No. 142, Original

In The
Supreme Court of the United States

STATE OF FLORIDA,

Plaintiff,

v.

STATE OF GEORGIA,

Defendant.

DIRECT TESTIMONY OF CHARLES A. MENZIE, Ph.D.

October 26, 2016

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I, Charles Menzie, Ph.D., offer the following as my Direct Testimony:[1]

1. I am an expert in environmental causal analysis and risk assessment, with extensive experience on the ecology of riverine and coastal ecosystems.

2. I have been retained by the State of Georgia to offer an expert opinion regarding the relative impact of Georgia's consumptive use of freshwater on the ecosystems supported by the Apalachicola River.

3. Specifically, I have been asked by Georgia to respond to claims raised by the State of Florida concerning alleged environmental impacts associated with Georgia's incremental consumption of freshwater within the Apalachicola-Chattahoochee-Flint ("ACF") River Basin. In general, Florida's claims allege that Georgia's use of water has caused or will cause harms to the ecology of Apalachicola Bay, the Apalachicola River, and the adjacent floodplain that supports wetland forests and other ecosystems. In response to Florida's experts, I have examined their claims regarding impacts associated overall consumptive use, including periods that precede 1992.

SUMMARY OF OPINIONS

4. My opinions relate to the ecological effects of incremental water consumption[2] by Georgia, with a particular focus on possible impacts on:

- Productivity of Apalachicola Bay
- Inundation of the floodplain and wetland forests.

5. I rely on a well-recognized scientific method for assessing the causal relationship between Georgia's water consumption and ecological effects, applying a tiered causal analysis that considers: (1) the evidence that ecological changes have occurred; (2) the degree to which

[1] Florida recently provided additional analysis conducted by Dr. Glibert on October 14, and new materials she relied upon in support of this analysis as recently as October 21. Given the limited time I have had to review this new analysis and materials, I reserve my right to supplement or modify my testimony related to this topic after I have had more time to review.

[2] Incremental water consumption refers to an upper bound on the amount of additional water consumed by Georgia since 1992. Unless specified otherwise, consumptive use refers to incremental consumptive use.

Georgia's consumption of water has or could contribute to ecological changes; and (3) the influence of other alternative causes. Importantly, this scientific method does not presume a conclusion but rather follows a deliberate process to assess potential causes of any ecological changes, based on the empirical evidence and supporting modeling. This contrasts sharply with the non-rigorous approach taken by Florida's ecological experts.

6. My analysis for this matter included an assessment of the current and historical states of the ecology of the Bay and River Floodplain, as well as an assessment of the prospective effect of incremental, increased flow on the ecology of that ecosystem. I hold the following overarching opinions regarding influences of freshwater flow on the productivity of Apalachicola Bay and River ecosystem:

a. **General Opinions Regarding the Historical and Natural Variability of the Apalachicola Bay and River Ecosystem**

- The Apalachicola Bay and River Floodplain is an ecosystem that has historically been sustained, and in fact has thrived, through multiple periods of natural variability, including periods of drought, changes in flow, and extreme conditions.

- The ecology of the Apalachicola Bay and River Floodplain system, like that of most estuarine systems, is inherently adaptable and therefore has persisted through multiple periods of variable conditions and cyclical changes.

- The system historically has exhibited the ability to recover from seemingly adverse conditions and changes, and there is no evidence that the ecosystem is behaving other than it has historically functioned. The system as it exists today is sustainable. Accordingly, any measures that are designed to protect the ecology of the system, in addition to those currently in place, must be carefully considered in light of historical and natural variability.

- Moreover, my analysis demonstrates that any contemplated protective measures that require incremental increases in flow would have negligible effects on the ecology of the Bay, and similarly negligible effects on the ecology of the Floodplain. Significantly, U.S. Army Corps ("USACE") operations independently have and will continue to have the ability to control flow affecting Floodplain habitat.

b. **General Opinions Regarding the Potential Effect of Georgia's Water Consumption on the Apalachicola Bay and River Ecosystem**

- Georgia's incremental consumption of water has had a negligible impact on salinity in the Bay, as confirmed by the opinions of both Florida and Georgia salinity experts.
- The annual and seasonal variations in biology in the Bay are caused by natural variations in environmental factors; this natural variation dwarfs any influence of Georgia's consumptive use of water.
- The Bay remains productive and supports a food web comprised of a diversity of fish and invertebrates, including oysters.
- Changes in inundation (flooding) in the River Floodplain, during low flow periods, as well as changes in river stage, are caused primarily by factors other than Georgia's consumptive use of water. Therefore, Georgia's consumptive use of water has had a negligible effect on any changes in the River and Floodplain ecosystems. Any observed changes are attributable to other factors.
- As recognized by the U.S. Fish and Wildlife Service's ("USFWS") recently-released 2016 Biological Opinion ("2016 BIOP"), the USACE's management of the flow regime in the River minimizes the potential for adverse effects to threatened and endangered ("T&E") populations and habitat in the River and Floodplain. In other words, the minimum flows and rate of river stage change are sufficient to protect critical habitats. This finding is consistent with the USFWS 2012 Biological Opinion ("2012 BIOP").

7. I hold the following specific opinions regarding influences of freshwater flow on the productivity of Apalachicola Bay:

a. **Assessment of Primary Producers (Phytoplankton, Algal Blooms, Submerged Aquatic Vegetation) at the Base of the Food Web**

- Georgia's incremental consumption of freshwater has a minor incremental influence on freshwater flow entering Apalachicola Bay. Natural climatic factors such as drought are responsible for most of the variation in flow in the past decade.

- Georgia’s incremental consumption of freshwater has a negligible influence on salinity in the Bay, and any salinity changes are within the range of natural variability in weekly average salinity.

- Because any salinity changes are lost in the noise of natural variability, salinity-related effects would be negligible for submerged aquatic vegetation (“SAV”). Biological effects would also be negligible for oysters, benthic invertebrates, fish, and other estuarine organisms in the Bay.

- There are sufficient nutrients to support phytoplankton production even at lower flows because nutrients are continually regenerated, and there is less flushing as less water is moved through the system.

- Phytoplankton biomass (as measured by chlorophyll-a) is sustained at low flows because of two factors: greater residence time for phytoplankton and greater light transparency to support plant growth.

- Phytoplankton biomass actually increases at low flows, meaning that there is more food available to upper levels of the food web.

- The occurrence of harmful algal blooms (“HABs”) in Apalachicola Bay is unrelated to lower river flows, and is completely unrelated to effects caused by Georgia’s incremental consumption of water.

b. **Assessment of Secondary Producers (Zooplankton, Benthic Invertebrates, Fish) and Upper Trophic Levels**

- Because primary production is not adversely affected by low flows, there are no nutrition-related effects on primary consumers (zooplankton and benthic invertebrates) that graze upon phytoplankton and contribute to secondary production.

- Because primary production is not affected by low flows and the plankton-based food web is sustained, there is a food/prey base for both oysters and fish.

- Populations of fish, Blue crabs, and White shrimp are not diminished as a result of drought-induced lower river flows. This indicates that the food webs are providing support to these upper trophic levels and that variations in salinity are not causing observable population-level effects.

- The fact that plankton-feeding fish (e.g. Bay Anchovies and Menhaden) continue to be abundant and sustained in the Bay provides evidence that the food web supporting oysters has remained intact.

- Because the consumption of water by Georgia has only a minor incremental influence on freshwater flows, and because populations of fish, crabs, and shrimp do not appear to be adversely influenced by lower flows, such water consumption would have a negligible effect on the populations of these animals in Apalachicola Bay.

8. I hold the following specific opinions regarding influences of freshwater flow on the productivity of Apalachicola River and Floodplain:

- Water consumption by Georgia has had a minor effect on freshwater flows in the Apalachicola River and thus a minor influence on inundation patterns during low-flow periods since 1992. Consequently, water consumption by Georgia has had little-to-no influence on floodplain habitats.

- The combination of extended high-flow conditions followed by drought can cause adverse effects to threatened and endangered (T&E) mussel species in the Apalachicola River by stranding them out of water, causing them to die. These extreme events are not caused by Georgia's consumptive water use. These types of events have likely occurred throughout history given that they are due to annual changes of river flows (low following high) and the historical hydrological regime, which naturally fluctuates between high and low flows.

- Quick decreases in river stage (fall rates or down-ramping rates) caused by historical flow management practices of the USACE have been documented to adversely affect the T&E mussel species in the Apalachicola River. When river flows drop more quickly than mussels can move in response to changing flow conditions, the mussels become stranded and die. Given the USACE's operation of the reservoirs, Georgia's consumptive water use does not cause rapid decreases in river stage.

- Quick decreases in river stage (fall rates or down-ramping rates) caused by flow management practices of the USACE have been documented to affect the Gulf sturgeon spawn in the Apalachicola River. When river flows drop too quickly during their spawning period, the fish eggs and larvae can become stranded and die. Given the USACE's operation of the reservoirs, Georgia's consumptive water use does not cause rapid decreases in river stage.

- Changes in inundation (flooding) have been caused primarily by changes in the shape of the river channel (caused by the USACE) and changes to regional climate (i.e., more frequent and severe droughts).

- Changes in lowland forest tree composition have occurred since the mid-1950s. Some wetland habitats have transitioned to drier upland-type habitats as a result of changes in inundation, although channel change is the primary cause of those changes.

9. My opinions are summarized in greater detail below with respect to my analysis of both primary and secondary producers in the Bay, as well as my analysis of the impact of freshwater flow on the productivity of the River and Floodplain.

BACKGROUND AND PROFESSIONAL QUALIFICATIONS

10. I received my Ph.D. in Ecology from the City University of New York. My dissertation research concerned secondary production in a shallow-water region of the Hudson River occupied by submerged aquatic vegetation (SAV). I have since worked on major river and coastal systems from Maine to Texas and on the west coast. Among these are the Penobscot River, Gulf of Maine, Merrimac River, Massachusetts Bay, Hudson River, Delaware River, Gulf of Mexico, San Diego Bay, San Francisco Bay and Puget Sound.

11. I am currently a Principal Scientist in the EcoSciences Practice at Exponent. As an ecologist, I have extensive experience with a broad range of ecological systems.

12. My primary areas of expertise are as an ecologist and risk assessor and in the conduct of causal analysis assessments regarding alleged environmental damages. I specialize in evaluating the effects of physical, biological, and chemical stressors on terrestrial and aquatic systems. I have worked on issues related to productivity of freshwater and marine ecosystems, with a specialized expertise in food-web relationships. I have also been involved in a number of Natural Resource Damage Assessments (NRDA) and environmental damage cases. My work as an expert over the last thirty years has included work on behalf of both plaintiffs and defendants. My expert work has also covered a variety of jurisdictions, including state courts, federal courts, administrative bodies, and the International Court of Justice.[3]

13. I specialize in the field of risk assessment and causal analysis and was awarded the Risk Practitioner Award by the Society for Risk Analysis (SRA), of which I am an Elected Fellow. Fellows of the SRA are nominated and elected based on their contributions to the science of risk assessment. I was awarded the lifetime achievement award from the Association for Environmental Health of Soils (AEHS). I have served on the Councils of SRA and the

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[3] I worked on two international cases before the International Court of Justice involving transboundary environmental issues: Argentina v. Uruguay and Colombia v. Ecuador.

Society of Environmental Toxicology and Chemistry (SETAC), the two major professional organizations in the fields of health and environmental risk assessment. I have led numerous peer reviews for industry and for government, and I have taken the lead in developing risk-related guidance documents for industry and government. On behalf of the U.S. Environmental Protection Agency ("EPA"), I carried out a survey of issues and research needs for the nation's estuaries, including those bordering the Gulf of Mexico.

14. Of particular relevance to this case is my work on methodologies for assessing multiple stressors on environments around the world. I developed and applied a formal causal-analysis approach for assessing causation in cases alleging environmental damage and have supported EPA's efforts in this area. I am a co-author of EPA's Report on the Environment, which sets forth the current understanding of the conditions of the nation's ecosystems. This work is based on consideration of a broad range of environmental indicators, along with an assessment of what those indicators mean for various ecosystems and environmental conditions. I have worked on a diverse array of ecosystems in North America, including river and coastal systems throughout the United States. I have carried out research on primary, secondary, and higher level biological production, SAV, oysters, endangered species, and other fish and wildlife. Of particular importance to the present case, I have significant expertise related to understanding how ecosystems respond to a myriad of physical, biological, and chemical factors.

PREAMBLE

General Approach to This Analysis

15. The Apalachicola River and Bay ecosystem has several components, including: 1) a hydrology with seasonally varying temperature and light, and 2) a diverse assemblage of biota that thrive in forests, wetlands, and estuarine and marine waters, with variable salinity and nutrient regimes. My report focuses on the productivity of this system and on the integrity, sustainability, and interrelationships of plant and animal populations that comprise the system.

16. It is important to approach this complex ecosystem holistically. Accordingly, I assembled a team of scientists with a deep knowledge and expertise in disciplines relevant to specific areas of the ecosystem. I drew upon all of these areas of expertise to support my causal analysis approach, which assesses change in the Apalachicola ecosystems.

Team Member	Causal Analyses	Marine Ecology	Freshwater Ecology	Wetland Ecology	Hydrology	Modeling	Statistics	GIS and spatial analyses
Kenneth Cerreto, MS		X	X	X				
Dr. Andrew Deines			X		X	X	X	X
Melanie Edwards, MS							X	
Dr. Tom Ginn	X	X	X			X		X
William Goodfellow, MS	X	X	X	X				X
Dr. Roxolana Kashuba	X	X	X			X	X	
Dr. Mike Kierski	X		X	X				
Dr. Jane Ma						X		X
Dr. Ann Michelle Morrison	X	X		X		X		X
Dr. Katherine Palmquist	X	X	X			X		
Dr. Susan Paulson					X	X		
Dr. Parmeshwar Shrestha					X	X		

17. In this preamble, I wish to highlight three aspects of my methodology that are critical to the reliability and strength of my opinions:

- Explicit consideration of the historical hydrological regime;
- Utilization of the available data to test hypotheses and claims; and
- Application of a formal causal analysis approach.

The Historical Hydrological Regime

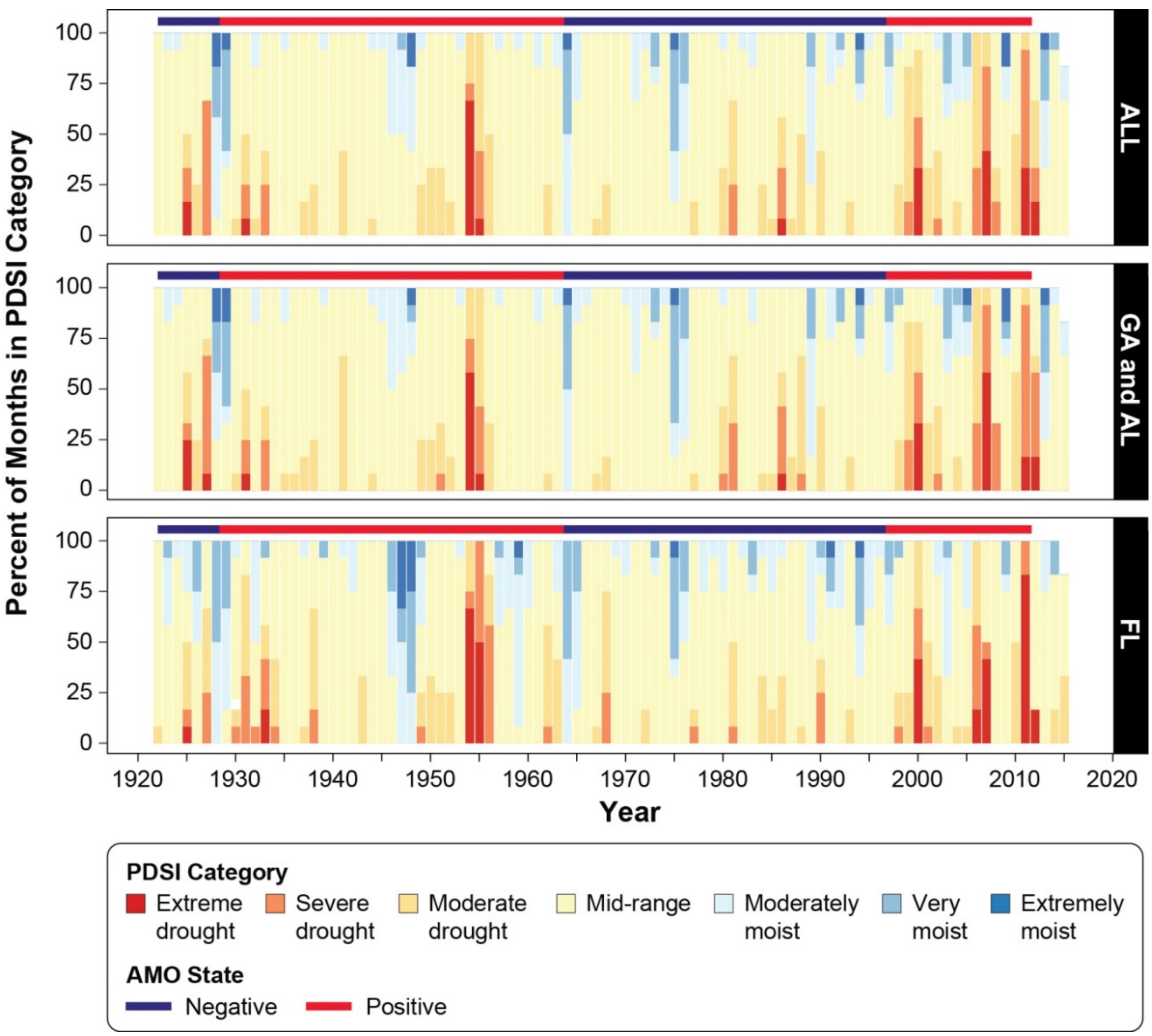
18. The historical hydrological regime is critically important for two reasons: it affects the ecology of the system, and it affects human perceptions of the system.

I. Ecological Importance of the Historical Hydrological Regime

19. The historical hydrological regime has shaped the structure, nature, and resiliency of the Apalachicola River and Bay ecosystem over the millennia. We can study the regime both from direct measurements of water flows and water availability, and from the fingerprint left on trees, namely in the tree ring record (greater tree growth and wider rings are formed in average or wetter years and distinctly lower tree growth and narrower rings are formed in drier years). I relied on both sources of information to examine the hydrological regime subsequent and prior to the 1900s.

20. To quantify the severity of dry periods since 1920, I used a drought index relied upon by the National Oceanic and Atmospheric Administration (NOAA), known as the Palmer Drought Severity Index (PDSI), which allowed me to examine the variation in drier and wetter conditions in the Apalachicola River watershed over time. This PDSI index is shown in **Menzie Demo. 1** below.

Menzie Demo. 1



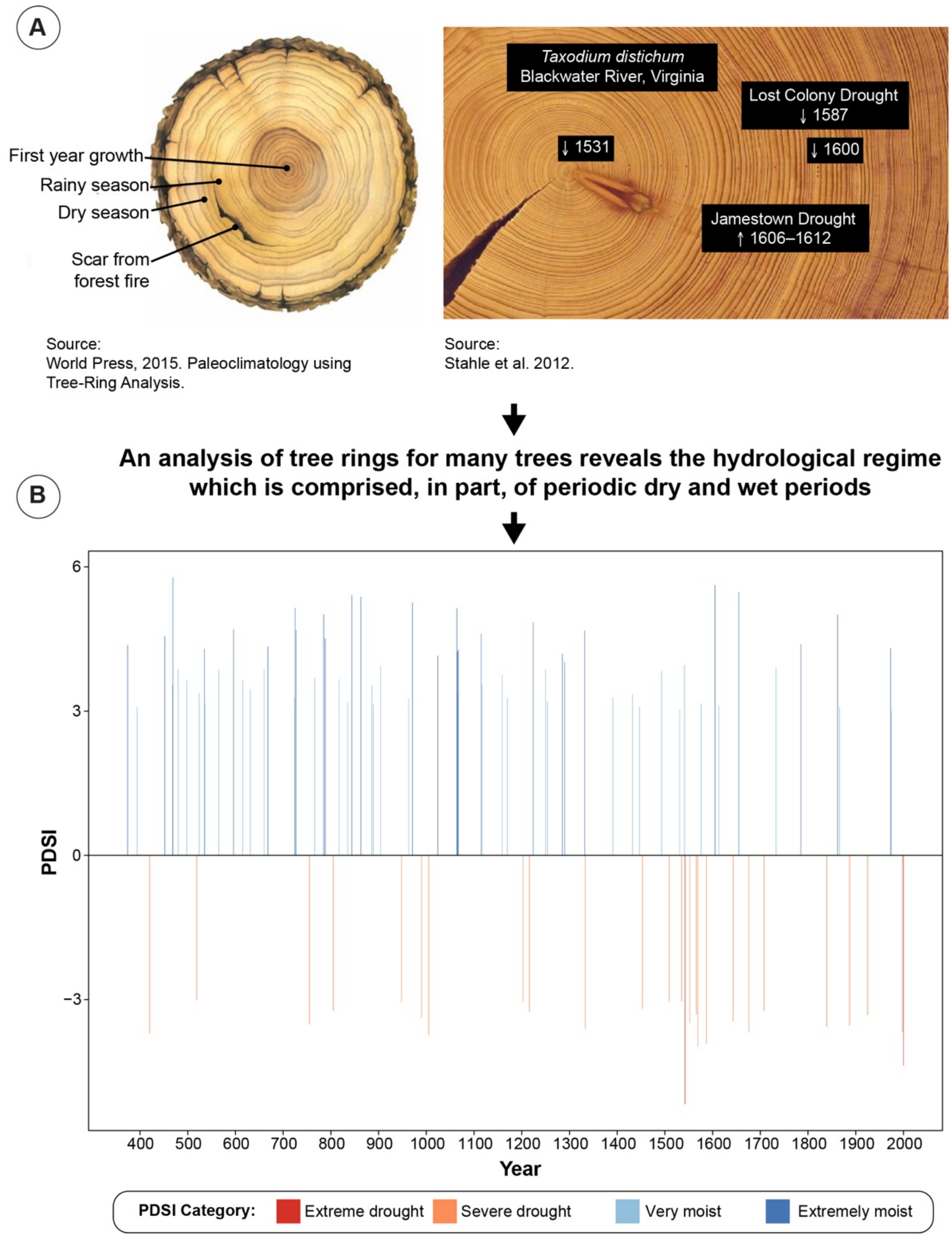
Demo. 1. This is Figure 7 from my Expert Report (GX-872). It shows the degree of drought or wet periods as reflected in an index—the PDSI—that the U.S. government relies upon for characterizing drought conditions. The PDSI is independent of any water consumption and not confounded by that factor. Orange and red colors reflect severe and extreme drought. Periodic occurrences of these droughts are seen in the figure for the 1920 to current timeframe. The three panels reflect different geographical areas: all of Georgia, Florida, and Alabama; Georgia and Alabama (watershed feeding to the Apalachicola River); and Florida.

21. As can be seen in **Menzie Demo. 1**, the Apalachicola Region has experienced an extreme dry period during the last few decades. In fact, this most recent period has proved

longer and more severe than others in the 20th century (including a notable drought in the 1950s). Understanding whether this type of natural variation between wet and dry periods is the norm, however, cannot easily be assessed when viewed only over a period of a few decades or even over a single century. A longer-term, historical context is necessary.

22. To understand natural climatic variation prior to 1920, I relied on tree ring data published in the scientific literature. The top figure below, **Menzie Demo. 2**, shows the general process used to derive climatic trends from this tree ring data—with dry periods characterized by slow growth (narrow ring) and wet periods by quick growth (wide rings). I used the tree ring data to derive the chart at the bottom of **Menzie Demo. 2**. This chart shows that the long-term hydrological regime of the Apalachicola Region is comprised of periodic wetter and drier periods that can be traced back for centuries.

Menzie Demo. 2

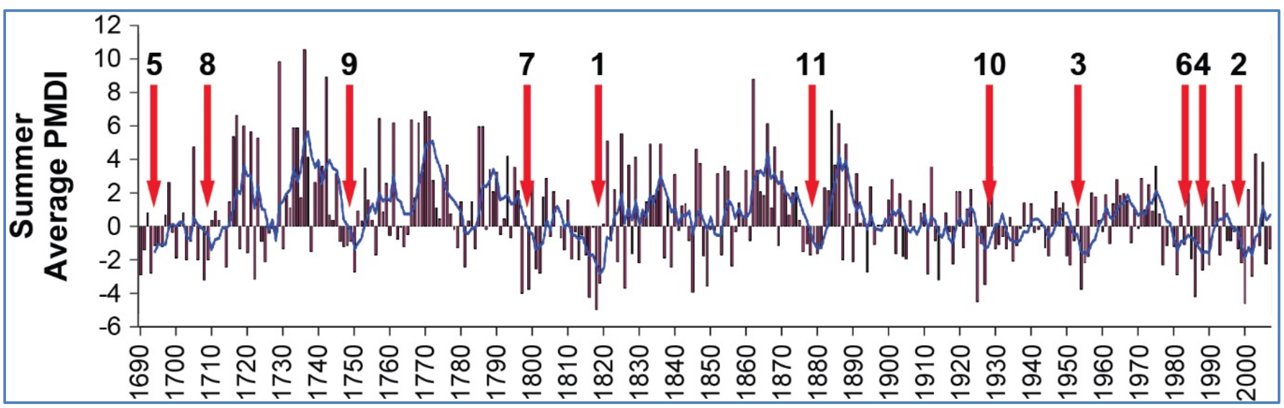


Demo. 2. This analysis is derived from Figure 8 of my Expert Report (GX-872). The top figure (A) shows the nature of tree rings analysis illustrating tree growth during wet and dry periods. The bottom figure (B) shows historical (400 AD to recent) PDSI drought reconstructions generated from published tree ring chronologies for the southeast United States. Data are from the North American Drought Atlas, a History of Meteorological Drought reconstructed from 835 tree-ring chronologies for the past 2005 years. GX-1102 (http://northgeorgiawater.org/conserve- http://iridl.ldeo.columbia.edu/SOURCES/.LDEO/.TRL/.NADA2004/.pdsi-atlas.html).

23. As **Menzie Demo. 2** shows, the most recent dry period is one of many that have occurred over the last several centuries, the most extreme of which appears to have occurred during the 16th century. Some of these dry periods are associated with notable historical events. For example, scientists have linked the 16th century drought to the fate of the Lost Colony of Roanoke Island (1587–1589). The evidence therefore shows that periodic variation between extreme wet and dry periods are not a recent phenomenon, but rather an important, long-term historical feature of the Apalachicola River and Bay ecosystems. Accordingly, the biological communities of these ecosystems have evolved in tandem with this natural variation.

24. The periodicity in dry and wet conditions found in the southeast United States is also verified in the tree ring data for the Piedmont area, which includes part of the ACF Basin, as shown in **Menzie Demo. 3**. Again, this data includes an extensive historical period that pre-dates the issues in this case. The index used is the Palmer Meteorological Drought Index (PMDI).[4] As can be seen below, the data show that there have been 11 periods of sustained drought in this region between 1690 and recent times. This figure confirms the naturally-occurring periodicity between wet and dry periods for the region.

