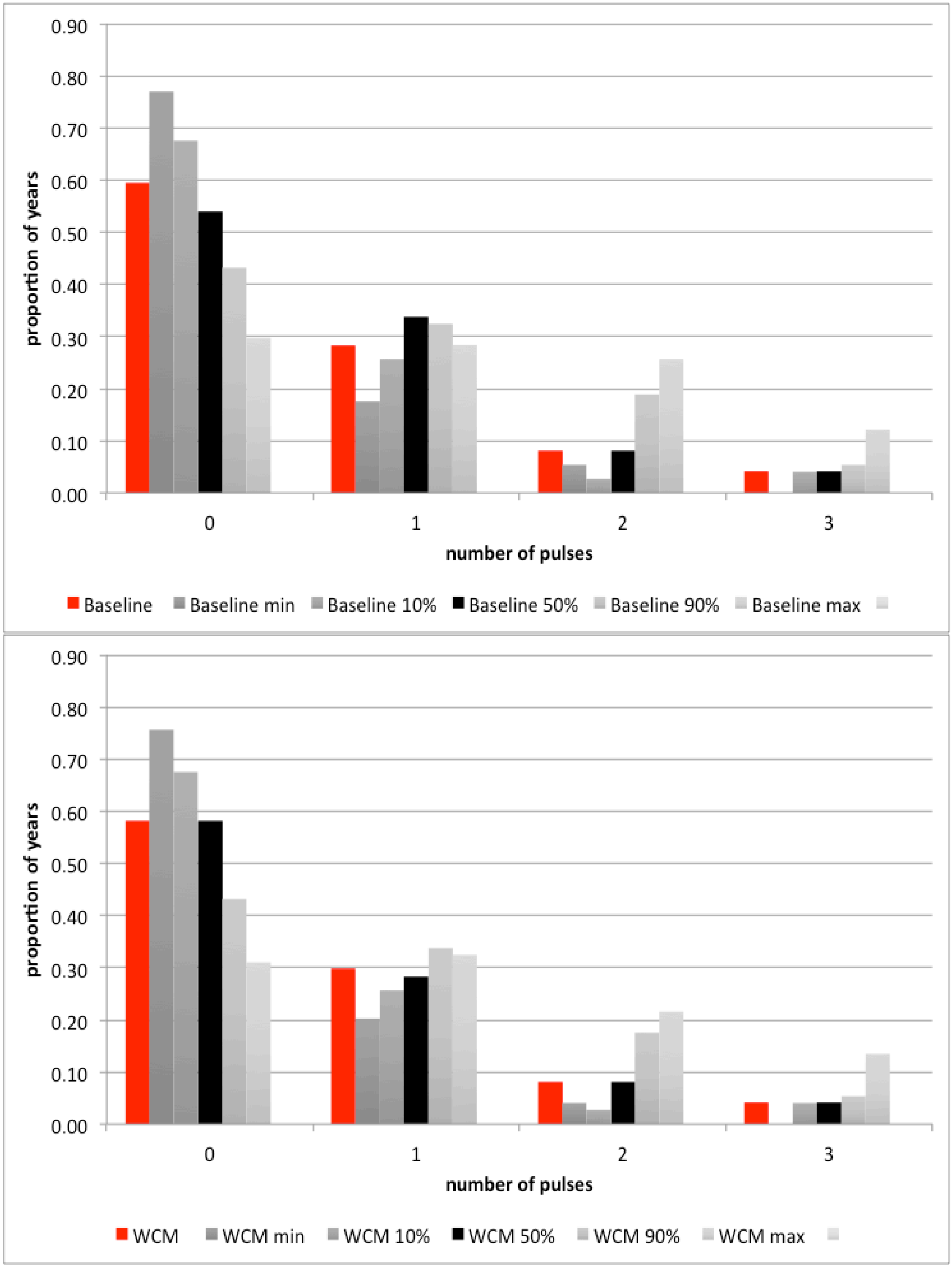


Figure 18.M6. Response of metric M6B to the minimum, 10%, median, 90%, and maximum of the climate change envelope for a) baseline, and b) WCM. The metric values for 1939-2012 (no climate change) are provided for comparison (red bar).

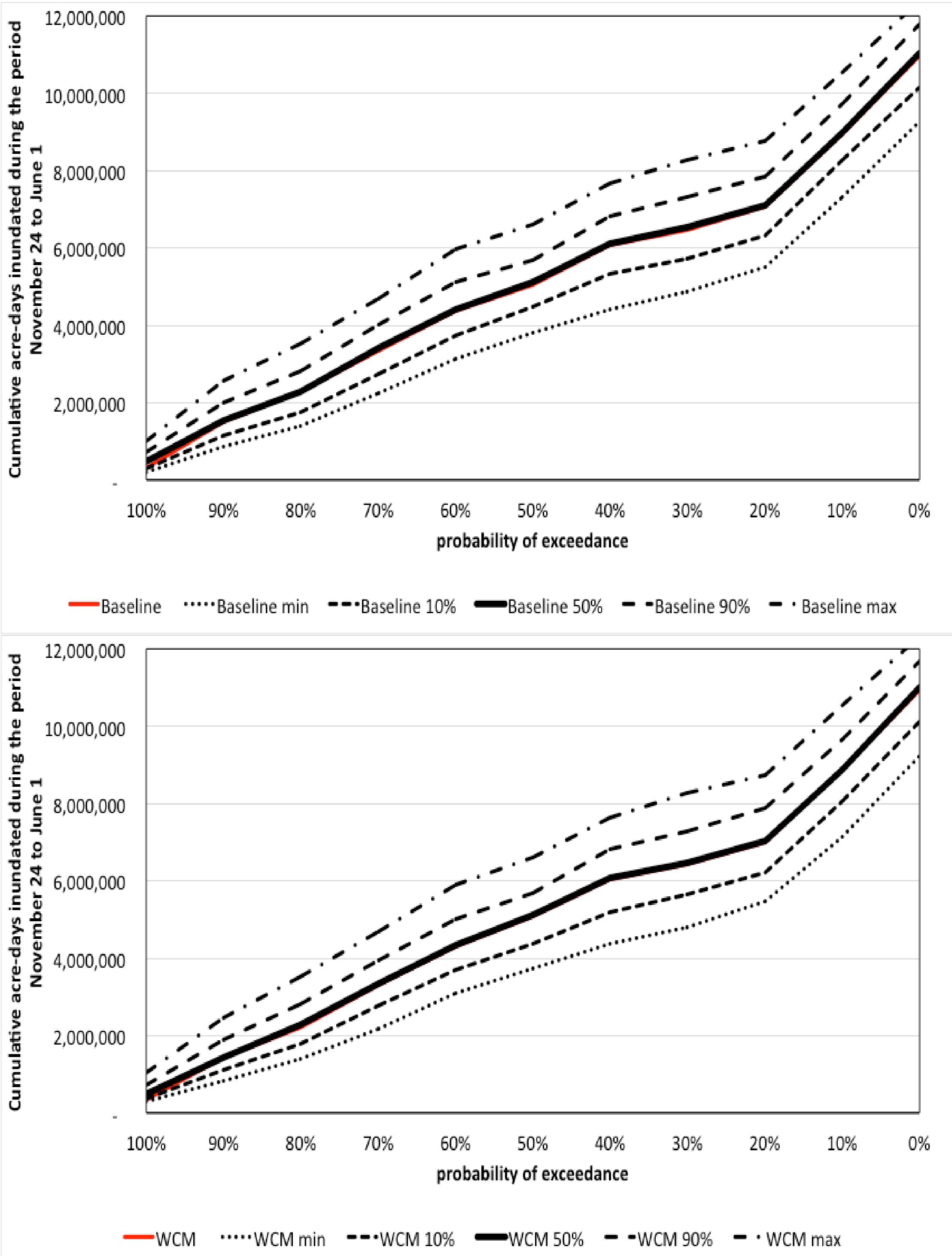


Figure 18.S2. Response of metric S2 to the minimum, 10%, median, 90%, and maximum of the climate change envelope for a) baseline, and b) WCM. The metric values for 1939-2012 (no climate change) are provided for comparison (red line).

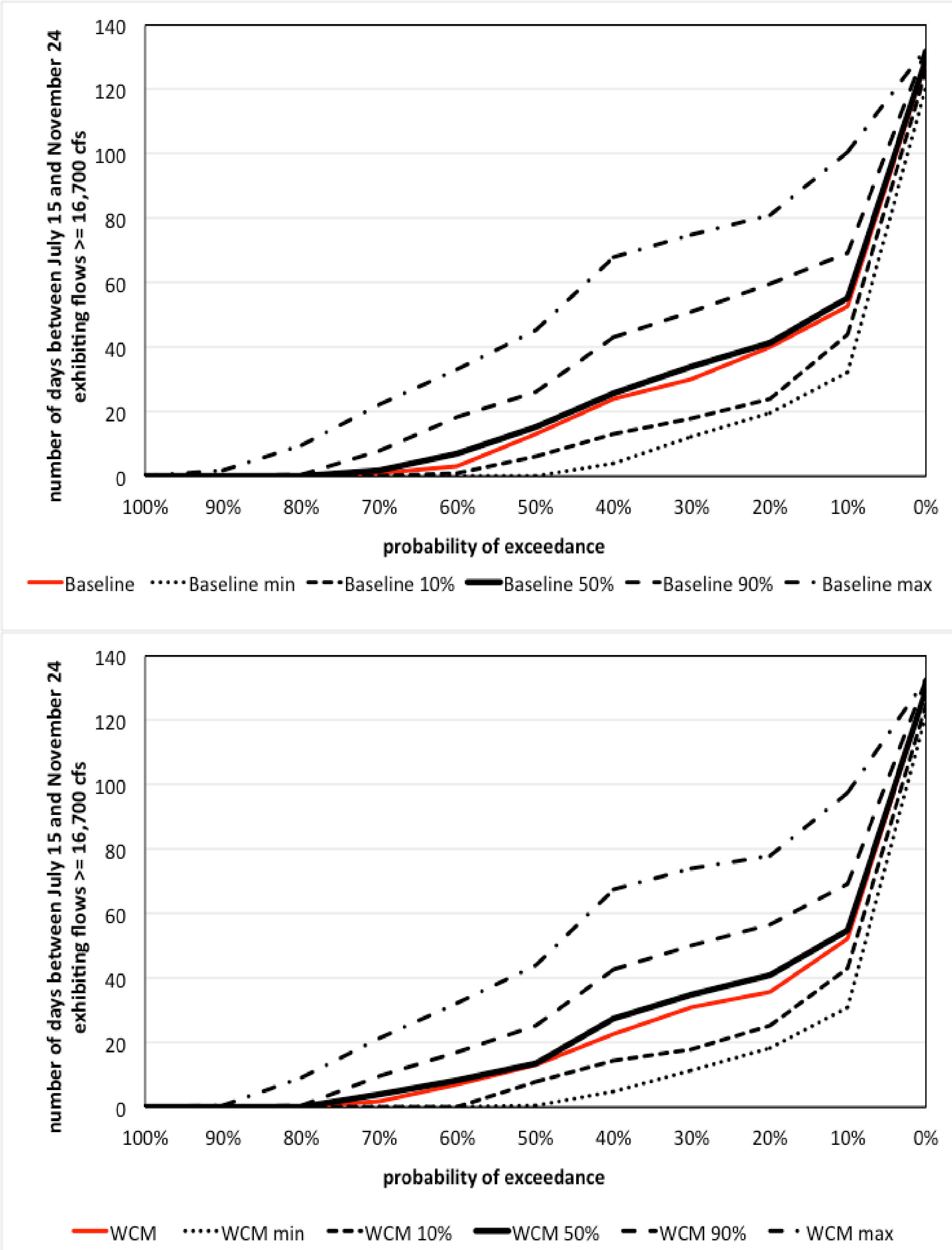


Figure 18.S3. Response of metric S3a to the minimum, 10%, median, 90%, and maximum of the climate change envelope for a) baseline, and b) WCM. The metric values for 1939-2012 (no climate change) are provided for comparison (red line).

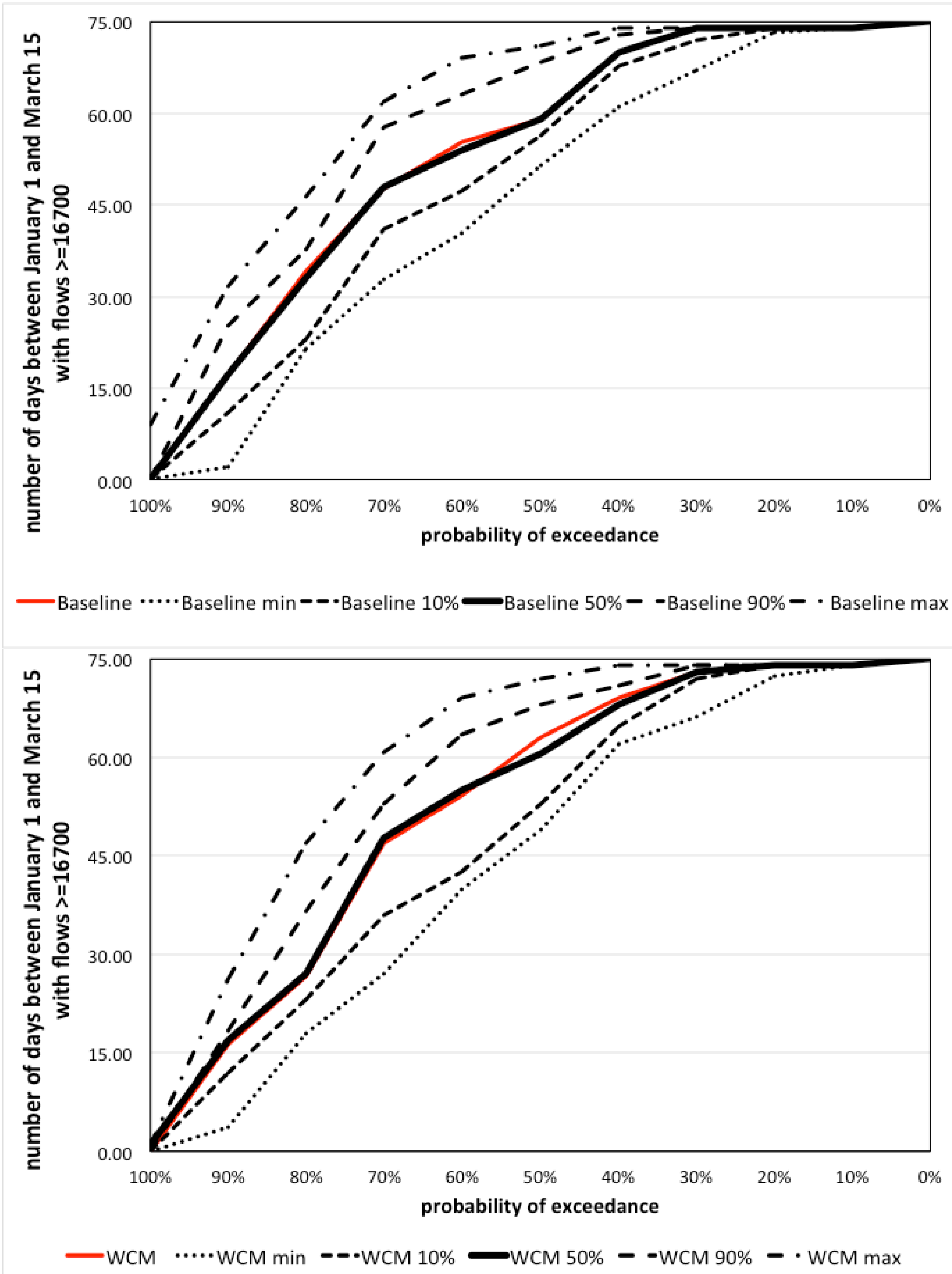


Figure 18.S7 Response of metric S7a to the minimum, 10%, median, 90%, and maximum of the climate change envelope for a) baseline, and b) WCM. The metric values for 1939-2012 (no climate change) are provided for comparison (red line).

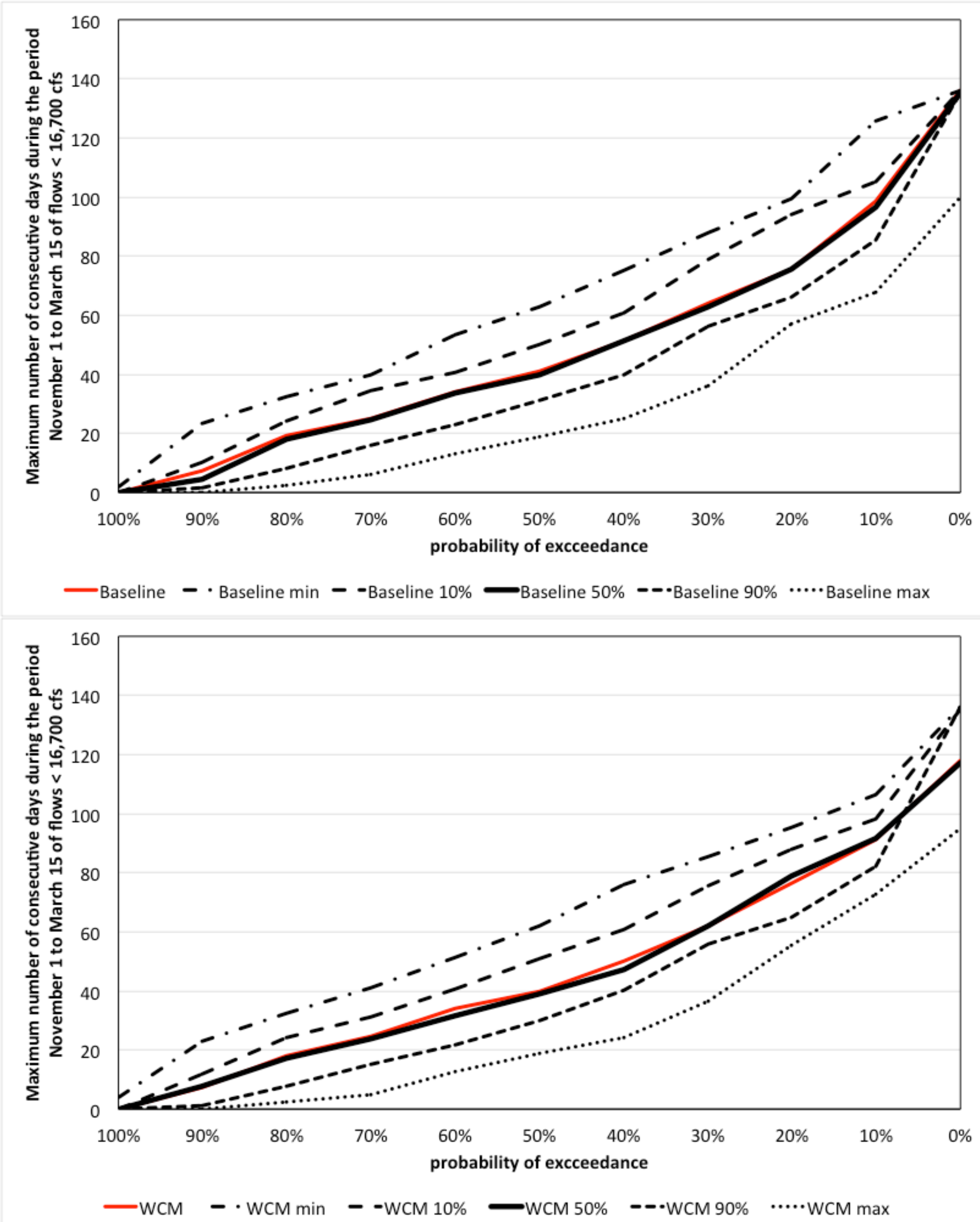


Figure 18.S8 Response of metric S8a to the minimum, 10%, median, 90%, and maximum of the climate change envelope for a) baseline, and b) WCM. The metric values for 1939-2012 (no climate change) are provided for comparison (red line).