<u>Menzie Demo. 3</u>



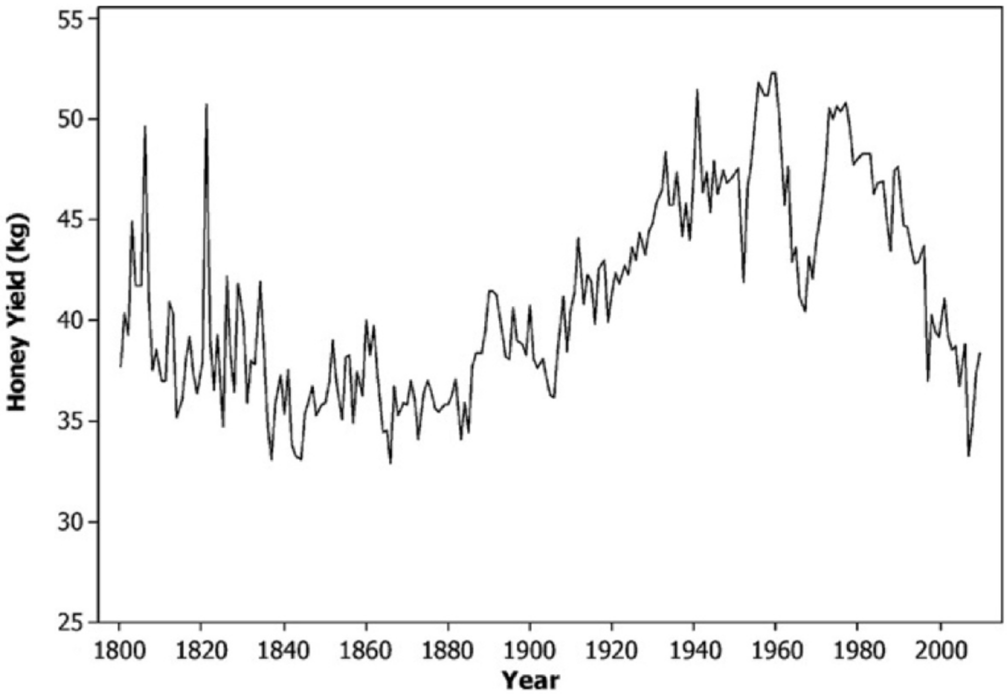
Demo. 3. This graph is a reconstruction of average summer drought values for Georgia climate division 5, which includes stations within the ACF Basin, taken from the Palmer Meteorological Drought Index (PMDI), 1690-1899 (1900-2007 are observed values). Columns represent annual values; the blue line shows the five-year moving average. During this period there were eleven periods of sustained drought. The source for this data is a 2008 Ph.D. dissertation by Jason Ortegren completed at The University of North Carolina at Greensboro.

[4] The Palmer Meteorological Drought Index (PMDI) is constructed in a manner similar to the PDSI, but is modified to factor in meteorology.

25. To further assess this longer, historical record of wetter and drier periods as it affects tree growth in the Apalachicola floodplain, I examined historical estimates of Tupelo tree honey yield based on an analysis of tree ring data for these trees in the Apalachicola River watershed. This work was published in 2013 by Justin Maxwell of the Tree-Ring Science Laboratory, Department of Geography, Indiana University, and scientists from other institutions engaged in dendrochronology (the scientific field in which tree rings are used to reconstruct past histories). These scientists were examining the influence of the Atlantic Multidecadal Oscillation (AMO) on Tupelo honey production from 1800 to 2010. Their findings were consistent with the longer time records presented in **Menzie Demos. 2 and 3**, and further confirm how these periodic oscillations between wet and dry periods have modified and will continue to modify the biology of the Apalachicola River and Bay ecosystem. These modifications are cyclical in nature.

26. The figure below, **Menzie Demo. 4,** shows the variation in Tupelo honey yield per hive in the Apalachicola River floodplain during the 19th and 20th centuries. As expected from what we know from the long-term tree ring data presented in **Menzie Demos. 2 and 3**, the tree ring data from which the honey yield per hive estimate is derived show periodic extreme effects of drier and presumably lower river flows and floodplain inundation patterns long before the construction of the Woodruff Dam, and long before any measurable water consumption by the State of Georgia. As depicted in **Menzie Demo. 4**, honey yield (as estimated from tree ring data) exhibits these same cyclical climatic variations. Tupelo honey yield per hive peaked in the 1930s to 1975 and has now returned to levels consistent with the 1800s.

Menzie Demo. 4



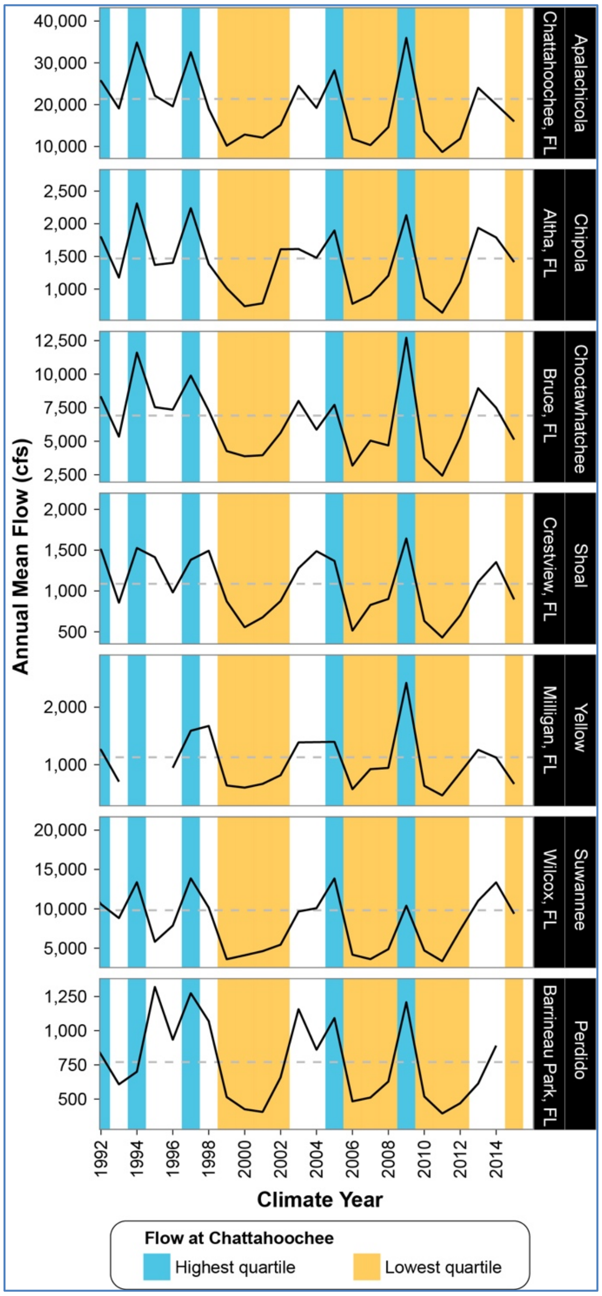
Demo. 4. This figure shows honey yield between the 1800s and recent times, as estimated from tree rings for Tupelo trees in the Apalachicola Bay Floodplain. The authors conclude from this work that variations in Tupelo honey yield illustrate how naturally occurring climatic cycles affect crop productivity. These data are taken from Maxwell et al 2013.

27. Natural periodic variation between wetter and drier conditions are characteristic of the Apalachicola River and Bay ecosystem and have existed for hundreds of years, and likely much longer. While there are many factors that will influence the timing and nature of future climate conditions in the region, it is reasonable to expect that the oscillating pattern of wet and dry periods will likely continue. The southeastern United States has been and may continue to be in a dry period as evidenced from the current status of the AMO, the primary factor contributing to the oscillations. If the historical record over the past centuries is any indicator for the future, this dry period will be followed by a wetter period in the 21st century as the pattern continues to cycle.

28. Historical flow data for all seven rivers in northern Florida also confirms that regional climate patterns—not upstream consumption—are driving the flow patterns of the Apalachicola River. If water consumption were the primary driver of variation, the Apalachicola River flow record would diverge from that of other regional rivers. Instead, **Menzie Demo. 5**

shows that the Apalachicola River reflects similar flow trends as other regional rivers, indicating that regional climatic variation is the predominant cause of these variations in flow.

Menzie Demo. 5



Demo. 5. This is Figure 6 from my Expert Report (GX-872). It shows average annual flow of the Apalachicola River and six other northern Florida rivers after 1992. Shaded regions indicate years when the average flow for the Apalachicola River at Chattahoochee was in the upper (blue) or lower (beige) quantile of all average annual flows at Chattahoochee since 1992. The figure shows that temporal variations in flow are similar across rivers indicating that they are all subject to a common regional climactic influence. Water consumption by Georgia cannot explain this common variation.

29. The importance of oscillating climatic conditions to the historical hydrologic regime affecting the Apalachicola River and Bay ecosystem is also recognized by the U.S. Fish and Wildlife Service (USFWS). In its 2016 BIOP, the USFWS states that:

> 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.

30. This statement is in complete agreement with what I have found from independent research presented in my Expert Report and underscores the importance of these cyclic dry and wet periods to the ecology of the Ecosystem. My findings and the conclusions reached by the USFWS point to the importance of separating these climactic factors from other factors that influence river flows, floodplain inundation, and salinity regimes in the Bay. I have taken care in my causal analysis to do that work; Florida's experts have not.

31. Therefore, both tree ring data and regional flow data over the centuries lead me to conclude that regional climactic influences are the primary driver of fluctuations in flows in the Apalachicola River. As I discuss in my Expert Report (GX-872) these climatic variations overwhelm any influence of water consumption by the State of Georgia.[5] Without an adequate

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[5] In reaching this conclusion, I am careful to distinguish between these periodic variations in climate—commonly referred to as oscillations—and what is generally known as "global climate change." Both climatic oscillations and global climate change can and do exist. However, the pattern of climatic oscillations is particularly important for understanding the historical hydrological regime that influences the Apalachicola ecosystem, as it explains most of the multi-decadal variation in water flows that have influenced this region for centuries.

understanding of these historical oscillations, however, it would be easy to assign too much influence to shorter-term causal factors.

32. In order to compare the relative influences of climatic factors and water consumption, it is essential to conduct analyses that separately isolate each factor. Accordingly, I separately analyzed the influences of climate and water consumption by holding one constant while varying the other. Florida's experts, on the other hand, used scenarios that hold climate constant to isolate the impacts of consumptive use, but they fail to hold consumptive use constant and evaluate changes in climate. Therefore, they fail to consider the relative contributions of each of these factors. Such analyses, given that they focus on only one causal factor, are incomplete and misleading.

II. Human Perception of the Historical Hydrological Regime

33. Individual perceptions of whether climatic conditions are either getting wetter or drier depend on their point of reference. For example, in the 1960s and 70s, an individual would have established a very different personal 'baseline' hydrological regime (plenty of water) than an individual in the early part of the 21st century, when extended droughts have been prevalent. Absent sufficient understanding of the historical hydrological regime, each of these individuals could assume some other cause of local variation in water flows that may not be based on scientific facts. Historical context and historical perspective are essential to a correct understanding of climatic conditions.

34. The failure to recognize the environmental significance of periodic climatic variation pervades Florida's expert reports. As a result, Florida's experts mistakenly attribute lower water flows in the Apalachicola River primarily to Georgia's water consumption, rather than to the climatic variation associated with natural oscillations and droughts. This fundamental misunderstanding of the system has also led Florida's experts to frame the future in terms of "tipping points." I have personally authored peer-reviewed scientific articles and given lectures about tipping points in relation to global climate change, but that is a directional process that is different from the climatic oscillations that are a natural feature of the Apalachicola River and Bay ecosystem.

35. Individuals also perceive “harm” or “adverse change” against individualized baselines and personal experience, which may restrict their ability to accurately understand “harm” or “change” in the appropriate historical and ecological context. Changes occur over time for all ecosystems, and not all changes are adverse or harmful for these ecosystems.

36. Perceptions of change are thus necessarily rooted in the baseline against which an individual is judging change. Because Florida’s experts fail to define the baseline of “harm” against which they are measuring change, or to consider historical context, they mistakenly identify natural fluctuations in the ecology and hydrology of the system as a detrimental shift caused by Georgia’s water consumption. Without an adequate understanding of these natural variations, environmental management decisions cannot be appropriately tailored to remedy the alleged “harm.”

Utilization of Available Data

37. The second aspect of my methodology relates to my utilization of the available hydrological and ecological data. As a scientist, I give highest priority and weight to firsthand observation, combined with available site-specific field data. While non-site-specific data and laboratory testing can inform what is being observed in the field, such data cannot be relied on in isolation.

38. The importance of considering all available information and taking a holistic systems approach is underscored by recognizing a fundamental biological principle, articulated by one of the leading biologists of the 20th century, called the *Principle of Emergence*: “In a structured system, new properties emerge at higher levels of integration which could not have been predicted from a knowledge of lower-level components.”[6] In the current context, this means that production, population dynamics, and species interactions in the Apalachicola River and Bay (i.e., the “system”) cannot be reliably predicted from piecemeal information gathered from other systems or derived from simple laboratory tests. Similarly, because ecosystems represent a higher level of integration than any single biological component, such as the presence of a particular species of phytoplankton, information about that single biological component in

[6] Ernst Mayr, *This is Biology: The Science of the Living World* (Cambridge: Belknap Press of Harvard University Press, 1997), at 19.

the Apalachicola system cannot be used to reliably predict what will occur at higher levels of biological organization. An examination of what is occurring at lower levels can only provide insights into ecosystem structure and functioning, but it cannot be used to demonstrate a series of cascading effects up the food web. Thus, as I show below, the opinions of Florida's experts, particularly those of Dr. Glibert, are theoretical constructs that cannot be considered predictive with any degree of reasonable certainty.

39. The importance of seeking, obtaining and considering all the relevant information for forming opinions regarding causal factors is also underscored by the important insights of Daniel Kahneman (2011) in his book, *Thinking Fast and Slow*. He points out that there is a tendency for people to rely on the data in hand, and to assume it is of sufficient quality and breadth to address an issue. He terms this the 'What You See Is All There Is' phenomenon: cognitively, people prefer consistency over completeness of information. He further notes that people innately feel more confident in judgments drawn from one-sided information than with possibly conflicting, but more complete, information. As such, people are predisposed to fail to account for the possibility that critical evidence could be missing. This is something I am aware of and make an effort to guard against by using formal causal analysis as described later in my direct testimony. Dr. Glibert, one of Florida's experts, takes a different approach, one which has significant flaws and limitations because of its reliance on one-sided sources of information.

40. Dr. Glibert's approach to developing opinions concerning system effects ignores the Principle of Emergence, as she extrapolates from limited pieces of information about lower levels of biological organization to system wide effects. She also selectively choses data to make her arguments and ignores other relevant information for the ecosystem that could be used to either verify or negate her initial views. As such, her approach is at odds with a fundamental biological principle and also suffers from Kahneman's "What You See Is All There Is" phenomenon. Throughout her report and direct testimony, Dr. Glibert extrapolates from small pieces of information without considering context or information about what is occurring at higher levels of ecological integration. Dr. Glibert puts forth little site-specific field data on the Apalachicola Bay system, but instead relies on lab testing and literature reviews. As a result, she mistakenly extrapolates isolated biological information to larger trends at higher levels of ecological integration. Based on the scientific principles described above, her approach is

plainly incorrect. Instead, she should have given greater weight to available data that reflect the actual nature of the system, as I do in my report and in the analysis below.

41. To this end, my field visit and observations of Apalachicola River and Bay were enormously informative. The fact that Florida's ecological experts, Drs. Glibert and Jenkins,[7] did not visit the Apalachicola region before their reports or depositions constrains their insights and limits the certainty of their opinions. Had I not made this site visit and collected data on biota and water quality, I would have remained uninformed about important aspects of the ecosystem and therefore less confident about my conclusions. For example, my in-person observations revealed that the East Bay region of Apalachicola Bay supported beds of submerged aquatic vegetation ("SAV"), including the salinity-sensitive tape grass *Valisneria americana* ("tape grass"). Because Florida's ecological experts, Drs. Glibert and Jenkins, did not observe conditions in the Bay or fully utilize site-specific data, they reached a different conclusion—claiming that tape grass is absent from East Bay (which is actually not the case), and attributing its purported absence to Georgia's consumption of water. Additional information about the value of my field visit and how it informed my opinions—and contradicts those of Florida's experts—are explained throughout my direct testimony below.

Application of a Formal Causal Analysis

42. Finally, I apply a formal causal analysis to evaluate whether alleged upstream consumptive use by Georgia leads to alleged harms or potential harms to the Apalachicola River or Bay ecosystems. A causal analysis is a systematic, transparent, and objective method of evaluating stressors on an ecosystem that could be potential causes of change to the system. The causal analysis process prevents gaps in logic by considering candidate stressors and their effects, and does not prematurely identify a cause or assume "harmful" effects. In short, causal analysis minimizes the potential for circular reasoning, a logical fallacy in which the reasoner begins with the conclusion he or she is trying to prove. It also avoids Kahneman's "What You

[7] Dr. Jenkins was Florida's Bay fisheries expert. He submitted an expert report, was deposed, and was extensively relied upon by Dr. Glibert in her expert report for allegations of harm to upper trophic levels, as well as mentioned repeatedly in her deposition. Accordingly, I analyzed the accuracy of Dr. Jenkins' work in my expert report, including its legitimacy as a basis for some of Dr. Glibert's analysis and opinions. I understand that Dr. Jenkins has not submitted any pre-filed written direct testimony and will not be offering opinions at trial.

See Is All There Is" phenomenon of relying on one-sided information to reach preformed conclusions about the relationship between environmental factors and ecological variation. Florida's ecological experts do not apply a proper causal analysis, but instead presume both a cause and effect: upstream consumptive use leading to ecological harm or potential harm. This circular reasoning leads to critical gaps in logic.

43. Evidence-based causal approaches, like the one I use here, are well accepted in a variety of disciplines, including in medicine, and by the U.S. government in environmental, health and defense applications. Specifically, causal analysis has been broadly applied throughout the United States to diagnose which stressors are impacting aquatic environments. For example, the EPA has developed an evidenced-based approach to determine the cause(s) of environmental changes and conditions in aquatic systems called the Analysis/Diagnosis Decision Information System (CADDIS). This type of formal approach helps to prevent potential biases and avoid premature and unsound conclusions.

44. On the CADDIS website, the EPA has selected the Presumpscot River of Maine as a case example for causal analysis. EPA and various states have also used the causal analysis framework to evaluate biological impairments in a diverse array of river systems including the Arkansas River, Colorado; Willimantic River, Connecticut; and Little Flood River, Iowa; as well as coastal embayments.[8] This causal analysis approach has also been used in Florida and is familiar to the environmental regulators in that state. Because formal causal analysis has become standard practice for diagnosing causes of biological impacts in waters of the United States, I rely on this methodology for the present matter.

45. I have been closely involved in causal analysis work for a number of decades and have applied it to many national and international environmental matters. For this matter, I use a tiered causal analysis framework that is appropriate for evaluating multiple stressors in an ecosystem and rely on this logical framework in developing and supporting my opinions. The

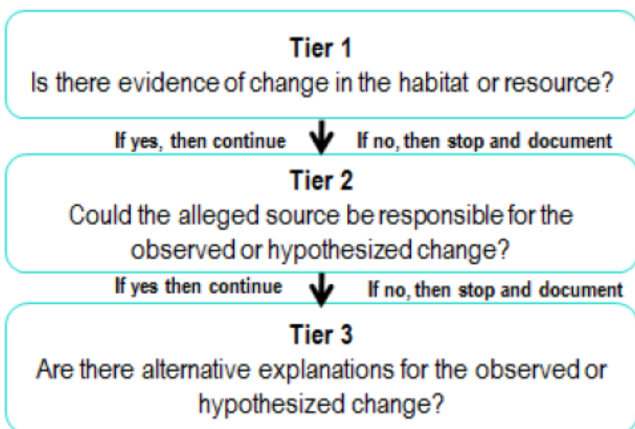
[8] U.S. EPA. 2012. CADDIS Volume 3: Examples and applications case studies. U.S. Environmental Protection Agency, Washington, DC. Available at http://www.epa.gov/caddis/ex_full_home.html; Frydenborg, B., and R. Frydenborg. 2015. New Regulatory Requirements for Stressor Identification Studies. Presented at Florida Stormwater Conference. http://www.florida-stormwater.org/assets/MemberServices/Conference/2015-Annual-Conference/15%20-%20frydenborg%20frydenborg.pdf.

approach is based on work funded by the EPA and has since been utilized by the National Research Council to support its recommendations in *Science and Decisions: Advancing Risk Assessment*.[9]

46. For a scientifically sound causal analysis of ecosystems such as the Apalachicola River and Bay, it is essential to consider the suite of plausible factors that can result in changes in the abundance or biomass of ecological receptors such as phytoplankton, trees, or fish. Additionally, as discussed above, it is particularly important to consider historical stressors that have shaped the ecosystem. Therefore, as part of my causal analysis, I relied on a team of experts at Exponent, Inc. who have expertise in the application of causal analysis and insight into multiple potential stressors on these ecosystems.

47. My tiered causal analysis approach begins with an evaluation of the evidence that any ecological change has occurred, and then proceeds to an in-depth examination of potential causes of that change, as illustrated below in **Menzie Demo. 6**.

Menzie Demo. 6



Demo. 6. This is Figure 1 from my Expert Report (GX-872). It displays the three-tier approach to conducting a formal causal analysis.

9 Menzie, C.A., M.M. MacDonell, and M. Mumtaz. 2007. A phased approach for assessing combined effects from multiple stressors. Environ. Health Persp. 115(5):807–816; NRC. 2009. Science and decisions: Advancing risk assessment. National Research Council, Committee on Improving Risk Analysis Approaches Used by the U. ISBN: 0-309-12047-0, 478 pp. http://wwwnap.edu/catalog/12209html.

I. Tier 1 — Have there been changes in the productivity of the Bay or the ecology of the floodplains?

48. Under Tier 1, I first examine whether the available evidence supports or refutes the premise that there is actual harm to the Apalachicola River and Bay ecosystems. This step serves to establish whether there is merit to the claim of harm or whether the claimed harm is based on speculation and/or lacks sufficient technical support.

49. It is important to define "harm" at the outset, with the understanding that change and variation are features of all ecological systems. Here, I define harm in terms of: 1) the nature of a change or potential change in productivity and species population status, 2) whether such change would be judged to be adverse, and 3) whether the change would be causally related to a mechanism of action associated with changes in river flows from Georgia into Florida. Florida's experts, in contrast, leave harm largely undefined.

50. An approach based, in part, on system productivity and population, recognizes that there can be losses of individual population members in ecosystems due to natural factors, manmade perturbations, and/or intentional harvesting. Mortality of individual animals and plants is a natural feature of floodplain and estuarine ecosystems. Therefore, I consider whether the system and its populations, as a whole, are sustainable and productive, despite the myriad of stressors that may be present and that might impact individual organisms (that is, members of populations).

II. Tier 2 — Has incremental water consumption by Georgia above 1992 consumption levels been an ecologically significant contributor to any of the alleged and observed changes in the Bay or floodplain?

51. If my Tier 1 analysis indicates there is change or harm, I then conduct a Tier 2 analysis to evaluate whether it is plausible that Georgia's consumptive water use could be the proximate cause of observed changes or harms in the ecosystem. This involves an in-depth examination of the interactions of the alleged cause with the ecosystem, and whether the cause is sufficient to result in the observed change or harm. If a connection is found, my Tier 2 analysis also allows me to quantify the relative contribution of the alleged cause.

52. In the current case, a Tier 2 analysis must address the question: "Has incremental water consumption on the part of Georgia since 1992 resulted in the types and magnitudes of changes and/or harms alleged by Florida, or could it have?" I have focused on the environmental consequences associated with the incremental use of water by Georgia since 1992, because Florida's complaint specifies a baseline for evaluation of ecological consequences. Florida states in its complaint that:

> *Florida further prays that the Court enter an order enjoining Georgia, its privies, assigns, lessees, and other persons claiming under it, from interfering with Florida's rights, and capping Georgia's overall depletive water uses at the level then existing on January 3, 1992.*

53. Even when I have found no indication of change to a resource as part of my Tier 1 analysis, I have completed a Tier 2 causal analysis to examine the strength of association between the alleged change, flow in the Apalachicola River, and Georgia's consumptive use of water. This was done to demonstrate the rigorousness of my approach and the importance of assessing causal relationships methodologically and in appropriate context to other stressors.

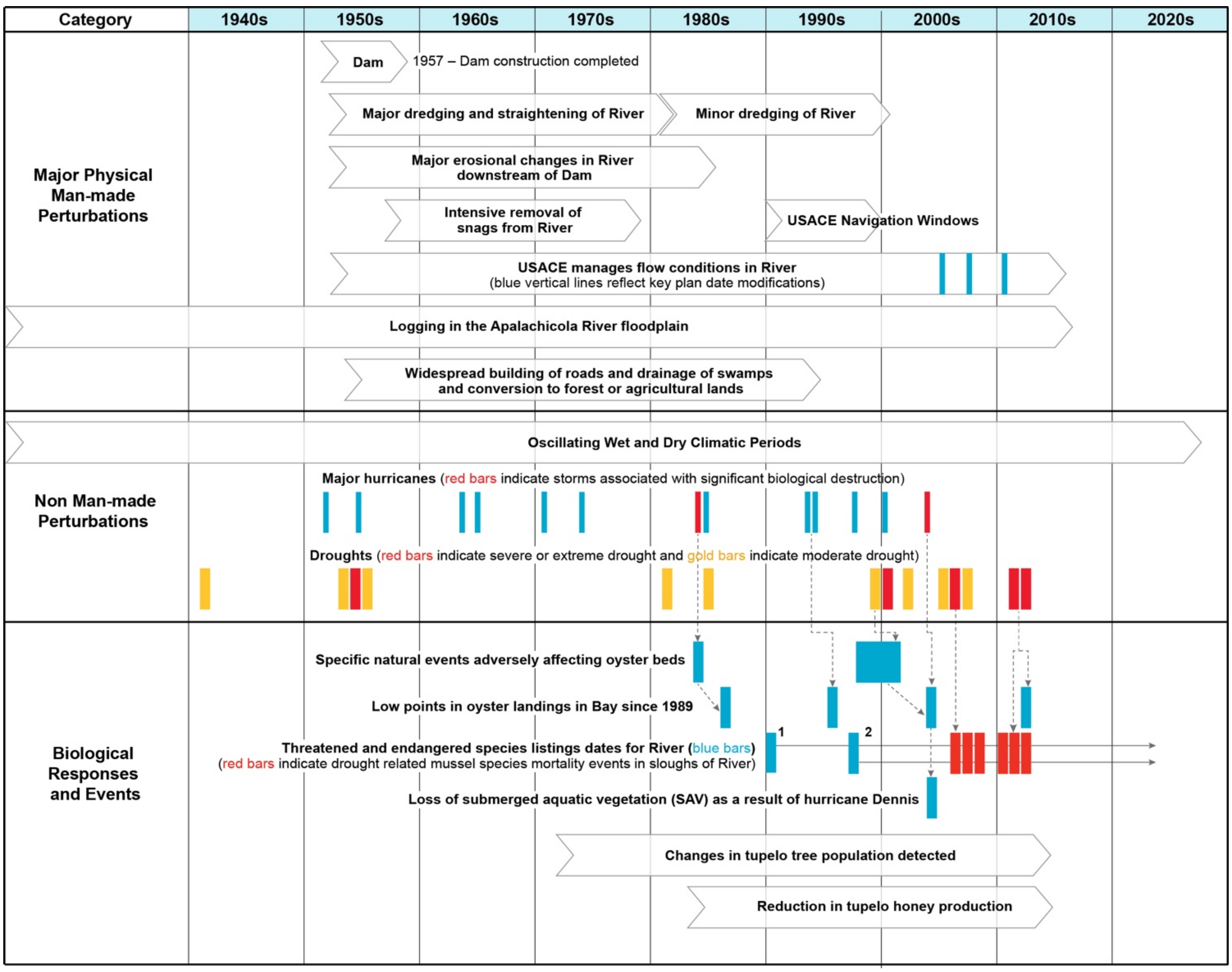
III. Tier 3 — Aside from the incremental water consumption by Georgia, are there other factors that are causing the observed changes in ecological resources within the Bay and floodplain?

54. If a Tier 2 analysis establishes that it is plausible for an alleged cause to potentially be associated with possible change or harm, I conduct a Tier 3 analysis to more fully examine the relative potential contribution of alternative causes. Although ecological resources may exhibit change over time, this does not necessarily mean that they were engendered by an alleged cause. Instead, the observed changes or harms may be due to combinations of factors that may or may not include the alleged cause. A multiple-stressor situation is, in fact, the norm in most ecosystems (i.e., typically, many stressors are involved in observed ecological change).

55. The goal of a Tier 3 analysis is therefore to examine the contributions of plausible stressors on specific ecological components for which change and/or harm has been observed or alleged. This is accomplished by considering several causal criteria – including the timing of the stressors and ecological change, the specificity of the stressor to cause the change, and the sufficiency of the stressor to cause the change.

56. There are many stressors within the Apalachicola system, in addition to those that influence freshwater flows. To better understand these other stressors, I assembled them along a timeline so that I could examine the temporal relationship between stressor events and responses in the ecosystem. That timeline is shown in the following figure, **Menzie Demo. 7.** This figure shows that natural stressors, such as the occurrence of hurricanes and droughts, as well as manmade stressors, such as the building of a dam and forestry activities, are evident through the historical record.

Menzie Demo. 7



Demo. 7. This is Figure 3 from my Expert Report (GX-872). It illustrates the temporal occurrence of two groups of stressors affecting the Apalachicola River and Bay ecosystem: man-made and non-man-made. The figure also shows documented changes in biology that result from the various stressors.

57. The record shows that hurricanes and droughts are among the most significant natural sources of stress to the Apalachicola River and Bay and have resulted in losses of biota. The most ecologically significant manmade source of stress, on the other hand, was the construction of the Jim Woodruff Lock and Dam ("JWLD") and subsequent maintenance of the river through dredging and straightening. Of particular significance for the floodplain was the depression (lowering) of the river bed due to erosion following dam construction.

58. Many of the potential stressors have ***some*** influence on the ecosystem. In the present case, I consider whether a stressor is sufficient to cause the alleged harm from two perspectives. First, with respect to the influence of Georgia's consumption of water on flows, inundation of floodplains, and changes in salinity of the Bay, I examine the relative influence on flow of water consumption in comparison to climatic variation and USACE operations of the JWLD. I conduct a series of analyses to parse these relative influences. Second, I utilize information on the relationships between the magnitudes of the causes and of the effects to examine how changes in a particular stressor might influence an ecological component.

59. In sum, my structured causal analysis framework prevents a common flaw in logic that equates causation with mere correlation of one causal factor with adverse change. It is very rare that one factor is solely correlated to an adverse change in an ecosystem. In most situations, multiple factors will demonstrate correlation, and identifying the causal agent(s) requires careful consideration of each of these factors. This is particularly true in estuarine ecosystems, which by definition are complex and subject to a variety of competing hydrological, climatological, physical, and biological factors.

CAUSAL ANALYSES OF ALLEGED HARMS TO THE APALACHICOLA BAY

60. Florida's experts claim that Georgia's consumption of water has harmed the productivity of Apalachicola Bay. To examine this claim of causation, I examined the biological productivity of Apalachicola Bay for three categories of resources: primary production that provides habitat (as represented by submerged aquatic vegetation), primary production that supports the Bay's planktonic food web (as represented by nutrients and phytoplankton), and secondary (animal) production (as represented by fish and invertebrates). I did not specifically examine oysters, as that is being addressed by another expert on behalf of Georgia. However,

my evaluation of salinity variations and phytoplankton productivity does provide useful information for considering whether water consumption by Georgia has or could affect the productivity of oysters, as these animals are secondary producers of animal biomass within the Bay. I conducted my tiered causal analysis, as described above, for each category of resources, and arrived at the following answers under each tier:

Menzie Demo. 8

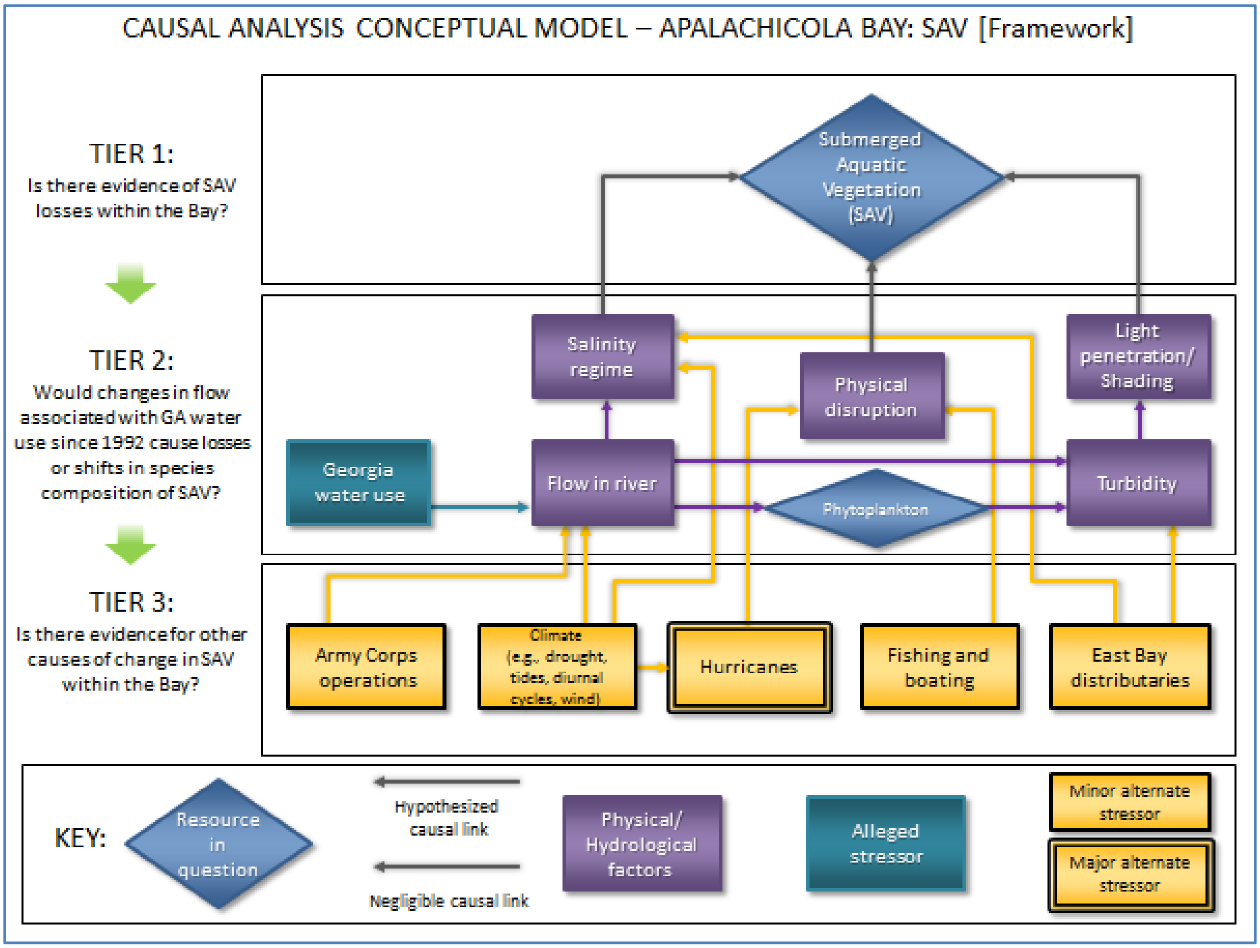
	Primary Production/Habitat (submerged aquatic vegetation)	Primary production (nutrients and phytoplankton)	Secondary production (fish and invertebrates)
Tier 1: Evidence of change or resource loss?	Yes	Yes	Negligible
Tier 2: Evidence of Georgia water use as causal factor?	Negligible	Negligible	Negligible
Tier 3: Evidence of other causal factors?	Yes	Not applicable based on Tier 1 and 2	Not applicable based on Tier 1 and 2

Demo. 8. Answers derived from tiered causal analyses conducted on three categories of resources for the Bay.

I. Changes in Submerged Aquatic Vegetation (SAV)

61. First, I evaluated the species composition and spatial distribution of SAV because these rooted plants are a key source of primary production in the Bay. SAV provides important habitat for fish, as well as benthic invertebrates such as Blue crabs. The conceptual framework for evaluating the factors that may cause shifts in the species composition or spatial distribution of SAV is shown below in **Menzie Demo. 9**. Because SAV beds occur at specific locations where light, substrate, and other environmental factors allow for its establishment and growth, these factors are included as potential stressors.

Menzie Demo. 9



Demo. 9. Conceptual model used to structure the analyses of causal factors affecting SAV in the Bay.

(a) Tier 1: Is there evidence of losses of SAV within Apalachicola Bay?

62. As part of my Tier 1 causal analysis, I first examined the merits of the claims made by Drs. Jenkins and Glibert concerning the extended loss of freshwater SAV from East Bay. Florida's expert Dr. Jenkins claims that losses of SAV within East Bay at the mouth of the Apalachicola River have and are occurring because of increases in salinity that he claims are causally related to Georgia's consumption of water. Dr. Glibert claims that SAV growth in East Bay is impeded at low river flows due to the occurrence of phytoplankton blooms that shade the SAV beds. She attributes these low flow events to Georgia's consumption of water. To analyze the validity of these claims, I examined whether or not the SAV beds have recovered from historical hurricane-related losses over the last decade, in spite of drought conditions and corresponding changes to the salinity regime of the Bay.

63. As Florida's expert Dr. Jenkins noted in his expert report, prior to Hurricane Dennis in 2005, SAV beds in Apalachicola Bay were thriving. JX-28 (Edmiston, L., *Tropical storm and hurricane impacts on a Gulf Coast estuary: Apalachicola Bay*). According to surveys conducted by FDEP at the time, species observed included salinity-sensitive *Vallisneria americana* and *Najas guadalupensis*, along with "other freshwater species tolerant of low salinity." JX-28 (Edmiston, L., *Tropical storm and hurricane impacts on a Gulf Coast estuary: Apalachicola Bay*). In fact, FDEP reported that their survey detected "large areas of SAV that had not been mapped previously [which] has significantly expanded the distribution of known SAV in East Bay." JX-28 (Edmiston, L., *Tropical storm and hurricane impacts on a Gulf Coast estuary: Apalachicola Bay*).

64. Even though Hurricane Dennis caused extensive losses of SAV beds in the lower River and East Bay, recent FDEP surveys show that SAV levels in those areas have since been slowly recovering, and SAV has actually increased elsewhere in the Bay. GX-1254 (FFWCC, *Summary report for Franklin County Coastal Waters in Seagrass, integrated mapping and monitoring report no. 1.1*, 2014). According to the available survey data, between 1992 and 2010 there was a net increase of 159 acres of SAV across all sub-regions of Apalachicola Bay.[10]

65. I conducted my own reconnaissance survey of East Bay on April 19, 2016. I visited major embayments (coastline recesses) of East Bay and the mouths of major distributaries (river branches that do not return to the main stream but instead discharge into East Bay), as well as other shorelines in the main part of the Bay. Because of the turbidity of the water, which allowed for only a few inches of visibility, I used a rake and an underwater camera to search for SAV, in addition to making visual observations at the surface.[11] As a result, I observed

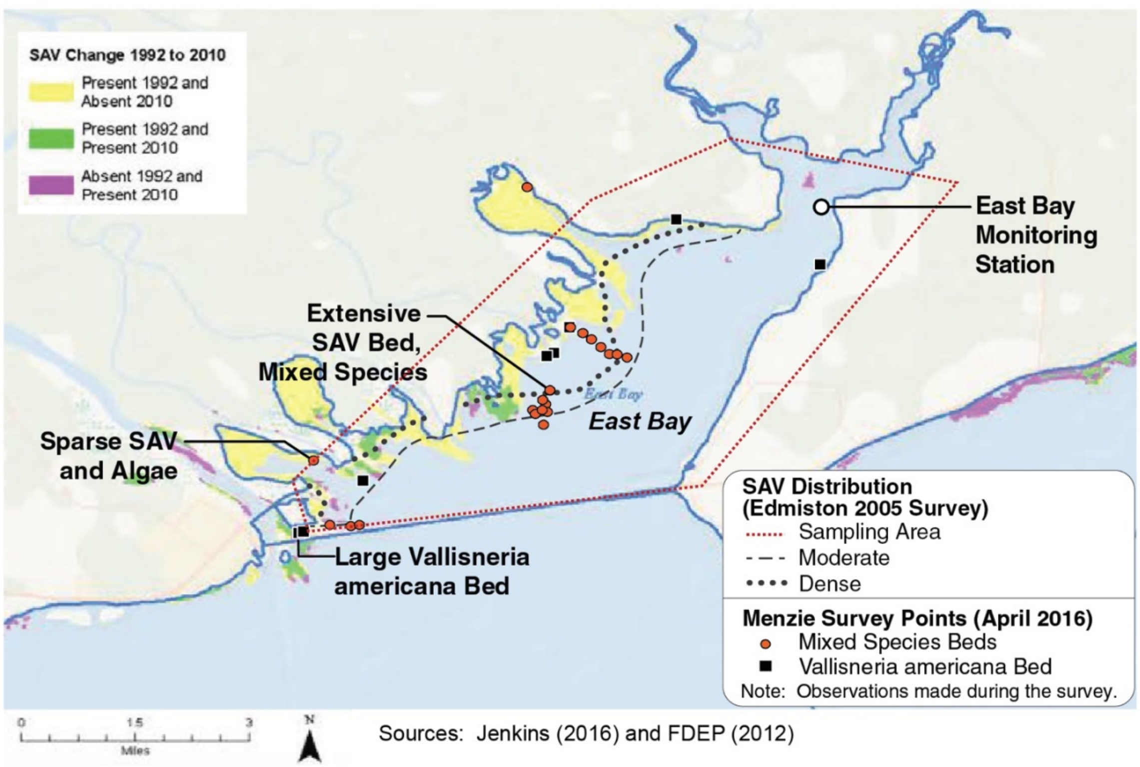
[10] These estimates were made by comparing maps of seagrass cover in Franklin County coastal waters observed in 1992. GX-352 (FFWCC, *Seagrass integrated mapping and monitoring for the State of Florida: Mapping and monitoring report no. 1*, 2011), with seagrass cover observed in 2010. GX-1254 (FFWCC, *Summary report for Franklin County Coastal Waters in Seagrass, integrated mapping and monitoring report no. 1.1*, 2014). Seagrass declined by 2,004 acres from 1992 to 2010 in the main region of the Bay and by 535 acres in Alligator Harbor and shoal. Seagrass increased by 1,901 acres in Dog Island and reef and surrounding areas, by 740 acres in St. George Sound, and by 56 acres in St. Vincent Sound. The net change in seagrass across all subregions of Apalachicola Bay between 1992 and 2010 was an increase of 159 acres. GX-1254.

[11] A standard dirt rake (also called a bow rake) was used to grab qualitative samples of submerged aquatic vegetation. The rake was purchased at a local hardware store and can be seen in several of the site visit photos. Plant samples for identification were individually labelled based on collection time and location, packed, and stored on ice and shipped in a cooler via overnight delivery (FedEx) to Exponent.

extensive beds of SAV that could have been easily missed in aerial or satellite photographs. The overall turbidity of the water in East Bay turbidity makes photography and satellite algorithms very difficult.

66. The map below, **Menzie Demo. 10**, shows my survey points overlain with the two surveys of SAV conducted in 1992 and 2005. Dr. Jenkins relied on only one of these, the 1992 survey, in his discussion of SAV. Given that the 2005 SAV coverage data was relied upon by the FDEP for a 2012 assessment of nutrients in Apalachicola Bay, it is unclear why it was not used in Dr. Jenkins' assessment. As shown in **Menzie Demo. 10**, I identified extensive SAV beds throughout East Bay, even in areas not previously captured by these earlier quantitative surveys.

Menzie Demo. 10



Demo. 10. Map of SAV in East Bay adapted from Figures 11 and 40 of my Expert Report (GX-872). Spatial distributions of plants are shown for surveys conducted between 1992 and the present. Results show that variations have occurred due to storm events. Current observations on SAV distribution are consistent with historical observations prior to impact of Hurricane Dennis in 2005, indicating recovery despite periodic droughts.

67. While the aerial surveys conducted by FDEP in 2005 and 2010 reliably document the *presence* of SAV, the ability of these surveys to quantify the *extent* of SAV coverage is

limited by turbidity and color in East Bay. GX-1252 (FDEP, Site-specific information in support of establishing numeric nutrient criteria in Apalachicola Bay). This means that satellite or other aerial observation of these regions can yield highly uncertain information and cannot be reliably used to provide quantitative estimates of the extent of SAV beds.

68. During my reconnaissance survey, I observed several species of SAV within East Bay, including Sago pondweed (*Stuckenia pectinate*), Widgeon grass (*Ruppia maritima*), Southern naiad (*Najas guadalupensis*), and Musk grass (*Chara* spp.). Beds of SAV within East Bay were quite dense, extensive in some locations, and often visible from the water's surface. I also observed *Vallisneria americana*, which is considered to be salinity-sensitive, at several locations along the East Bay shoreline. Where they broke the water's surface, it was possible to get a sense of the extent of these and other SAV beds.

<u>Menzie Demo. 11</u>

Demo. 11. These are Figures 12 and 13 from my Expert Report. They are a few of many such photographs and videos that were taken during my April 2016 field visit to Apalachicola Bay and East Bay. These pictures document the presence of SAV in areas where these plants were historically present prior to droughts or hurricanes.

69. Although they identify SAV losses, both Drs. Jenkins and Glibert cite to the same Florida agency report that shows SAV in the Apalachicola Bay region has been steadily increasing since Hurricane Dennis in 2005. GX-1254 (FFWCC, *Summary report for Franklin County Coastal Waters in Seagrass, integrated mapping and monitoring report no. 1.1*, 2014) Other reports from Florida agencies similarly suggest that SAV in Apalachicola Bay has recovered following Hurricane Dennis: "seagrasses have returned in similar density and composition to what was documented prior to [Hurricane] Dennis." GX-1252 (FDEP, *Site-*

specific information in support of establishing numeric nutrient criteria in Apalachicola Bay, 2012).

70. An additional indicator of SAV recovery in the Bay is the presence of animals that rely on SAV for food. In 2011, ANERR reported that manatees frequent East Bay and the mouth of the Apalachicola River because "manatees feed on a wide variety of marine, estuarine and freshwater vegetation . . . [and] there are considerable amounts of SAV in the Apalachicola River and East Bay, mainly tape grass (*Vallisneria americana*) and Eurasian water milfoil (*Myriophyllum spicatum*)." GX-351 (ANERR Fall 2011 Oyster Catcher (http://apalachicolareserve.com/news-fll11.php)). During my reconnaissance survey in April 2016, I also observed manatees within East Bay near areas where there were SAV beds.

71. Therefore, my personal observations combined with the available literature demonstrate that the premise that salinity was causing or impeding SAV growth is unsupported. While my Tier 1 causal analysis did indicate some historical losses of SAV from East Bay during the 2005 timeframe, I needed to proceed with a Tier 2 analysis to examine whether these losses were attributable to increased salinity due to Georgia's consumption of water, as Florida's experts claim.

(b) Tier 2: Is the consumption of water by Georgia sufficient to be a major factor causing shifts in the salinity regime of the Bay that in turn would cause losses or shifts in species composition of SAV?

72. For Tier 2 of my SAV causal analysis, I performed robust statistical modeling to examine whether Georgia's water consumption could affect SAV species in Apalachicola Bay. I relied on salinity data from three monitoring stations collected by the Apalachicola National Estuarine Research Reserve (the same data used by Dr. Glibert) and on flow data provided by Dr. Bedient, showing river flow with simulated 1992 withdrawals and 2011 withdrawals. Using this data, I developed a statistical model predicting flow-related salinity changes at each of these ANERR monitoring stations. My analysis shows that salinity changes associated with Georgia's water consumption since 1992 are negligible compared to the natural variation in salinity in the

Bay. Notably, this conclusion is consistent with surface water salinity modeling conducted by both Florida and Georgia experts.[12]

73. Many species of SAV, as well as animal biota, are adapted to short-term variation in salinity associated with tides, diurnal cycles, and wind. JX-32 (Moore, K. *Appendix 9. B. Submerged Aquatic Vegetation (SAV) in the Lower St. Johns River and the Influences of Water Quality Factors on SAV*, 2009). For example, *V. americana*, considered to be a salinity sensitive species, tolerates salinities of up to 18 ‰,[13] and exhibits growth in waters with salinities of up to 10 ‰. JX-27 (Mazzotti, F.J.. *Stressor response model for tape grass* (Vallisneria americana), 2008). Other East Bay species exhibit an even wider tolerance range than *V. americana*.

74. To examine the natural variability of salinity in the Bay, I calculated weekly average salinity values using the available ANERR data and examined how these weekly values related to freshwater flow as measured at both the USGS Sumatra and Chattahoochee gages. My analysis shows that weekly average salinity in Apalachicola Bay varies widely at a given flow rate. For example, at the Cat Point monitoring station, at any given flow, predicted weekly average salinity varies by 18.6 ‰.

75. In the context of this natural variability in salinity (due to tides and climate variation), I then evaluated how Georgia's water consumption may influence salinity by selecting incremental flows to add back into the actual recorded river flow at Sumatra. The values I selected for water added back into the flow at Sumatra were a constant 400 cfs and 1,000 cfs. These values were selected because 400 cfs approximates an average flow difference between the 1992 and 2011 consumptive use scenarios modeled by Dr. Bedient, and because 1,000 cfs is the bound below which most of the differences in flow between 1992 and 2011 fall. These values are consistent with the incremental flow additions values I used to evaluate the effect of Georgia's water consumption on floodplain inundation.

76. My analysis showed that incremental increases in freshwater flow of 400 and 1,000 cfs, respectively, would result in less than a 1.2‰ change in salinity, a minor change

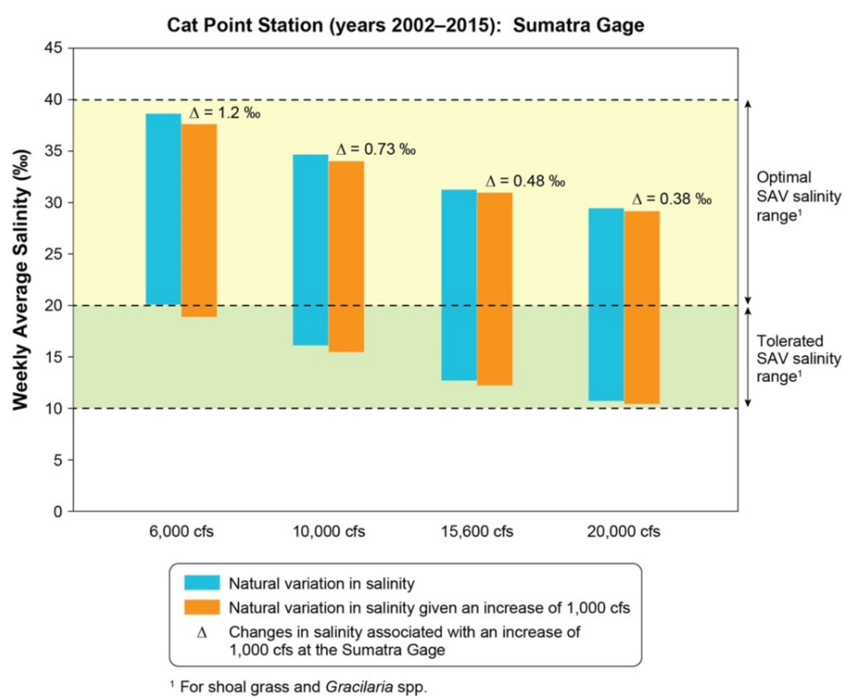
12 *See* FX-787 (Greenblatt Expert Report); GX-871 (McAnally Expert Report).

13 The symbol "‰" is commonly used for salinity and is in units of parts per thousand.

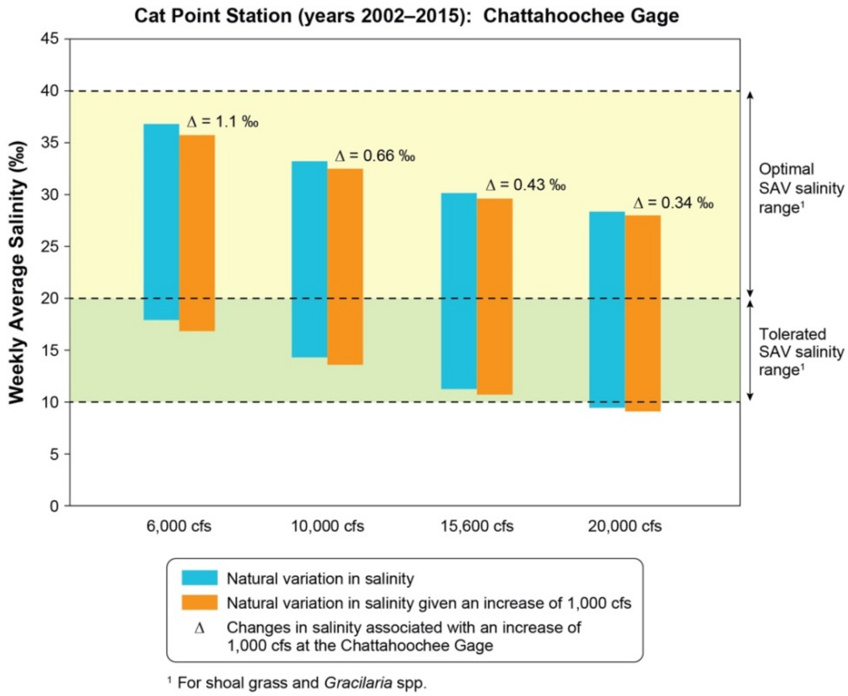
relative to the natural variation in weekly mean salinity.[14] I performed this analysis for all three ANERR water quality stations—Cat Point, East Bay, and Dry Bar. My comparison of weekly average salinities at Cat Point showed that these additional flows would result in an average difference of 0.2‰ across all flows. The addition of another 400 cfs at the Sumatra gage changed salinity by 0.06 – 0.5‰. The addition of another 1000 cfs at the Sumatra gage changed salinity by 0.15 –1.2‰. Even at the higher end, these small changes are dwarfed by the natural variation in salinity, which fluctuates within a range of 18.6‰ at a given flow, as stated above. My analysis produced similar results for the two other monitoring stations in Apalachicola Bay—East Bay and Dry Bar. When the Chattahoochee gage is used to represent river flow, the results are essentially the same. This is shown in **Menzie Demo. 12**.

77. More importantly, the wide salinity tolerance ranges of estuarine plants and biota in the Bay far exceed any salinity changes caused by these incremental increases in freshwater flow, as demonstrated by the figures below in **Menzie Demo. 12**.

Menzie Demo. 12



[14] My findings are corroborated by Dr. McAnally's evaluation of the effect of different consumptive use scenarios on salinity.



Demo. 12. These figures, adapted from Figures 18 and 19 of my Expert Report (GX-872), illustrate the natural variability in salinity and the relative contribution of an additional increment of freshwater in the amount of 1,000 cfs. The figures show that such additions would result in minor changes that would be lost in the larger natural variability. While salinity is important ecologically this addition would have negligible ecological influence on the Bay's ecosystem. Figures are provided for flows from both the Sumatra and Chattahoochee gages. As demonstrated by these figures, the results using flows from either of these gages are essentially the same.

78. While I focus my examination in this section on how river flow, specifically the consumption of water by Georgia, influences the salinity regime with respect to growth and distribution of SAV, the methods applied and the conclusions reached are equally applicable to other biota such as oysters, shrimp, fishes and Blue crabs. Like SAV, these animals experience the same natural salinity variations within which the variations associated with water consumption would be negligible and of no biological or ecological consequence. Furthermore, all of the estuarine and marine animals that utilize the Bay have evolved to be adaptable to varying salinity regimes. The incremental changes that may result from water consumption by Georgia are minor and, as shown above, are well within the natural changes in salinity to which these biota are accustomed.

79. In short, my Tier 2 analysis showed that changes in SAV growth cannot be attributed to changes in salinity caused by low flow, which fall well within the range of natural variability. My analysis clearly demonstrated that Georgia's consumption of water has a

negligible influence on the Bay's salinity regime—less than 1‰. Such small salinity fluctuations, in turn, would have no impact on SAV. However, because Florida's experts have attributed a reduction of SAV growth to salinity and shading associated with algae blooms, I proceeded with a Tier 3 analysis to identify what causal factors could influence SAV in the Bay.

(c) Tier 3: What are the primary causal factors influencing change in SAV within the Bay?

80. There are several causal factors than can influence SAV in the Bay. The species composition and spatial distribution of SAV in the Bay are influenced by salinity, water depth, substrate, and level of coastal energy. These factors influence SAV distribution in all estuarine systems. In addition, other factors may result in SAV losses. The most notable of these are hurricanes, such as Hurricane Dennis in 2005, which, as Florida's experts acknowledge, caused a near total loss of SAV in the Bay: "[u]nfortunately after the most detailed SAV map for East Bay was created in Summer 2005, Hurricane Dennis, with a storm surge of 2.5 meters impacted the area. All the SAV in East Bay was eliminated and did not reappear that summer. The Reserve is documenting its recovery since the storm."[15] A variety of other factors also put SAV at risk, including scarring and trenching by boat propellers, anchors, and fish trawls. *See* Sargent, F.J., et al., Scarring of Florida's seagrasses: Assessment and management options, 1995 (http://aquaticcommons.org/114/1/TR1.pdf).