19 APPENDIX C. USFWS IDENTIFIED ECOLOGICAL GAPS FOR ADAPTIVE MANAGEMENT

For consideration with Term and Condition 9.4.1, Adaptive management, the following uncertainties about ACF basin system dynamics should be evaluated by the adaptive management working group for inclusion in the adaptive management framework:

<u>Supporting mussels and sturgeon uncertainties related to action</u>

1. What are the upstream and downstream passage requirements of Gulf Sturgeon, Alabama shad and Gulf striped bass (all identified or proposed mussel hosts) at USACE dams in the ACF Basin. These uncertainties surround entrainment, both upstream and downstream adult and juvenile passage, and consider spill, flow attraction, and temperature.
2. How does hydropeaking affect listed mussel and sturgeon habitat near Woodruff?
3. How does water temperature affect listed species and can operations influence temperature?
    1. What is thermal availability of habitat in the Apalachicola?
    2. What is thermal habitat in Flint & Apalachicola and changes in reservoirs?
    3. What is relationship between flow and air temperature across the ACF basin?
    4. What happens at RM 55-60 to cause changes in DO & temp? see Harvey et al. report from 2008 or 2009 and make it a great spot for mussels

<u>Mussel spp. uncertainties related to action</u>

1. Do juvenile mussels have cues for dropping off of fish hosts?
    a. Are there cues that cause them to drop in mass in certain locations? (Examine in purple bankclimber)
2. What is effect of 2-3 ft/15 min drop in water level on mussel survival, and other life history characteristics
    a. What are daily stranding rates on this fine a scale? (i.e., how long can you hold your breath?)
    b. How far down the river before these pulses are attenuated and what does this mean for floodplain inundation and stranding?
3. What is the role of inter-annual variation in structuring mussel populations?
    a. Do several wet years make floodplains good mussel habitat and do these big production years drive the viability of the population?
4. What is duration of refill under drought conditions that mussels can recolonize?
5. How do mussels respond to temperature variances in habitat? Can they behaviorally thermo-regulate? (can do caged studies)
6. What is the ratio of number of host fishes to viable juvenile mussels in the Apalachicola?
7. What makes habitat in the lower Chipola River more ideal for mussels than the Apalachicola?
8. What is the proportion of the mussel population that is gravid?

<u>Gulf sturgeon uncertainties related to action</u>

4. Effect of flow on salinity in the bay on juvenile sturgeon
    1. How does this change foraging habitat available for juvenile sturgeon?
5. What is relationship between flow in winter and juvenile sturgeon survival (year class strength)?
6. What is the effect of temperature on spawning, holding areas, and foraging for sturgeon?
7. Are there seasonal shifts in juvenile sturgeon diet across the year and what range does floodplain inundation play in structuring this available food?

Supporting biology of the overall system

1. Hydrological uncertainties
    a. What is the relationship of groundwater and precipitation in each sub-basin?
    b. What is the respective contribution of the reservoirs vs. rivers vs. groundwater?
2. Climate change uncertainties
    a. How does climate change structure and regulate growth of the floodplain system?
    b. How does uncertainty about precipitation and evapotranspiration in the basin influence management?

20 APPENDIX D. POTENTIAL ACTIONS FOR ADAPTIVE MANAGEMENT

In the process of the WCM being prepared, the USFWS internally developed an alternative for consideration (USFWS 2013a). This alternative (labeled USFWS in the figures below) was developed based on a set of performance metrics which represented the best scientific understanding of what was needed to protect Gulf sturgeon, mussels and the associated floodplain of the Apalachicola River. Since development of this alternative the scientific understanding of what is needed to protect these species has advanced and a new set of metrics have been developed which are included in this BO to aid in identifying potential actions that could be addressed within the authority of the WCM through adaptive management under RPM 2016-1. The analyses in this appendix should be revisited once the STELLA model calibration is complete as described in Appendix A.

Identical metrics calculated for the mussel metrics were calculated to show five flow regimes (Baseline [NAA], WCM [PAA], USFWS, UIF, and where applicable pre-dam conditions). We present modified versions of the figures presented in sections 5 and 10 with comparison of the USFWS alternative to the other flow regimes.

The intention of including the USFWS alternative in the following figures is to illustrate that it is possible to better protect these species if management is designed to accomplish this task. In the future, an alternative approach to managing the basin can be designed based on the current set of environmental metrics. This USFWS alternative as well as UIF and pre-dam conditions can be used to inform and explore potential actions to be considered by the adaptive management technical team under RPM 2016-1. Based on the insights from the USFWS alternative, the adaptive management technical team should explore potential actions that relative to the baseline in this consultation:

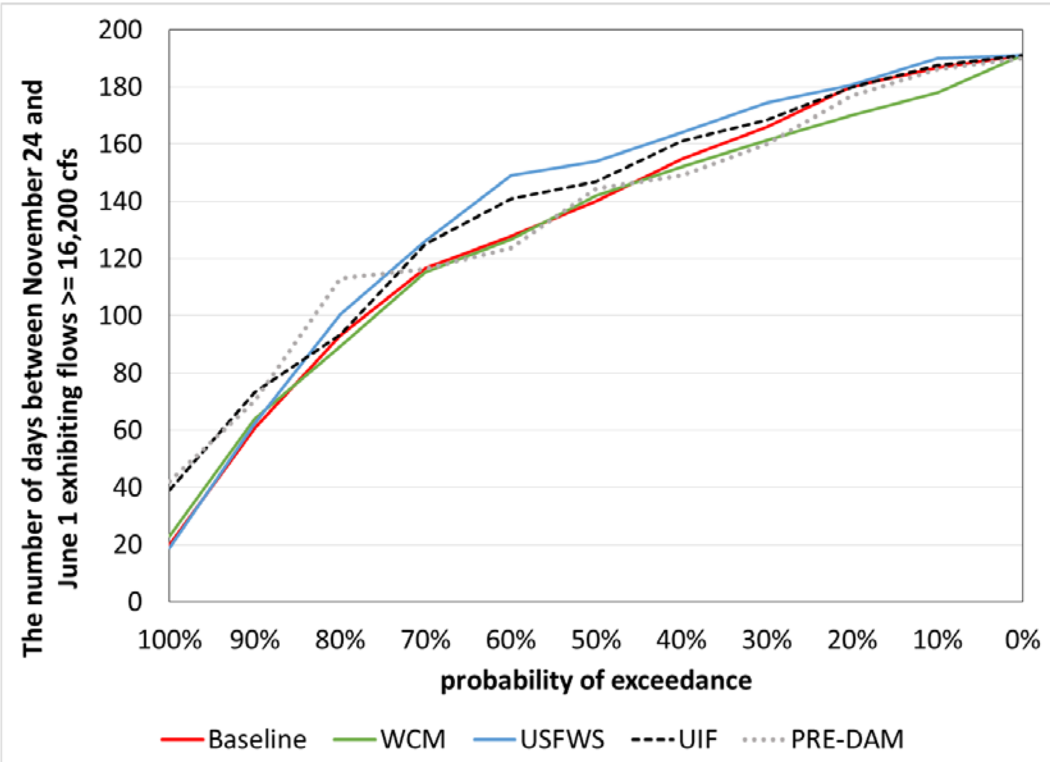
1) Provide more floodplain inundation
    a. ~10 days more in the winter (GS1)
    b. ~1% more (in terms of acres) (GS4), and ~10% more 15-day pulses (GS5, M6) in the summer and fall
    c. ~20 more days during the growing season (M1-M3)
2) Reduce the conditions appropriate for hydropeaking at Jim Woodruff
    a. ~3% fewer days during spring (GSQ1)
3) Maintain more stability near the low flow threshold (e.g., 5,000 cfs) when flows are below 10,000 cfs (M4-M8)

20.1 Sturgeon Analyses

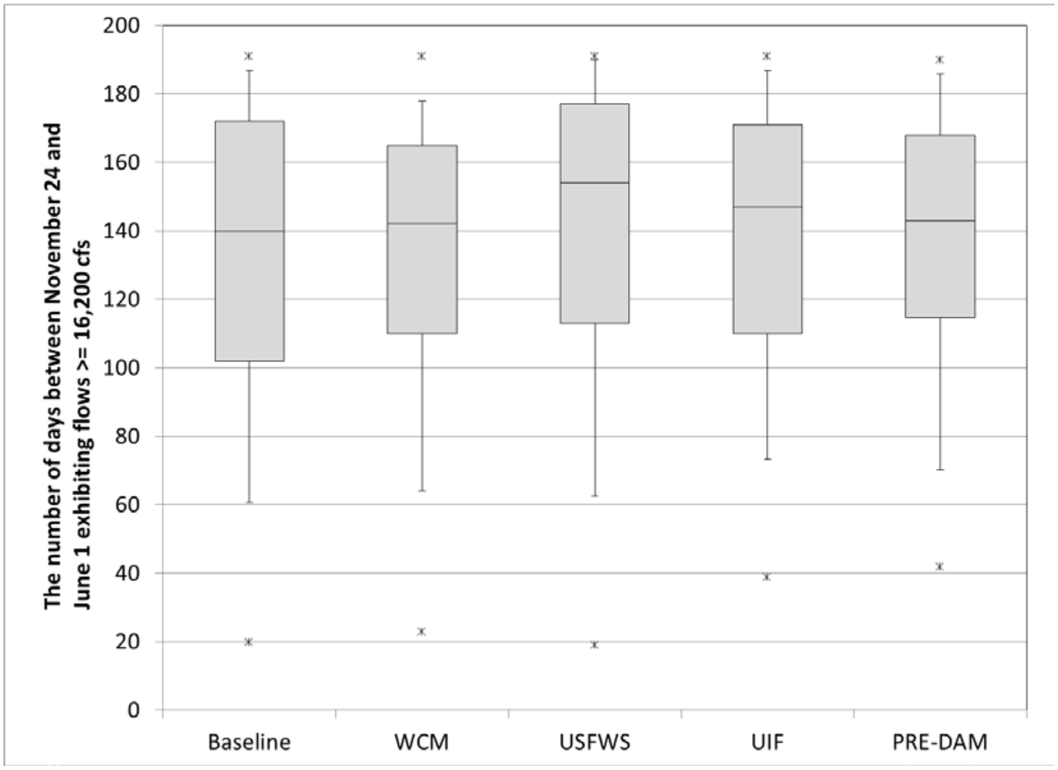
20.1.1 Flows for Estuarine Invertebrate Production

Gulf Sturgeon Hydroecological Metric 1 (GS 1) - General Floodplain Forest Inundation and Organic Matter Supply (Total Days)

The USFWS plan provides on average 6.7 days (505 days across the 74 years) more of floodplain inundation during November 24 to June 1 than the baseline. In the average year (i.e., 50% exceedance), the USFWS plan exhibited a benefit of 14 more days of floodplain inundation compared to the baseline and overall provided 4% more days of floodplain inundation than the baseline (10243 of 19832 days vs. 9738 days under the baseline). Additionally, the USFWS plan provided floodplain inundation similar to that expected under the Unimpaired Flow scenario (on average <1 days more) or pre-dam conditions (on average 3.5 days more).



A



B

Figure 20.1.1: Number of days with flows ≥16,200 cfs for the Apalachicola River at Chattahoochee between November 24 and June 1 as a probability of exceedance plot (A) and box plot (B)

Gulf Sturgeon Hydroecological Metric 4 (GS 4) - General Floodplain Forest Inundation and Nutrient Supply (Cumulative Acre-days)

The USFWS plan was not designed to provide inundation at this timing. The USFWS plan provides on average 747,059 acre-days (of 781 mil total) less of floodplain inundation during July 15 and November 24 than the baseline. As with the WCM, this difference comes primarily in years with lower inundation (i.e., 90-70% exceedance). Additionally, the USFWS plan provided less floodplain inundation to that expected under the Unimpaired Flow scenario (about 1.2% less) as did the baseline and WCM.

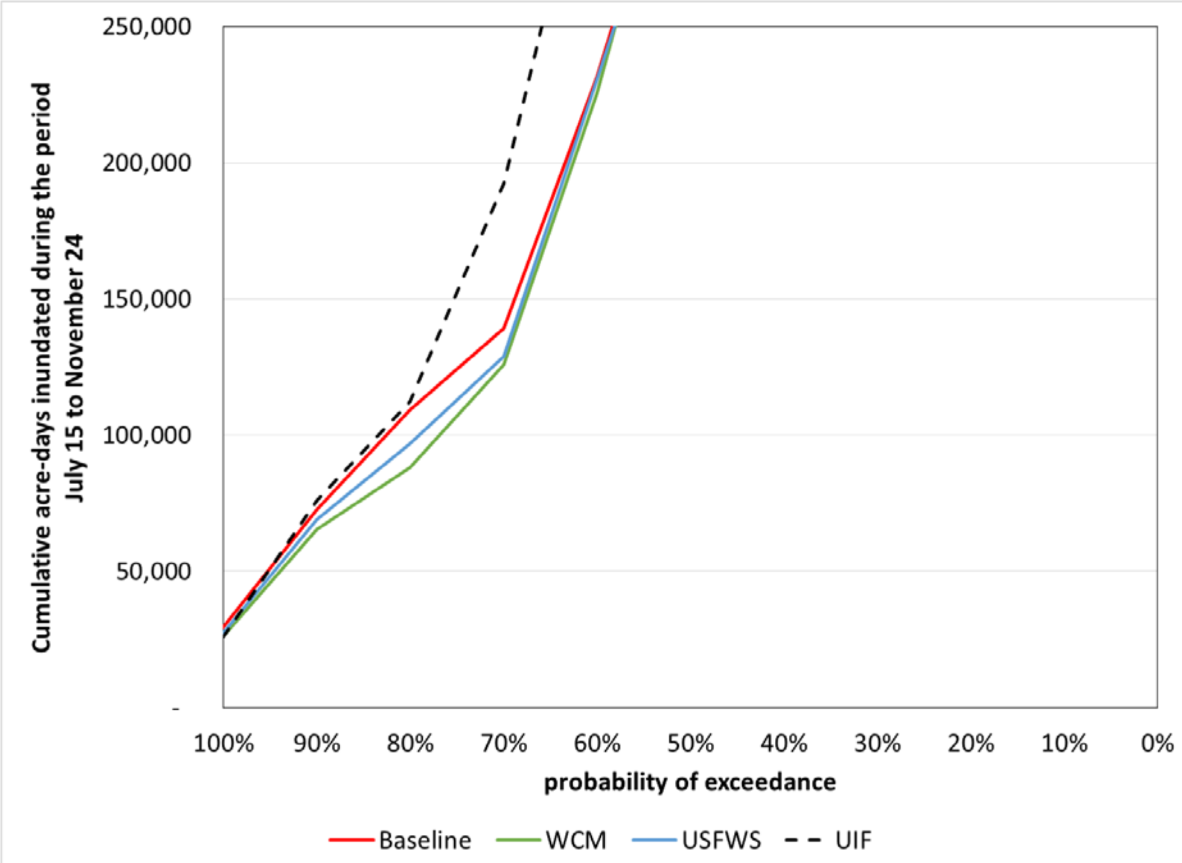
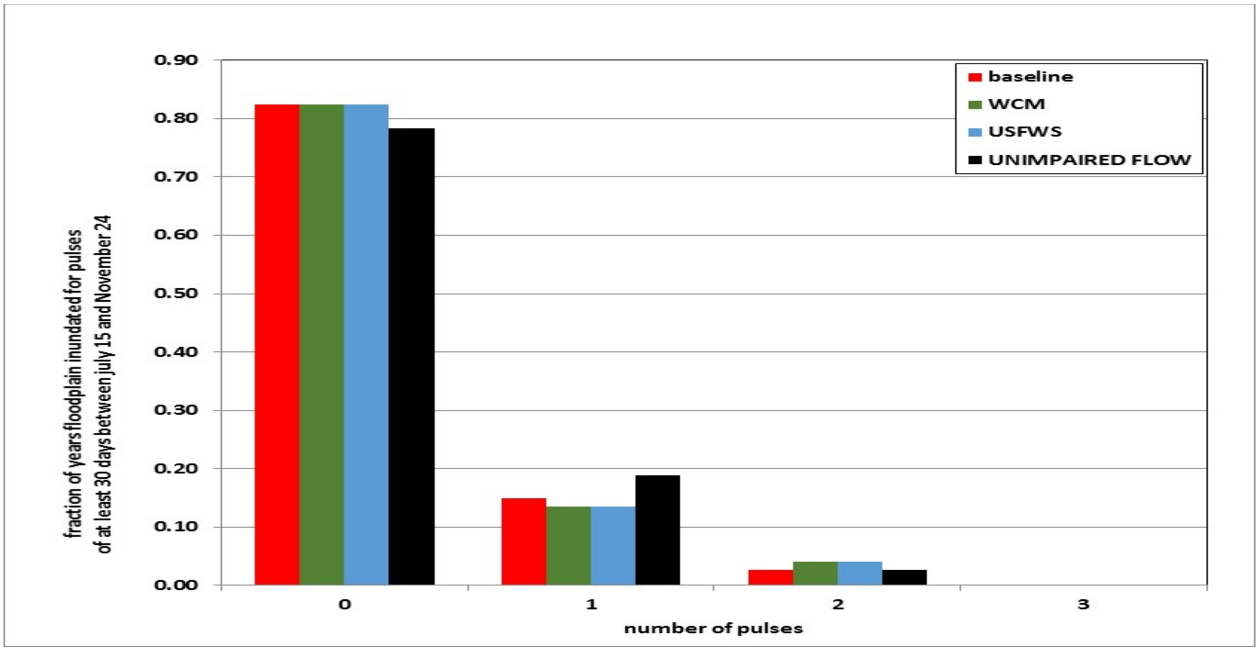


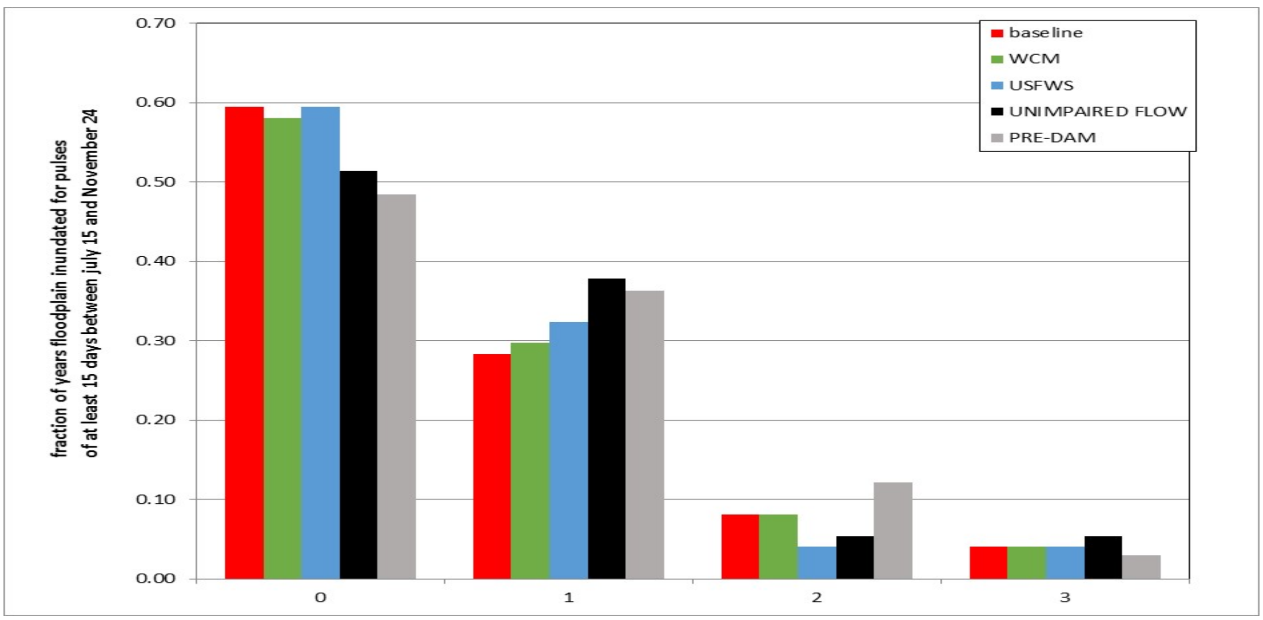
Figure 20.1.2: Total number of acre-days of floodplain inundation at ≥16,200 cfs between July 15 and November 24 for the Apalachicola River at Chattahoochee

Gulf Sturgeon Hydroecological Metric 5 (GS 5) - Pulsed Floodplain Forest Inundation and Nutrient Supply (Number of pulses)

The USFWS management plan provides an identical number of years as the WCM with one and two 30-day floodplain pulses between July 15 and November 24 across the 74-year record (13 years or 18% of the time) and one fewer years with a single 30-day pulse and one more year with two 30-day pulses than the baseline. These 30-day pulses are equivalent to the pre-dam record, but represent a decrease from the UIF scenario (16 years or 22%). Looking at the shorter 15-day pulses provides a different picture when comparing to the baseline and WCM or the pre-dam record or UIF scenarios. The USFWS management plan provides one fewer years than the WCM with one, two, or three 15-day floodplain pulses between July 15 and November 24 across the 74-year record and an equivalent number of years with 15-day pulses as the baseline (30 years or 41% of the time). It provides the pulses as three additional years with single 15-day pulses. These 15-day pulses represent an 11% drop (8 years) from the pre-dam record and a 8% drop (6 years) from the UIF scenario. Thus, we see fewer 15-day pulses than we did historically or if flows through the basin were unimpaired.



A



B

Figure 20.1.3: Fraction of years the Apalachicola River's floodplain was inundated by pulses of at least 30 days (A) and 15 days (B) between July 15 and November 24.

20.1.2 Effects on Spawning Habitat Availability and Quality

Gulf Sturgeon Egg and Fry Exposure and Survival during Hydropeaking (GS Q1)

The USFWS plan provides on average 2.3 days (225 days across the 74 years) less opportunity to hydropeak during the March 1-May 31 sturgeon spawning season than the baseline. In the average year (i.e., 50% exceedance), the USFWS plan exhibited a benefit of 15 fewer days of hydropeaking compared to the baseline and overall provided 3% less opportunity to hydropeak than the baseline (1757 of 6808 days vs. 1982 days under the baseline). In addition, the USFWS plan provided floodplain inundation similar to that expected under the Unimpaired Flow scenario (on average <1 days less) or pre-dam conditions (on average 1.6 days less).

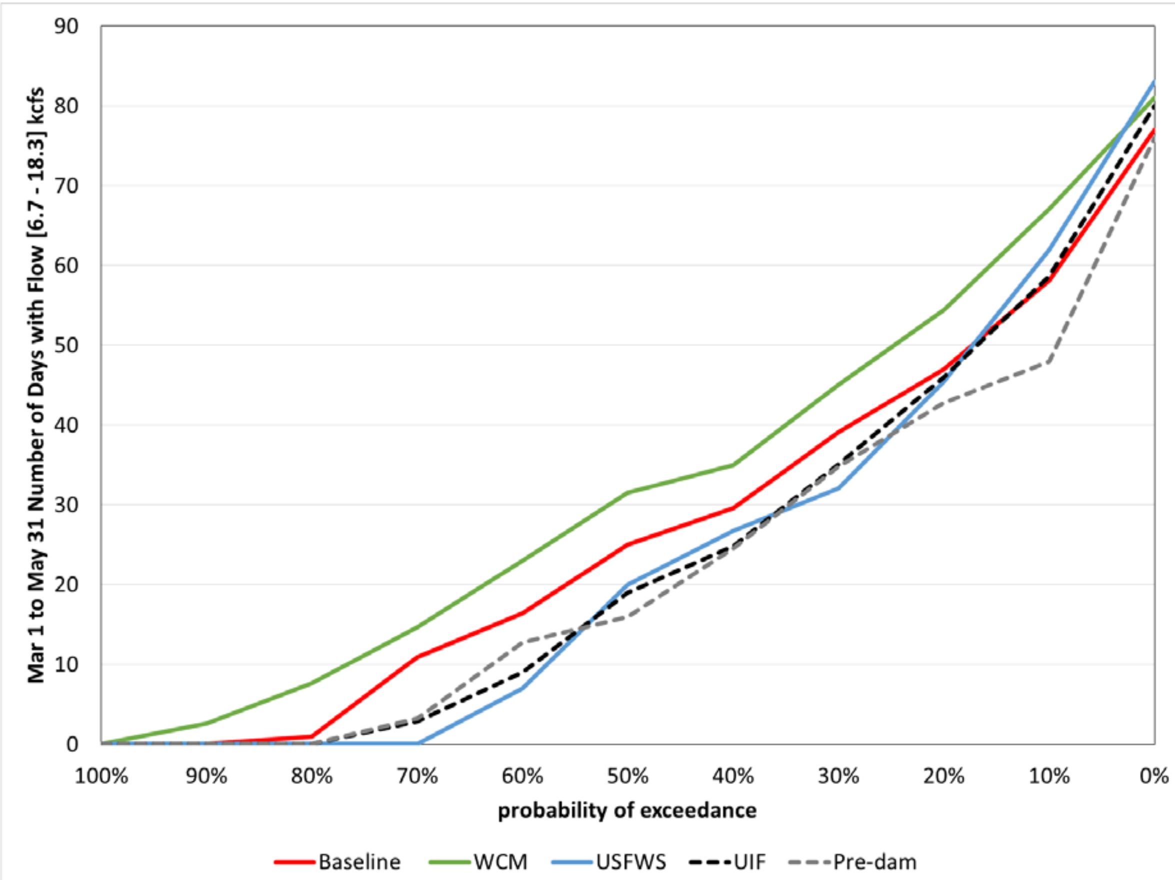


Figure 20.1.4: Number of days with flows between 6,700 and 18,300 cfs for the Apalachicola River at Chattahoochee between March 1 and May 31

20.2 Mussel Analyses

20.2.1 Flows for Mussel Host Fish Production

Freshwater Mussel Hydroecological Metric 1 - Access to Floodplain for Spawning and Rearing of Host Fish

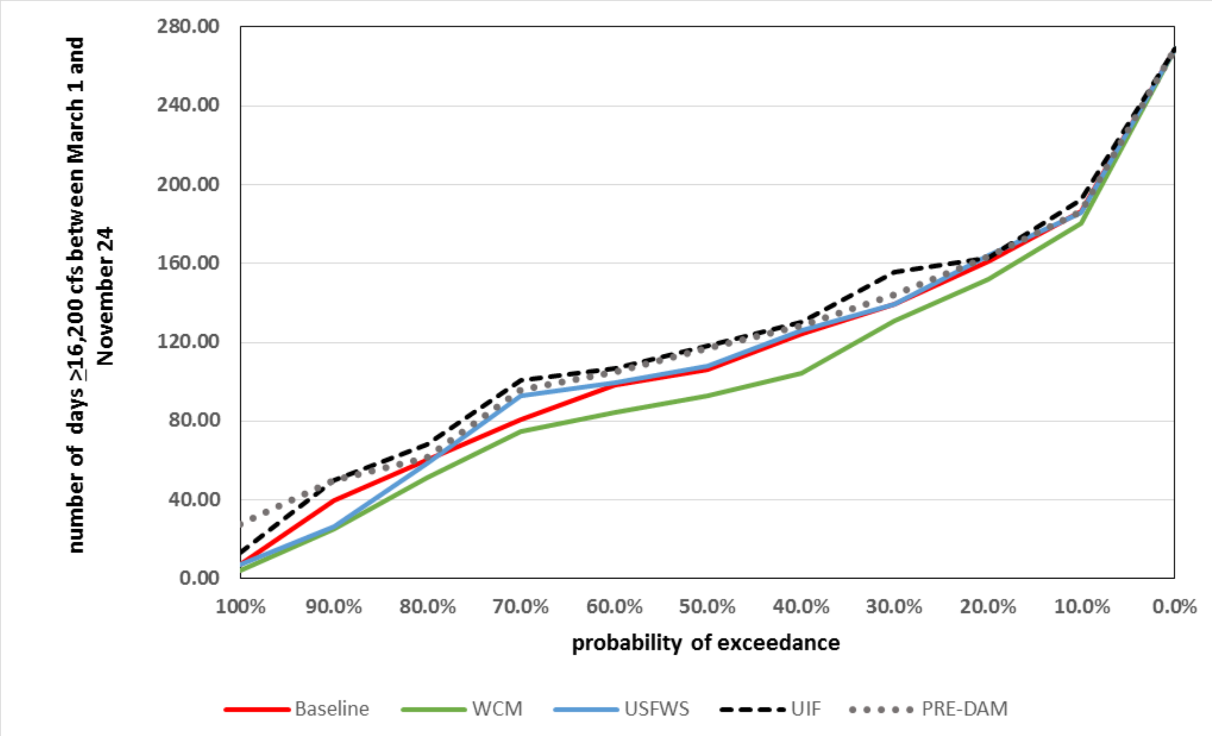


Figure 20.2.1: number of days' flow for the Apalachicola River at Chattahoochee ≥ 16,200 cfs between March 1 and Nov 24

The USFWS management plan provided for greater number of days of floodplain inundation across most years of examination compared to the WCM (140 day increase total, 12 day average increase per exceedance probability decile) and baseline (21 day increase total, 2 day average increase per exceedance probability decile), with the exception of those years exhibiting the lowest number of days of inundation (i.e., the driest years; probability of exceedance range 80-100%). During years of low floodplain inundation, the USFWS management plan results were similar to that of the WCM and baseline. The USFWS plan exhibited the highest benefit with an added 12 days of floodplain inundation compared to the baseline at 70% probability of exceedance. However, the USFWS plan did not provide floodplain inundation similar to that expected under the Unimpaired Flow scenario (99 days less) or pre-dam conditions (96 days less).

Freshwater Mussel Hydroecological Metric 2 - Access to Floodplain for Spawning of Host Fish

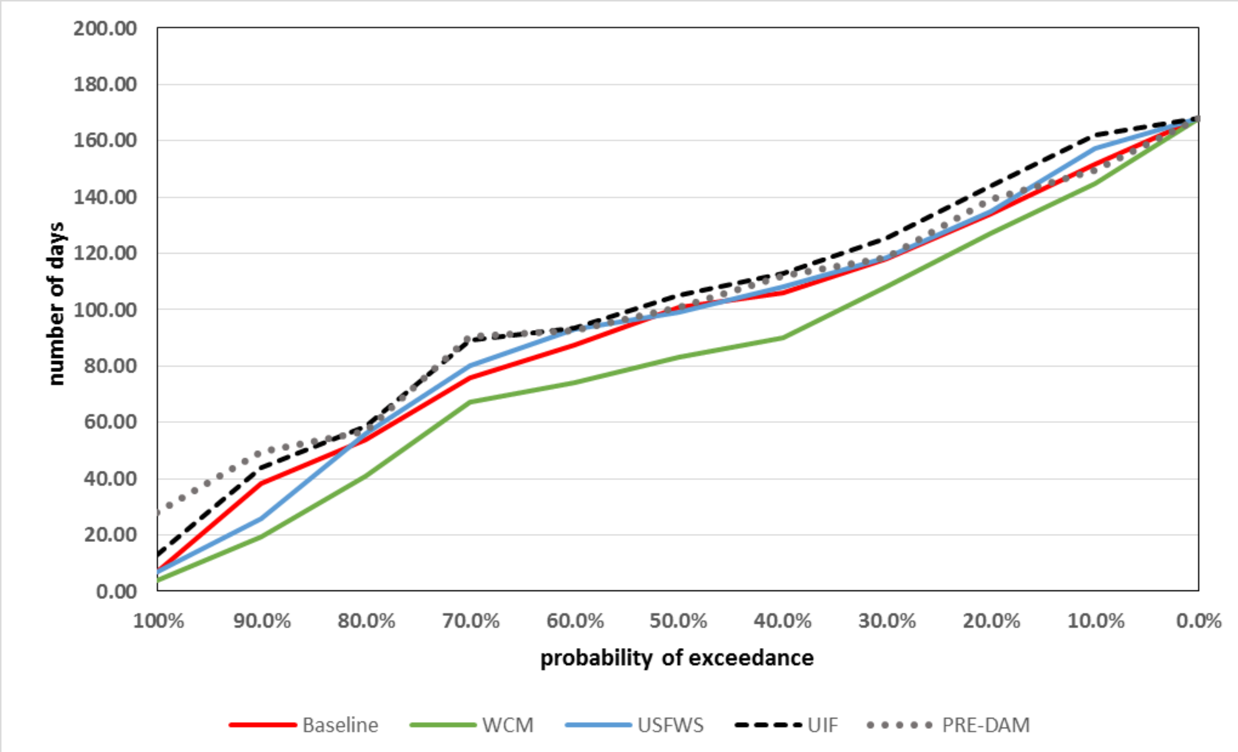
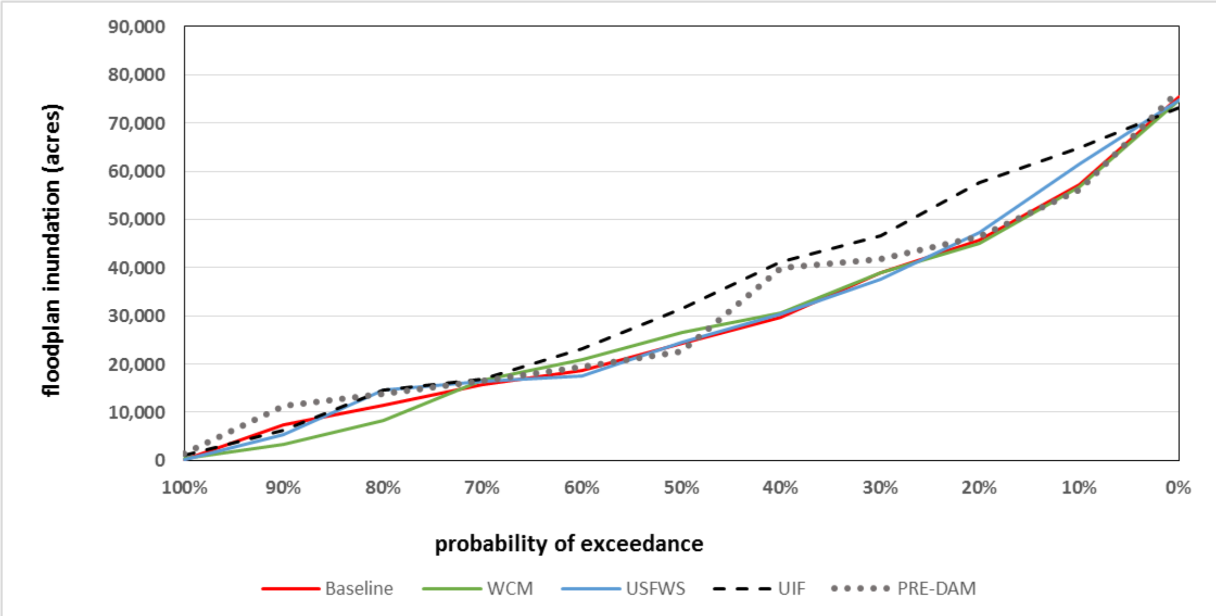


Figure 20.2.2: number of days' flow for the Apalachicola River at Chattahoochee ≥ 16,200 cfs between March 1 and Aug 15

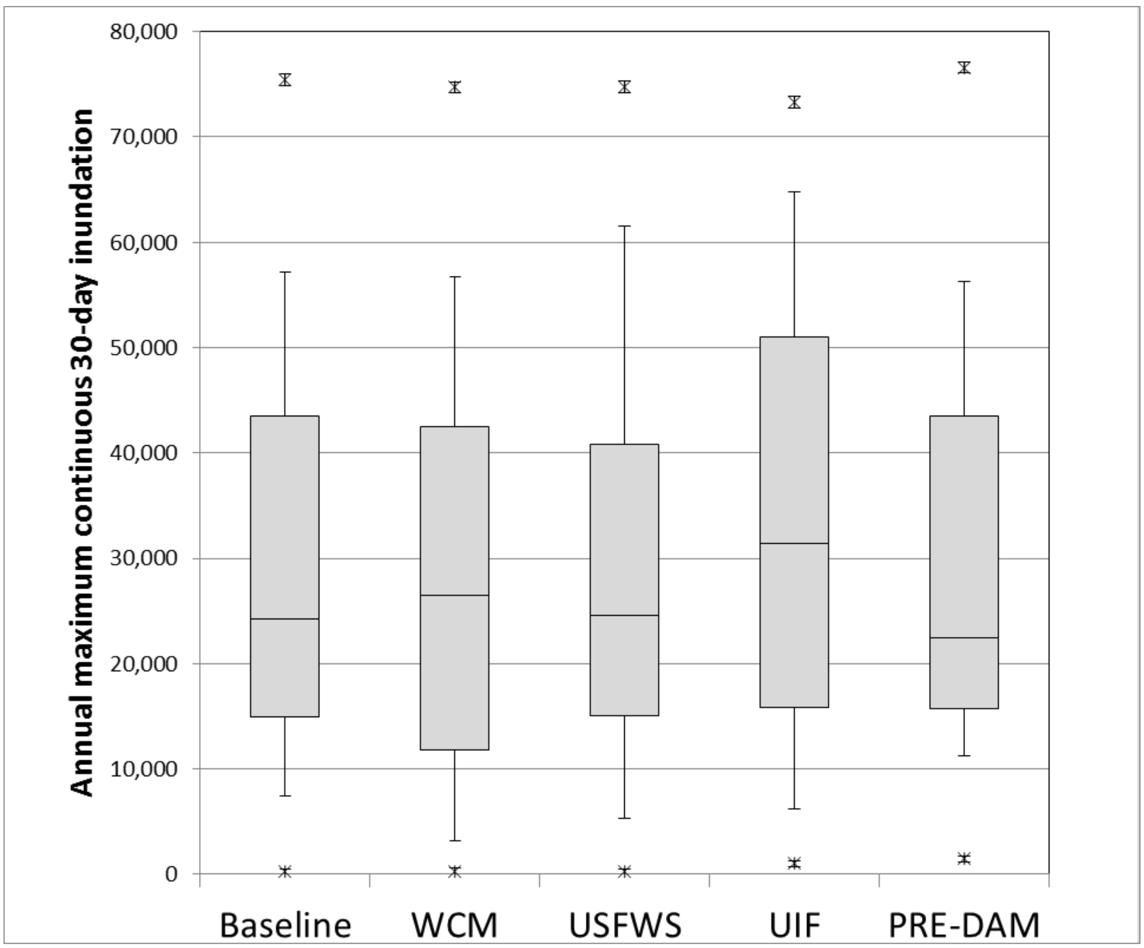
The USFWS management plan provided for greater a number of days of floodplain inundation across most years of examination compared to the WCM (119 day increase, 11 days on average per exceedance probability decile) and baseline (3 day increase, 0.3 days on average per exceedance probability decile), with the exception of those years exhibiting the lowest number of days of inundation (i.e., the driest years; probability of exceedance range 90-100%). During years of low floodplain inundation, the USFWS management plan results were similar to that of the WCM and baseline. The USFWS plan exhibited the highest benefit with an added 5 days of floodplain inundation compared to the baseline at 60% probability of exceedance. However, the USFWS plan did not provide floodplain inundation similar to that expected under the Unimpaired Flow scenario (68 days less) or pre-dam conditions (58 days less).

Freshwater Mussel Hydroecological Metric 3 - Access to Floodplain for Spawning of Host Fish



floodplain inundation (acres)
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
probability of exceedance
Baseline
WCM
USFWS
UIF
PRE-DAM

A



Annual maximum continuous 30-day inundation
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Baseline
WCM
USFWS
UIF
PRE-DAM

B

Figure 20.2.3: Floodplain acres inundated between March 1 and Aug 15 as a probability of exceedance plot (A) and box plot (B)

The USFWS management plan provided for greater floodplain inundation compared to the WCM (8159 ac increase) and baseline (5088 ac increase), and provided only a 298 ac increase at the median. However, similar to the WCM, the USFWS plan had both beneficial and adverse effects across the range of wet to dry years. During years of low floodplain inundation (i.e., drier years), the USFWS management plan results were similar to that of the WCM and baseline. The USFWS plan reduced floodplain inundation by 2113 ac compared to the baseline at 90% probability of exceedance (i.e., the driest years) and reduced by 1367 ac at 30% probability of exceedance (i.e., slightly wetter years). The USFWS plan exhibited the highest benefits with an added 3000 ac of floodplain inundation compared to the baseline at 80% probability of exceedance (i.e., drier years) and an added 4351 ac at 10% probability of exceedance (i.e., wetter years). Further, the USFWS plan did not provide floodplain inundation similar to that expected under the Unimpaired Flow scenario (46,927 ac less) or pre-dam conditions (15,891 ac less).