81. Florida's expert, Dr. Glibert, did not focus on the factors listed above, but instead opined that the growth of SAV was impeded by shading effects associated with phytoplankton blooms during low flow periods. She made a number of assumptions to support this opinion. First, she assumed that the increase in algal particulate matter caused by an increase in the abundance of phytoplankton would create a shading effect in the water. Second, she assumed that this condition would occur at lower flows, which she believes are caused and/or exacerbated by Georgia's water consumption. My personal observations and research showed that while turbidity (i.e. cloudiness or particulate matter in the water) in Apalachicola Bay can affect light penetration, such turbidity is most closely associated with silt delivered by the river and is

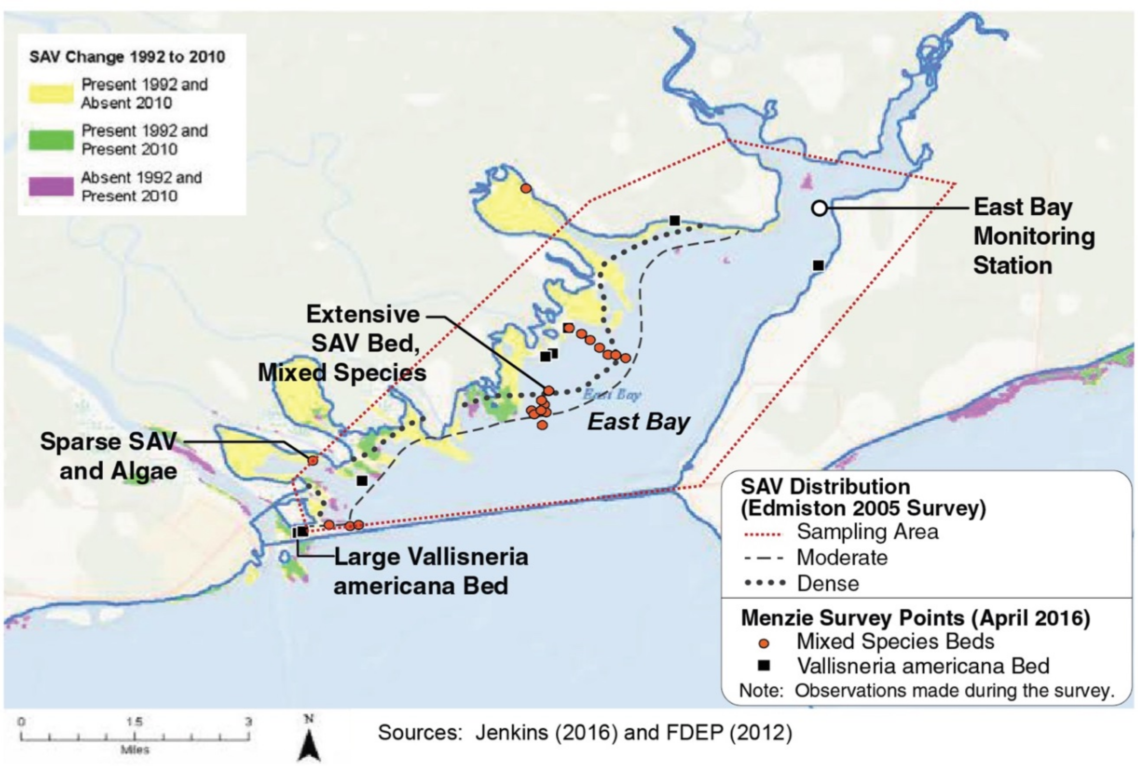
[15] JX-29 (Edmiston, H.L., *A river meets the bay: A characterization of the Apalachicola River and Bay System*, ANERR 2008); JX-28 (Edmiston, H.L., *Tropical storm and hurricane impacts on a Gulf Coast estuary: Apalachicola Bay*).

therefore greatest during higher rather than lower flows. Similarly, my analysis of the available data on light penetration in East Bay revealed that light penetration is highest at lower flows, which is the opposite of Dr. Glibert's assumption. Based on the available data, the factor to which Dr. Glibert mistakenly attributes SAV loss—algal blooms—is actually a negligible causal factor influencing SAV in the Apalachicola Bay system.

82. If Dr. Glibert had performed a proper causal analysis, she would have realized that the relative contribution of algal blooms to SAV loss is minimal at best. Yet, even setting that aside, Dr. Glibert's misguided presumption that shading limits SAV growth reflects two additional, significant limitations of her approach to thinking about causation:

83. The first limitation to her approach is that she presumed that the East Bay monitoring station is representative of East Bay, as the name of the station might suggest. This is incorrect because the geographic location of East Bay monitoring station in the uppermost part of East Bay prevents it from being representative of that area as a whole, as shown in **Menzie Demo. 10** (reproduced here).

[Reproduced] Menzie Demo. 10



84. My personal observations of East Bay, water quality analysis, and historical data, all indicate that the East Bay monitoring station does not share the same water quality or bathymetry characteristics as the rest of East Bay. Therefore, it cannot be presumed to be representative of East Bay as a whole. As a result, Dr. Glibert's extrapolations from this sampling point to the rest of East Bay are scientifically unsound.

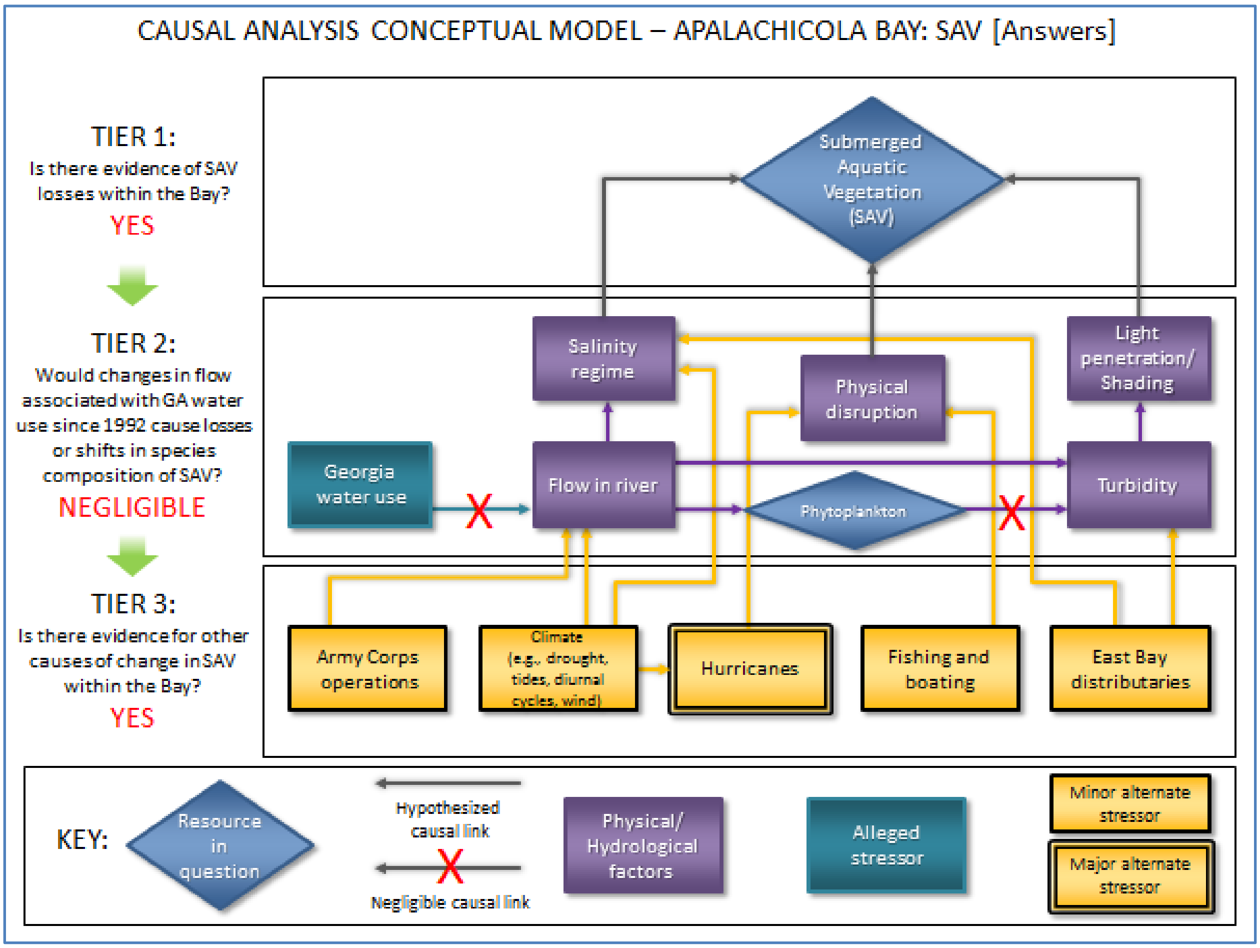
85. East Bay is a broad, shallow region influenced by freshwater discharges from numerous distributaries of the Apalachicola River, and supports extensive SAV beds. The East Bay monitoring station, on the other hand, is in a deeper area at the mouth of drainage from Tate's Hell State Forest. This drainage is comprised of tea-colored "black water" which is naturally enriched with dissolved organic matter leached from swamps and forests. Unlike in other parts of the Bay, SAV beds do not occur in the deeper waters at the East Bay monitoring station. These marked differences in water quality and bathymetry make East Bay monitoring station an inappropriate, and scientifically unsound, proxy for East Bay as a whole. Dr. Glibert's reliance on East Bay monitoring station to draw conclusions about East Bay is therefore flawed and significantly limits the applicability of any related analysis about water quality parameters or SAV.

86. The second limitation of Dr. Glibert's approach to assessing SAV losses is that she tends to extrapolate from limited data, failing to make use of available information and data for Apalachicola Bay to verify that her opinions regarding the occurrence of harmful algal blooms were correct. For example, in drawing her conclusions about algal bloom shading, she did not consult the available data on light transparency, but simply presumed that light decreases as river flow decreases. The facts show otherwise.

87. The results of all three Tiers of my causal analysis for SAV are provided in the following figure, **Menzie Demo. 13**. In sum, I conclude that SAV can be influenced by a variety of natural factors that affect the distribution of growth of these plants in estuarine systems. Hurricanes are the major historical factor that has resulted in periodic losses of SAV. However, the available evidence indicates that SAV has recovered from these events and is currently well distributed throughout the nearshore and shallower areas of East Bay and Apalachicola Bay. Based on my own reconnaissance survey of East Bay and areas of Apalachicola Bay, as well as

surveys relied on by FDEP, there is no evidence of ongoing losses of SAV as alleged by Florida's experts. Moreover, the evidence demonstrates that Georgia's consumption of water has a negligible influence on SAV, if any at all. My statistical analysis of the relative influence of Georgia's consumption on the salinity regime is confirmed by the salinity modeling of both Florida and Georgia experts, my own field observations of the present status of SAV in East Bay, and the evidence of SAV recovery published in Florida agency reports.

<u>Menzie Demo. 13</u>

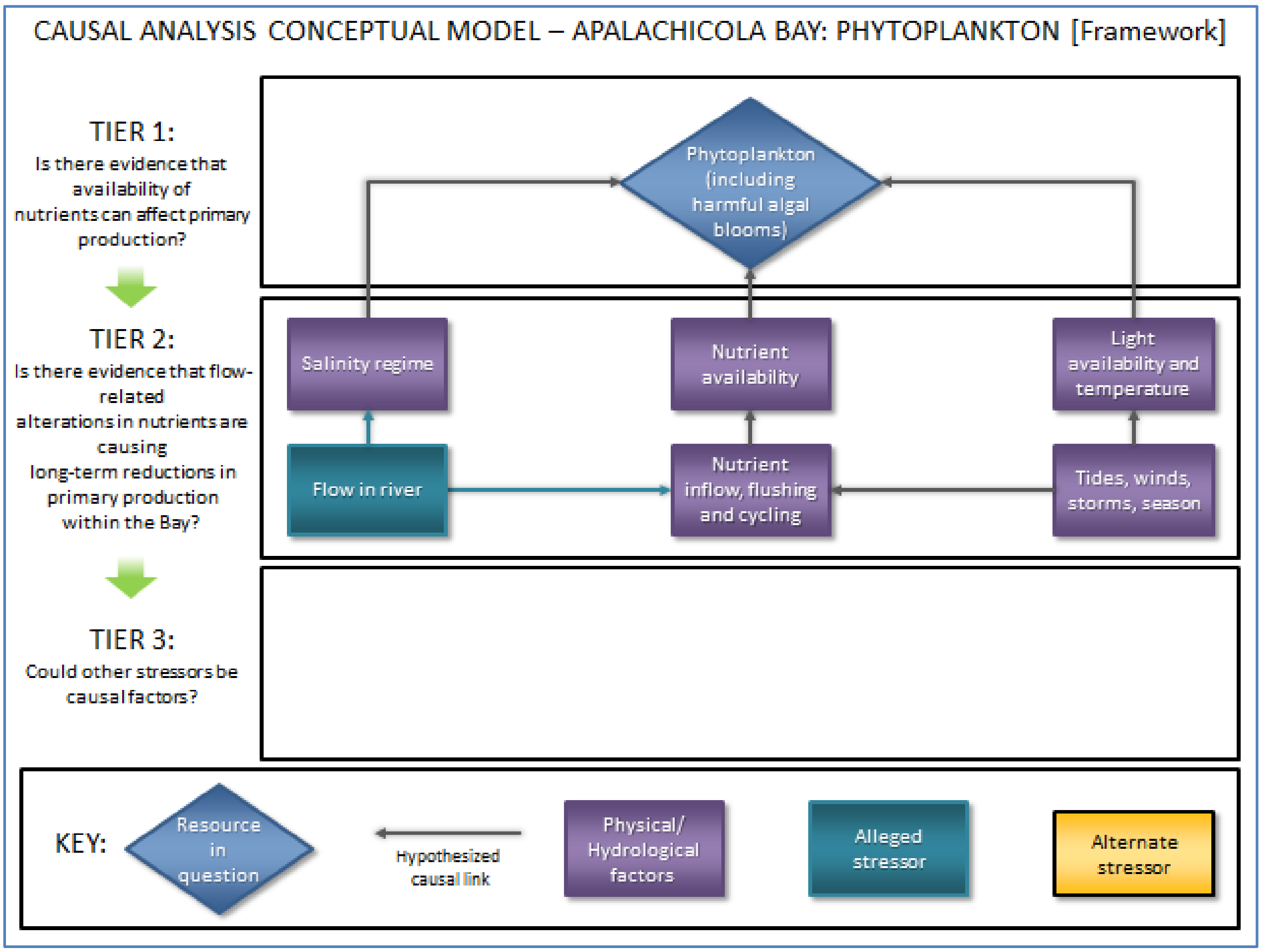


Demo. 13. Conceptual model for SAV illustrating the results of my causal analysis. This conceptual model shows that consumption of water by Georgia is a negligible factor influencing SAV in Apalachicola Bay, and specifically in East Bay. Other factors unrelated to Georgia's consumption, such as hurricanes, are responsible for any variation in SAV.

I. Nutrients and Primary Productivity

88. Next, I conducted the same causal analysis for phytoplankton, which are the primary producers supporting the Bay food web(s). The conceptual framework for evaluating factors that may cause shifts in the abundance or composition of phytoplankton is shown below in **Menzie Demo. 14**.

Menzie Demo. 14



Demo. 14. Conceptual model used to structure the analyses of causal factors affecting nutrients and phytoplankton productivity in the Bay.

(a) Tier 1 – Is there evidence that variations in nutrients within Apalachicola Bay can affect primary production of phytoplankton?

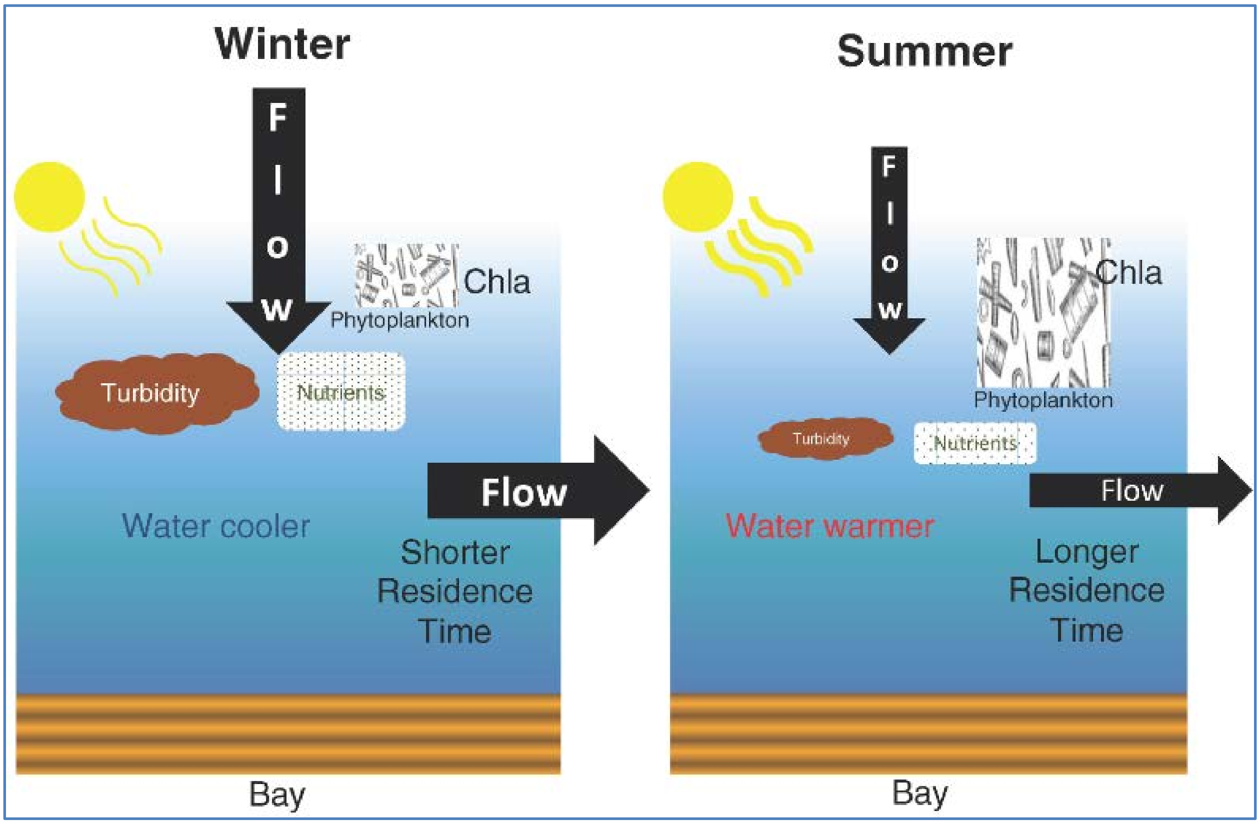
89. Under Tier 1, I evaluated whether there is any evidence of changes to the abundance or composition of phytoplankton caused by flow-related variations in nutrients. Phytoplankton provide food for zooplankton (e.g. small crustaceans known as copepods),

oysters, some types of fish larvae, adult fish that feed primarily on plankton (e.g. Bay anchovy and Menahden), as well as higher-trophic-level fish and wildlife. The process by which these phytoplankton convert inorganic nutrients (i.e., nitrates and phosphates) into organic material required by more complex life forms (i.e., proteins, fats, and carbohydrates) is what is referred to as "primary productivity." The availability of nutrients is itself dependent on a variety of factors, as discussed below. The concentration of chlorophyll-a, a specific molecule involved in photosynthesis, is often considered a surrogate for phytoplankton biomass. Thus, the relationship between nutrients and chlorophyll-a can be used to understand primary productivity in the Bay.

90. It is important to understand that primary productivity in an estuary can vary extensively among seasons, locations, and years, for a variety of reasons and mechanisms. JX-142 (Estabrook, R.H., *Phytoplankton ecology and hydrography of Apalachicola Bay*, Masters thesis, Florida State University, FL, 1973). Nutrients come in several different forms (inorganic, dissolved organic, and particulate) from various locations in the Apalachicola-Chattahoochee-Flint watershed and along the floodplain. The rates at which they flow into the Bay, are suspended and transformed into biomass, and are flushed out, are influenced by a complex set of overlapping factors (e.g., river discharge rates, tides, winds, storms, light availability). For this reason, nutrients and chlorophyll-a in the Bay vary greatly across space and time.

91. The figure below, **Menzie Demo. 15**, shows important seasonal drivers of variation in nutrient inputs and processing.

Menzie Demo. 15



Demo. 15. Illustration of the major seasonal processes influencing the primary production of phytoplankton in Apalachicola Bay. This illustrates why primary production is sustained at low flows in the summer time, when there is more light, more light penetration, and less flushing from the Bay. Primary production in the winter is lower because of lower light, lower temperature, and higher flows which flush the algae out of the Bay.

92. Winter and spring are typically associated with higher flows and increased dissolved nutrient inputs. However, because there is also less sunlight for photosynthesis, more turbidity that blocks sunlight, and more flushing out of the Bay, these factors together result in lower chlorophyll-a concentrations and decreased phytoplankton production in the winter and spring. Summer and fall, by contrast, are typically associated with lower flows and lower dissolved nutrient input, but are also associated with more sunlight, less turbidity that blocks sunlight, and less flushing out of the Bay. These factors together result in higher chlorophyll-a concentrations and increased phytoplankton production. In other words, due to these combined seasonal drivers, chlorophyll-a concentrations (and phytoplankton production) are actually *higher* at lower flows.

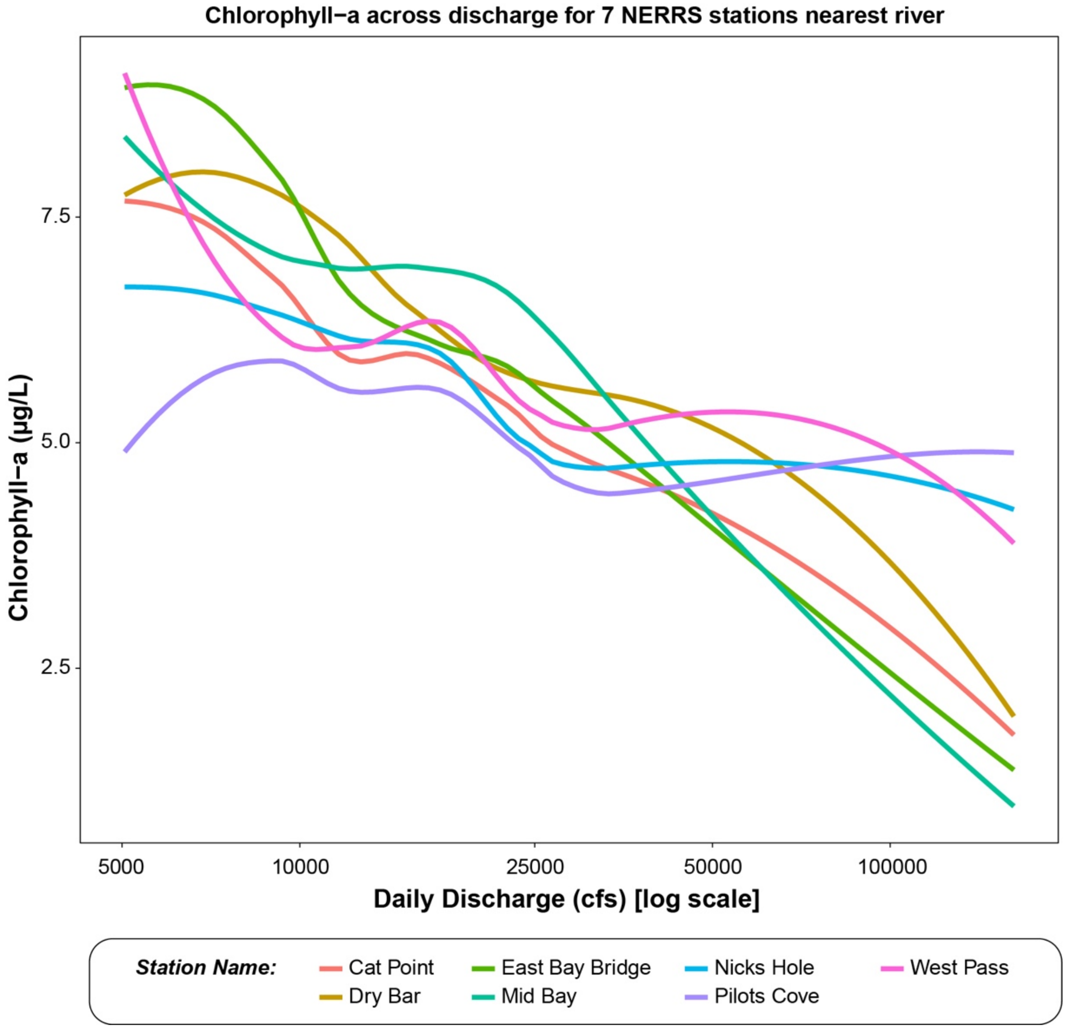
93. My Tier 1 analysis therefore indicates that seasonal variations in nutrients are important for the primary production of phytoplankton, as is well recognized for all estuaries. The pattern of higher chlorophyll-a at low flows suggests that the relationship between river flows, nutrient delivery, and primary production is complicated, however, and warrants a more in-depth examination. The specific question raised by Florida's experts is whether variations in river flow associated with Georgia's consumption of water is sufficient to cause changes in nutrient delivery and/or availability that then result in reductions in phytoplankton production and/or the presence of undesirable or less nutritive phytoplankton species that could be harmful to the Bay. I evaluate that question in my Tier 2 analysis below.

(b) Tier 2 – Is there evidence that flow-related alterations in nutrients are causing long-term reductions in phytoplankton primary production or causing harm to the plankton-based food web in Apalachicola Bay?

94. Under my Tier 2 analysis for primary production, I examine whether there is any evidence that *flow-related* (rather than seasonal) alterations in nutrients are causing long-term reductions in primary production. Based on my own statistical modeling and prior studies, there does not appear to be a clear relationship between flow-related alterations in nutrients from the River and phytoplankton biomass. In fact, at low flows, phytoplankton biomass, as measured by chlorophyll-a, increases or remains stable. This means that food for grazers, such as zooplankton and oysters, is readily available at low flows.

95. I examined the relationship between nutrients, flow and chlorophyll-a abundance using a series of statistical models. To do this, I matched the available monthly grab samples from ANERR sampling stations to corresponding flow discharge at the Sumatra gage. My analysis showed a direct relationship between increases in dissolved nitrite + nitrate concentrations and increases in flow at all measured locations in the Bay (excluding the Apalachicola River and Sikes Cut). However, chlorophyll-a concentrations exhibited the opposite pattern with flow. In contrast to dissolved nitrite + nitrate concentrations, chlorophyll-a concentrations were higher at lower flows, as depicted in **Menzie Demo. 16** below.

Menzie Demo. 16



Demo. 16. This figure was adapted from Figure 22 of my Expert Report (GX-872). As this figure shows, chlorophyll-a is higher at lower flows at various stations in the Bay. These analyses are based on data collected as part of the ANERR monthly sampling program.