20.2.2 Flows for Mussel Host Fish Infection and Juvenile Mussel Recruitment

Freshwater Mussel Hydroecological Metric 4 - Low Flows during Host Infection and Juvenile Settlement

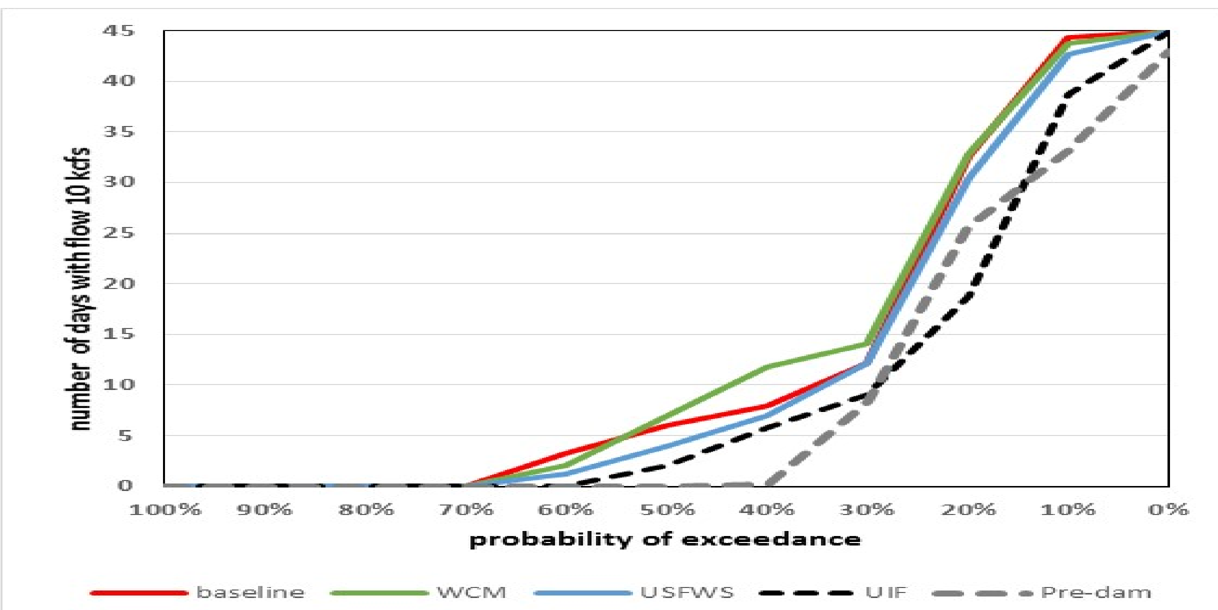


Figure 20.2.4: Number of days flows for the Apalachicola River at Chattahoochee are less than 10,000 cfs between June 1 and July 15.

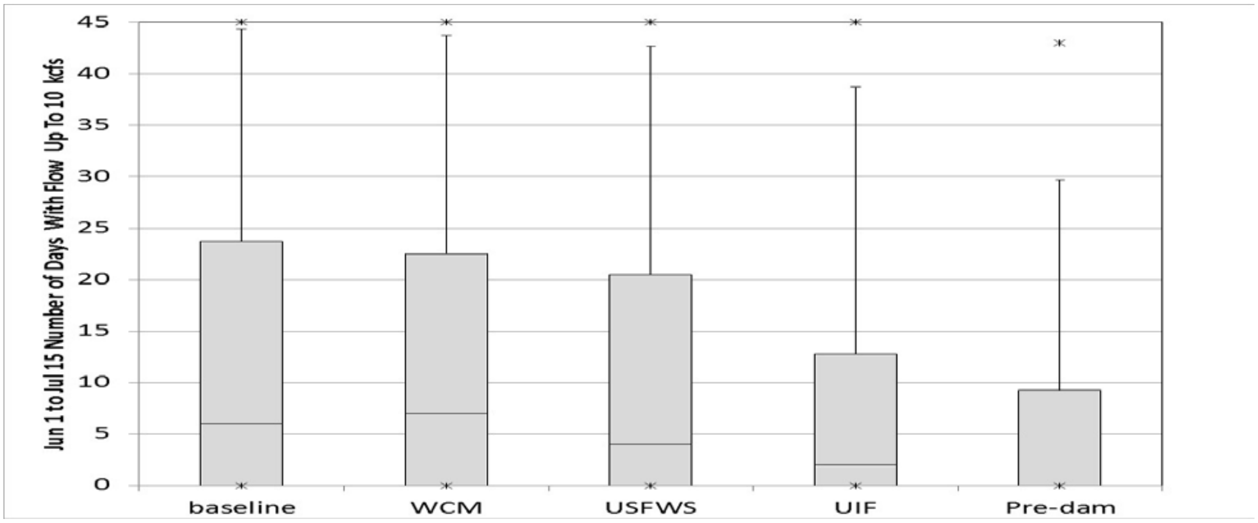


Figure 20.2.5: Number of days flows for the Apalachicola River at Chattahoochee are less than 10,000 cfs between June 1 and July 15.

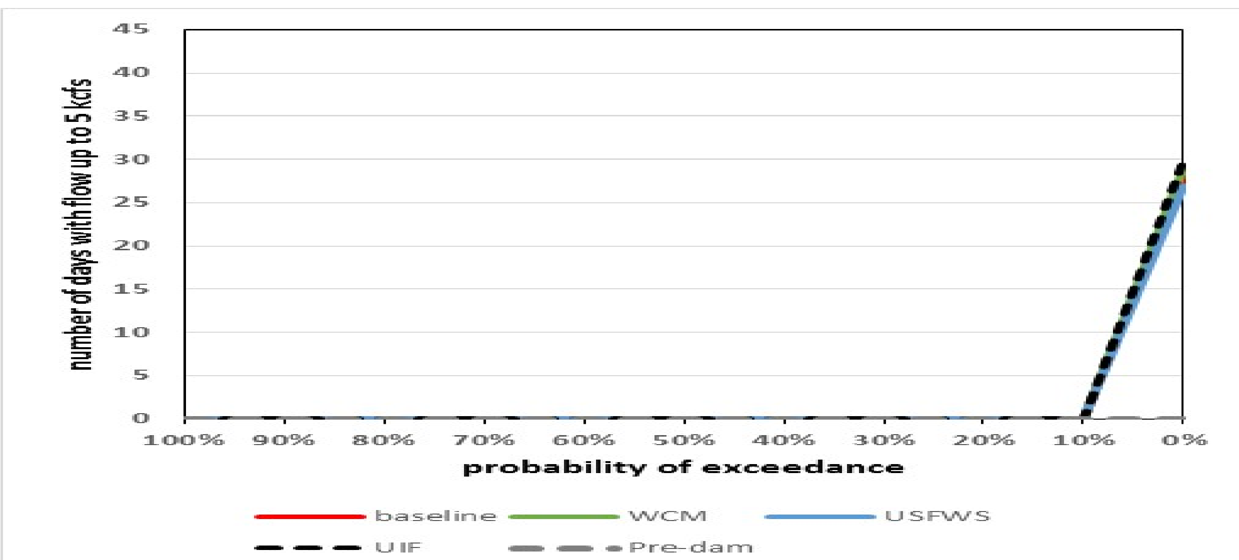


Figure 20.2.6: Number of days flows for the Apalachicola River at Chattahoochee are less than 5,000 cfs between June 1 and July 15.

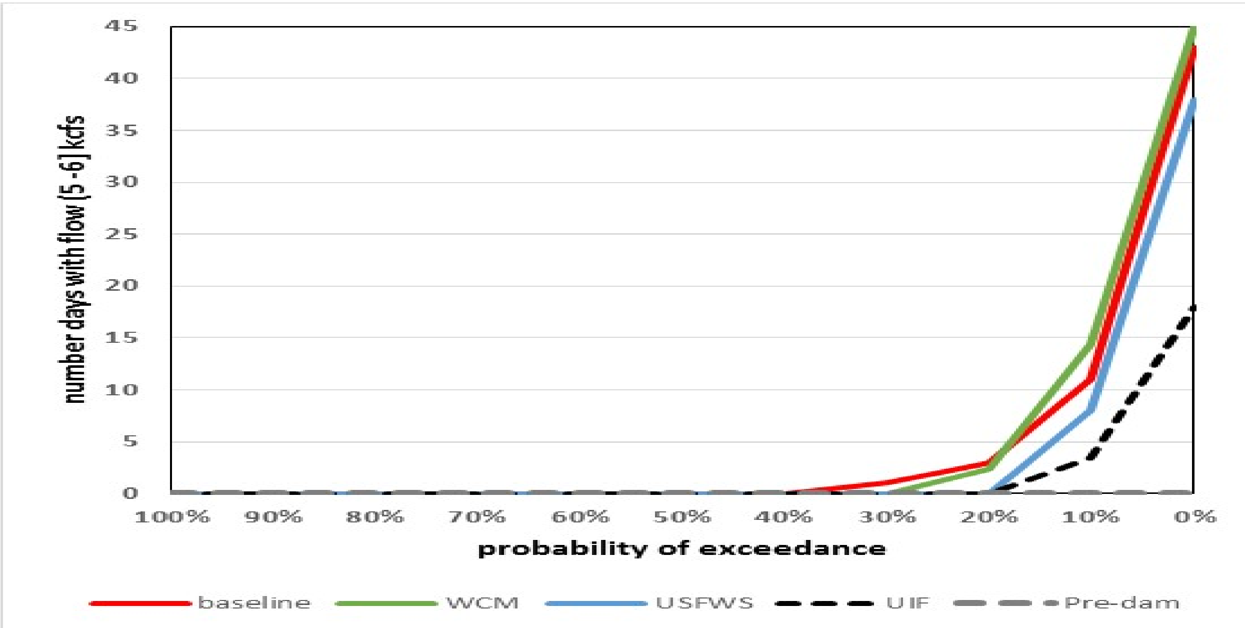


Figure 20.2.7: Number of days flows for the Apalachicola River at Chattahoochee are between 5,000 and 6,000 cfs between June 1 and July 15.

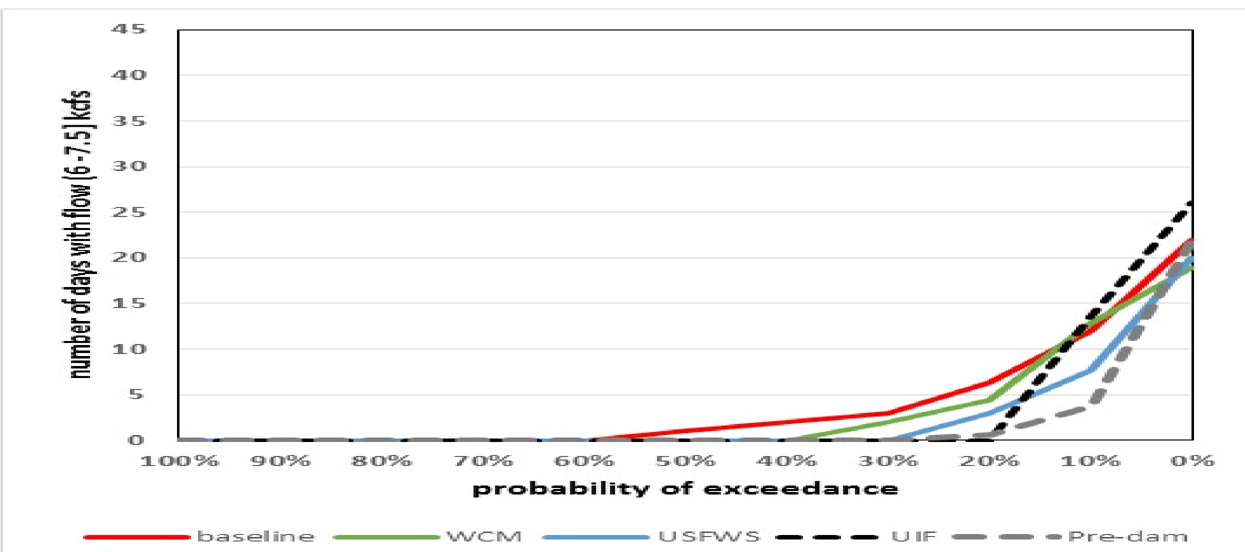


Figure 20.2.8: Number of days flows for the Apalachicola River at Chattahoochee are between 6,000 and 7,500 cfs between June 1 and July 15.

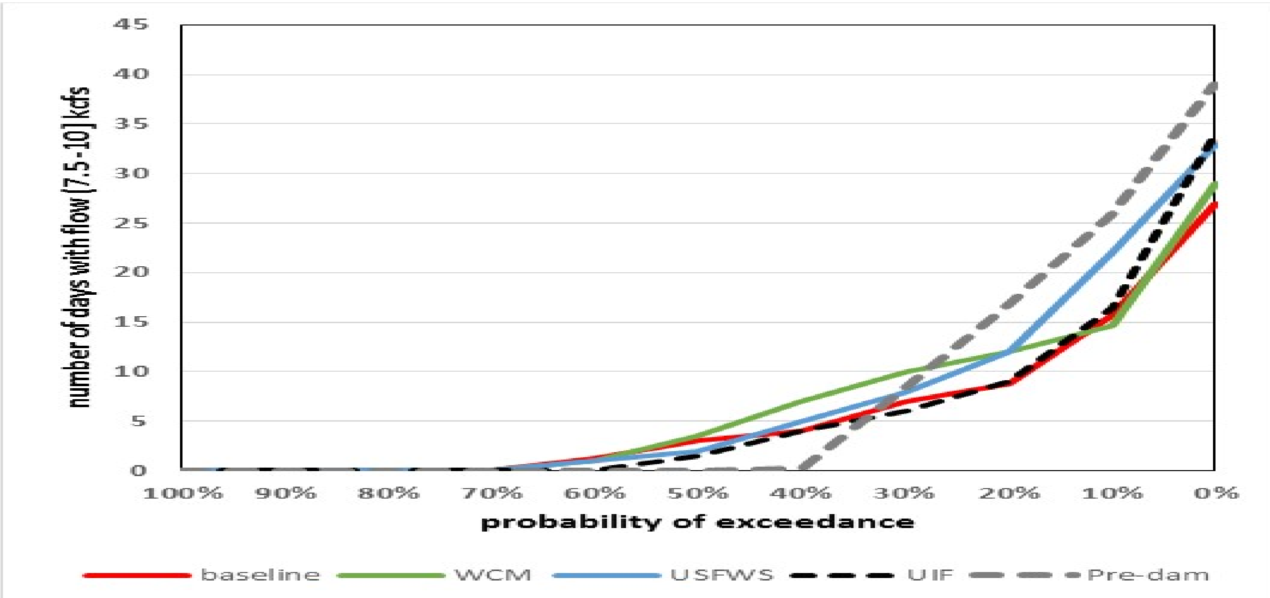


Figure 20.2.9: Number of days flows for the Apalachicola River at Chattahoochee are between 7,500 and 10,000 cfs between June 1 and July 15.

The USFWS management plan was designed to generally provide higher flows and generally avoid flows <10,000 cfs and not surprisingly provides mostly adverse effects compared to the WCM and baseline. At very low flows <5,000 cfs, the USFWS management plan results were similar to that of the WCM and baseline, but it provided 12 fewer days than the baseline at flows in the 5,000-5,999 cfs range, 16 fewer days than the baseline at flows in the 6,000-7,499 cfs range, and 16 more days than the baseline at flows in the 7,500-10,000 cfs range. However, it is worth noting that the USFWS plan, the baseline, or the WCM did not provide flows in these ranges similar to that expected under the Unimpaired Flow scenario or pre-dam conditions. Generally, both unimpaired flow and pre-dam scenarios have fewer days in the low and very low flow ranges (<7,500 cfs).

Freshwater Mussel Hydroecological Metric 5 - Stable Low Flows during Host Infection and Juvenile Settlement

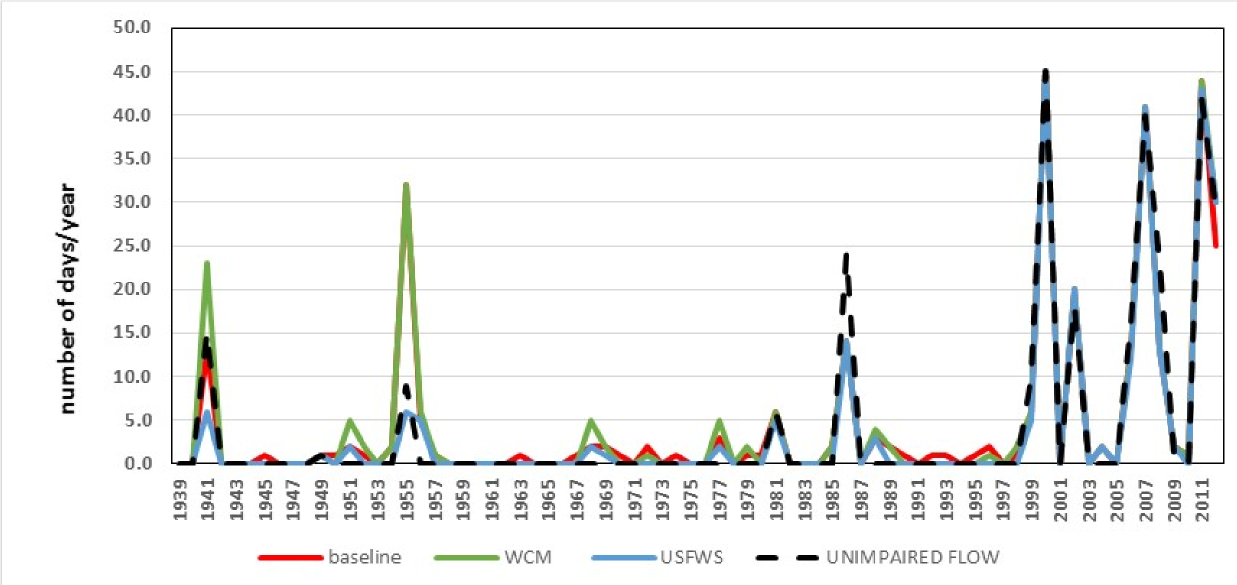


Figure 20.2.10: Number of days per year flows for the Apalachicola River at Chattahoochee are below 7,500 between June 1 and July 15.