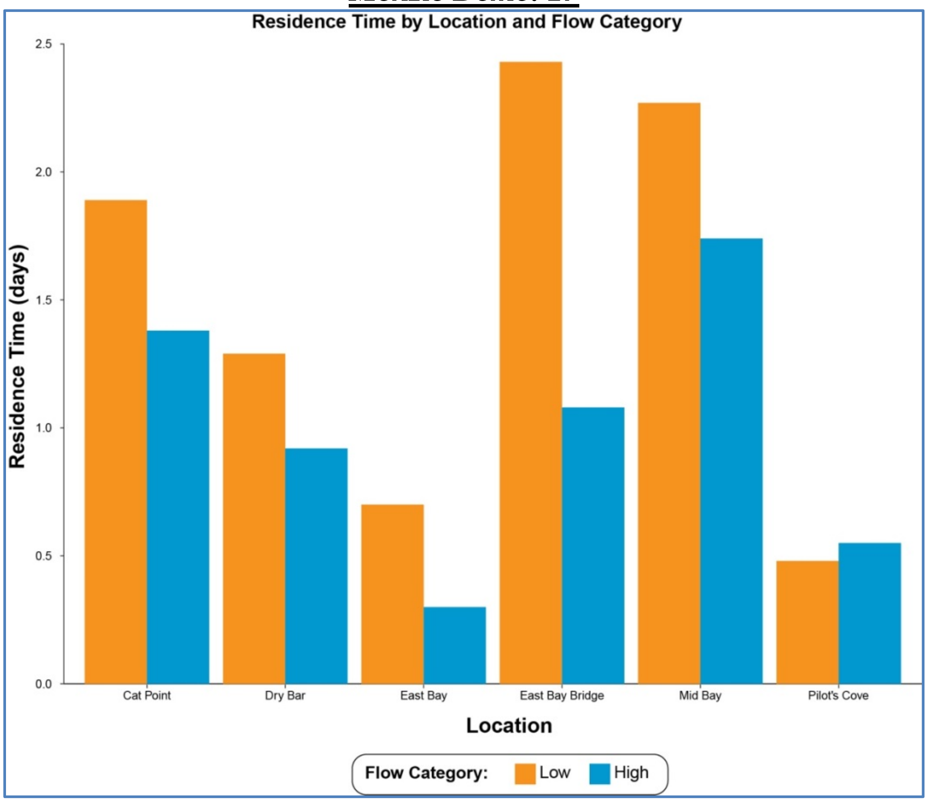
96. The fact that primary productivity (as measured by chlorophyll-a concentrations) is higher during times of lower dissolved nutrient input demonstrates that there is not a drop-off in phytoplankton primary production as a result of lower flow. This conclusion is supported by the work of Viveros Bedoya (2014), which Dr. Glibert relies on for her own analysis. JX-15 (Viveros Bedoya, P., *Phytoplankton biomass and composition in Apalachicola Bay, a subtropical river dominated estuary in Florida*, Dissertation, University of Florida, FL, 2014). Viveros Bedoya similarly found that chlorophyll-a concentrations are higher during low discharge. In addition, the fact that higher flow is associated with higher nitrite + nitrate concentrations but lower chlorophyll-a concentrations also suggests a temporal de-coupling

between dissolved nutrient delivery and phytoplankton productivity in the Apalachicola Bay ecosystem (i.e., chlorophyll-a concentrations at a point in time are not related to incoming dissolved nutrient concentrations coming in at that same point in time). This is supported by the fact that there does not appear to be a clear relationship between dissolved nutrient concentrations and chlorophyll-a.

97. Two factors contribute to sustaining primary production in Apalachicola Bay at lower river flows: increased residence time for phytoplankton and increased light penetration.

98. Longer residence times support the development of primary production by reducing the flushing of water, dissolved nutrients, and microscopic plants from the Bay. In **Menzie Demo. 17**, I show residence times at all sampling stations in both low and high flow conditions, and demonstrate that residence times are much longer during low flows.

Menzie Demo. 17



Demo. 17. This graph shows that residence time of water in the Bay is higher at lower flows because of less flushing of particulate matter as less water is moved through the system. These analyses were performed for particular regions of the Bay and results are specific to the areas around those locations. The longer residence time at lower river flows allow algal biomass and production to increase at those times within the Bay. This graph was adapted from Figure C-13 of my Expert Report (GX-872).

99. As the phytoplankton suspended in the water column stay longer within the Bay, these microscopic plants are able to grow to greater abundance. Therefore, not only is the productivity of phytoplankton not reduced—as might be inferred from a paradigm that presumes a direct relationship between nutrient loading from the River and production in the Bay—but primary productivity is increased and sustained under lower flow conditions.

100. Increased light also contributes to sustained productivity during low flow conditions. Light is a necessary source of energy for the primary production of phytoplankton. Like residence time, penetration of light into the water column is highest during low flow periods, because suspended sediment loads from the River are at their lowest. I documented that this is the case for lower river flows by examining the available secchi disc[16] data collected as part of the fish trawls in Apalachicola Bay conducted by the Florida Fish and Wildlife Conservation Commission. Each trawl collection is accompanied by basic water quality measurements, one of which is light transparency, to help characterize the physical environment important to fish populations. These measurements are routinely made as standard practice during the monthly collection of fish samples. I used this data to compare the degree of light transparency at different flow regimes and found that light transparency increased as flow decreased. This is explained by the reduced silt load from the river as flow decreases.

101. Dr. Glibert does not dispute the fact that there is an *increase*, rather than a decrease, in the abundance of phytoplankton at lower river flows. Yet she maintains that the overall productivity of the Apalachicola Bay food web is still compromised by a shift in the community composition of these phytoplankton. Specifically, she maintains that there is a decline in diatoms (one type of phytoplankton) and a higher proportion of cyanobacteria (another type of phytoplankton) during low river flows. Her opinion simply misrepresents the data. The two-year (2008-2009) Bedoya dataset, on which Dr. Glibert relies, shows that diatom biovolume and composition remain relatively *constant* across water temperature and flow. In fact, the data reveals a higher proportion of diatoms in the drier of the two years for which Bedoya conducted her Ph.D. work, as shown in **Menzie Demo. 18** below. JX-15 Viveros Bedoya, P., *Phytoplankton*

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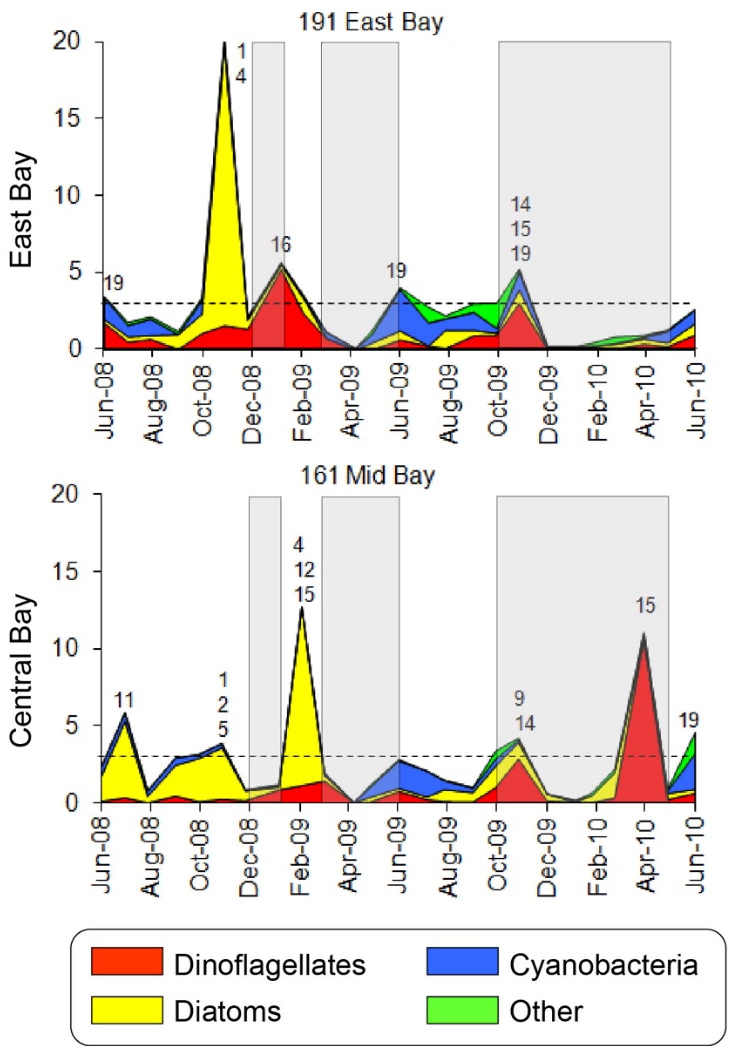
[16] A secchi disc is a simple device used to measure the light transparency of water and this method has been used by coastal researchers, oceanographers, and limnologists for many decades. The device works by measuring the depth of water transparency as it is lowered into the water. Within the Bay, these measurements have been made over many years and in all seasons.

biomass and composition in Apalachicola Bay, a subtropical river dominated estuary in Florida, Dissertation, University of Florida, FL, 2014).

<u>Menzie Demo. 18</u>



Demo. 18. This is Figure 23 from my Expert Report (GX-872), which reflects changes in the phytoplankton community composition in response to high or low flow. Gray boxes indicate periods of high flow. This figure is taken from the work of Viveros Bedoya, and is also cited by Dr. Glibert in her expert report.

102. This data reveals that diatoms remain available as a food source across a range of conditions, at relatively the same level of abundance, regardless of the relative abundance of other types of picoplankton such as cyanobacteria. This directly refutes Dr. Glibert's opinion that low river flows cause a decline in diatoms as a food source for the food web.

103. Dr. Glibert's presumption that an increase in the abundance of cyanobacteria picoplankton is harmful to the Bay's food web is also incorrect. While diatoms are an important source of food for zooplankton[17] and the food web of the Bay, so too are picocyanobacteria. Thus, the presence of picocyanobacteria does not indicate limited food availability, as assumed by Dr. Glibert. To the contrary, studies specific to Apalachicola Bay show that many grazers (referred to as mesozooplankton) are able to consume picocyanobacteria, as well as the microzooplankton which graze on picocyanobacteria. This is reported in the literature on the Bay and for other estuaries. The conceptual model below, **Menzie Demo. 19**, clearly shows the alternative pathways by which primary production reaches mesozooplankton, and in turn is available to fish and other planktonic feeders. This model was taken from a Putland 2005 paper on the ecology of mesozooplankton specifically in Apalachicola Bay. JX-16 (Putland, J.N., *Ecology of phytoplankton, Acartia tonsa, and microzooplankton in Apalachicola Bay, FL*, Ph.D. Dissertation, Florida State University, 2005).

[17] Zooplankton are comprised of small animals, just visible to the naked eye, that are suspended and swim over small distances within the water column. Examples include copepod crustaceans which are the base of many food webs and serve to connect primary producers such as phytoplankton to small fish who are in turn eaten by larger fish. Copepods readily feed upon diatoms as well as other smaller plants. Even smaller zooplankton known as microzooplankton such as ciliates feed on smaller algae such as cyanobacteria picoplankton. The microzooplankton are eaten by larger zooplankton and complete the food chain pathway leading to fish.

Menzie Demo. 19

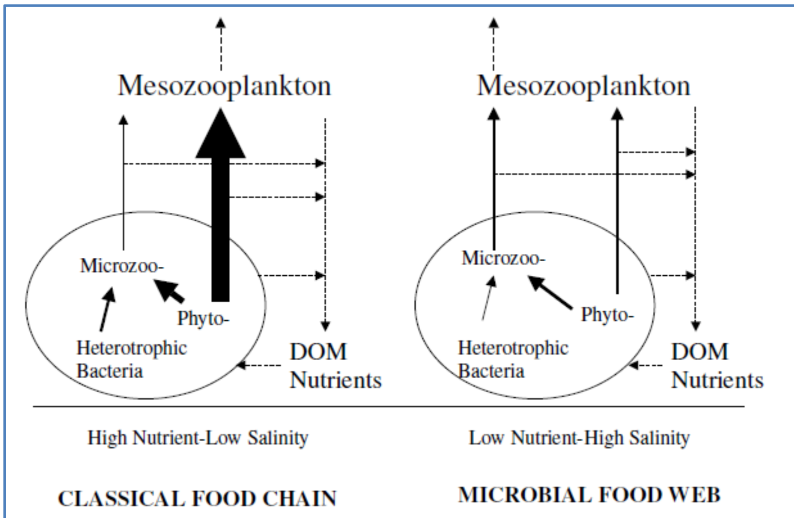


Fig. I. 2. Proposed planktonic food web structure in Apalachicola Bay. Width of solid arrows denotes the *predicted* relative magnitude of carbon transfer. Dashed arrows denote other known pathways that have not been quantified. Microzoo- and phyto- refer to microzooplankton and phytoplankton, respectively. DOM refers to dissolved organic matter.

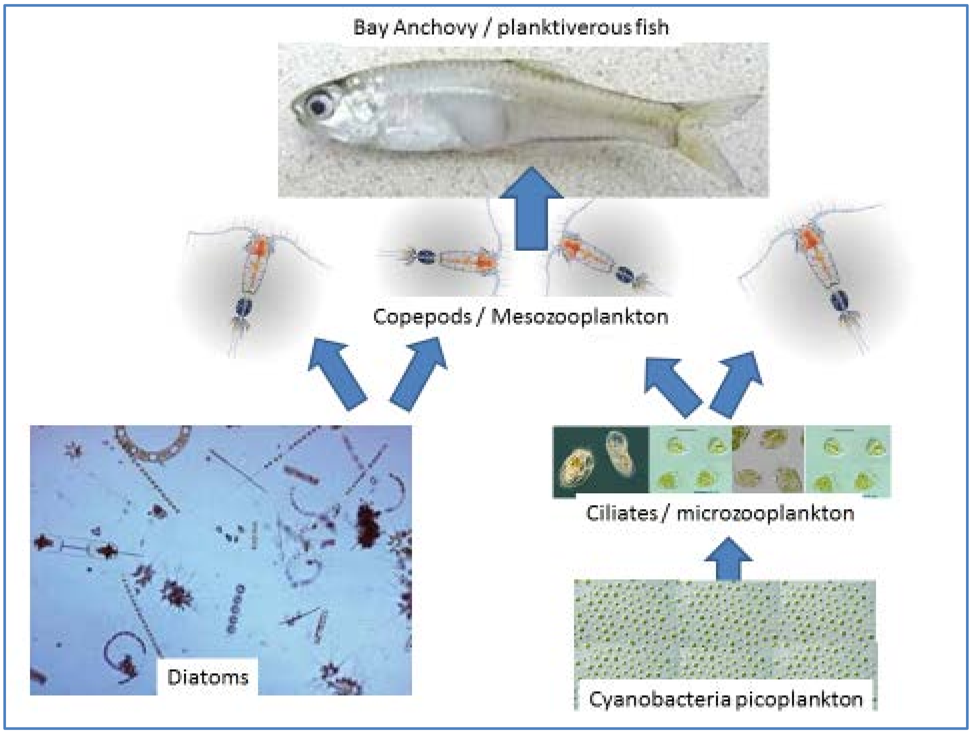
Demo. 19. This figure is a conceptual model of food webs developed by Putland (2005) to illustrate pathways by which primary production in Apalachicola Bay reaches mesozooplankton under two different salinity and nutrient regimes. The figure illustrates that there are alternative paths for primary producers to support higher trophic levels in the Bay.

104. Dr. Glibert cites to this literature in her report, but ignores the alternate planktonic pathways that support the food web during fluctuations in phytoplankton composition. *See* JX-16 (Putland, J.N., *Ecology of phytoplankton, Acartia tonsa, and microzooplankton in Apalachicola Bay, FL,* Ph.D. Dissertation, Florida State University, 2005). Based on studies in the Gulf of Florida and elsewhere, picocyanobacteria are especially important as a source of primary production and nourishment to the food web during the warmer summer months. The figure above represents the alternative paths by which primary production by phytoplankton supports the plankton-based food webs for Apalachicola Bay.

105. This continued phytoplankton productivity is further reflected in the fish community, as described later in my testimony, based on extensive collections of fish by trawls and seines for the Bay. Decades of such data are available. Because the biota in Apalachicola Bay comprises a food web, the available data on specific biota (e.g., a fish species) can provide insights not only into that specific biota but also into the food web as a whole. Throughout the period of lower flows as well as higher flows, plankton-feeding Bay Anchovy remain abundant and that demonstrates that there is an ongoing plankton-based food web. I used the available

data for Bay Anchovy and for phytoplankton to infer the nature and productivity of zooplankton, as shown in **Menzie Demo. 20**:

<u>Menzie Demo. 20</u>



Demo. 20. This figure is based on the conceptual model in Putland (2005) and on other available data for the Bay. It reflects that Bay anchovy and other plankton-feeding fish eat mesozooplankton in the Bay. The fact that plankton-feeding fish remain abundant and productive in the Bay throughout the period of record means that primary production continues to support this food web, whether it supports it through cyanobacteria picoplankton or other phytoplankton, such as diatoms.

106. The logic of using fish data to determine the status of zooplankton and the overall productivity of the food web is straightforward: 1) available data show that chlorophyll-a (an indicator of phytoplankton biomass and production) is higher during the warmer and lower flow months of the year; 2) the limited studies of phytoplankton for the Bay show that diatoms and cyanobacteria picoplankton are dominant components of the phytoplankton; 3) extensive studies of fish in the Bay document that the Bay Anchovy, a fish that feeds on zooplankton, is very abundant throughout lower flow periods; 4) although data on zooplankton are not available, these tiny planktonic animals must be present in sufficient biomass and production to support the high abundance and productivity of Bay Anchovy; 5) Bay Anchovy is known to be a key forage fish for higher level predators in the Bay; and 6) the necessary energy from phytoplankton can reach

and support the fish community via either a diatom-based food web or a cyanobacteria-based food web.

107. Dr. Glibert did not examine the available fish data, and therefore her presumption of adverse impacts on the Bay's fish community is based on incomplete information, as discussed in more detail below. Moreover, her theories about seasonal shifts in phytoplankton composition causing "cascading" adverse effects to the plankton-based food web is strongly refuted by actual data. The relationship between cyanobacteria and flow described by Dr. Glibert is a naturally occurring seasonal trend, and not an indication of ecological harm. Increased abundance of cyanobacteria picoplankton during the warmer summer months is commonly observed in estuaries of the northeast Gulf of Mexico and throughout the world. And, as Dr. Glibert acknowledges, chlorophyll-a levels increase at lower flows, meaning that there is actually more food available for grazers during low flows.

108. Dr. Glibert relied on non-site-specific information to conclude that increased levels picoplankton cyanobacteria during low flows would be a poorer food source for higher trophic levels, and would cause a shift in the food web away from a plankton-based system to a more detrital-based system (organic material feeding benthic invertebrates).

109. By making use of the available site-specific data, I reached very different conclusions. In stark contrast to Dr. Glibert, I performed a careful and detailed analysis of phytoplankton and food chain relationships and found that fish productivity and community composition were being sustained at all levels of the food web even during low flows. My analysis showed that Dr. Glibert's claim that the food web is of lower quality that cannot sustain upper trophic levels is simply incorrect, as demonstrated by the Bay anchovy example in **Menzie Demo. 20**.

110. Dr. Glibert also opines that low river flows caused by Georgia's water consumption will result in harmful algal blooms within the Bay. This theory is similarly unsupported by the available site-specific data for the Bay. Contrary to what Dr. Glibert claims, multiple lines of evidence indicate that there is no relationship between low flow and harmful algal blooms in Apalachicola Bay. GX-1092 (HAB Monitoring Database. FWC. (http://myfwc.com/research/redtide/monitoring/databse)). Harmful algal blooms that have

occurred in the northeast Gulf of Mexico begin offshore, and combinations of wind and current can bring these blooms into areas where they can present harm to people and the environment. Low flow is not a major determinant in the occurrence of these blooms. In fact, none of the three HAB events in the Bay between 2000 and 2015 occurred during years of extreme drought, as shown in **Menzie Demo. 21**.[18]

111. In her direct testimony, Dr .Glibert cites to 2011-2013 phytoplankton data only recently published by Dr. Phlips. I have reviewed this data, and my observations concerning the lack of any evidence for flow or drought-related harmful algal blooms is consistent with the findings of Professor Phlips. Professor Phlips observed the presence of algal species within the Bay that have the potential to result in such blooms. I also observed these algal species, and it was for this reason I looked for evidence of harm but found none with the exception of *Karenia brevis* (commonly known as "red tide"), which occurs offshore and is unrelated to river flow. Professor Phlips similarly concludes that the exposure levels of other algal species within the Bay are lower than they are elsewhere: *However, since biomass levels [or potentially harmful algae] in Apalachicola Bay are for the most part not high by comparison to more restricted estuaries of Florida, it will be important to define threshold biomass levels for suspected HAB species in the bay which may represent dangerous levels for oyster species.* Based on Professor Phips work and my own research, I conclude that, while these potentially harmful algae are present (as they are in most coastal systems), they are not at exposure levels that result in harm to humans, oysters, or other biota of the Bay.

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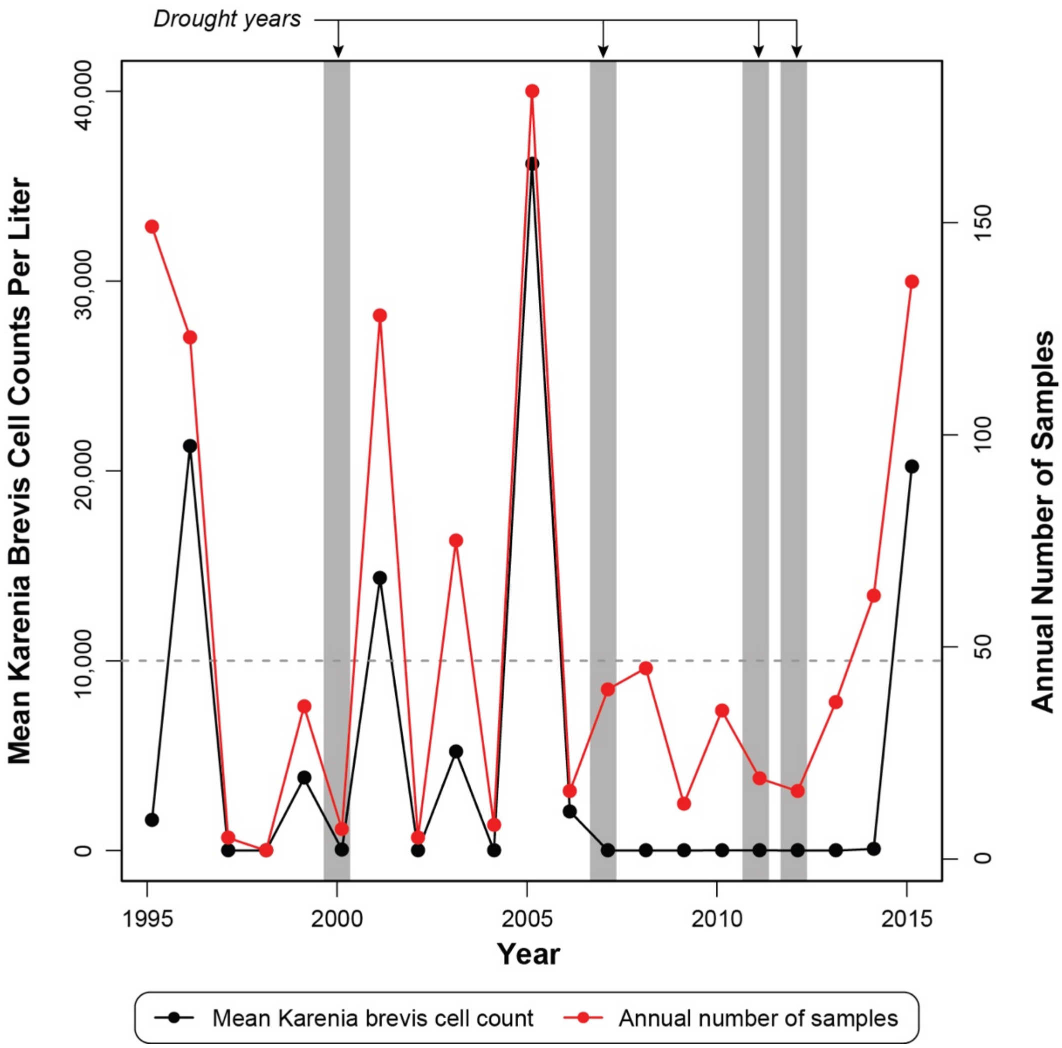
[18] This was verified by a formal news media literature review. *See* Ritchie, B. 2005. Oyster industry asking for help to stay afloat: Storms, red tide hurting more than livelihoods. Publication info: Tallahassee Democrat [Tallahassee, Fla] (10 Oct 2005): A.1.; Parker, G. 2005. Red Tide Subsides. Publication info: Tampa Tribune [Tampa, Fla] (05 Dec 2005): 1); Deslatte, A. 2005. Red tide still defies experts. Publication info: Florida Today [Melbourne, Fla] (20 Oct 2005): B.6); Burr, R. 2005. Signs of red tide in Bay waters. Publication info: The News Herald [Panama City, Fla] (08 Sep 2005): 1); Ritchie, B. 2007b. Apalachicola Bay free of red tide, for now. Publication info: Tallahassee Democrat [Tallahassee, Fla] (11 Oct 2007): A.7.

Menzie Demo. 21



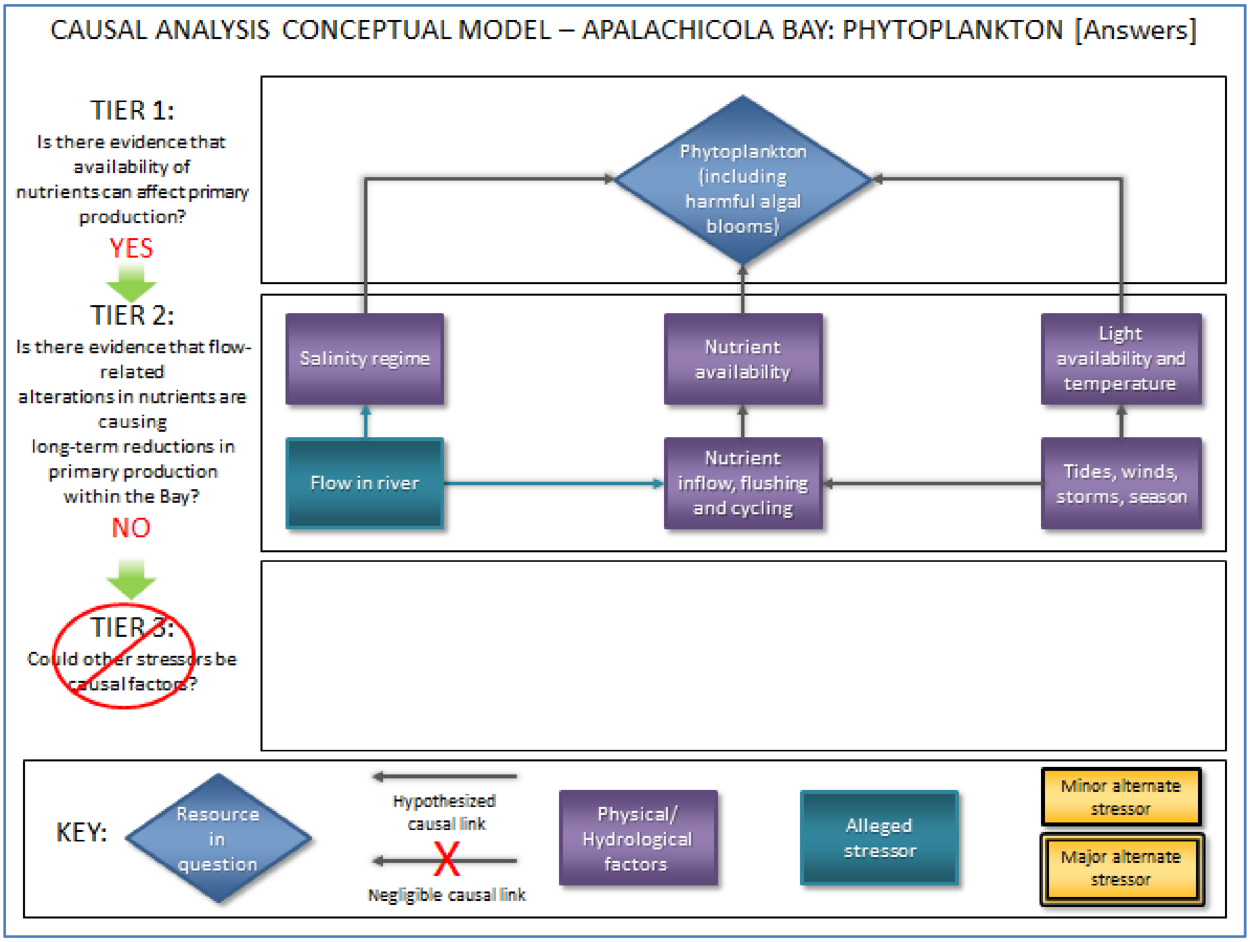
Demo. 21. The figure above, which is taken from my Expert Report (GX-872), is an analysis of abundance for the one species of algae that has periodically caused harmful blooms within the Bay. These blooms originate outside the Bay and, as the figure shows, their occurrence in the Bay is not associated with low river flow or drought conditions.