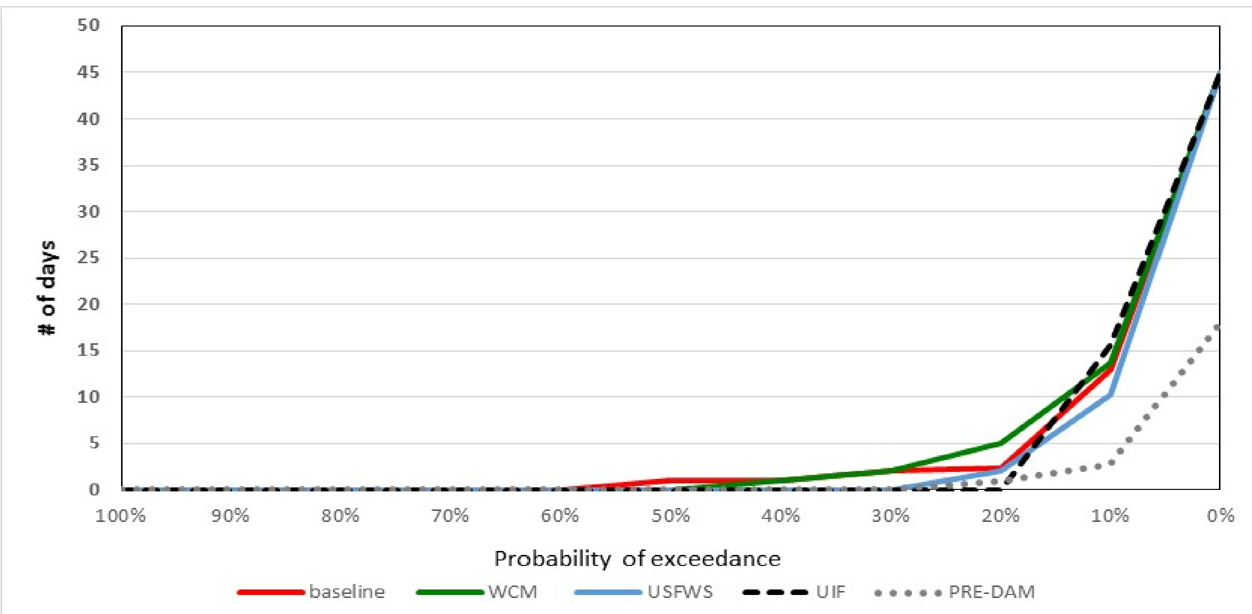
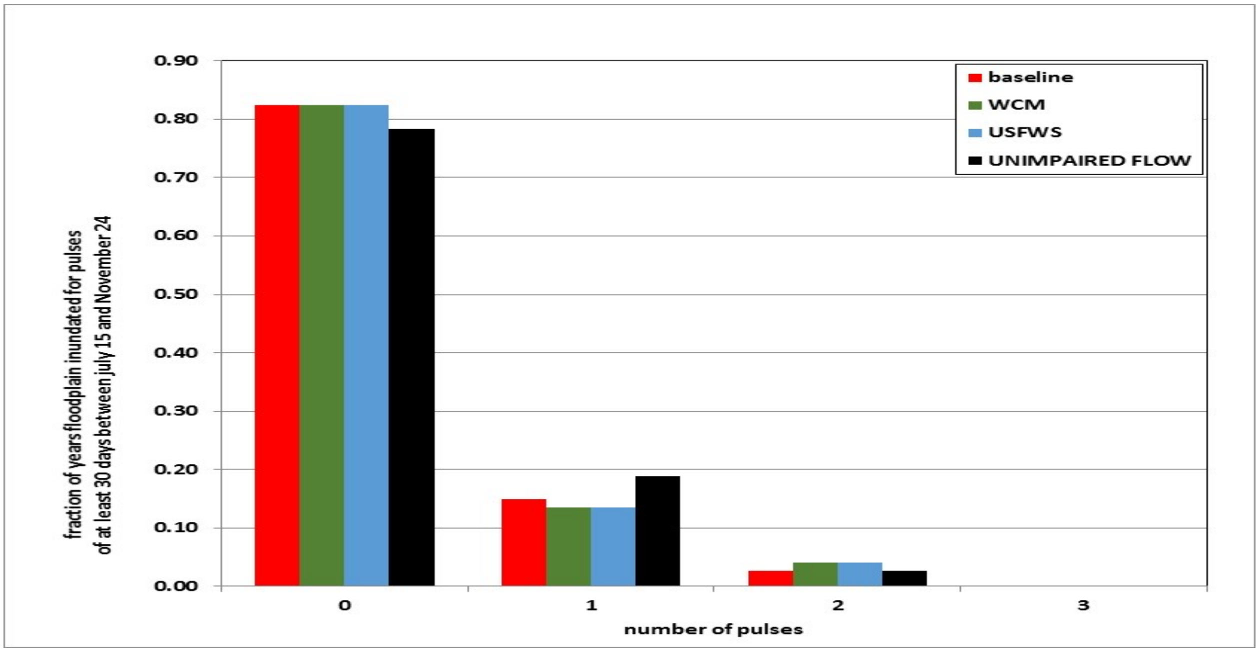


Figure 20.2.11: Number of days per year flows for the Apalachicola River at Chattahoochee are below 7,500 between June 1 and July 15.

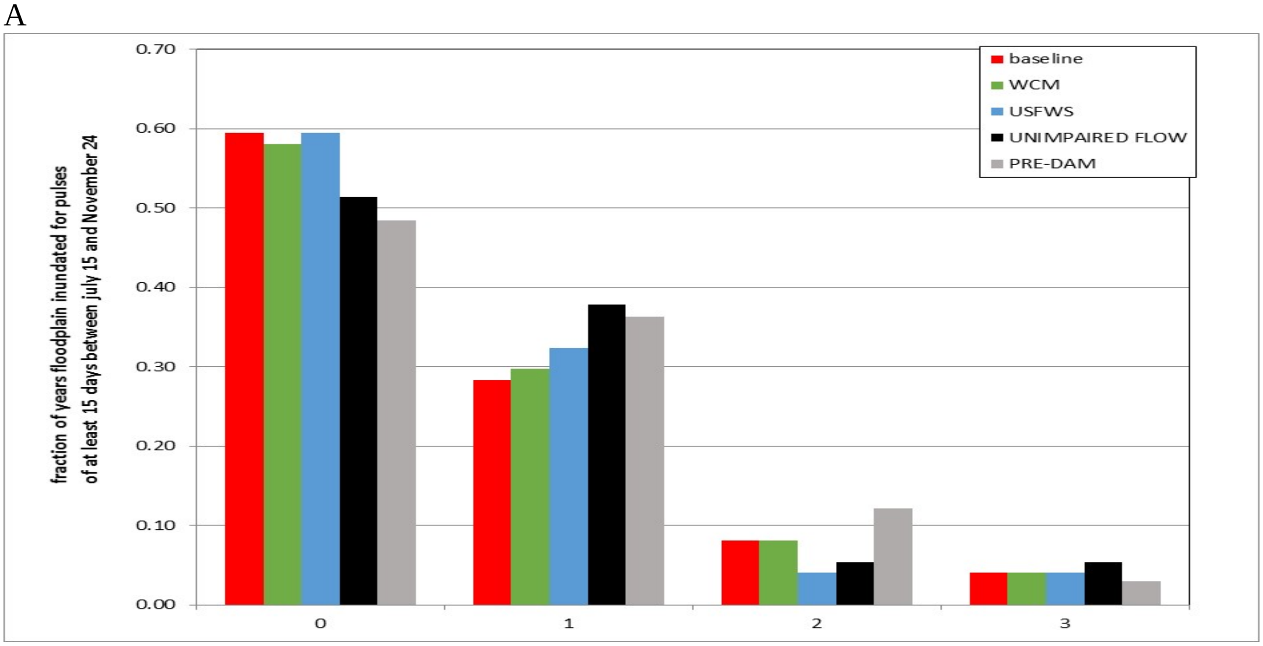
The USFWS management plan was designed to generally provide higher flows and generally avoid flows <10,000 cfs and not surprisingly provides mostly adverse effects compared to the WCM and baseline. The USFWS management plan provided 7 fewer days of consecutive flows <7,500 cfs range compared to the baseline and 9 fewer compared to the WCM. However, it is worth noting that the USFWS plan, the baseline, or the WCM did not provide flows in these ranges similar to that expected under the Unimpaired Flow scenario or pre-dam conditions. Generally, both unimpaired flow and pre-dam scenarios have fewer days in the low and very low flow ranges (<7,500 cfs).

20.2.3 Flows for Mussel Growth and Fecundity with respect to Floodplain Inundation

Freshwater Mussel Hydroecological Metric 6 - Pulsed Floodplain Inundation during Summer-Fall



A



B

Figure 20.2.12: Fraction of years the Apalachicola River's floodplain was inundated by pulses of at least 30 days (A) and 15 days (B) between July 15 and November 24.

The USFWS management plan provides an identical number of years as the WCM with one and two 30-day floodplain pulses between July 15 and November 24 across the 74-year record (13 years or 18% of the time) and one fewer years with a single 30-day pulse and one more year with two 30-day pulses than the baseline. These 30-day pulses are equivalent to the pre-dam record, but represent a decrease from the UIF scenario (16 years or 22%). Looking at the shorter 15-day pulses provides a different picture when comparing to the baseline and WCM or the pre-dam record or UIF scenarios. The USFWS management plan provides one fewer years than the WCM with one, two, or three 15-day floodplain pulses between July 15 and November 24 across the 74-year record and an equivalent number of years with 15-day pulses as the baseline (30 years or 41% of the time). It provides the pulses as three additional years with single 15-day pulses. These 15-day pulses represent an 11% drop (8 years) from the pre-dam record and a 8% drop (6 years) from the UIF scenario. Thus, we see fewer 15-day pulses than we did historically or if flows through the basin were unimpaired.

20.2.4 Flows for River Drawdown and Mussel Survival in Ephemeral Habitats

Freshwater Mussel Hydroecological Metric 7 - Mussel Exposure and Survival during Extreme Low Flows

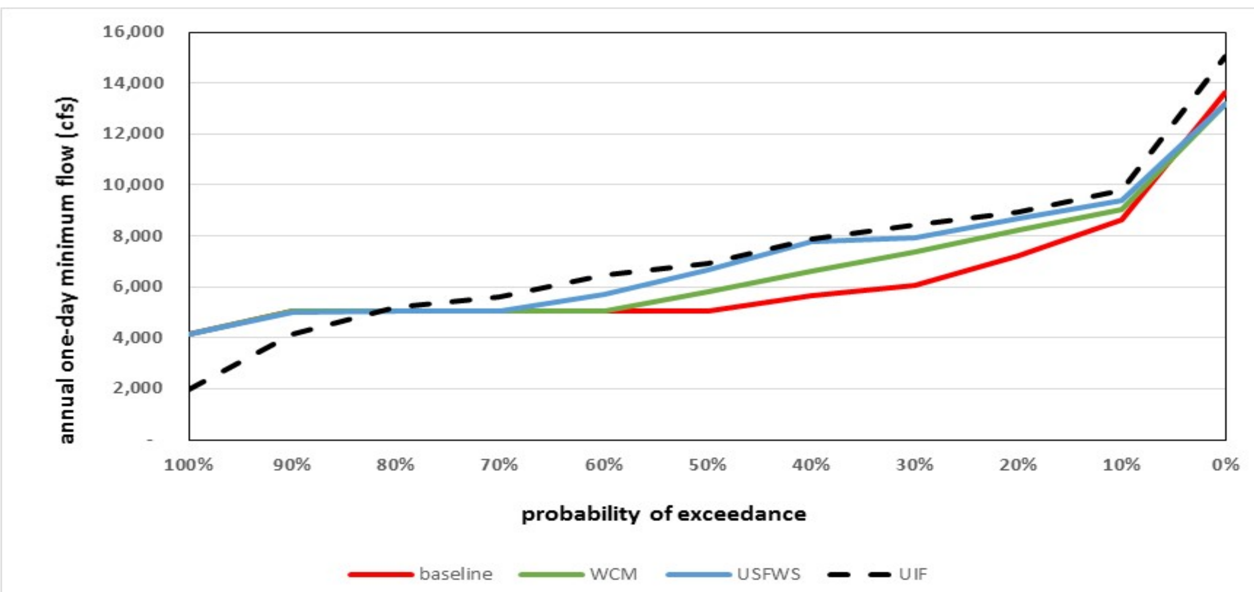


Figure 20.2.13: Frequency of annual one-day minimum flows for the Apalachicola River at Chattahoochee for 1939 - 2012.

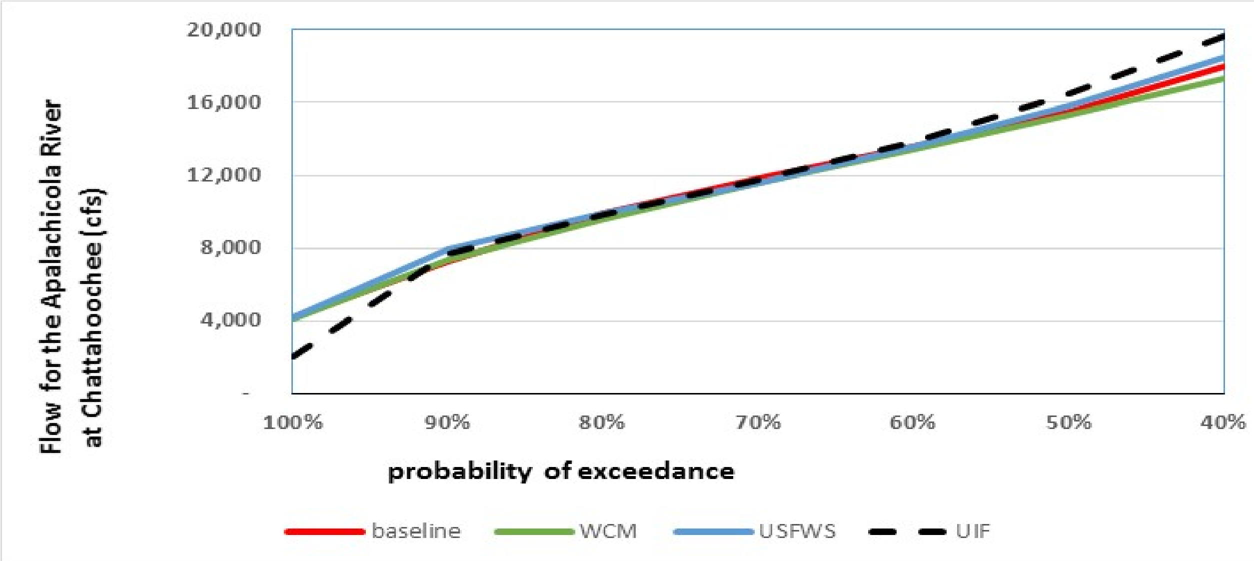
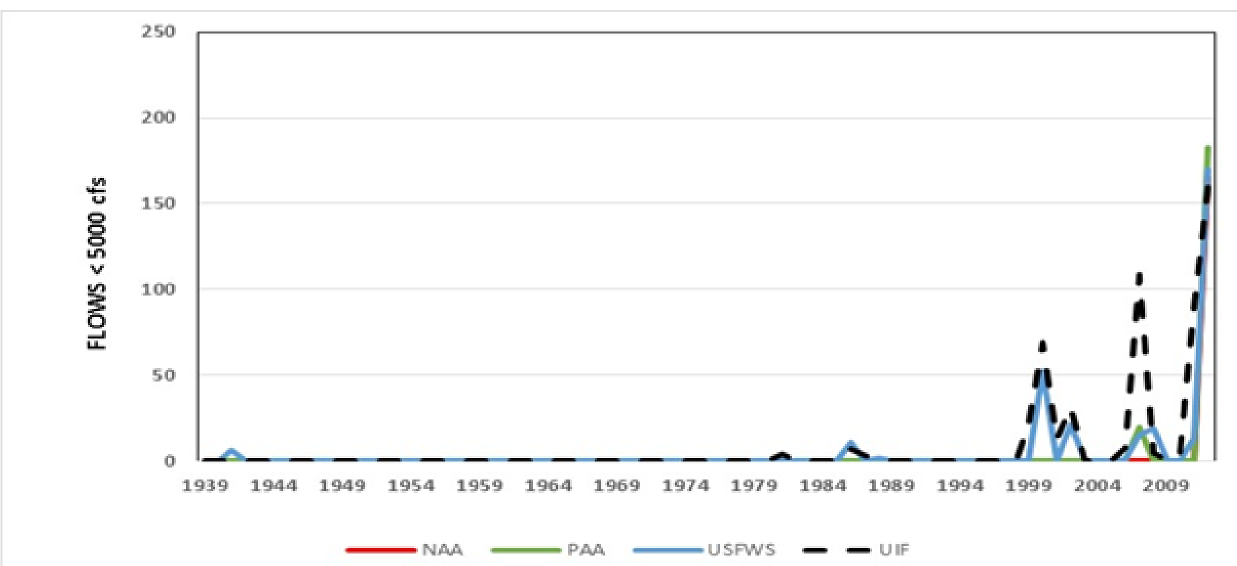


Figure 20.2.14: Probability of exceedance of flow for the Apalachicola River at Chattahoochee (1939 – 2012).

The USFWS, WCM and baseline management plans provides an identical minimum flows as per the rule set in each management plan and approximately a 10% probability of minimum flows below 5,000 cfs compared to the WCM and 20% reduction in probability of minimum flows compared to the WCM. The USFWS plan provides a higher absolute minimum flow but a 10% increase in probability of minimum flows at or below 5,000 cfs compared to the unimpaired flow dataset.

Freshwater Mussel Hydroecological Metric 8 - Mussel Exposure and Survival during Extreme Low Flows



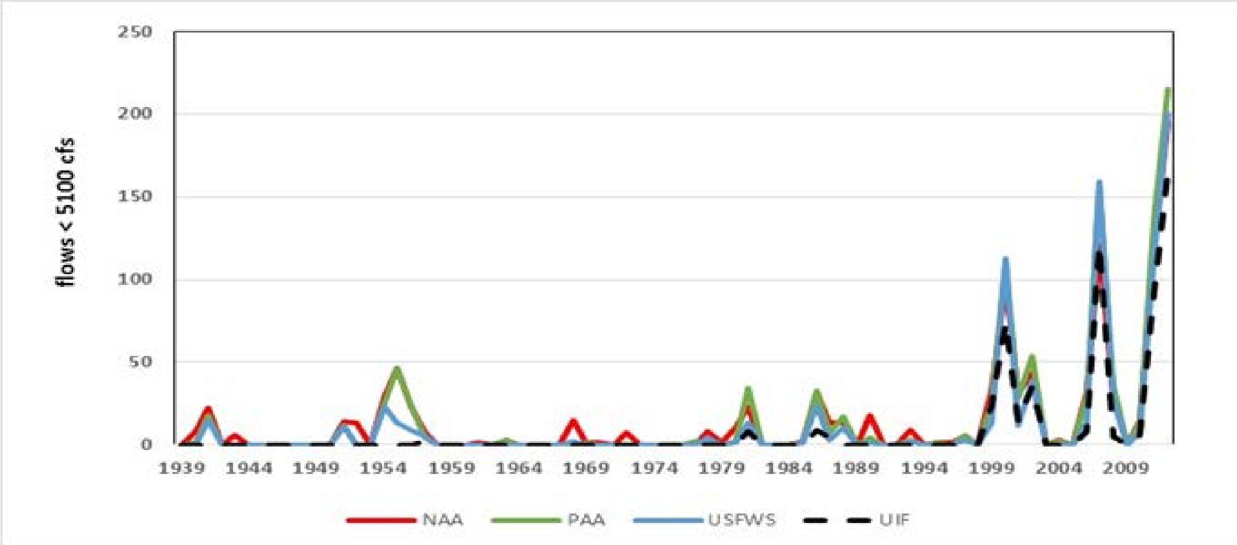


Figure 20.2.15: Number of days of flow <5,000 and <5,100 for the Apalachicola River at Chattahoochee (1939 – 2012).

The USFWS management plan allows drop below 5,000 cfs more frequently than both the WCM and baseline with 10 years and a total of 311 days across the 74 year record. However, when we calculate the total number of days when flows are <5,100 cfs, we see a different pattern. The USFWS pan spends only 27 years (36%) and 837 days total below 5,100 cfs across the 74 year record. All three management plans spent more days (567) and years (14 or 19%) below 5,100 cfs than the unimpaired flow dataset indicating that they manage for flows near this threshold.