112. My Tier 2 analysis demonstrates that primary production in the Bay is sustained throughout the recent period. A holistic understanding of the system allowed me to conclude with a very high degree of confidence that the productivity of Apalachicola Bay has not been reduced in recent times and, moreover, is not being imperiled by Georgia's water consumption. There is no evidence to support the premise that primary production of phytoplankton decreases with decreasing flow. Instead, the opposite is true. Primary production, as measured by the abundance of chlorophyll-a, increases at low flows due to increased residence time of nutrients in the Bay and also because of increased light transparency. Although some seasonal shifts in

the composition of phytoplankton do occur, a diversity of phytoplankton remain available as food sources for secondary producers (zooplankton), as well as upper trophic levels. In addition to diatoms, which remain prevalent even at low flows, picocyanobacteria form an important part of the Bay's food web. These tiny photosynthetic bacteria are readily eaten by microzooplankton, who in turn are eaten by larger zooplankton. Thus, picocyanobacteria support an alternative pathway of food resources in the Bay. This steady supply of primary production is further reflected in the available fish data, as discussed in further detail below. Finally, contrary to Dr. Glibert's opinions, there is simply no evidence to support the view that lower river flows are causing blooms of harmful algae in the Bay. Because lower river flow periods are not causing reduced primary production or harmful effects to the plankton food web, it follows that the consumption of water by Georgia throughout this period, which itself has a minor influence on river flow, has had a negligible influence on the Bay's primary production.

(c) Tier 3 - Because there is no evidence of long-term change in primary productivity in Apalachicola Bay, there is no need to examine alternative causes of change. This is summarized in the figure below:

Menzie Demo. 22



Demo. 22. This conceptual model shows the results of my causal analysis for phytoplankton. The results of Tiers 1 and 2 indicate there is no indication of adverse effects associated with variations in river flow and delivery of nutrients. There is also no indication that blooms of harmful algae are occurring as a result of lower river flows.

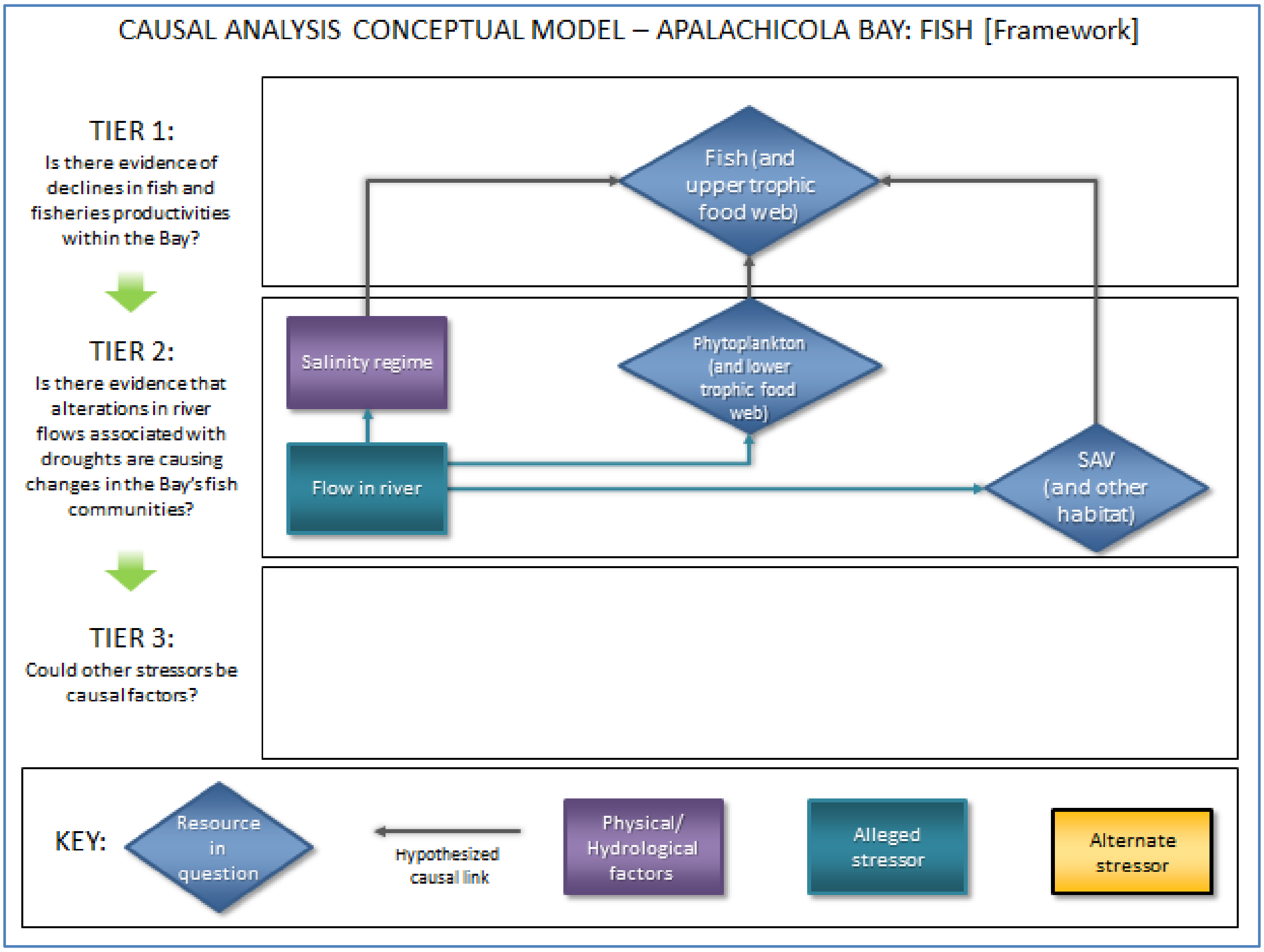
II. Secondary Productivity In The Bay

(a) Tier 1 – Is there evidence of a decline in secondary productivity in Apalachicola Bay?

113. Since my analysis above shows that primary production is sustained under low flow and Georgia's consumptive use of water would have a negligible effect on the Bay's primary production, I would not expect to see any effects on secondary production (transformation of primary production products into more complex biomass). To test this, I

applied my causal analysis approach to the production of animal life in the Bay. The conceptual framework for evaluating factors that could contribute to shifts in composition or abundance of fish and invertebrates is shown below in Menzie Demo. 25.

Menzie Demo. 23



Demo. 23. Conceptual model used to structure the analyses of causal factors affecting secondary productivity of fish and invertebrates in the Bay.

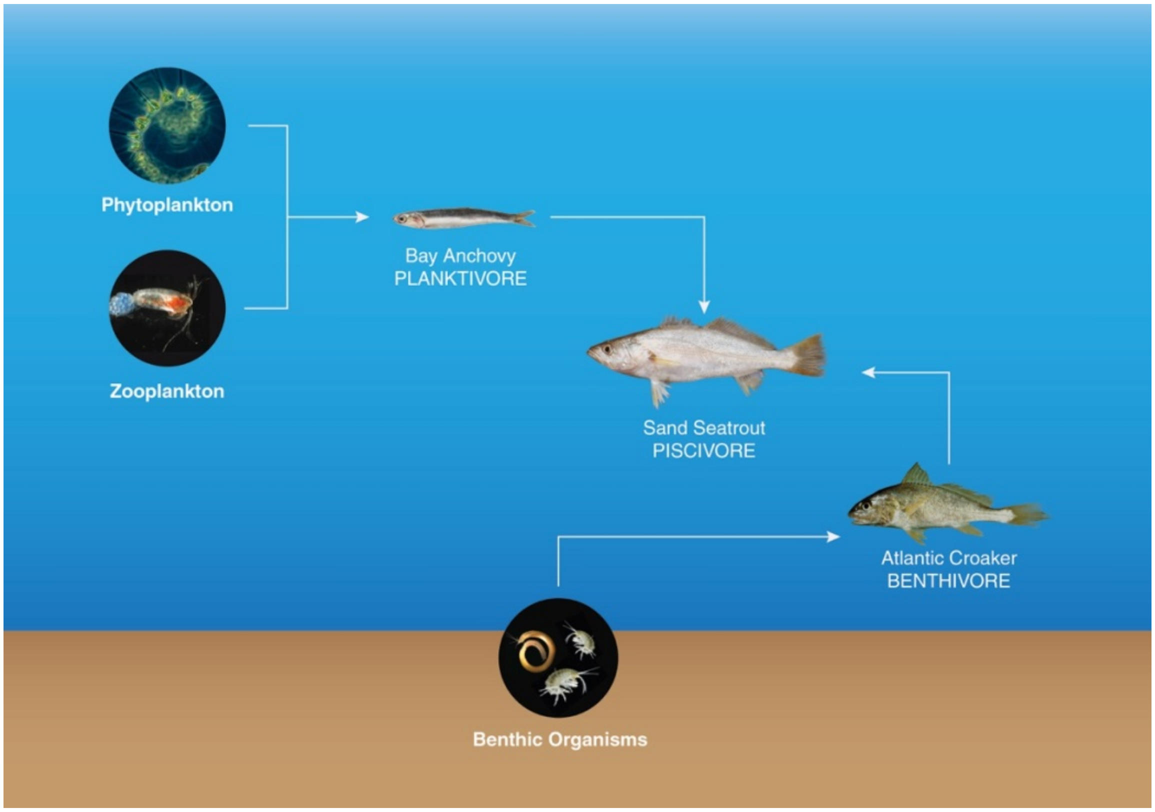
114. I looked at several species: zooplankton and benthic invertebrates (which rely heavily on plankton production as a food base),[19] fish, larger crustaceans such as crab and shrimp, and marine mammals.

[19] JX-29 (Edmiston, H.L., *A river meets the bay: A characterization of the Apalachicola River and bay system*, 2008).

115. The most robust data set for evaluating the actual secondary (animal) production in the Bay comes from collection of fish. Extensive collections have been made for many decades by scientists for the State of Florida and for the U.S. government. Of particular importance for this case, such data exist for the 1970s and early 1980s, as well as from the late 1990s to the present. Therefore, it is possible to identify temporal patterns in the abundance and composition of fish. While the available data does include species that are harvested commercially, it also includes numerous non-harvested fish species. This allows for an assessment of food web conditions that are not subject to the annual removal of large portions of the biomass for commercial purposes, as is the case for oysters. Whereas increases and decreases in oyster abundance reflects oyster management and harvesting activities, as well as environmental influences, fluctuations in fish populations provide a clearer picture of the relative influences of environmental factors, including variations in river flows.

116. I evaluated the entire fish community of the Bay to determine the food web structure as well as to assess overall productivity. Predominant fish species have been sustained for all three of the major trophic pathways in the Apalachicola Bay foodweb (planktonic, benthic, and piscivore). My observations confirm that these populations are thriving in the Bay, contrary to the opinions of Florida's experts.

Menzie Demo. 24



Demo. 24. Conceptual model illustrating the major food webs supporting fish in the Bay. Some species feed on plankton, others on benthic invertebrates in the sediments, and still others on fish. I provide more detail for the predominant fish species that represent each of these trophic pathways later in my testimony.

117. Drs. Glibert and Jenkins cannot cite to any evidence that indicates zooplankton communities within the Bay have been altered. There are in fact no recent surveys of zooplankton in the Bay, so the best indicator of zooplankton abundance is the health of lower levels of the food web (phytoplankton) and upper levels of the food web (plankton-feeding fish). Because primary production of phytoplankton is not adversely affected by low flows, nutrition-related effects on zooplankton, are not expected. As demonstrated below, plankton-feeding fish are predominant in the Bay, further confirming that zooplankton production is being sustained. Drs. Glibert and Jenkins did not carry out this type of logical food chain analysis.

118. Drs. Glibert and Jenkins similarly cannot cite to any evidence that indicates benthic infauna communities within the Bay have been altered. Given the limited data on benthic infauna, the best indicator of abundance is the sustained abundance of benthic-feeding fish. My analysis of fish species shows that benthic-feeding fish are being sustained, and

therefore, benthic invertebrate production is being sustained in the Bay. This conclusion is further supported by my reconnaissance survey on April 19, 2016, which revealed a wide biological gradient of invertebrate composition on SAV in East Bay.[20]

119. Based on my comprehensive quantitative and qualitative review of four different datasets,[21] I found no evidence that fish productivity is declining in the Bay; if anything fish productivity is somewhat higher as reflected in the abundance of Bay Anchovy, a key forage fish in the Bay. Since the historical patterns of the five dominant fish species have remained consistent, the three trophic pathways for the upper food web remain intact.

120. To assess the overall structure of the fish community, I compared the relative abundance of fish present in the Bay in recent sampling by ANERR to that for the 1970s and early 1980s by Livingston as shown in the figure below, **Menzie Demo. 25**. The comparison shows that five predominant fish species present in the 1970s and 1980s are still the predominant fish species in the recent period. This implies that the ecological structure of the Bay, and associated productivity, are remarkably similar between the two time periods.

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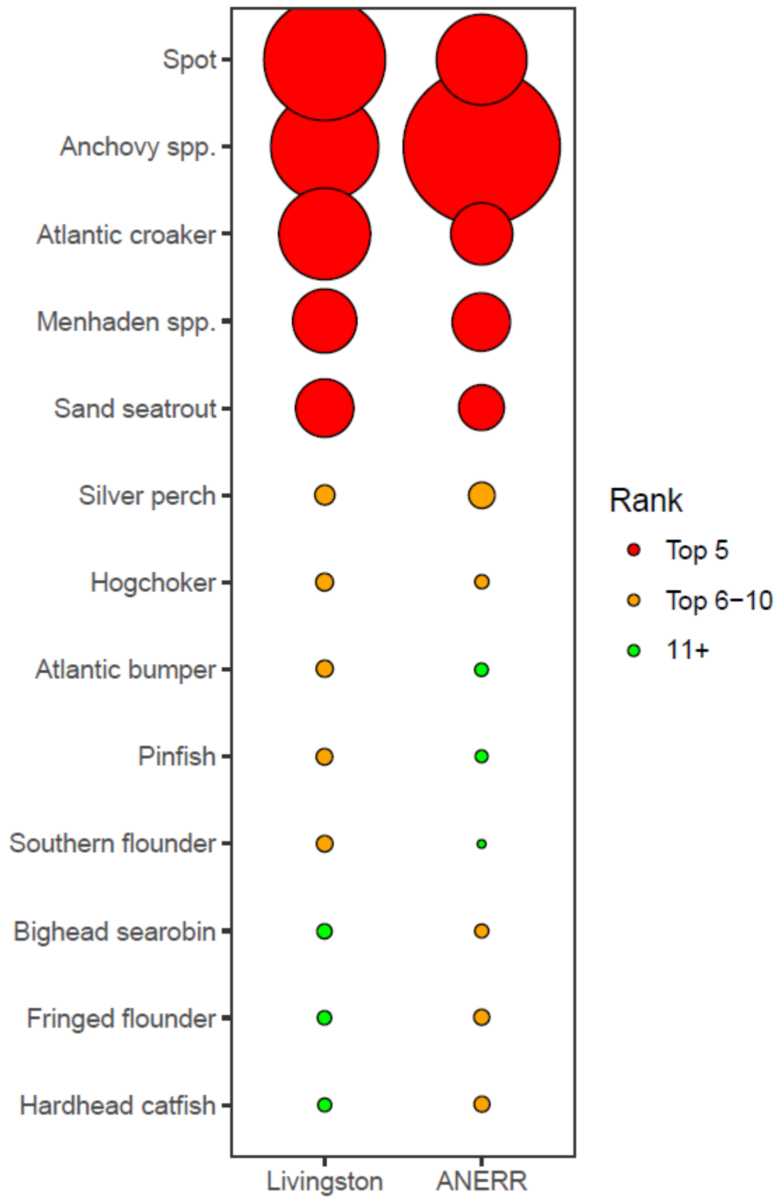
[20] I collected samples of bottom sediments to learn more about the nature of these sediments. The sediment samples were submitted to ALS Labs for analysis of total organic carbon. These samples were individually labelled, packed, and stored on ice and shipped in a cooler via overnight delivery (FedEx). All samples arrived at the lab in good condition and were preserved at the proper temperature.

[21] GX-988 (1972-1984 Livingston trawls, file “BioticData.mdb” from Jenkins reliance materials); GX-393 (2002-2012 ANERR trawls); GX-976 (2014-2015 ANERR trawls); GX-1061 (1998-2014 FIM trawls, file “Apalachicola_FIM_data.mdb” from Jenkins reliance materials).

Menzie Demo. 25



Demo. 25. Comparison of the relative abundances of predominant fish species in the 1970s and 1980s (Livingston) with abundances in recent times (ANERR). The analysis is based on trawl locations in the two studies . This figure shows that the species composition is similar over both periods, indicating that the food web structure remains the same.

121. In addition to considering the overall fish community structure, I examined the abundances of predominant fish over time. Like Livingston did, I examined the status of the five predominant fish species, which represent the three major trophic pathways in the Bay: planktivores (which eat the small plants and animals suspended in the water column), benthivores (which eat the small animals living on or in the mud and other bottom substrate), and

piscivores (which eat other fish). The preceding figure, **Menzie Demo. 25**, shows that the Bay has been dominated by the same five species since the 1970's: Spot, Anchovy, Atlantic croaker, Menhaden, and Sand Seatrout. Notably, Livingston, who conducted the 1970s study on fish abundance, focused his discussion of fish species on these same five species. My analysis shows that the recent abundance and corresponding productivity of these species is comparable between the recent period and the 1970s and early 1980s when Livingston conducted his work.

122. Periodic occurrences of fish species are expected given that fish are mobile and respond to natural changes within the system. Based on my review of the data, species that only occur incidentally in Apalachicola Bay comprise a very small part of the overall Bay fish community. This is an important insight, inasmuch as fish communities are made up of populations and species that will exhibit variation year to year. Thus, to the extent that a fish community can be thought of as "stable", the available data indicate that fish populations are stable within the Bay.

123. To illustrate how these predominant fish species are related in the Apalachicola Bay food web, I have assembled information on their historical and current status in the Bay along with a brief description of their ecological roles in the following table.

<u>Menzie Demo. 26</u>

Predominant species	**Status in Bay**
Fish that feed primarily on the Bay's plankton and transfer energy from phytoplankton and zooplankton to higher trophic levels (fish and birds)	
 Bay anchovy	• The most abundant species in the bay in recent years, up to 60% of fish sampled in East Bay. Abundance is steady or increasing. • Peak abundance in summer, fall, and early winter • Spawn near passes into bay, with juveniles found in January and February.
 Menhaden	• The 4th most abundant species in both time periods, 6% to 7% of catch throughout the bay. Abundance remains steady in recent years. • Spawning offshore fall through spring[22] • Menhaden are an important Gulf fishery[23]
Fish that feed primarily on invertebrates that live in the sediments of the Bay; the invertebrates feed on organic matter falling to the sediments; some of these fish do also eat fish and are in turn eaten by other fish	

[22] http://www.gsmfc.org/publications/Miscellaneous/Gulf%20Menhaden%20Brochure.PDF
[23] http://www.gsmfc.org/publications/GSMFC%20Number%20240.pdf

Spot

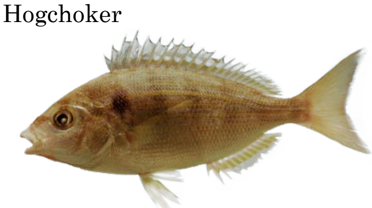
- The most abundant species in the ‘70s and ‘80s, surpassed by Anchovies in recent years. Bay-wide abundance trending down from highs around 2005.
- Peak abundance January-April
- Spawn near passes into bay, juveniles found January and February.

Atlantic croaker

- The third most abundant species in both time periods, 10%-20% of fish sampled. Peaking in 2010, abundance is steady or declining.
- Peak abundance January-April
- Spring spawning in estuaries

Hogchoker

- Less than 1% of fish sampled, either 14th or 15th most abundant species in any time period.
- “Hogchoker” is said to derive from feeding these small often abundant fish to pigs, which had difficulty eating their scales and fins.[24]

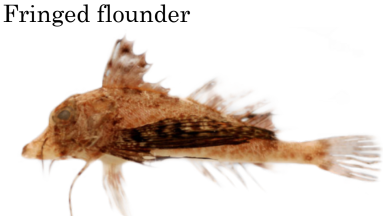


Pinfish

- About 1% of fish sampled, is the 6th most abundant species in both time periods.
- Found often in sea grass beds[25]
- Spawn offshore in fall and early winter[26]

Fringed flounder

- Less than 1% of fish sampled, the 13th most abundant species in recent years.
- Often abundant in vegetated habitats[27]
- Spawning spring through summer in shallow coastal waters[28]



Bighead searobin

- The 16th most abundant species sampled in both time periods.
- Active at night, uses pectoral spines to search for prey[29]

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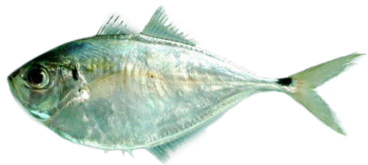
[24] http://www.chesapeakebay.net/fieldguide/critter/hogchoker
[25] http://www.sms.si.edu/irlspec/Lagodon_rhomboides.htm
[26] http://fisheries.tamu.edu/files/2013/10/SRAC-Publication-No.-7210-Species-Profile-Pinfish-Lagodon-rhomboides.pdf
[27] http://www.dnr.sc.gov/swap/supplemental/marine/fringedflounder2015.pdf
[28] http://www.dnr.sc.gov/swap/supplemental/marine/fringedflounder2015.pdf
[29] https://tpwd.texas.gov/fishing/sea-center-texas/flora-fauna-guide/gulf-waters/animals-of-the-gulf-waters/bighead-sea-robin

Fish that are primarily omnivorous, feeding on detrital matter, zooplankton, and smaller fish



Atlantic bumper

- About 0.5% of fish sampled, ranked 8th in early data, currently the 12th most abundant species.
- Peak abundance July-October
- Spawns in spring and summer[30]
- Typically found in shallow coastal waters, juveniles may be found offshore, associated with jellyfish[31]

Silver perch

- Currently about 1% of fish sampled, has increased to the 7th most abundant species.
- Peak abundance fall and winter
- Spring spawning in estuaries, juveniles summer in bay
- Found inshore associated with seagrass beds and estuaries[32]

Hardhead catfish

- About 0.5% of fish sampled in both time periods, currently ranked as the 11th most abundant.
- Spring spawning male mouth-brooder[33]
- One of only two marine catfish species[34]

Fish that feed primarily on other fish in the Bay; smaller individuals of these species also eat invertebrates; these fish are also preyed upon by larger fish-eating fish and birds

Sand seatrout

- About 4-6% of the fish sampled and ranked 6th in both time periods. Abundance trends steady or increasing.
- Peak abundance March-August
- Found mainly inshore in bays and inlets, move offshore in winter[35]
- Springtime spawning inshore[36]

Southern flounder

- Ranked 15th in the early time period, the relative abundance of southern flounder has decreased more than any other species in the former top 20.
- Fall and winter offshore spawning in the Gulf with buoyant eggs[37]
- Often associated with oyster reefs and vegetation[38]

124. Dr. Glibert's opinion in her expert report that there is a trophic-level impact on fisheries is refuted by the data. By her own admission, she did not evaluate the fish community of the Bay in either her expert report or in her direct testimony. In deposition, Dr. Glibert testified that she had "no data or information indicating any fish species in the Apalachicola Bay

[30] http://dx.doi.org/10.2305/IUCN.UK.2015-4.RLTS.T16437187A16510252.en
[31] http://dx.doi.org/10.2305/IUCN.UK.2015-4.RLTS.T16437187A16510252.en
[32] http://myfwc.com/wildlifehabitats/profiles/saltwater/drums/silver-perch/
[33] http://tpwd.texas.gov/huntwild/wild/species/hardhead/
[34] http://www.dnr.sc.gov/cwcs/pdf/Hardheadcatfish.pdf
[35] http://myfwc.com/wildlifehabitats/profiles/saltwater/drums/sand-seatrout/
[36] http://myfwc.com/wildlifehabitats/profiles/saltwater/drums/sand-seatrout/
[37] http://gcrl.usm.edu/public/fish/flounder.php
[38] http://tpwd.texas.gov/huntwild/wild/species/flounder/

has been negatively impacted by impaired food availability in the bay," because her "analyses did not go into specific fish species." Glibert Dep. Tr. 76:17-77:1. My analysis indicates that fish populations are being sustained and that fish supported by a plankton-based food web continue to predominate in the Bay. This refutes Dr. Glibert's theories that there are cascading effects on upper trophic levels as a result of shifts at the base of the food web, and that these (non-existent) effects are destabilizing the ecosystem.

125. To help visualize the magnitude of the fish sampling program, I include a map of the sampling stations below (**Menzie Demo. 27**). In total, there are about 25,000 fish trawls and almost 6,000 seine collections of fish. This unusually rich data base can be used to answer basic questions that are most relevant to this case:

a. Has productivity as reflected by the fish community declined in Apalachicola Bay as compared to pre-1992 conditions?

b. Have the structure of the fish community and the food web changed in Apalachicola Bay as compared to pre 1992 conditions?

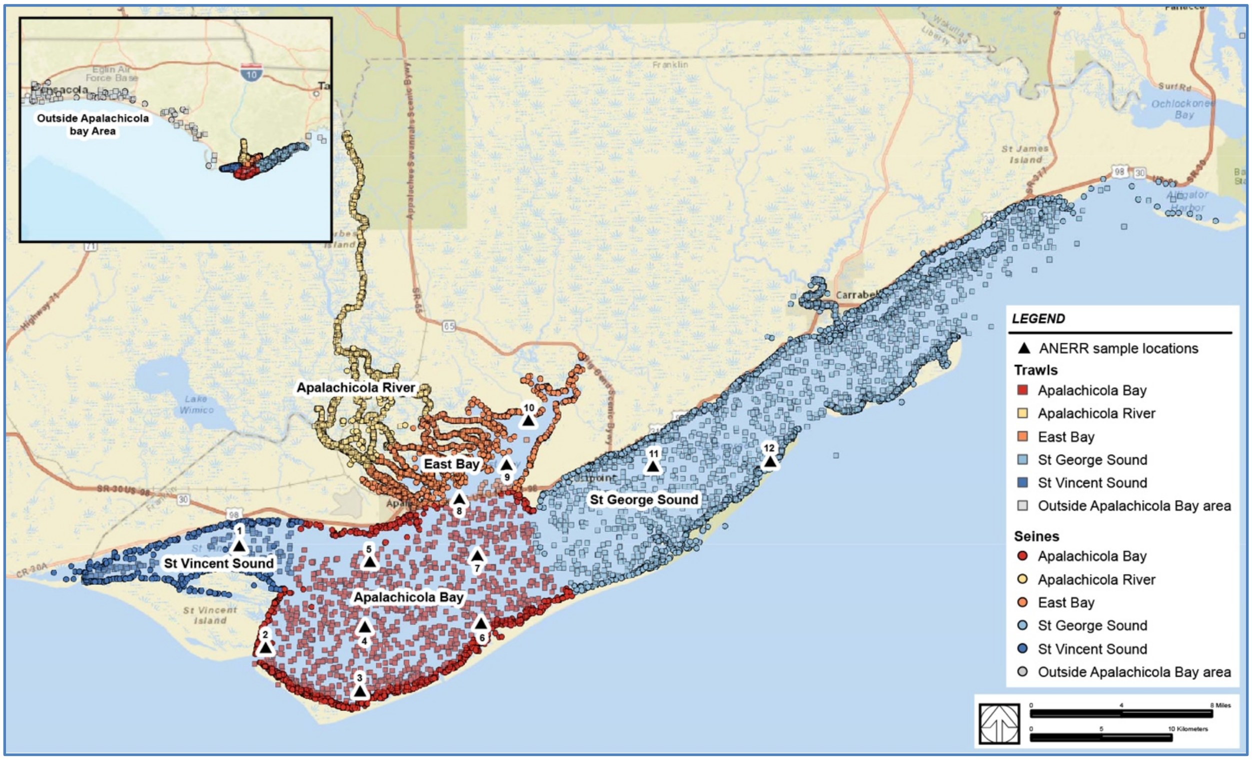
c. Is there evidence that the natural period of droughts that have occurred in recent years are causing particular changes in the fish community and productivity?

d. Is there evidence that the capacity of East Bay to serve as an important fish nursery area has declined over time due to periodic lower river flows?