Freshwater Mussel Hydroecological Metric 9 - Mussel Exposure and Survival during Drawdown

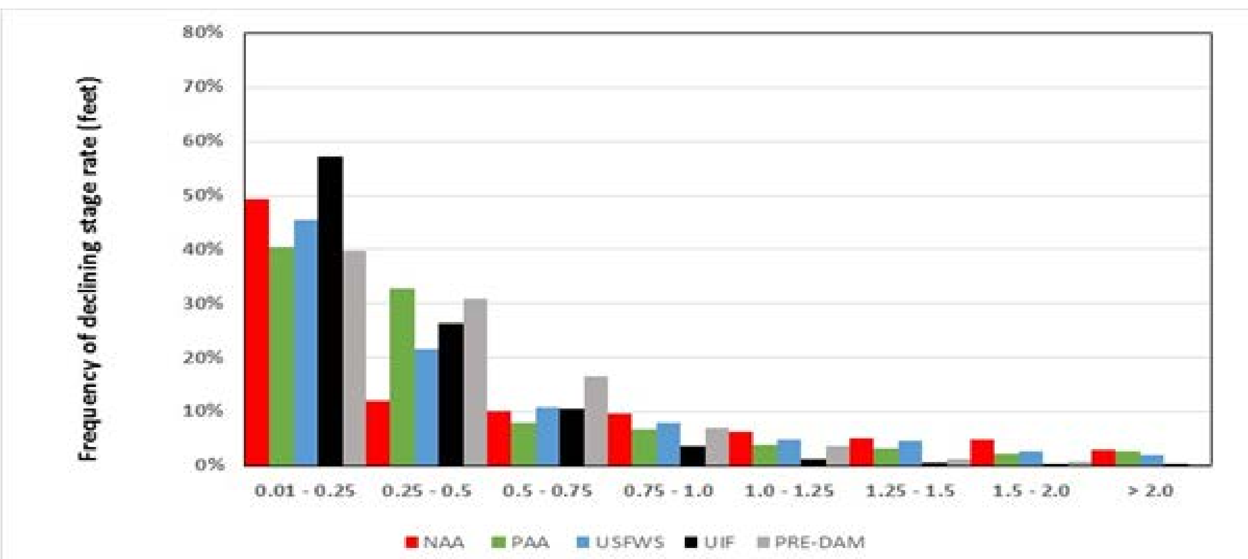


Figure 20.2.16: Frequency of occurrence of declining stages for the Apalachicola River at Chattahoochee for 1939 – 2012

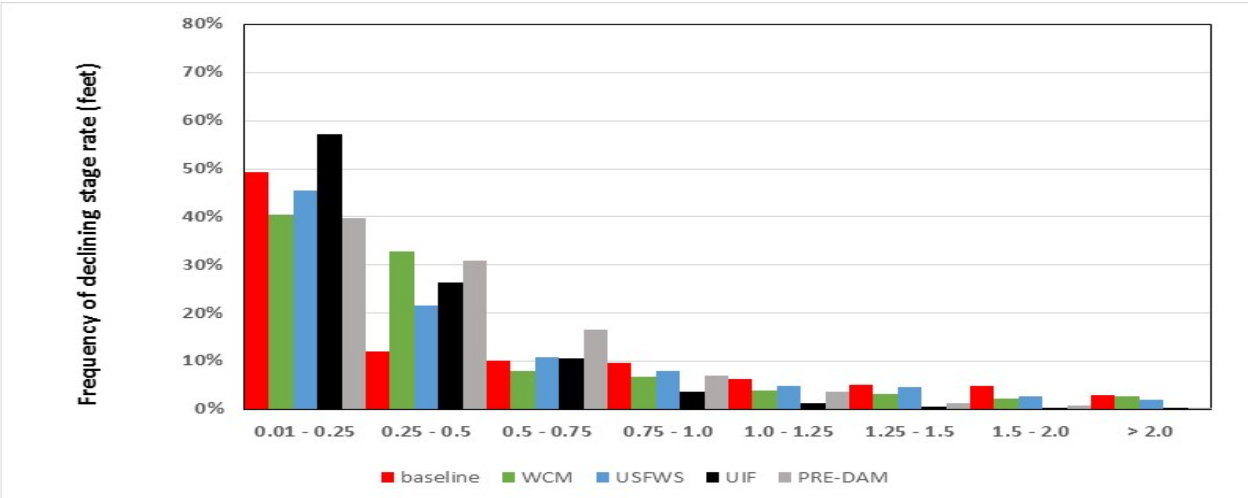


Figure 20.2.17: Frequency of occurrence of declining stages for the Apalachicola River at Chattahoochee for 1939 – 2012 when flow is less than 10,000 cfs

USFWS management plan has 4% fewer days with ramp rates ≤0.25 ft/day and 10% more days at ramp rates 0.26-0.5 ft/day than the baseline when looking at all flows. When flows are <10,000 cfs, the USFWS plan has 2% more days with ramp rates ≤0.25 ft/day and 1% less days at ramp rates 0.26-0.5 ft/day than the baseline. The biggest insight from the analysis of flows <10,000 cfs is that both the UIF and pre-dam conditions had much higher frequencies of ramp rates ≤0.25 ft/day than any of the management plans when flows are <10,000 cfs. The WCM provides ramp rates ≤0.25 ft/day approximately 30, 31, and 32% of the time while the UIF and pre-dam conditions have those ramp rates approximately 75 and 58% respectively. This indicates water levels recede approximately twice as fast as they did before the ACF Basin dams were installed.

20.2.5 Other Effects of the WCM on Mussel Life History and Critical Habitat

Freshwater Mussel Qualitative Metric 2 - Mussel Exposure, Survival, and Habitat Loss during Hydropeaking

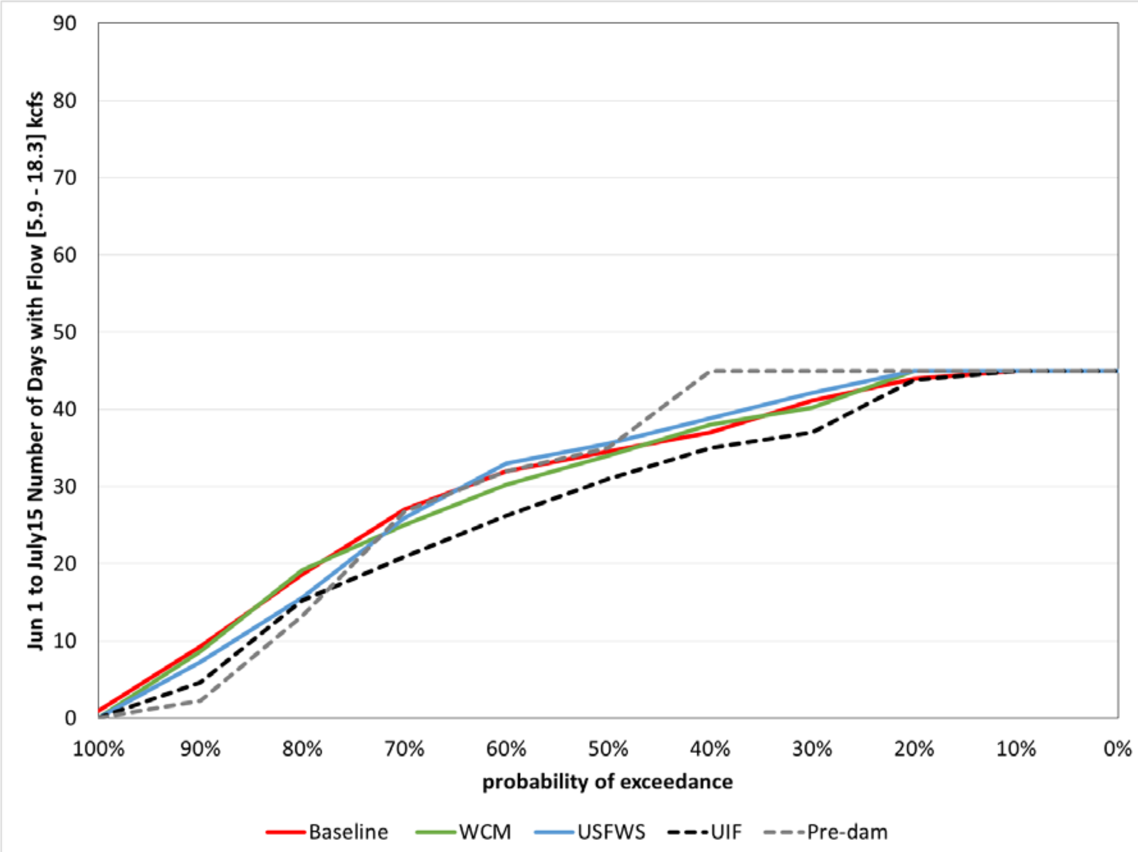


Figure 20.2.18: Probability of exceedance of flow for the Apalachicola River at Chattahoochee (1939 – 2012).

The total number of days at flows between 5,900 and 18,300 cfs between June 1 and July 15 occurring under the 5 flow regimens (baseline, WCM, USFWS, UIF, pre-dam) is presented as a probability of exceedance plot. The USFWS plan provides 12 days fewer of appropriate conditions for hydropeaking compared to the baseline across the 74 years (i.e., 0.1 days on average). Essentially, the USFWS plan represents no change the probability of conditions when hydropeaking may occur. The biggest insight from the analysis is that the baseline, WCM, and USFWS are similar to pre-dam conditions in average to dry years, (exceedance >50%) but in drier years. In addition, the UIF met the conditions for hydropeaking in 229 fewer days across the 74 years. This indicates water levels recede approximately twice as fast as they did before the ACF Basin dams were installed.

21 LITERATURE CITED

1. Altinok, I., and J. M. Grizzle. 2001. Effects of brackish water on growth, feed conversion and energy absorption efficiency by juvenile euryhaline and freshwater stenohaline fishes. Journal of Fish Biology 59:1142-1152.
2. Altinok, I., S.M. Galli, and F.A. Chapman. 1998. Ionic and osmotic regulation capabilities of juvenile Gulf of Mexico sturgeon, *Acipenser oxyrinchus desotoi*. Comparative Biochemistry and Physiology 120:609-616.
3. Amyot, J. P. and J.A. Downing. 1998. Locomotion in *Elliptio complanata* (Mollusca: Unionidae): a reproductive function? Freshwater Biology 39:351-358.
4. Angermeir, P.L. 1987. Spatiotemporal variation in habitat selection by fishes in small Illinois streams. Pp. 52-60 in: W. Matthews and D. Heins, editors. Community and Evolutionary Ecology of North American Stream Fishes. University of Oklahoma Press, Norman, Oklahoma.
5. 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, 20 pp.
6. Auer, N.A. 1996. Importance of habitat and migration to sturgeons with emphasis on lake sturgeon. Canadian Journal of Fisheries and Aquatic Sciences 53:152-160.
7. 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.
8. Bailey, R.G. 1983. Delineation of ecosystem regions. Environmental Management 7:365-373.
9. Balazik, M.T., G.C. Garman, J.P. Van Eenennaam, J. Mohler, and L.C. Woods III. 2012. Empirical evidence of fall spawning by Atlantic sturgeon in the James River, Virginia. Transactions of the American Fisheries Society 141:1465-1471.
10. Balazik, M.T., and J.A. Musick. 2015. Dual annual spawning races in Atlantic Sturgeon. PLoS ONE 10(5):e0128234.
11. 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.
12. Barnhart, C.M., W.R. Haag, and W.N. Roston. 2008. Adaptations to host infection and larval parasitism in Unionoida. Journal of the North American Benthological Society. 27(2):370-394.
13. Beamesderfer, R.C.P., and R.A. Farr. 1997. Alternatives for the protection and restoration of sturgeons and their habitat. Environmental Biology of Fishes 48:407-417.
14. 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.
15. Bogan, A.E. 1993. Freshwater bivalve extinctions (Mollusca: Unionoida): a search for causes. American Zoologist 33:599-609.
16. 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.

17. Bowen, Z.H., K.D. Bovee, and T J. Waddle. 2003. Effects of flow regulation on shallow-water habitat dynamics and floodplain connectivity. Transactions of the American Fisheries Society 132:809-823.
18. Braaten, P.J., D.B. Fuller, L.D. Holte, R.D. Lott, W. Viste, T.F. Brandt, and R.B. Legare. 2008. Drift dynamics of larval pallid sturgeon and shovelnose sturgeon in a natural side channel of the Upper Missouri River, Montana. North American Journal of Fisheries Management 28:808-826.
19. Braun, C.L., C.L. Stevens, P.D. Echo-Hawk, N.A. Johnson, and J.B. Moring. 2014. Abundance of host fish and frequency of glochidial parasitism in fish assessed in field and laboratory settings and frequency of juvenile mussels or glochidia recovered from hatchery-held fish, central and southeastern Texas, 2012-13. USGS Scientific Investigations Report 2014-5217. DOI: 10.3133/sir20145217.
20. Brekke, L., A. Wood, and T. Pruitt. 2014. Downscaled CMIP3 and CMIP5 Hydrology Projections: Release of Hydrology Projections, Comparison with Preceding Information, and Summary of User Needs. Bureau of Reclamation. [Available at: http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/techmemo/BCSD5HydrologyMemo.pdf].
21. 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.
22. 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.
23. 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.
24. 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.
25. Bruno, M.C., B. Maiolini, M. Carolli, and L. Silveri. 2010. Short time-scale impacts of hydropeaking on benthic invertebrates in an Alpine stream (Trentino, Italy). Limnologica - Ecology and Management of Inland Waters 40:281-290.
26. Bruno, M.C., A. Siviglia, M. Carolli, and B. Maiolini. 2013. Multiple drift responses of benthic invertebrates to interacting hydropeaking and thermopeaking waves. Ecohydrology 6(4):511-522.
27. Bruno, M.C., M.J. Cashman, B. Maiolini, S. Biffi, and G. Zolezzi. 2016. Responses of benthic invertebrates to repeated hydropeaking in semi-natural flume simulations. Ecohydrology 9:68-82.
28. Bunn, S. E., and A. H. Arthington. 2002. Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity. Environmental Management 30:492-507.
29. Burgess, O.T., W.E. Pine III, and S.J. Walsh. 2013. Importance of floodplain connectivity to fish populations in the Apalachicola River, Florida. River Research and Applications 29:718-733.
30. 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.

31. Carr, A. 1983. All the way down upon the Suwannee River. Audubon Magazine. p. 80-101.
32. Carr, S.H, F. Tatman, and F.A. Chapman. 1996. Observations on the natural history of the Gulf of Mexico sturgeon (*Acipenser oxyrinchus desotoi*, Vladykov 1955) in the Suwannee River, southeastern United States. Ecology of Freshwater Fisheries 5:169-174.
33. Castro, D.M.P., R.M. Hughes, and M. Callisto. 2013. Effects of flow fluctuations on the daily and seasonal drift of invertebrates in a tropical river. International Journal of Limnology 49:169-177.
34. Chamberlain, T.K. 1931. Annual growth of freshwater mussels. Bulletin of the U.S. Bureau of Fisheries 46:713-739.
35. Chambers, R.C., and W.C. Leggett. 2011. Size and age at metamorphosis in marine fishes: an analysis of laboratory-reared winter flounder (*Pseudopleutonectes americanus*) with a review of variation in other species. Canadian Journal of Fisheries and Aquatic Sciences 44(11):1936-1947.
36. Chanton, J., and F.G. Lewis. 2002. Examination of coupling between primary and secondary production in a river-dominated estuary: Apalachicola Bay, Florida, U.S.A. Limnology and Oceanography 47(3):683-697.
37. Chapman, F.A. and S.H. Carr. 1995. Implications of early life stages in the natural history of the Gulf of Mexico sturgeon, *Acipenser oxyrinchus desotoi*. Environmental Biology of Fishes 43:407-413.
38. Chapman, F.A., S.F. O'Keefe, and D.E. Campton. 1993. Establishment of parameters critical for the culture and commercialization of Gulf of Mexico sturgeon, *Acipenser oxyrhynchus desotoi*. Fisheries and Aquatic Sciences Dept., Food Science and Human Nutrition Dept., University of Florida, Gainesville, FL. Project Final Report. NOAA No. NA27FD0066-01. National Marine Fisheries Service. St. Petersburg, FL.
39. 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.
40. Clugston, J.P., A.M. Foster, and S.H. Carr. 1995. Gulf sturgeon, *Acipenser oxyrinchus desotoi*, in the Suwannee River, Florida. Pp. 215-224 in A.D. Gershanovich and T.I.J. Smith, editors. Proceedings of International Symposium on Sturgeons. Moscow, Russia. September 6- 11, 1993, 370 pp.
41. Cocherell, S.A., D.E., Cocherell, G.J. Jones, J.B. Miranda, L.C. Thompson, J.J Cech, and A.P. Klimley. 2011. Rainbow trout *Oncorhynchus mykiss* energetic responses to pulsed flows in the American River, California, assessed by electromyogram telemetry. Environmental Biology of Fishes 90:29-41.
42. 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.
43. Collins, M.R., T.I.J. Smith, W.C. Post, and O. Pashuk. 2000. Habitat utilization and biological characteristics of adult Atlantic sturgeon in two South Carolina rivers. Transactions of the American Fisheries Society 129:982-988.
44. 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.

45. Craft, N.M., B. Russell, and S. Travis. 2001. Identification of Gulf sturgeon spawning habitats and migratory patterns in the Yellow and Escambia River systems. Final Report to the Florida Marine Research Institute, Fish and Wildlife Conservation Commission. 19 pp.
46. Crossman, J.A., and L.R. Hildebrand. 2012. Evaluation of spawning substrate enhancement for white sturgeon in a regulated river: effects on larval retention and dispersal. River Research and Applications 30:1-10.
47. 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.
48. Daraio, J.A., L.J. Weber, S.J. Zigler, T.J. Newton, and J.M. Nestler. 2012. Simulated effects of host fish distribution on juvenile unionid mussel dispersal in a large river. River Research and Applications 28:594-608.
49. Dewson, Z.S., A.B.W. James, and R.G. Death. 2007. A review of the consequences of decreased flow for instream habitat and macroinvertebrates. Journal of the North American Benthological Society 26(3):401-415.
50. 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.
51. Dibble, K.L., C.B. Yackulic, T.A. Kennedy, and P. Budy. 2015. Flow management and fish density regulate salmonid recruitment and adult size in tailwaters across western North America. Ecological Applications 25(8):2168-2179.
52. 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.
53. Duke, S., P. Anders, G. Ennis, R. Hallock, J. Hammond, S. Ireland, J. Laufle, R. Lauzier, L. Lockhard, B. Marotz, V.L. Paragamian, and R. Westerhof. 1999. Recovery plan for Kootenai River white sturgeon (*Acipenser transmontanus*). Journal of Applied Ichthyology 15:157-163.
54. Dumont, P., J. D'Amours, S. Thibodeau, N. Dubuc, R. Verdon, S. Garceau, P. Bilodeau, Y. Mailhot, and R. Fortin. 2011. Effects of the development of a newly created spawning ground in the Des Prairies River (Quebec, Canada) on the reproductive success of lake sturgeon (*Acipenser fulvescens*). Journal of Applied Ichthyology 27:394-404.
55. Dunne, T., and L.B. Leopold. 1978. Water in environmental planning. W.H. Freeman Company, San Francisco. 818 pp.
56. Dutterer, A.C., C. Mesing, R. Cailteux, M.S. Allen, W.E. Pine III, and P.A. Strickland. 2012. Fish recruitment is influenced by river flows and floodplain inundation at Apalachicola River, Florida. River Research and Applications 29:1110-1118.
57. Edwards, R.E., K.J. Sulak, M.T. Randall, and C.B. Grimes. 2003. Movements of Gulf sturgeon (*Acipenser oxyrinchus desotoi*) in nearshore habitat as determined by acoustic telemetry. Gulf of Mexico Science 21(1):59-70.
58. Edwards, R.E., F.M. Parauka, and K.J. Sulak. 2007. New insights into marine migration and winter habitat for Gulf sturgeon. Pp. 183-196 in: J. Munro, J.E. Hightower, K. McKown, K.J. Sulak, A.W. Kahnle, and F. Caron, editors. Anadromous sturgeons:

habitats threats, and management. American Fisheries Society Symposium 56. Bethesda, Maryland.

59. 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.
60. 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.
61. 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.
62. Etnier, D.A. 1997. Jeopardized southeastern freshwater fishes: a search for causes. Pp. 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.
63. Florida Department of Environmental Protection (FDEP). 2002. Division of Water Resource Management, Basin Status Report, Northwest District, Group 2 Basin, Apalachicola-Chipola.
64. Florida Department of Environmental Protection (FDEP). 2005. Division of Water Resource Management, Water Quality Assessment Report, Northwest District, Group 2 Basin, Apalachicola-Chipola.
65. 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 (USACE) dated February 22, 2011.
66. Flowers, H.J. 2008. Age-structured population model for evaluating Gulf sturgeon recovery on the Apalachicola River, Florida. M.S. Thesis, University of Florida, Gainesville.
67. Flowers, H.J., W.E. Pine III, A.C. Dutterer, K.G. Johnson, J.W. Ziewitz, M.S. Allen, and F.M. Parauka. 2009. Spawning site selection and potential implications of modified flow regimes on viability of Gulf sturgeon populations. Transactions of the American Fisheries Society 138:1266-1284.
68. Foster, A.M. 1993. Movement of Gulf sturgeon, *Acipenser oxyrinchus desotoi* in the Suwannee River, Florida. Master Thesis, University of Florida, Gainesville, FL. 131 pp.
69. Foster, A.M., and J.P. Clugston. 1997. Seasonal migration of Gulf sturgeon in the Suwannee River, Florida. Transactions of the American Fisheries Society 126:302-308.
70. Foster, A.M., C.F. Jordan, and J.P. Clugston. 1994. Salinity tolerance of juvenile Gulf sturgeon identifies habitat limitations. Research Information Bulletin 63, Southeastern Biological Science Center. Gainesville, Florida.
71. Fox, D.A., J.E. Hightower, and F.M. Parauka. 2000. Gulf sturgeon spawning migration and habitat in the Choctawhatchee river system. Alabama-Florida. Transactions of the American Fisheries Society129:811-826.