126. The fish data base allows me to answer these questions and this represents an important difference between my opinions and those of Dr. Glibert, Florida's expert on impacts to the Apalachicola Bay food web. Dr. Glibert never makes use of this information. Instead, she offers hypotheses about what *could* happen, and never checks her opinions against the available real world data. In every case where I have made such a check, I find that Dr. Glibert's opinions are incorrect. This does not represent a difference in experts' use of a particular data set or knowledge of literature, but instead reflects the fact that Dr. Glibert ignored the most important data set, the extensive data for the fish community. She did not have to guess about what might

happen; she could have learned about what actually has happened simply by looking at the available fish data.

Menzie Demo. 27



Demo. 27. This is Figure C-17 from my Expert Report (GX-872). There have been over 20,000 fish trawls and almost 6,000 seine collections of fish in the Bay. In most cases, these are monthly collections, allowing for an analysis of both temporal and spatial variations. Numerous fish species and invertebrates, such as White shrimp and Blue crabs, are represented in this data.

127. Florida's former fish expert, Dr. Jenkins, also emphasized Livingston's work, but did not use the work to compare abundances over time, despite the fact that much of the more recent sampling was intended to replicate the work of Livingston. Thus, Dr. Jenkins did not obtain the same insight regarding the stability of populations over time. In his expert report, Dr. Jenkins reached opinions that are the opposite of mine and I sought to understand why there were differences. Upon investigation, I found that Dr. Jenkins' made three major/primary mistakes that led to invalid scientific opinions on this particular matter: (1) he used truncated data sets and flawed equations to draw conclusions about changes in fish species composition; (2) he relied on a flawed statistical methodology to show changes in fish abundance between the two

datasets; and (3) he failed to connect natural variation in fish abundance to any "destabilization" of the ecosystem.

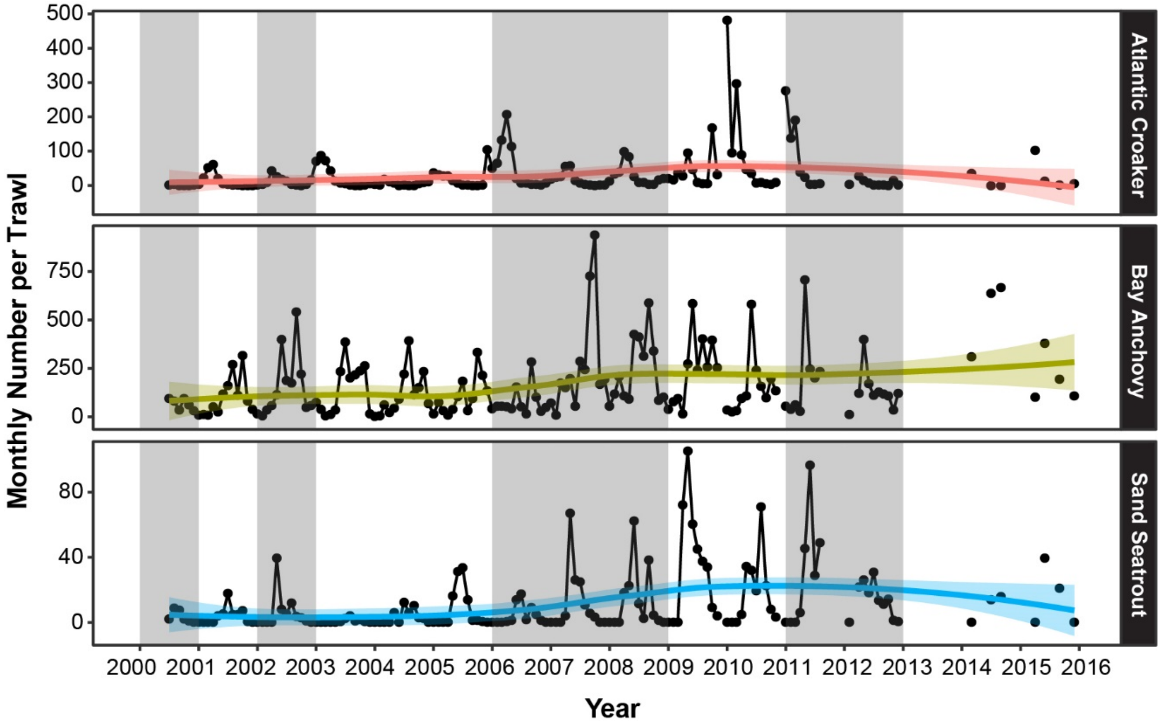
(b) Tier 2 – Is there evidence that alterations in river flows associated with droughts are causing changes in the Bay's fish communities?

128. Florida's Bay ecology experts, Drs. Glibert and Jenkins, attribute alleged harms to the productivity and community structure of the Bay's fish communities to Georgia's consumption of freshwater. As described above, there is no evidence to support such claims of any harm to these fish populations. However, I examined this claimed association between fish community structure and abundance and water flows more carefully in a Tier 2 causal analysis. To conduct this Tier 2 analysis of the fish population, I examined the available trawl and seine data for trends in abundance relative to drought years. GX-1153 (NOAA Palmer Drought Index). My statistical analysis of the recent trawl and seine data[39] (1998 to 2014) reveals that, despite several years of natural drought, there were no apparent trends in the variation of predominant fish species or diminishment of young fish within East Bay. This is consistent with my understanding that the spatial distribution for several fish species in the Bay, including Gulf sturgeon, also includes the Apalachicola River. During periods of higher salinity, young fish will migrate up-river to more favorable habitat.

129. My analysis shows that the population abundances of the three major trophic groups of fish (planktavores, benthivores, and piscivores) are sustained or increasing in the recent drought periods (since 2000), as shown in **Menzie Demo. 28**.

[39] Trawls and seines are two different sampling methods for fish. Trawls are towed behind boats over fixed distances of times. Seines as used for the Apalachicola Bay are long nets that are deployed by boat or from the shore in arcs that catch the fish in the bow of the net as it is closed.

Menzie Demo. 28



Demo. 28. This figure shows the temporal variations for three predominant species of fish that represent different trophic groups in the Bay. The shaded areas are periods of drought. This figure demonstrates that there is no apparent relationship between fish abundances and drought periods. These figures are taken from data in Appendix C of my Expert Report (GX-872), which includes similar analyses for several other fish and invertebrate species.

130. This figure shows that the predominant plankton-feeding fish species in the Bay— the Bay Anchovy—generally increased in abundance over the period from 2000-2014, which included several drought periods. Since Bay Anchovy feeds on zooplankton, the increase in abundance supports my conclusion that productivity is sustained, not decreased, during low-flow drought periods. Sand seatrout, a piscivore species, also exhibits higher abundances in the more recent trawls. This suggests that there is a productive prey base for this species.

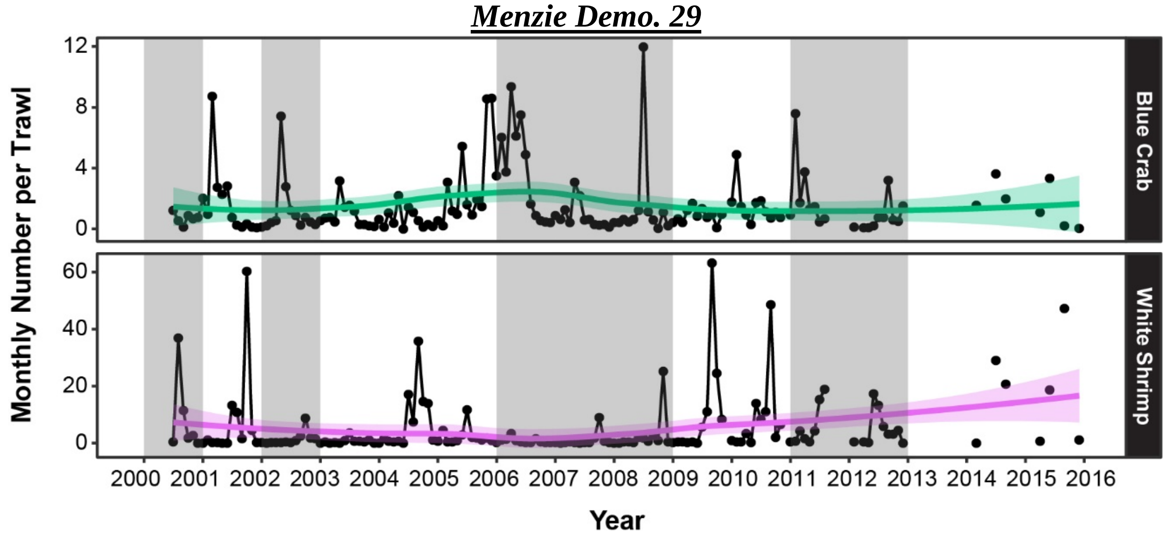
131. The Atlantic croaker and Spot represent the predominant benthic-feeding fish species in the Bay. While the abundance of Atlantic croaker is higher in the recent period than in the past, Spot populations increased in the early dataset but appear lower in the most recent data. This, in my opinion, simply reflects natural long-term variability in the species. Taken collectively, these results do not indicate diminished productivity of the underlying prey base for benthic-feeding fish in recent years. Had both species declined, that could be an indication that perhaps the food base or some other factor was involved. However, the sustained presence of

benthic-feeding fish confirms that the productivity of their food source, benthic invertebrates, is sustained.

132. East Bay is believed to serve as an important nursery ground for the Bay's fish community. To evaluate whether East Bay continues to serve as a nursery during droughts, I conducted a careful and comprehensive analyses of the available seine data for the Bay. Seine data is especially important because seines collect small juvenile fish that reside in shallower regions. I found that the abundance of young and juvenile fish was sustained throughout the recent drought periods. This is direct evidence that East Bay continues to serve as a nursery ground for the Bay's fish community, despite the occurrence of droughts. Notably, the seine data were not evaluated or even reported by Florida's experts Glibert or Jenkins.

133. In addition to revealing the stability of the Bay fish community, my statistical analysis of trawl data also revealed that there were no obvious relationships between droughts and the abundance of Blue crab or White shrimp in the Bay, as shown in **Menzie Demo. 29**. This is consistent with my understanding of the spatial distribution for Blue crabs, which includes Apalachicola River. During periods of higher salinity, crabs migrate to more favorable habitat. When I conducted my reconnaissance survey, I learned that there are active fisheries for both Blue crabs and White shrimp in Apalachicola Bay, which could also affect species abundance.

Menzie Demo. 29



Demo. 29. Temporal patterns in the abundances of Blue crab and White shrimp as presented in my Expert Report. Drought periods are shaded. The figure shows that there are no adverse influences of drought period on the abundances of these two invertebrate species. These figures are taken from data in Appendix C of my Expert Report (GX-872), which includes similar analyses for several other fish and invertebrate species.

134. Dr. Jenkins reached different opinions than I did, primarily because of mistakes in his data analysis and interpretation. Because Dr. Glibert relies *entirely* upon this flawed analysis of Dr. Jenkins in her report, her opinions regarding impacts on fish are also similarly flawed and at odds with the actual data. These analyses are based on real data, albeit inappropriately analyzed and interpreted. The errors are compounded by Dr. Jenkins additional work, which involved modeling the future using a model known as Ecopath with Ecosim (EwE). This modeling framework, as applied by Dr. Jenkins, yields unreliable results regarding changes in the structure of the Apalachicola Bay food web. The EwE model consists of a core mass-balance model (Ecopath) that simulates biomass and trophic relationships for the functional groups being modeled.

135. As demonstrated in the chart below, **Menzie Demo. 30**, Dr. Jenkins failed to follow best practices regarding model inputs.[40]

Menzie Demo. 30

Best practices in EwE		Jenkins' Use of EwE
Conceptual model construction		
	Model reflects ecosystem in realistic ways	Incorrect
	Realistic forcing functions for modeled taxa (i.e. changing ***average*** salinity)	Incorrect
	Known biomass flows into and out of system accounted for	Not implemented
Model Parameterization - Biomass estimates (upon which entire model is based)		
	Use site specific biomass data	Partially implemented
	If site specific data unavailable, use appropriate surrogate data	Poorly justified, some inappropriate values
Model Parameterization - Salinity preferences (upon which predictions of changes in biomass are based)		
	Use measured values from literature for salinity preference	Partially implemented, some incorrect values
	Use salinity preference plots for each biotic group	Not implemented
	Use salinity preference for each life stage, when relevant	Not implemented
Technical model construction best practices		
	Testing, balancing, and validating the model	Partially balanced, no testing or validation
	Accurate statistical testing of results	Not implemented
	Characterization of uncertainties	Not implemented

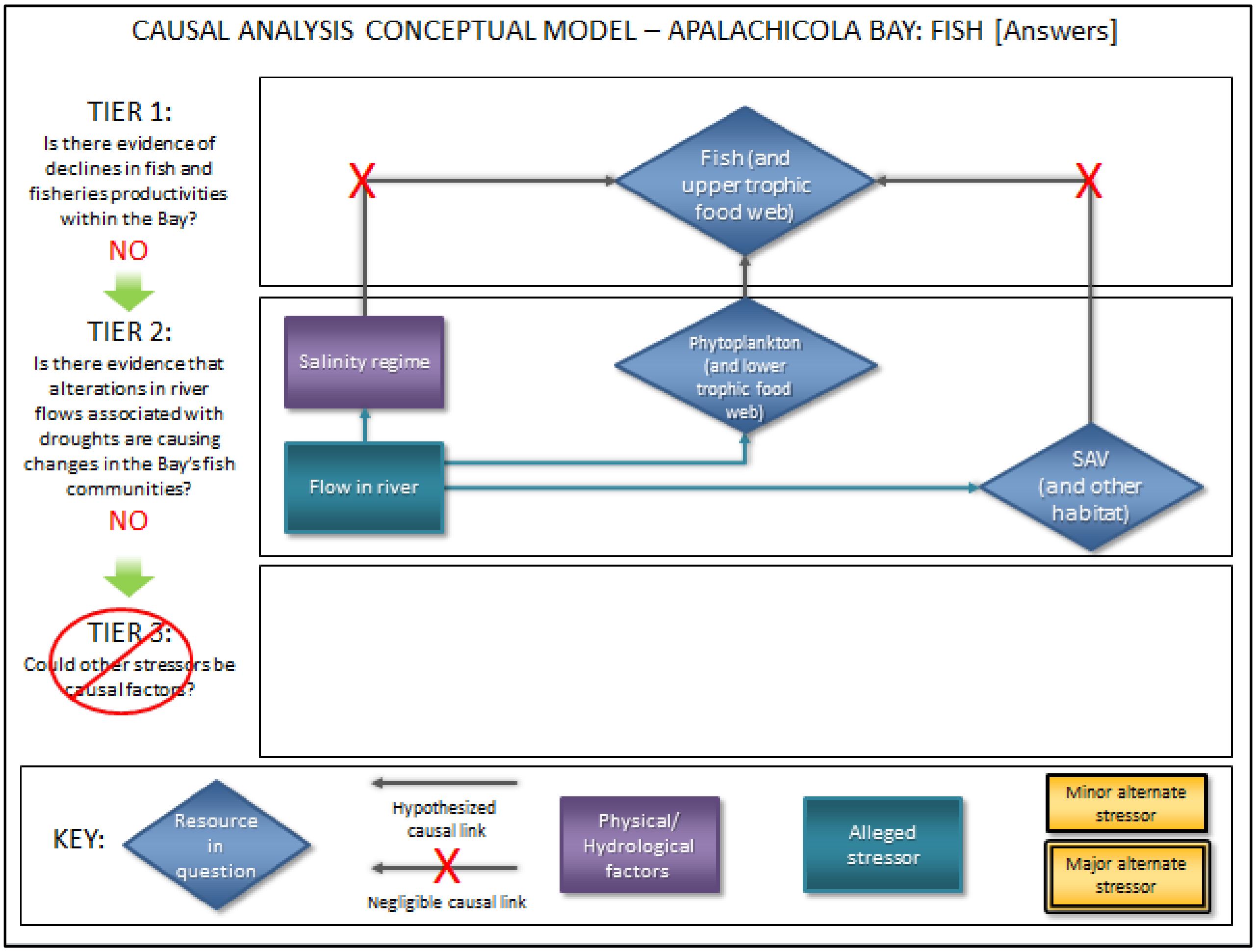
(c) Tier 3 - Because there is no evidence of long-term change in fish communities and fisheries productivity in Apalachicola Bay, there is no need to examine other alternative causes of change.

136. My analysis of all of the available evidence demonstrates a sustained fish community in the Bay that has the same general species composition in recent times as in the 1970s. Fish abundance and associated productivity are also comparable between the two time

[40] Heymans, J.J., et al., *Best practice in Ecopath with Ecosim food-web models for ecosystem-based management* (http://dx.doi.org/10.1016/j.ecolmodel.2015.12.007).

periods. Because I did not find any evidence of any long-term change to the fish communities, there was no need to look at alternative causes of change under a Tier 3 analysis. My conclusions regarding factors causing variation in secondary production in the Bay are summarized in the following figure, **Menzie Demo. 31**.

Menzie Demo. 31



Demo. 31. This conceptual model shows the results of my causal analysis for secondary producers (fish and invertebrates) in the Bay. The results of Tier 1 and Tier 2 indicate that no adverse changes are occurring for the fish community. Thus, a further analysis of other potential causal factors is not necessary.

137. Fluctuations in river flow caused by droughts do not appear to be a major determinant of overall secondary productivity and composition. It is reasonable to presume that mobile fish and crustaceans will respond to periodic natural shifts in salinity regime by moving to more favorable salinity zones. This type of mobility occurs in estuaries from Maine to Texas,

and it is well known to local Apalachicola fishermen, who decide where to fish depending on environmental circumstances. Dr. Glibert incorrectly presumed that shifts in phytoplankton composition at lower river flows would translate into cascading effects on the Bay's plankton-based food web. My analysis demonstrates that Dr. Glibert not only missed important ecological food pathways leading from phytoplankton to fish, but also that the available data on the abundance and composition of plankton-feeding fish strongly refutes her contention. In sum, there is no evidence that there has been a decline in the productivity of the Bay's fish community. There is also no evidence in declines of other secondary producers such as shrimp and blue crabs.

138. My conclusion that the primary production of the Bay is supporting secondary production of grazers also provides insights into whether the phytoplankton primary production of the Bay continues to support the production of oysters. In her direct testimony, Dr. Glibert suggests that temporal variations in phytoplankton composition (less diatoms, more cyanobacteria) can have negative effects on oyster growth or vitality. Leaving aside Dr. Glibert's erroneous conclusions regarding the phytoplankton populations themselves, there is simply no evidence that this has occurred. To the contrary, the robust data available for fish indicates and invertebrates confirms that the food web and secondary animal production of the Bay continue to be supported at levels and with a structure comparable to that in the 1970s and 1980s. Moreover, many of the observed species feed on the same planktonic food sources that oysters rely on. The fact that these species continue to be sustained is evidence that the same planktonic food web is sustained for oysters as well. As a causal analyst I recognize that there are many possible stressors that influence oyster abundance, not the least of which is shell placement and harvesting resulting from the fact that oysters are a managed resource. However, looking to other species in the Bay that are not affected by these management-related stressors, it is evident that lack of nutrition does not appear to be a limiting factor based on the Bay food web.

III. Glibert's Response to My Opinions Presented in Her Direct Testimony

139. In Section VI of Dr. Glibert's direct testimony, she presents information under the heading *Dr. Menzie's Analyses Do Not Cast Doubt on My Work.* In this section, I respond to

the several misrepresentations, misunderstandings, and criticisms contained in Dr. Glibert's testimony.

140. With respect to my opinion regarding the sources of nutrients to the Bay, Dr. Glibert notes that, *While there is no doubt that this organic matter and other food sources play a role in the food web, they cannot replace the importance of dissolved nutrients that are delivered with River flow and the primary production that depends on these nutrients*. Dr. Glibert's response to my opinion is not supported by evidence and misses important processes recognized for the Bay. Specifically, based on evidence, we know that: 1) primary production and algal biomass are highest at low flows, and 2) fish populations, and therefore the zooplankton prey base that supports those fish populations, remain productive through low flow periods. Further, Dr. Glibert ignored the generation of dissolved nutrients by organisms in the Bay, an important process concerning sources of nutrients to phytoplankton. Re-generated nutrients are produced by bacteria, by benthic invertebrates feeding on the organic materials from the floodplain, as well as by organic material produced within the Bay and by micro- and meso-zooplankton. The dissolved nutrients generated by these organisms within the Bay are not dependent on the river flow during the lower flow periods, but instead re-work organic matter delivered to the Bay during previous periods. These regenerated nutrients are in turn utilized by phytoplankton. This process of regeneration helps explain why primary production is sustained rather than diminished at low flows.

141. Dr. Glibert misrepresents my assessment of her analyses of declines in dissolved oxygen, and further misunderstands the biological and physical processes governing oxygen. I have maintained that the main problem with Dr. Glibert's opinion on eutrophication-related consequences of low flows, is that they are based largely on data from a station that cannot be considered representative of much of the rest of the area. The East Bay Station relied upon by Dr. Glibert is deeper and subject to unique influences that differ from those present throughout most of East Bay. The different physical characteristics of this deeper station sharply contrast with the shallow area comprising most of East Bay. This difference in water depth is especially important because mixing of oxygen from overlying air down into the water column is influenced by both winds and water depth, and therefore oxygenation would be higher for shallower waters. Data for the East Bay station cannot be presumed to be representative of data

that would be found in broad areas that do not share the physical features found of East Bay station used as the basis for extrapolation.

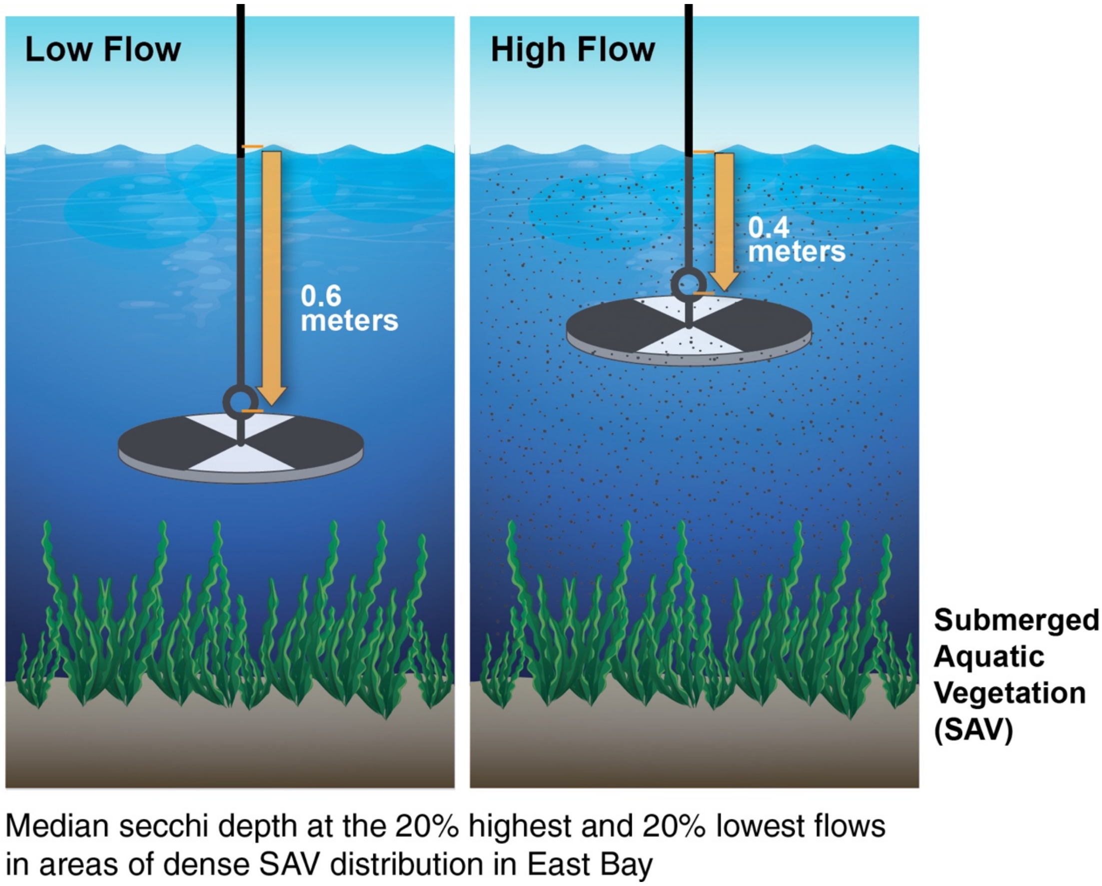
142. Dr. Glibert seemed to imply that my knowledge of conditions at the East Bay station came solely from my site visit. While I did document that there was low oxygen in the creeks discharging to the East Station location during the time of my visit, there had been many observations made over time concerning the influence of Tate's Hell Forrest drainage on water quality conditions at and near the East Bay Station, including water quality measurements and satellite photographs. My attention would not have been drawn to the influence of the creeks draining the forest, had it not been for the substantial information already gathered by others about this phenomenon.

143. Dr. Glibert noted that because there was diurnal variation in oxygen at the East Bay station, that my opinion was unsupported. What Dr. Glibert does not consider, however, is that photosynthesis by phytoplankton produce oxygen only during the day, when there is light, while the consumption of oxygen via respiration by all organisms occurs at all times. Thus, higher oxygen during the day and lower oxygen at night does not indicate that respiration of phytoplankton biomass alone is causing the decrease in oxygen as opined by Dr. Glibert. Instead, any increase in oxygen is as readily explained by the fact that phytoplankton are generating oxygen when light is present, causing there to be an increase in oxygen during the day, resulting in a diurnal pattern. For a myriad of reasons, the East Bay station cannot be presumed to be representative of East Bay, and there is considerable uncertainty about the actual processes affecting conditions at this station

144. Dr. Glibert misunderstands my response to her opinion on shading when she states, *This [Menzie's] opinion, however, contradicts fundamental laws of light absorption (the physics of photosynthesis): if there are more phytoplankton, they absorb more light, and less light is left for the submersed aquatic vegetation.* The issue I raised is not related to the laws of physics but to understanding the degree to which light is affected and whether that is sufficient to cause shading of SAV to a degree that would matter. Dr. Glibert begins with the premise that algal blooms would be sufficient to cause shading that would impair the growth of SAV. I, on the other hand, know from personal experience in Apalachicola Bay that SAV is already growing

in the Spring when light penetration is very low. The main factor controlling light penetration in the Bay is the amount of silt in the water, and this amount decreases as the river flow decreases. As a result, the water becomes steadily clearer at lower flows despite the occurrence of algal blooms that may be present at lower flows. I demonstrated this relationship in my report using data collected by secchi disc. Dr. Glibert has neither taken issue with these data nor consulted these data to test whether her hypothesis is correct. It is not. So, my opinion is entirely consistent with the law of physics: particulate levels decrease with decreasing river flow due to decreasing amounts of silt; in turn, light penetration increases, even though there is an increase in algae. To illustrate the point that light transparency is higher at the lowest flows as compared to the highest flows, I have constructed **Menzie Demo. 32** from the available secchi disc data for the area of East Bay that supports growth of SAV. As shown by this figure, light transparency is greatest at the lowest flows. I also checked both drought years and the years reflected in the studies that Dr. Glibert cites to, and found that none of these years exhibited unusual declines in light transparency. Dr. Glibert's opinion that substantial shading impedes the growth of plants during low flows is therefore unsupported and in fact at odds with the actual light transparency data available for the Bay.

Menzie Demo. 32



Demo. 32. Comparison of light transparency as measured by secchi disc depths in East Bay, where SAV beds are located for the highest and lowest flows.[41] *This figure shows that light transparency is greatest at the lowest flows. These secchi disc data are collected monthly throughout East Bay as part of ANERR's fish sampling program.*

145. Dr. Glibert again misrepresents my opinion when she states that, *Dr. Menzie opines that cyanobacteria are not dominant at low flows*. I have noted the following: First, cyanobacteria are correlated with temperature, and increase as waters warm; higher temperatures occur in the summer, when low flows also occur; thus, presuming a simple relationship between river flow and cyanobacteria is seriously confounded. Second, during the year that had the lowest flow in the short data record (2008), cyanobacteria biovolume was lower than the year with higher flow. In short, a relationship is apparent in the data because cyanobacteria, water temperature, and river flow all vary together. However, it is scientifically unsound to presume

[41] This refers to upper and lower 20% of flows.

that a cause and effect relationship exists between increments of flow and the amount of cyanobacteria.