72. Fox, D.A., J.E. Hightower, and F.M. Parauka. 2002. Estuarine and nearshore marine habitat use by Gulf sturgeon from the Choctawhatchee River system, Florida. Pp. 111-126 in: W. Van Winkle, P.J. Anders, D.H. Secor, and D.A. Dixon, editors. Biology, protection, and management of North American sturgeon. American Fisheries Society, Symposium 28. Bethesda, Maryland.
73. Freeman, M.C., Z.H. Bowen, K.D. Bovee and E.R. Irwin. 2001. Flow and habitat effects on juvenile fish abundance in natural and altered flow regimes. Ecological Applications 11(1):179-190.
74. French, S.K. and J.D. Ackerman. 2014. Responses of newly settled juvenile mussels to bed shear stress: implications for dispersal. Freshwater Science 33(1):46-55.
75. 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.
76. Fritts, A.K., M.W. Fritts, D.L. Peterson, D.A. Fox, and R.B. Bringolf. 2012. Critical linkage of imperiled species: Gulf Sturgeon as host for Purple Bankclimber mussels. Freshwater Science 31:1223-1232.
77. Fritts, A.K. and R.B. Bringoff 2014. Host fishes for four federally endangered freshwater mussels (Unionidae) in the Apalachicola-Chattahoochee-Flint River basin. Walkerana 17(2):51-59.
78. Fuller, S.L.H. 1974. Clams and mussels (Mollusca: Bivalvia). Pp. 215-273 in: C.W. Hart and S.L.H. Fuller, editors. Pollution ecology of freshwater invertebrates. Academic Press, New York.
79. 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.
80. 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.
81. Gangloff, M.M. 2012. Population size and depth distribution of three federally-protected mussels in the Apalachicola and lower Chipola rivers. Final Report to the U.S. Army Corps of Engineers, Mobile District, Mobile, Alabama.
82. Garcia, X.F., I. Schnauder, and M.T. Pusch. 2012. Complex hydromorphology of meanders can support benthic invertebrate diversity in rivers. Hydrobiologia 685:49-68.
83. 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.
84. 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.
85. Gates, K.K., C.C. Vaughn, and J.P. Julian. 2015. Developing environmental flow recommendations for freshwater mussels using the biological traits of species guilds. Freshwater Biology 60:620-635.

86. Geist, D.R., R.S. Brown, V. Cullinan, S.R. Brink, K. Lepla, P. Bates, and J.A. Chandler. 2005. Movement, swimming speed, and oxygen consumption of juvenile White Sturgeon in response to changing flow, water temperature, and light level in the Snake River, Idaho. Transactions of the American Fisheries Society 134(4):803-816
87. Gibson, C.A., J.L. Meyer, N.L. Poff, L.E. Hay, and A. Georgakakos. 2005. Flow regime alterations under changing climate in two river basins: implications for freshwater ecosystems. River Research and Applications 21:849-864.
88. 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.
89. Graf, W.L. 2006. Downstream hydrologic and geomorphic effects of large dams on American rivers. Geomorphology 79:336-360.
90. Gross, M.R., J. Repka, C.T. Robertson, D.H. Secor, and W. Van Winkle. 2002. Sturgeon conservation: insights from elasticity analysis. American Fisheries Society Symposium 28:13-30.
91. Gu, B., D.M. Schell, T. Frazer, M. Hoyer, and F.A. Chapman. 2001. Stable carbon isotope evidence for reduced feeding of Gulf of Mexico sturgeon during their prolonged river residence period. Estuarine, Coastal, and Shelf Science 53:275-280.
92. Guillory, V. 1979. Utilization of an inundated floodplain by Mississippi River fishes. Florida Scientist 42:222-228.
93. Gutreuter, S., A.D. Bartles, K. Irons, and 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.
94. Haag, W.R. 2012. North American freshwater mussels: natural history, ecology, and conservation. Cambridge University Press.
95. 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.
96. Haag, W.R., and J.L. Staton. 2003. Variation in fecundity and other reproductive traits in freshwater mussels. Freshwater Biology 48:2118-2130.
97. 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.
98. 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.
99. 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.
100. 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.
101. Haag, W.R., and A.L. Rypel. 2010. Growth and longevity in freshwater mussels: evolutionary and conservation implications. Biological Reviews 86:225-247.

102. Hamel, M.J., J.J. Spurgeon, M.A. Pegg, J.J. Hammen, and M.L. Rugg. 2014. Hydrologic variability influences local probability of Pallid Sturgeon occurrence in a Missouri River tributary. River Research and Applications 32(3):320-329.
103. 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.
104. Hardy, R.S., and Litvak, and M.K. 2004. Effects of temperature on the early development, growth, and survival of Shortnose Sturgeon, *Acipenser brevirostrum*, and Atlantic Sturgeon, *Acipenser oxyrhynchus*, yolk-sac larvae. Environmental Biology of Fishes 70:145-154.
105. Harris, J.E., D.C. Parkyn, and D.J. Murie. 2005. Distribution of Gulf of Mexico sturgeon in relation to benthic invertebrate prey resources and environmental parameters in the Suwannee River estuary, Florida. Transactions of the American Fisheries Society 134:975-990.
106. Hartfield, P.D. 1993. Headcuts and their effect on freshwater mussels. Pp. 131-141 in: K.S. Cummings, A.C. Buchanan, and L.M. Koch, editors. Conservation and management of freshwater mussels. Proceedings of a symposium, October 1992, St. Louis, Missouri. Upper Mississippi River Conservation Committee, Rock Island, Illinois.
107. 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.
108. 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.
109. Hassell, M.P. 2000. Host-parasitoid populations dynamics. Journal of Animal Ecology 69:543-566.
110. 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.
111. 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).
112. Heard, W.H. 1979. Identification manual of the freshwater clams of Florida. Unpublished report, Florida Department of Environmental Regulation Technical Series 4. 83 pp.
113. Heard, R.W., J.L. McLelland, and J.M. Foster. 2000. Benthic invertebrate community analysis of Choctawhatchee bay in relation to Gulf sturgeon foraging: an overview of year 1. Interim report to the Florida Fish and Wildlife Conservation Commission, St. Petersburg.
114. Heise, R.J., S.T. Ross, M.F. Cashner, and W.T. Slack. 1999a. Movement and habitat use of the Gulf sturgeon (*Acipenser oxyrinchus desotoi*) in the Pascagoula drainage of Mississippi: year 3. Museum Technical Report No. 74. Funded by U.S. Fish and Wildlife Service, Project No. E-1, Segment 14.

115. Heise, R.J., S.T. Ross, M.F. Cashner, and W.T. Slack. 1999b. Gulf sturgeon (*Acipenser oxyrinchus desotoi*) in the Pascagoula Bay and Mississippi Sound. Museum Technical Report No. 76.
116. Hightower, J.E., K.P. Zehfuss, D.A. Fox, and F.M. Parauka. 2002. Summer habitat use by Gulf sturgeon in the Choctawhatchee River, Florida. Journal of Applied Ichthyology 18:595-600.
117. Hook, J.E., G. Hoogenboom, J. Paz, J. Mullen, J. Bergstrom, and P. Risse. 2010. Agricultural irrigation water demand: Georgia's major and minor crops 2011 – 2050. [Available at: http://www.nespal.org/SIRP/waterinfo/State/AWD/AgWaterDemand.htm and http://gfvga.org/wp-content/uploads/2010/03/3.-Forecasting-Georgias-Irrigation-Water-Needs.pdf].
118. 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.
119. Huff, J.A. 1975. Life History of the Gulf of Mexico Sturgeon, *Acipenser oxyrhynchus desotoi* in Suwannee River, Florida. Mar. Res. Publ. No. 16. 32 pp.
120. Humphries, P., and P.S. Lake. 2000. Fish larvae and the management of regulated rivers. Regulated Rivers: Research and Management 16:421-432.
121. Hupp, C.R. 2000. Hydrology, geomorphology, and vegetation of coastal plain rivers in the south-eastern USA. Hydrological Processes 14:2991-3010.
122. Iowa Mussel Team (IMT). 2002. Freshwater Mussels of Iowa. [Available at: https://www.fws.gov/midwest/mussel/documents/freshwater_mussels_of_iowa.pdf].
123. Isom, B.G., and R.G. Hudson. 1982. In Vitro culture of parasitic freshwater mussel glochidia. The Nautilus 96(4):147-151.
124. Jacobson, R.B., M.J. Parsley, M.L. Annis, M.E. Colvin, T.L. Welker, and D. James. 2015. Development of conceptual ecological models linking management of the Missouri River to pallid sturgeon population dynamics: U.S. Geological Survey Open-File Report 2015-1038. 47 p. [Available at http://dx.doi.org/10.3133/ofr20151038].
125. 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.
126. Jeanne, D.G. 2002. A history of the Mobile District USACE of Engineers, 1815-1985. U.S. Army Corps of Engineers, Mobile District. 119+pp.
127. 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.
128. Jones, L.E., and L.J. Torak. 2006. Simulated effects of seasonal ground-water pumpage for irrigation on hydrologic conditions in the Lower Apalachicola-Chattahoochee-Flint River Basin, Southwestern Georgia and parts of Alabama and Florida, 1999-2002. US Geologic Survey Scientific Investigations Report 2006-5234.
129. Junk, W.J., P.B. Bayley, and R.E. Sparks. 1989. The flood pulse concept in river-floodplain systems, Pp. 110-127 in: D. P. Dodge, editor. Proceedings of the International Large River Symposium. Canadian Special Publication of Fisheries and Aquatic Sciences106.

130. Kaeser, A.J., T.L. Litts, and T.W. Tracy. 2013. Using low-cost side-scan sonar for benthic mapping throughout the Lower Flint River, Georgia, USA. River Research and Applications 29(5):634-644.

131. Kennedy, T.A., J.D. Muehlbauer, C.B. Yackulic, D.A. Lytle, S.W. Miller, K.L. Dibble, E.W. Kortenhoeven, A.N. Metcalfe and C.V. Baxter. 2016. Flow management for hydropower extirpates aquatic insects, undermining river food webs. BioScience doi:10.1093/biosci/biw059.

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

133. King T.L., B.A. Lubinski, and A.P. Spidle. 2001. Microsatellite DNA variation in Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) and cross-species amplification in the Acipenseridae. Conservation Genetics 2(2):103-119.

134. King, A.J., D.A. Crook, W.M. Koster, J. Mahoney, and Z. Tonkin. 2005. Comparison of larval fish drift in the Lower Goulburn and mid-Murray Rivers. Ecological Management and Restoration 6(2):136-139.

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

136. Kistenmacher, M., and A.P. Georgakakos. 2011. Environmental Flow and Ecological Impacts of Alternative Regulation Scenarios for the ACF River Basin. Proceedings of the 2011 Georgia Water Resources Conference, April 11, 12, and 13, 2011, Athens, Georgia. [Available at: https://smartech.gatech.edu/handle/1853/46111].

137. Kistenmacher, M., and A.P. Georgakakos. 2015. Assessment of reservoir system variable forecasts. Water Resources Research 51(5):3437-3458.

138. Korman, J. and S.E. Campana. 2009. Effects of hydropeaking on nearshore habitat use and growth of age-0 rainbow trout in a large regulated river. Transactions of the American Fisheries Society138:76-87

139. 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.

140. Kynard, B. 1997. Life history, latitudinal patterns, and status of the shortnose sturgeon, *Acipenser brevirostrum*. Environmental Biology of Fishes 48:319-334.

140.1. Kynard, B., and M. Horgan. 2002. Ontogenetic Behavior and Migration of Atlantic Sturgeon, *Acipenser oxyrinchus oxyrinchus*, and Shortnose Sturgeon, *A. brevirostrum*, with Notes on Social Behavior. Environmental Biology of Fishes 63:137-150.

141. Kynard, B. and E. Parker. 2004. Ontogenetic behavior and migration of Gulf of Mexico sturgeon, *Acipenser oxyrinchus desotoi*, with notes on body color and development Environmental Biology of Fishes70:43-55.

142. Layzer, J., and E.M. Scott. 2006. Restoration and colonization of freshwater mussels and fish in a southeastern United States tailwater. River Research and Applications 22(4):475-491.

143. 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.

144. 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.

145. Leitman S., W. Pine, and G. Kiker. 2016. Management options during the 2011-2012 drought on the Apalachicola River: a systems dynamic model evaluation. Journal of Environmental Management 58(2):193-207.

146. Leitman, S., and G.A. Kiker. 2015. Development and comparison of integrated river/reservoir models in the Apalachicola-Chattahoochee-Flint basin, USA. Environment, Systems and Decisions 35:410-423.

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

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

149. 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.

150. 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.

151. Liebig, H., R. Cereghino, P. Lim, A. Belaud, and S. Lek. 1999. Impact of hydropeaking on the abundance of juvenile brown trout in a Pyrenean stream. Archiv fur Hydrobiologie 144(4):49-454.

152. 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.

153. Light, H.M., K.R. Vincent, M.R. Darst, and F.D. Price. 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.

153.1. Livingston, R.J. 1997. Trophic response of estuarine fishes to long-term changes in river runoff. Bulletin of Marine Science 60(3):984-1004.

154. Livingston, R.J., X. Niu, G.F. Lewis, G.C. Woodsum. 1997. Freshwater input to a Gulf estuary: long-term control of trophic organization. Ecological Applications 17:277-299.

155. Maiolini, B., L. Silveri, and V. Lencioni. 2007. Hydroelectric power generation and disruption of the natural stream flow: effects on the zoobenthic community. Studi trentini di scienze naturali, Acta biologia 83:21-26.

156. Marbury, J.A. 2016. Assessing Gulf sturgeon recruitment in the Apalachicola-Chattahoochee-Flint River Basin. Masters Thesis. University of Georgia, Athens. 114 p.

157. Marchant, R.S., and M.K. Shutters. 1996. Artificial substrates collect Gulf sturgeon eggs. North American Journal of Fisheries Management 16:445-447.

158. Mason, W.T. and J.P. Clugston. 1993. Foods of the gulf sturgeon in the Suwannee River, Florida. Transactions of the American Fisheries Society 122:378-385.

159. McAdam, S.O. 2011. Effects of substrate condition on habitat use and survival by white sturgeon (*Acipenser transmontanus*) larvae and potential implications for recruitment. Canadian Journal of Fish and Aquatic Science 68:812-822.

160. 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.
161. 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.
162. McDowall, R.M. 1988. Diadromy in fishes migrations between freshwater and marine environments. Truder Press and Croom Helm. 308pp.
163. 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.
164. McMahon, R.F., and A.E. Bogan. 2001. Bivalves. Pp 331-428 in: J.H. Thorp and A.P. Covich, editors. Ecology and classification of North American freshwater invertebrates. Second edition. Academic Press, New York, NY.
165. Merritt, R.W. and K.W. Cummins. 1996. An introduction to the aquatic insects of North America. Third Edition. Kendall/Hunt Publishing Company, Dubuque, IA.
166. Metcalf, A.L. 1983. Mortality in unionacean mussels in a year of drought. Transactions of the Kansas Academy of Science 86:89-92.
167. 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.
168. 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.
169. 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.
170. 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.
171. 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.
172. 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.
173. 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.
174. Moog, O. 1993. Quantification of peak hydropower effects on aquatic fauna and management to minimize environmental impacts. Regulated Rivers: Research and Management 8:5-14.

175. 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.
176. Morrow, J.V, K.J. Killgore, J.P. Kirk, and H.E. Rogillio. 1996. Distribution and population attributes of Gulf sturgeon in the lower Pearl River System, Louisiana. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 50:79-90.
177. Mundt, C.C., L.D. Sackett, L.D. Wallace, C. Cowger, and J.P. Dudley. 2009. Long-distance dispersal and accelerating waves of disease: empirical relationships. American Naturalist 173:456-466.
178. 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.
179. National Oceanic and Atmospheric Administration (NOAA). 2016. National Climatic Data Center. Asheville, NC. [Available at: http://www.ncdc.noaa.gov/oa/climate/onlineprod/drought/xmgr.html].
180. 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.
181. Neves, R.J. 1993. A state-of-the-unionids address. Pp 1-10 in: K.S. Cummings, A.C. Buchanan, and L.M. Koch, editors. Conservation and management of freshwater mussels. Proceedings of an Upper Mississippi River Conservation Committee symposium, October 1992, St. Louis, Missouri. UMRCC, Rock Island, Illinois.
182. Neves, R.J., and S.N. Moyer. 1988. Evaluation of techniques for age determination of freshwater mussels (Unionidae). American Malacological Bulletin Vol. 6(2):179-188.
183. Neves, R.J., and J.C. Widlak. 1987. Habitat ecology of juvenile freshwater mussels (Bivalvia: Unionidae) in a headwater stream in Virginia. American Malacological Bulletin 5(1):1-7.
184. 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.
185. 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.
186. 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. Pp. 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.
187. Newton, T.J., S.J. Zigler, and B.R. Gray. 2015. Mortality, movement and behaviour of native mussels during a planned water-level drawdown in the Upper Mississippi River. Freshwater Biology 60:1-15.
188. 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.

189. 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.

190. Odenkirk, J.S. 1989. Movement of Gulf of Mexico sturgeon in the Apalachicola River, Florida. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 43:230-238.

191. Palmer, R.N. 1998. A History of Shared Vision Modeling in the ACT-ACF Comprehensive Study: A Modeler's Perspective. Pp. 221-226. in: W. Whipple Jr., editor. Proceedings of Special Session of ASCE's 25th Annual Conference on Water Resources Planning and Management and the 1998 Annual Conference on Environmental Engineering. Chicago, IL.

192. Panel on Adaptive Management for Resource Stewardship (PAMRS) 2004. Adaptive Management for Water Resources Project Planning. Panel on Adaptive Management for Resource Stewardship, Committee to Assess the U.S. Army Corps of Engineers Methods of Analysis and Peer Review for Water Resources Project Planning, National Research Council. National Academies Press, Washington, DC. pp. 138.

193. Parauka, F.M., S.K. Alam, and D.A. Fox. 2001. Movement and habitat use of subadult Gulf sturgeon in Choctawhatchee Bay, Florida. Proceedings Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 55:280-297.

194. Parauka, F.M., W.J. Troxel, F.A. Chapman, and L.G. McBay. 1991. Hormone-induced ovulation and artificial spawning of Gulf of Mexico sturgeon, *Acipenser oxyrhynchus desotoi*. Progressive Fish-Culturist 53:113-117.

195. Parkyn, D.C., D.J. Murie, J.E. Harris, D.E. Colle, and J.D. Holloway. 2007. Seasonal movements of Gulf of Mexico sturgeon in the Suwannee River and estuary. Pp. 51-68 in: J. Munro, D. Hatin, J. E. Hightower, K. McKown, K. J. Sulak, A. W. Kahnle, and F. Caron, editors. Anadromous sturgeons: habitats, threats, and management. American Fisheries Society Symposium 56. Bethesda, Maryland.

196. Pederson N., A.R. Bell, T.A. Knight, C. Leland, N. Malcomb, K.J. Anchukaitis, K. Tackett, J. Scheff, A. Brice, B. Cantron, W. Blozan, J. Riddle. 2012. A long-term perspective on a modern drought in the American Southeast. Environmental Research Letters 7(1):014034.

197. 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.

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

199. Pine III, 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.

200. Pine III, W.E., M.S. Allen, and V.J. Dreitz. 2001. Population viability of the Gulf of Mexico sturgeon in the Suwannee River, Florida. Transactions of the American Fisheries Society 130:1164-1174.

201. 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 39pp.

202. 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.

202.1. Poff, N.L., and J.C. Schmidt. 2016. How dams can go with the flow. Science 353(6304):1099-1100.

203. 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.

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

205. Price, J.E., and C.B. Eads. 2011. Brooding patterns in three freshwater mussels of the genus *Elliptio* in the Broad River, South Carolina. American Malacological Bulletin 29:121-126.

206. Price, F.D., H.M. Light, M.R. Darst, E.R. Griffin, K.R. Vincent, and J.W. Ziewitz. 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. [Available at: http://fl.water.usgs.gov/Water_data/ApalachRchannel_change.html].

207. 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.

208. Randall, M.T., and K.J. Sulak. 2012. Evidence of autumn spawning in Suwannee River Gulf sturgeon, *Acipenser oxyrinchus desotoi* (Vladykov, 1955). Journal of Applied Ichthyology 28:489-495.

209. Reckendorfer, W., A. Funk, C. Gschopf, T. Hein, and F. Schiemer. 2013. Aquatic ecosystem functions of an isolated floodplain and their implications for flood retention and management. Journal of Applied Ecology 50:119-128.

210. Reynolds, C.R. 1993. Gulf sturgeon sightings, historic and recent - a summary of public responses. U.S. Fish and Wildlife Service. Panama City, Florida. 40pp.

211. 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.

211.1. Richmond, A.M., and B. Kynard. 1995. Ontogenetic behavior of shortnose sturgeon, *Acipenser brevirostrum*. Copeia 1995(1):172-182.

212. Ritter, A., and R. Muñoz-Carpena. 2013. Predictive ability of hydrological models: objective assessment of goodness-of-fit with statistical significance. Journal of Hydrology 480(1):33-45.

213. 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.

214. 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.

215. Rogillio, H.E., E.A. Rabalais, J.S. Forester, C.N. Doolittle, W.J. Granger, and J.P. Kirk. 2002. Status, movement and habitat use study of Gulf sturgeon in the Lake Pontchartrain Basin, Louisiana. Louisiana Department of Wildlife and Fisheries. 43pp.
216. 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.
217. Roseman, E.F., B. Manny, J. Boase, M. Child, G. Kennedy, J. Craig, K. Soper, and R. Drouin. 2011a. Lake sturgeon response to a spawning reef constructed in the Detroit River. Journal of Applied Ichthyology 27:66-76.
218. Roseman, E.F., J. Boase, G. Kennedy, J. Craig, and K. Soper. 2011b. Adaptation of egg and larvae sampling techniques for lake sturgeon and broadcast spawning fishes in a deep river. Journal of Applied Ichthyology 27:89-92.
219. 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.
220. Ross, S.T., R.J. Heise, W.T. Slack, J.A. Ewing, III, and M. Dugo. 2000. Movement and habitat use of the Gulf sturgeon (*Acipenser oxyrinchus desotoi*) in the Pascagoula drainage of Mississippi: year 4. Mississippi Department of Wildlife, Fisheries, and Parks and Museum of Natural Science. Funded by U.S. Fish and Wildlife Service, Project No. E-1, Segment 15. 58 pp.
221. Ross, S.T., R.J. Heise, W.T. Slack, and M.A. Dugo. 2001a. Gulf sturgeon habitat in the Gulf of Mexico. Annual Report, Submitted to Mississippi Alabama Sea Grant Consortium, project NA86RG0039-4.
222. Ross, S.T., R.J. Heise, W.T. Slack, and M. Dugo. 2001b. Habitat requirements of Gulf sturgeon (*Acipenser oxyrinchus desotoi*) in the northern Gulf of Mexico. Final Report submitted to the Shell Marine Habitat Program, National Fish and Wildlife Foundation, Washington, D.C.
223. Rugel, K., S.W. Golladay, C.R. Jackson, and T.C. Rasmussen. 2016. Delineating groundwater/surface water interaction in a karst watershed: lower Flint River basin, SW Georgia, USA. Journal of Hydrology: Regional Studies 5:1-19.
224. 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.
225. 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.
226. 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.
227. Sauchyn, D.J., J.M. St-Jacques, E. Barrow, M.W. Nemeth, R.J MacDonald, A.M.S. Sheer, and D.P. Sheer. 2016. Adaptive water resources planning in the South Saskatchewan river basin: Use of scenarios of hydroclimate variability and extremes. Journal of the American Water Resources Association 52(1):222-240.
227.1. Schemel, L.E., T.R. Sommer, A.B. Muller-Solger, and W.C. Harrell. 2004. Hydrologic variability, water chemistry, and phytoplankton biomass in a large floodplain of the Sacramento River, CA, U.S.A. Hydrobiologia 513:129-139.

228. Schiemer F., H. Keckeis, W. Reckendorder, and G. Winkler. 2001. The "inshore retention concept" and its significance for large rivers. Archiv für Hydrobiologie, Supplement 12:509-516.
229. Schiemer F., H. Keckeis, and E. Kamler. 2003. The early life history stages of riverine fish: ecophysiological and environmental bottlenecks. Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology 133:439-449.
230. Schlosser, I.J. 1985. Flow regime, juvenile abundance, and the assemblage structure of stream fishes. Ecology 66:1484-1490.
231. Schludermann E., M. Tritthart, P. Humphries, and H. Keckeis. 2012. Dispersal and retention of larval fish in a potential nursery habitat of a large temperate river: an experimental study. Canadian Journal of Fisheries and Aquatic Sciences 69:1302-1315.
232. Schwalb, A.S., T.J. Morris, N.E. Mandrak, and K. Cottenie. 2012a. Distribution of unionid freshwater mussels depends on the distribution of host fishes on a regional scale. Diversity and Distributions 2012:1-9.
233. Schwalb, A.S., T.J. Morris, and J.D. Ackerman. 2012b. The effect of settling velocity on the transport of mussel larvae in a cobble-bed river: Water column and near-bed turbulence. Limnology and Oceanography: Fluids and Environments 2:28-40.
234. Scollan, D. and F.M. Parauka. 2008. Documentation of Gulf sturgeon spawning in the Apalachicola River, Florida. U. S. Fish and Wildlife Service, Panama City, Florida.
235. Scruton, D.A., C.J. Pennell, L.M.N. Ollerhead, K. Alfredsen, M. Stickler, A. Harby, M.J. Robertson, K.D. Clarke, and L.J. LeDrew. 2008. A synopsis of 'hydropeaking' studies on the response of Juvenile Atlantic Salmon to experimental flow alteration. Hydrobiologia 609:263-275.
236. Seager, R., A. Tzanova, and J. Nakamura. 2009. Drought in the southeastern United States: causes, variability over the last millennium, and the potential for future hydroclimate change. Journal of Climate 22:5021-5045.
237. 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.
238. Sheer, A.M.S., M.W. Nemeth, D.P. Sheer, M. Van Ham, M. Kelly, D. Hill, and S.D. Lebherz. 2013. Developing a new operations plan for the Bow River basin using river basin collaborative modeling for decision support. Journal of the American Water Resources Association 49(3):654-668
239. Singer, E.E., and M.M. Gangloff. 2011. Effects of a small dam on freshwater mussel growth in an Alabama (U.S.A.) stream. Freshwater Biology 56:1904-1915.
240. Smit, R.B. 2014. Using sonar habitat mapping and GIS analyses to identify freshwater mussel habitat and estimate population size of a federally endangered freshwater mussel species, *Amblema neislerii*, in the Apalachicola River, FL. M.S. thesis Auburn University. 93pp.
241. Smit, R.B. and A.J. Kaeser. *In press.* Defining freshwater mussel mesohabitat associations in an alluvial, Coastal Plain river. Freshwater Science.
242. 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.

243. Smith, J.A., H.J. Flowers, and J.E. Hightower. 2015. Fall spawning of Atlantic Sturgeon in the Roanoke River, North Carolina. Transactions of the American Fisheries Society 144:48-54.
244. 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.
245. Stabile J., J.R. Waldman, F. Parauka, and W. Wirgin. 1996. Stock structure and homing fidelity in Gulf of Mexico Sturgeon (*Acipenser oxyrinchus desotoi*) based on restriction fragment length polymorphism and sequence analysis of mitochondrial DNA. Genetics 144:767-775.
246. Stahle, R.W., F.W. Fye, E.R. Cook, and R.D. Griffin. 2007. Tree-ring reconstructed mega droughts over North America since A.D. 1300. Climatic Change 83(1-2):133-149.
247. Stanford, J. A., and J.V. Ward. 1983. Insect species diversity as a function of environmental variability and disturbance in streams. Pp. 265-278 in: J.R. Barnes, and G.W. Minshall, editors. Stream Ecology: Application and Testing of General Ecological Theory. Plenum Press, New York, NY.
248. Stansbery, D.H. 1961. The naiads (Mollusca, Pelecypoda, Unionacea) of Fishery Bay, South Bass Island, Lake Erie. Sterkiana 5:1-37.
249. Stansbery, D.H. 1971. Rare and endangered molluscs in the eastern United States. Pp. 5-18 in: S.E. Jorgensen and R.W. Sharpe, editors. Proceedings of a symposium on rare and 121 endangered mollusks (naiads) of the United States. U.S. Fish and Wildlife Service, Twin Cities, Minnesota.
250. Strayer, D.L. 1999. Use of flow refuges by unionid mussels in rivers. Journal of the North American Benthological Society 18(4):468-476.
251. Strayer, D.L. 2008. Freshwater mussel ecology: a multifactor approach to distribution and abundance. University of California Press, Berkeley. 204pp.
252. 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.
253. 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.
254. Sulak, K.J., and J.P. Clugston. 1998. Early life history stages of the Gulf sturgeon in the Suwannee River, Florida. Transactions of the American Fisheries Society 127:758-771.
255. Sulak, K.J., and J.P. Clugston. 1999. Recent advances in life history of the Gulf of Mexico sturgeon *Acipenser oxyrinchus desotoi*, in the Suwannee River, Florida, USA: a synopsis. Journal of Applied Ichthyology 15:166-128.
256. Sulak, K.J., M. Randall, J. Clugston, and W.H. Clark. 2004. Critical spawning habitat, early life history requirements, and other life history and population aspects of the Gulf sturgeon in the Suwannee River. Final Report to the Florida Fish and Wildlife Conservation Commission, Nongame Wildlife Program. U.S. Geological Survey, Gainesville, FL.
257. Sulak, K.J., R.A. Brooks, and M.T. Randall. 2007. Seasonal refugia and trophic dormancy in Gulf sturgeon: test and refutation of the thermal barrier hypothesis. Pp. 19-

50 in: J. Munro, D. Hatin, J. E. Hightower, K. McKown, K. J. Sulak, A. W. Kahnle, and F. Caron, editors. Anadromous sturgeons: habitats, threats, and management. American Fisheries Society Symposium 56. Bethesda, Maryland.

258. Sulak, K.J., M.T. Randall, R.E. Edwards, T.M. Summers, K.E. Luke, W.T. Smith, A.D. Norem, W.M. Harden, R.H. Lukens, F. Paruaka, S. Bolden, and R. Lehnert. 2009. Defining winter trophic habitat of juvenile Gulf Sturgeon in the Suwannee and Apalachicola rivermouth estuaries, acoustic telemetry investigations. Journal of Applied Ichthyology 25:505-515.
259. Sulak, K.J., M.T. Randall, and J.J. Berg. 2012. Feeding habitats of the Gulf sturgeon, *Acipenser oxyrinchus desotoi*, in the Suwannee and Yellow rivers, Florida, as identified by multiple stable isotope analyses. Environmental Biology of Fishes 95:237-258.
260. Surber, T. 1912. Identification of the glochidia of freshwater mussels. U.S. Bureau of Fisheries Document No. 771. 10pp.
261. 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.
262. Taylor, M.K., and S.J. Cooke. 2012. Meta-analyses of the effects of river flow on fish movement and activity. Environmental Reviews 20:211-219.
263. Tramer, E.J. 1978. Catastrophic mortality of stream fishes tapped in shrinking pools. American Midland Naturalist 115:667-695.
264. 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.
265. 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.
266. U.S. Army Corps of Engineers (USACE). 2013. Benchmarks for Incorporating Adaptive Management into Water Project Designs, Operational Procedures, and Planning Strategies. Report I. Federal Agency Inventory of Adaptive Management Practices and Policies. U.S. Army Engineer Institute for Water Resources, Alexandria, Virginia. 28pp.
267. U.S. Army Corps of Engineers (USACE). 2014. Apalachicola-Chattahoochee-Flint (ACF) Watershed: HEC-ResSim Modeling of Reservoir Operations in Support of Water Control Manual Update and Water Supply Storage Assessment. Prepared by US Army Corps of Engineers, Institute for Water Resources, Hydrologic Engineering Center for the Mobile District, Planning and Environmental Division, Mobile, Alabama. 730pp.
268. U.S. Army Corps of Engineers (USACE). 2015a. Draft Environmental Impact Statement. Update of the Water Control Manual for the Apalachicola-Chattahoochee-Flint River basin in Alabama, Florida, and Georgia and a Water Supply Storage Assessment. Prepared Tetra Tech for the Mobile District, Planning and Environmental Division, Mobile, Alabama. 794pp.
269. U.S. Army Corps of Engineers (USACE). 2015b. Sustainable Solutions To America’s Water Resource Needs: Civil Works Strategic Plan 2014-2018. U.S. Army Corps of Engineers, Washington, DC.
270. U.S. Army Corps of Engineers (USACE). 2016. Revised Amended Biological Assessment: Update of the Water Control Manual for the Apalachicola-Chattahoochee-

Flint River Basin in Alabama, Florida, and Georgia and a Water Supply Storage Assessment. Prepared by the Mobile District, Planning and Environmental Division, Mobile, Alabama. 75 + 7 + 2pp.
271. U.S. Fish and Wildlife Service (USFWS) and Gulf States Marine Fisheries Commission. 1995. Gulf Sturgeon Recovery Plan. Atlanta, Georgia. 170pp.
272. U.S. Fish and Wildlife Service (USFWS). 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.
273. U.S. Fish and Wildlife Service (USFWS). 1998b. Final Endangered Species Act Section 7 Consultation Handbook, March 1998. U.S. Government Printing Office ISBN 0-16-049596-2.
274. 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.
275. 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. 165pp.
276. 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.
277. 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.
278. U.S. Fish and Wildlife Service (USWFS). 2008. Biological opinion 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. 225pp.
279. U.S. Fish and Wildlife Service (USFWS). 2011a. 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. 28pp.
280. U.S. Fish and Wildlife Service (USWFS). 2012. Biological opinion 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. 166pp.

281. U.S. Fish and Wildlife Service (USFWS). (2013a). July 19, 2013 letter from Donald Imm, Project Leader, U.S. Fish and Wildlife Service, Panama City Area Office to Curtis Flakes, Chief of Planning and Environmental Division, U.S. Army Corps of Engineers, Mobile District.

282. U.S. Fish and Wildlife Service (USFWS). (2013b). Planning Aid Letter, Apalachicola-Chattahoochee-Flint Water Control Manual Update. August 29, 2013 letter from Robin Goodloe, Acting Field Supervisor, U.S. Fish and Wildlife Service, Athens, Georgia sub-office to Curtis Flakes, Chief of Planning and Environmental Division, U.S. Army Corps of Engineers, Mobile District.

283. U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS). 2009. Gulf Sturgeon (*Acipenser oxyrinchus desotoi*) 5-Year Review: Summary and Evaluation. U.S. Fish and Wildlife Service, Southeast Region. Panama City Ecological Services Field Office, Panama City, Florida. 49pp.

284. U.S. Fish and Wildlife Service (USFWS) and U.S. Environmental Protection Agency (USEPA). 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. 13pp + appendices.

284.1. Valett, H.M., M.A. Baker, J.A. Morrice, C.S. Crawford, M.C. Molles, Jr., C. Dahm, D.L. Moyer, J.R. Thibault, and L.M. Ellis. 2005. Biogeochemical and metabolic responses to the flood pulse in a semiarid floodplain. Ecology 86(1):220-234.

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

286. 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.

287. Vaughn, C.C., S.J. Nichols, and D.E. Spooner. 2008. Community and foodweb ecology of freshwater mussels. Journal of the North American Benthological Society 27:409-423.

288. 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.

289. Vladykov, V.D. 1955. A comparison of Atlantic sea sturgeon with a new subspecies from the Gulf of Mexico (*Acipenser oxyrhynchus desotoi*). Journal of the Fisheries Research Board of Canada12:754-761.

290. Wakeford, A. 2001. State of Florida conservation plan for gulf sturgeon (*Acipenser oxyrinchus desotoi*). Florida Marine Research Institute Technical Report TR-8. 100pp.

291. 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. 124pp.

292. Walsh, S.J., Buttermore, E.N., O.T. Burgess, and W.E. Pine, 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. 28pp.
293. 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. Pp. 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.
294. Watters, G.T. 1992. Unionids, fishes, and the species-area curve. Journal of Biogeography 19:481-490.
295. 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. 158pp.
296. Watters, G.T. 1997. Individual-based models of mussel-fish interactions: a cautionary study. Pp. 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.
297. Watters, G.T., and S.H. O'Dee. 2000. Glochidial release as a function of water temperature: beyond bradyticty and tachyticty. Pp. 135-140 in: R.A. Tankersley, D. Warmolts, G.T. Watters, B. Armitage, P.D. Johnson, and R.S. Butler, editors. Freshwater Mollusk Symposia Proceedings-Part I: Conservation, Captive Care, and Propagation symposium, March 1998, Columbus, Ohio. Ohio Biological Survey, Columbus, Ohio.
298. 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.
299. Welcomme, R.L. 1979. Fisheries ecology of floodplain rivers. Longman. New York, NY.
300. White, D.S. 1979. The effects of lake level fluctuations on Corbicula and other pelecypods in Lake Texoma, Texas and Oklahoma. Pp. 82-88 in: J.C. Britton, editor. Proceedings of the first international Corbicula symposium. Texas Christian University Research Foundation, Fort Worth.
301. Williams, B.K., R.C. Szaro, and C.D. Shapiro. 2007. Adaptive Management: The U.S. Department of the Interior Technical Guide. Adaptive Management Working Group, U.S. Department of the Interior, Washington, DC. 84 pp.
302. Williams, B.K., and E.D. Brown. 2012. Adaptive Management: The U.S. Department of the Interior Applications Guide. Adaptive Management Working Group, U.S. Department of the Interior, Washington, DC. 136pp.
303. Williams, J.D., and R.S. Butler. 1994. Class Bivalvia, freshwater bivalves. Pp. 53-128 and 740-742 in: R. Ashton, editor. Rare and endangered biota of Florida. Volume 6. Invertebrates. University of Florida Press, Gainesville.
304. Williams, J.D., J.T. Garner, and A.E. Bogan. 2008. Freshwater mussels of Alabama and the Mobile Basin in Georgia, Mississippi, and Tennessee. The University of Alabama Press, Tuscaloosa.
305. 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.

306. Wooley, C.M. 1985. Evaluation of morphometric characters used in taxonomic separation of Gulf of Mexico sturgeon, *Acipenser oxyrhynchus desotoi*. Pp. 97-103 in: F.P. Binkowski and S.I. Doroshov, editors. North American Sturgeons: Biology and Aquaculture Potential, Dr W. Junk Publishers, Dordrecht.

307. Wooley, C.M., and E.J. Crateau. 1982. Observations of Gulf of Mexico sturgeon (*Acipenser oxyrhynchus desotoi*) in the Apalachicola River, Florida. Florida Scientist 45:244-248.

308. Wooley, C.M., and E.J. Crateau. 1985. Movement, microhabitat, exploitation and management of Gulf of Mexico sturgeon, Apalachicola River, Florida. North American Journal of Fisheries Management 5: 590-605.

308.1. Wrona, A., D. Wear, J. Ward, R. Sharitz, J. Rosenzweig, J.P. Richardson, D. Peterson, S. Leach, L. Lee, C.R. Jackson, J. Gordon, M. Freeman, O. Flite, G. Eidson, M. Davis, and D. Batzer. 2007. Restoring ecological flows to the Lower Savannah River: a collaborative scientific approach to adaptive management. Proceedings of the 2007 Georgia Water Resources Conference, held March 27–29, 2007, at the University of Georgia. Institute of Ecology, University of Georgia, Athens.

309. 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.

310. 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.

311. 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.

312. 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.

313. 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.

314. Ziewitz. J. 2006. Gulf sturgeon spawning habitat availability on the Apalachicola River. Presentation at the 8th Annual Sturgeon Meeting. October 11-13, 2006. White Springs, Florida.