146. Beyond the argument over the temporal pattern of cyanobacteria, it is clear that the occurrence of these microscopic photosynthetic organisms is not having a negative influence on the food web. Instead, the productivity of this group of organisms helps explain why primary and secondary productivity in the Bay are not diminished during lower flow periods. Accordingly, Dr. Glibert's contention that primary productivity of this group of phytoplankton represents a harm to the Bay is not supported by the data for the Bay and is at odds with other studies in the literature.

147. Dr. Glibert also questioned my knowledge of phytoplankton taxonomy, noting that, *Dr. Menzie critiqued my phytoplankton historical analysis in his report, but in so doing revealed that he has only limited knowledge of phytoplankton taxonomy*. To the contrary, I have significant experience identifying freshwater and estuarine phytoplankton. Dr. Glibert makes her point in reference to my critique of her work concerning *Asternionella*. In fact, my critique pointed out six errors in Dr. Glibert's analysis with respect to interpretation of phytoplankton data. She has not taken issue with my broader critique, and her direct testimony does not rely on such comparisons of recent and historical phytoplankton. Further, she apparently missed the point I was making about *Asternionella,* which is that it was rarely observed and thus not a reliable indicator for major shifts in phytoplankton.

148. Dr. Glibert misrepresents my opinion on the occurrence of harmful algae in Apalachicola Bay, stating, *Dr. Menzie has stated he has not found evidence of harmful algae in Apalachicola Bay that can be tied to lower flows.* I made a distinction between the presence of such algae and the levels at which reportable or observable harm would occur. I specifically looked for evidence of blooms that had actually caused harm, as opposed to presuming that because such species are present, harm is implied. For my analysis, I examined scientific data as well as public records concerning harmful algal blooms in the Bay. None of the species referred to as harmful by Dr. Glibert, other than *Karenia brevis*, rose to the level of reportable or observable harm. I did not ignore these other potentially harmful species; there simply is no evidence that they reached levels that caused harm to oysters, people, or other animals in the

Bay. Had that occurred, there would have been associated reportable events by the agencies that look for these problems and/or by the public and oystermen that experienced them. No such reports were made.

149. My findings concerning harmful algal blooms are entirely consistent with the report by Professor Edward Phlips of the University of Florida upon which Dr. Glibert relies. As noted earlier in my testimony, my research did not reveal that the algal species considered by Dr. Glibert to be harmful had actually caused harm. It is true that these algal species are present and can increase in numbers during the warmer summer months. But Professor Phlips concludes: *However, since biomass levels [of potentially harmful algae] in Apalachicola Bay are for the most part not high by comparison to more restricted estuaries of Florida, it will be important to define threshold biomass levels for suspected HAB species in the bay which may represent dangerous levels for oyster species.* I look at this from the perspective of my expertise as a risk assessor. It is essential to understand that impact and environmental risk is related to both hazard and exposure. In the present case, while these potentially hazardous algal species are present (as they are in most coastal systems), blooms of these species have not reached exposure levels sufficient to cause observable or reportable harm.

CAUSAL ANALYSIS OF ALLEGED HARMS TO THE APALACHICOLA FLOODPLAIN

150. Florida claims that Georgia's consumption of water has caused harm to the floodplain habitats and resources, as well as to threatened and endangered mussel and fish species that inhabit the river and floodplain. I conducted my tiered causal analysis for each category of resource, and arrived at the following answers under each tier:

<u>Menzie Demo. 33</u>

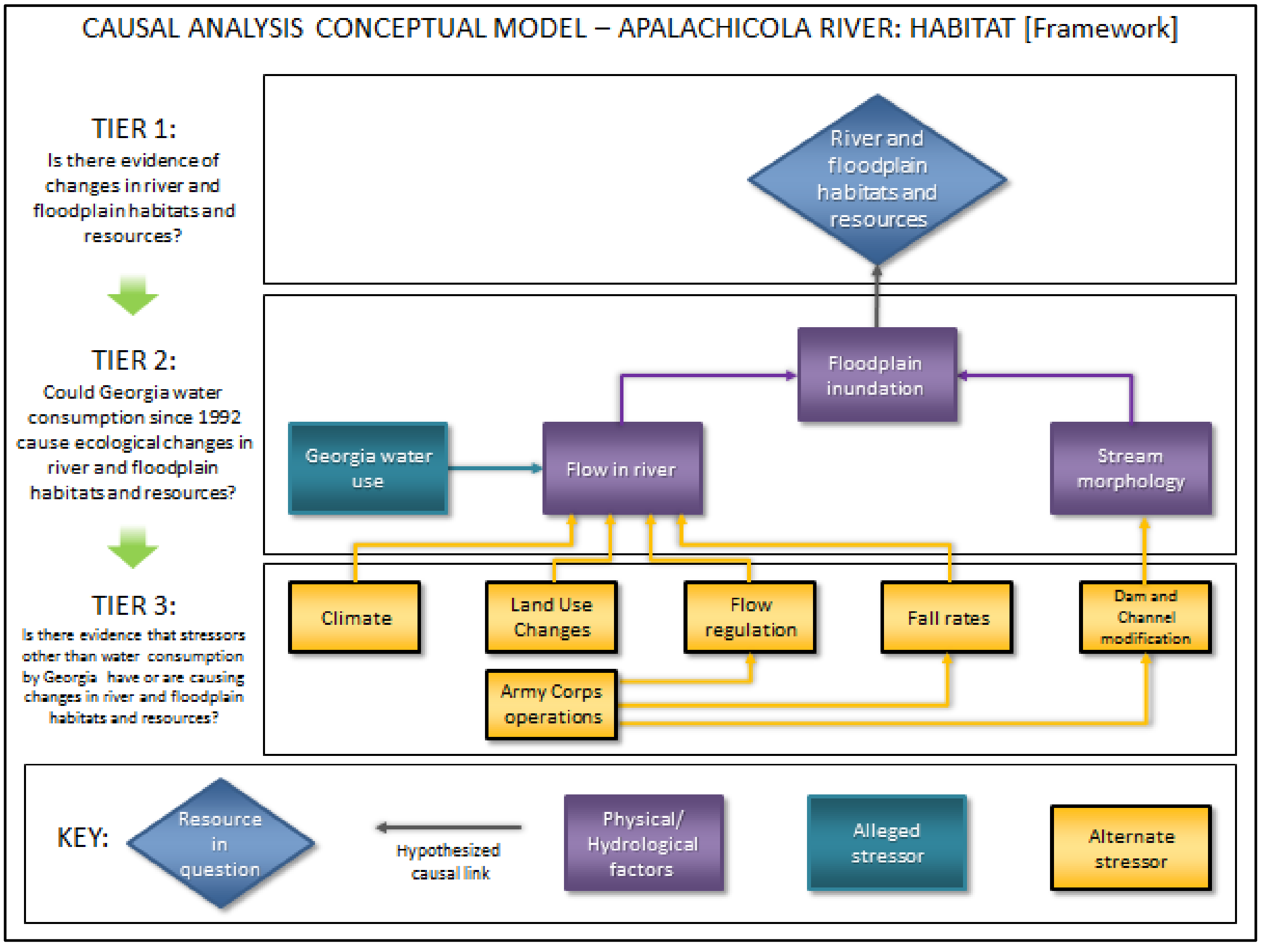
	Floodplain habitats and resources	T&E Mussel species	T&E Gulf Sturgeon
Tier 1: Evidence of change or resource loss?	Yes	Endangered but populations generally stable or increasing	Endangered but stable
Tier 2: Evidence of Georgia water use as causal factor?	Negligible	Negligible	Negligible
Tier 3: Evidence of other causal factors?	Yes	Yes	Yes

Demo. 33. Answers derived from tiered causal analyses conducted on three categories of resources for Apalachicola River and Floodplain.

151. The Apalachicola River floodplain consists of a variety of forested aquatic habitats, including Tupelo cypress swamps, low bottomland hardwood forests, and high bottomland hardwood forests. These floodplain areas are connected to the main channel of the Apalachicola River via sloughs or channels that branch off of the River. During periods of lower flows or drought, water levels can fall below the mouth of the sloughs. As water levels rise, water enters the sloughs, flooding their streambeds. As flow increases, the inundation expands beyond the boundaries of the slough streambeds, inundating low-lying swamps first, and then low bottomland hardwood forests and high bottomland forests. The inundation cycle of floodplain depends upon the seasonal river flow.

152. My causal analysis related to the Apalachicola River and Floodplain examines the weight of evidence to support allegations of "harm" to mussels, fishes, and trees, as presented by Florida's expert, Dr. Allan. Dr. Allan maintains that Georgia's consumptive use of water has caused and will continue to cause harm to these resources based on the water level of the Apalachicola River corresponding to specific flow rates. Accordingly, my causal analysis focuses on evaluating natural and anthropogenic factors that have the potential to affect the water level of the Apalachicola River, as shown in the figure below, **Menzie Demo. 34**.

Menzie Demo. 34



Demo. 34. This figure shows a conceptual model of my tiered causal analysis of changes to River and Floodplain habitats and resources, including Georgia's consumptive use of water and alternative causal factors that were considered.

153. Based on the analyses conducted and data reviewed, I conclude that Dr. Allan's allegations of harm due to Georgia's consumptive use of water are unsupported. Dr. Allan fails to validate his predictions of harm with consistently observed harm in the field; he fails to determine whether his "metrics of harm" are relevant to populations; and, most importantly, Dr. Allan fails to adequately consider other alternative causes of water level changes in the Apalachicola River, including the USACE's role in managing water flows into the Apalachicola River.

154. Dr. Allan presents no evidence that any population of any animal species in the Apalachicola River or floodplain is declining. Populations of threatened and endangered (T&E) species in the Apalachicola River have generally been increasing or stabilizing over the period

during which Georgia's consumptive use of freshwater has increased, which suggests that Georgia's consumptive use has little impact on these species. While there are observed changes in the composition of tree species, my causal analysis demonstrates that river channel modifications as a result of USACE operations and natural climate patterns are the primary causes of the observed changes in water level that have affected the resources and habitats of the Apalachicola River Floodplain. Consequently, there is no evidence that Georgia's consumptive use of water is the cause of changes to resources in the Apalachicola River and Floodplain. Given the role of the USACE, a cap on Georgia's consumption of freshwater would have no impact on water levels in the Apalachicola River and Floodplain during drought operation periods.

I. Changes in Composition of Forested Wetlands Were Caused by Channel Modifications and Natural Climate Patterns—Not Georgia

(a) Tier 1 — Is there evidence of changes in floodplain forest composition?

155. To determine whether there is evidence of a change in floodplain forests, I reviewed published studies examining the species composition and density of floodplain tree species, as well as the extent of floodplain forest habitat types. Because the trees of the forest are long-lived, the size of the trees can be used to infer the time period over which the trees have grown and been exposed to natural and man-made stressors. As such, the trees represent the integrated influence of multiple different factors, including climate, channel modifications, and Georgia's consumptive use. From my review of available studies, I believe that over the past several decades, there is evidence of a decline in the densities of tree species that are characteristic of swamps throughout the non-tidal floodplain and evidence of a successional shift through the floodplain forest habitats to species that are more typical of the next-drier habitat (e.g., low bottomland hardwood forest is the next drier habitat to swamps even though total biomass has remained constant). This has not been an instantaneous change but rather a gradual change to floodplain forests, particularly swamp habitats.[42]

[42] FX-870 (Darst, M.R., and H.M. Light. 2008. Drier forest composition associated with hydrologic change in the Apalachicola River Floodplain, Florida. U.S. Geological Survey Scientific Investigations Report 2008-5062. 81 pp., plus 12 apps).

(b) Tier 2 — Would incremental water consumption by Georgia since 1992 cause ecological changes in the River and Floodplain habitats and resources?

156. In this tier, I first consider the role of river flow on inundation and floodplain habitats and examine the influence on inundation associated with Georgia's incremental consumption of water. The evidence indicates that river flow is important for inundation, but my analysis reveals that Georgia's water consumption is negligible.

157. The USGS has commissioned numerous studies to analyze the cause of the observed shift in forest composition. The USGS researchers have found that floodplain inundation has changed over time, with a decline in annual inundated floodplain acres since the late 1970s. Inundation of the floodplain forest depends on the geomorphology—or physical structure—of the river and the amount of water flowing through the river. In this tier, I focus only on river flow and the relative influence of Georgia's consumptive use on floodplain inundation. I analyze the geomorphology (channel change) in Tier 3.

158. The river floodplain includes portions that are influenced by tidal forces from the Gulf of Mexico. This portion of the floodplain is called the tidal floodplain. Both the non-tidal and tidal floodplains of the Apalachicola River include forested floodplain habitats, sloughs, and creeks that are affected by changing flows in the River. However, my analysis focuses on the relationship between flow and acreage of inundated habitat in the non-tidal floodplain—not the tidal—for the following reasons:

- The relationship between river flow and inundation in the tidal portion of the floodplain is poorly understood and highly spatially variable.

Stallins, J.A., M. Nesius, M. Smith, and K. Watson. 2009. Biogeomorphic characterization of floodplain forest change in response to reduced flows along the Apalachicola River, Florida. River Res.Appl. 26(3):242–260.

la Cecilia, D., M. Toffolon, C.E. Woodcock, and S. Fagherazzi. 2016. Interactions between river stage and wetland vegetation detected with a Seasonality Index derived from LANDSAT images in the Apalachicola delta, Florida. Adv. Water Resour. 89:10–23.

Maxwell, J.T., and P.A. Knapp. 2012. Reconstructed Tupelo-honey yield in northwest Florida inferred from Nyssa Ogeche tree-ring data: 1850–2009. Agricult. Ecosyst. Environ. 149:100–108.

Maxwell, J.T., P.A. Knapp, and J.T. Ortegren. 2013. Influence of the Atlantic Multidecadal Oscillation on Tupelo honey production from AD 1800 to 2010. Agri. Forest Meteorol. 174:129–134.

- Apalachicola River tidal floodplains maintain a water level ± 20 cm of the ground level regardless of river flows except during high river flows above 24,000 cfs.[43]

- Tidal floodplains show opposite seasonality to the relationship between flow and inundation extent in the non-tidal portion of the River, meaning that examining the entirety of the river using the same assumptions about the relationship between flow and inundation produces false and unreliable results.[44]

- While the non-tidal floodplain experiences a direct relationship between flow rate and inundation, water level in the tidal floodplain results from the combined influences of river flow, mean sea level, tide, and wind direction/speed.[45]

- The non-tidal portion of the floodplain is also the primary portion of the River supporting the economically valuable Ogeechee Tupelo trees.

- A precise demarcation between tidal and non-tidal floodplain forests can be difficult to assess and variable. For purposes of my analysis, I used the delineation relied upon by USGS scientists at river mile (rm) 20.6. *See, e.g.*, GX-07 (Light et al.1998), GX-88 (Light et al. 2006); FX-870 (Darst and Light 2008).

<u>Using the USGS-developed Relationship Between Flow-and-Inundation, the Impact of Georgia's Consumptive Use on Floodplain Inundation Is Negligible</u>

159. The first method I used to analyze the impact of Georgia's consumptive use on floodplain inundation relied on a relationship between flow and inundation calculated by the USGS. Helen Light of the USGS studied the relationship between flow at the Chattahoochee gage and the number of inundated acres of floodplain habitat. Her published study provided information to estimate total inundated acres for different simulated flow amounts.

160. To analyze the impact of Georgia's consumptive use, I used three simulated outputs at the Chattahoochee gage provided by Dr. Philip Bedient. All three scenarios provided simulated outputs for the years 1993 to 2011, but the simulated flows were adjusted depending on simulated consumption. The "1992 consumption" scenario applies Georgia's consumptive use of water in 1992, and the "2011 consumption" applies Georgia's consumptive use of water.

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[43] Anderson, C.J., and B.G. Lockaby. 2012. Seasonal patterns of river connectivity and saltwater intrusion in tidal freshwater forested wetlands. River Res. Appl. 28(7):814–826; Anderson, C.J., and B.G. Lockaby. 2011. Forested wetland communities as indicators of tidal influence along the Apalachicola River, Florida, USA. Wetlands, 31(5):895–906.

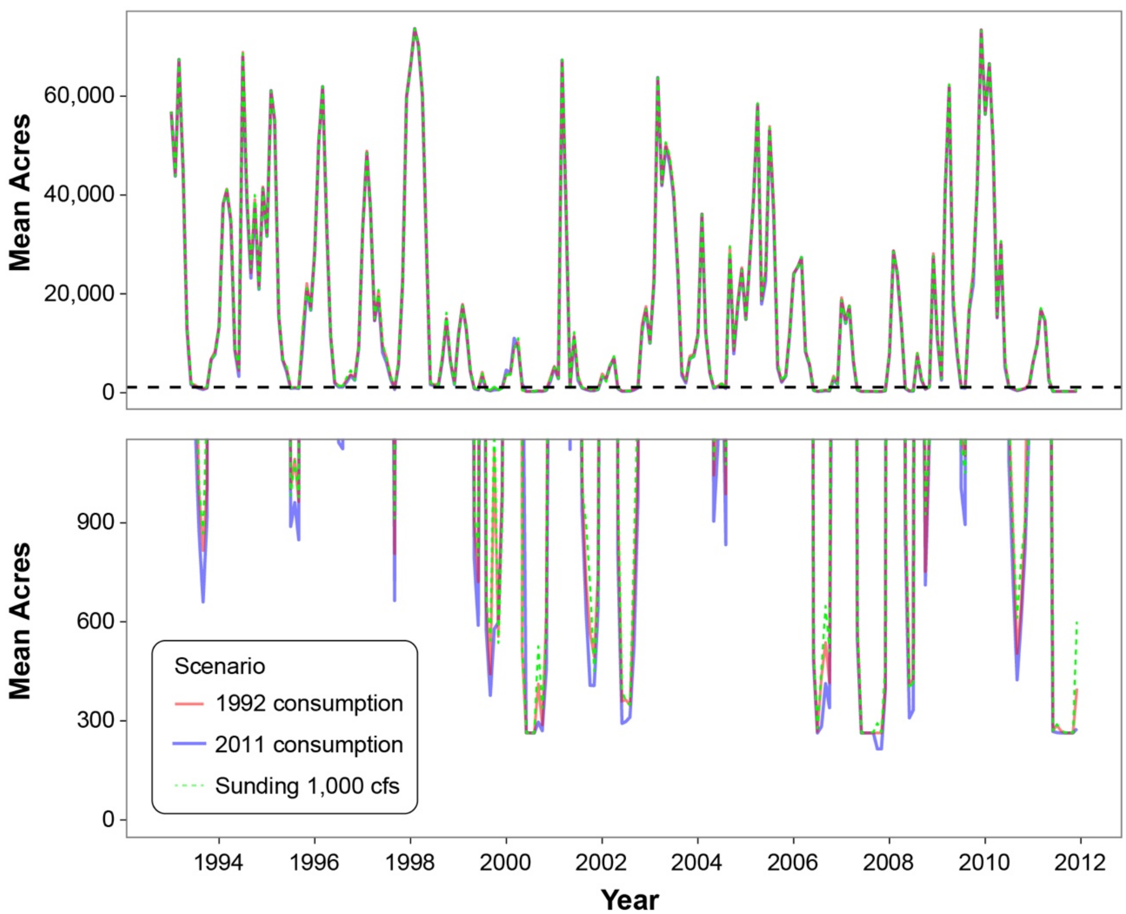
[44] *Id.*

[45] *Id.*

The Sunding 1,000 cfs scenario was based on a recommended increase in peak summer flows of 1,000 cfs by Florida's expert, Dr. Sunding. The Sunding 1,000 cfs scenario assumes an increase of 1,000 cfs in June flows, and adjusts monthly increases in flow based on monthly distributions provided by Florida's expert, Dr. Hornberger.

161. These simulated daily discharges were input to the floodplain inundation relationship developed by Light et al. (1998) to estimate the amount of inundated acres of non-tidal floodplain that correspond to the daily flow rate. The results are shown in **Menzie Demo. 35** (Fig. G-5 from my Expert Report).

Menzie Demo. 35

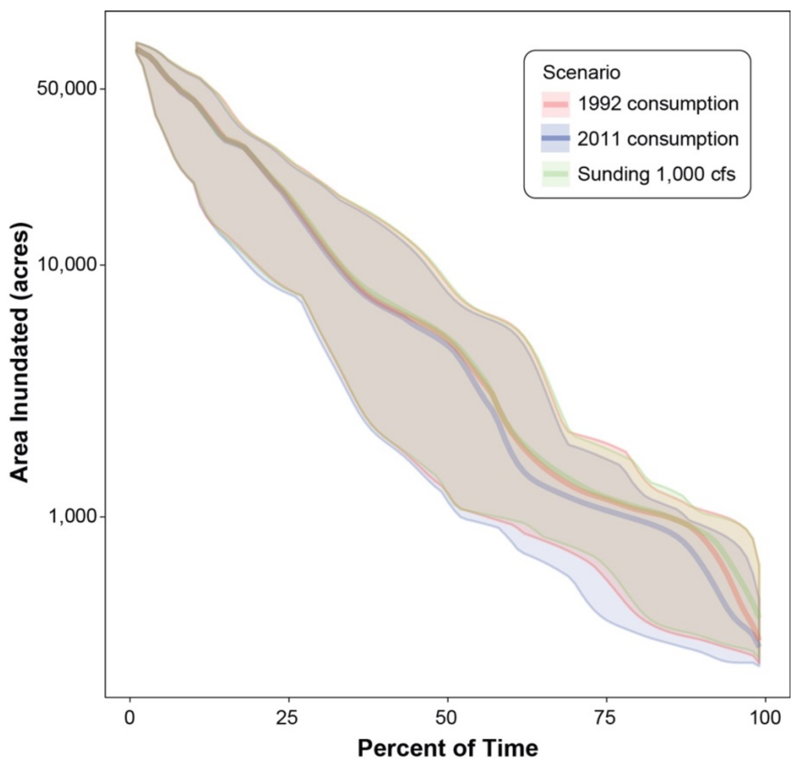


Demo. 35. This figure shows a time series of simulated floodplain inundation areas under three different consumptive use scenarios. This figure was provided in my Expert Report (GX-872) as Figure G-5 and has not been modified. It relies on data provided by Dr. Bedient.

162. **Demo. 35** shows that the amounts of non-tidal floodplain inundated under each of these scenarios are almost indistinguishable. Even in the lower panel, which shows the difference in inundation below 1,000 acres, there is no material difference between the inundated acres when comparing across scenarios. The maximum average difference over the entire 20-year period never exceeds a few hundred acres.

163. Another way to analyze this same data is by examining the frequency of exceedance of inundated acreage between 1993 and 2011 under the various consumptive use scenarios using flow duration curves. This approach plots the probability of amounts of inundated floodplain acreage under a 1992 consumptive use scenario, a 2011 consumptive use scenario, and the Sunding 1,000 cfs scenario. As can be seen, there is little difference between the exceedance curves. If there were a significant difference between the scenarios, I would expect the 95% confidence intervals to have some separation. The fact that there is no such separation tells me that these scenarios do not present materially different results.

Menzie Demo. 36

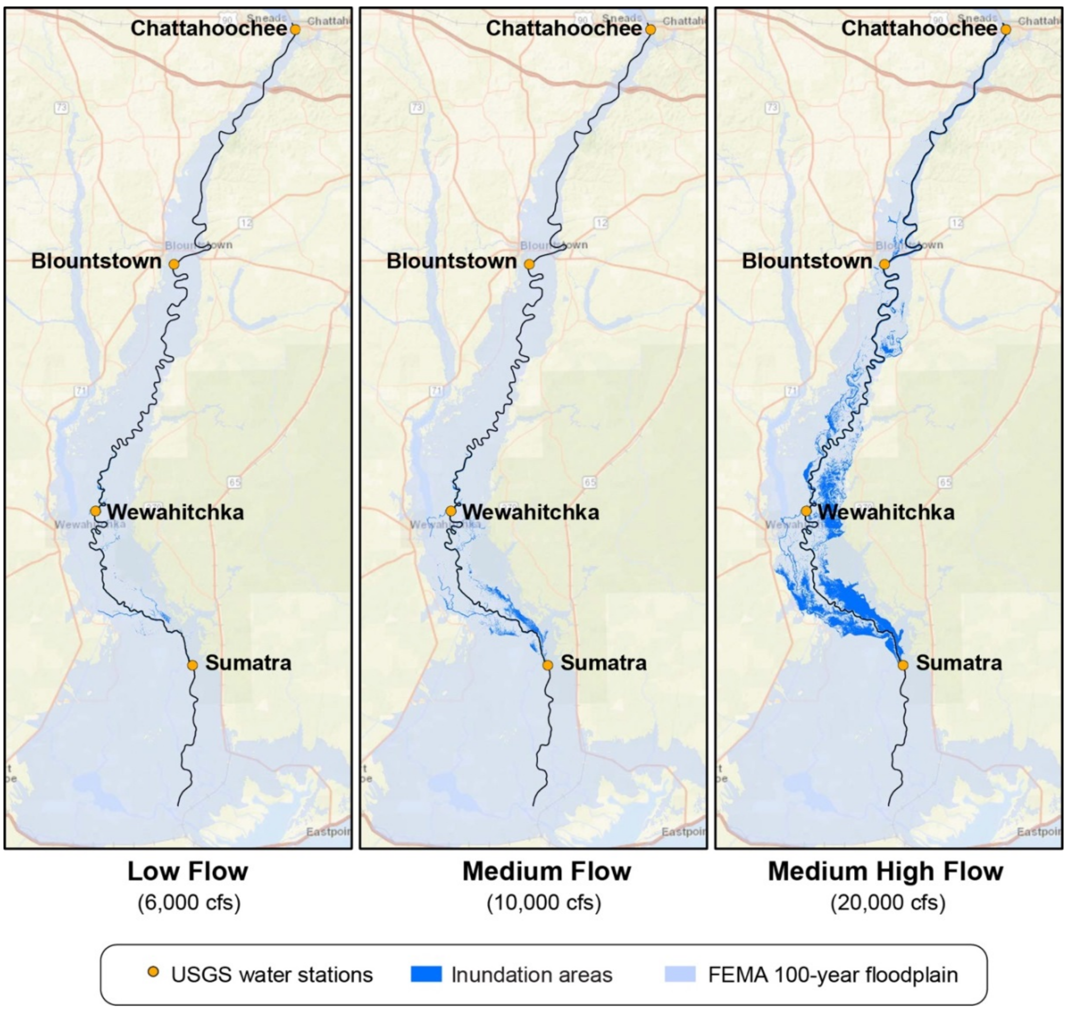


Demo. 36. This is Figure G-6 from my Expert Report (GX-872), and shows the median and variability of floodplain acreage inundated between 1993 and 2011 under three different consumptive use scenarios relative to the percent of time at least that area is inundated.

<u>LIDAR Spatial Analysis Shows the Impact of</u>
<u>Georgia's Consumptive Use on Floodplain Inundation Is Negligible</u>

164. In addition to relying on the USGS flow-inundation relationship, I conducted a spatial analysis using updated satellite imagery that allowed me to analyze the relationship between flow rates and habitat inundation. Light Detection and Ranging (LiDAR) elevation data collected from satellite observations for the Apalachicola River watershed were used in a geographic information system (GIS) platform to see how much area is inundated at different water levels. The results of that analysis are presented in **Menzie Demo. 37**.

<u>Menzie Demo. 37</u>



Demo. 37. This is Figure 29 from my Expert Report (GX-872), which shows the spatial pattern of inundation in the Apalachicola Floodplain relative to different flow rates. To create this figure, I relied on LiDAR digital elevation map (DEM) data for all the 53 sub-watersheds of the Apalachicola River watershed and Douglas Slough sub-watershed, as well as surface water elevation data from four USGS stations on the Apalachicola River.

165. In order to analyze how floodplain inundation impacted specific floodplain habitats, the LIDAR inundation map[46] was used with high-resolution land cover and habitat coverage from the Centralized Data Management Office (CDMO) website of the NERRS.[47] The acreage of inundated habitats under different flow scenarios was calculated by overlaying the inundation areas with the habitat layer. The NERRS habitat layer was available only for the area of the Apalachicola River below river mile (rm) 50. Therefore, all spatial analyses are constrained to the non-tidal portion of the habitat layer (rm 50 – rm 20.6), which includes the primary locations of Ogeechee Tupelo trees.

LIDAR Analysis Method 1

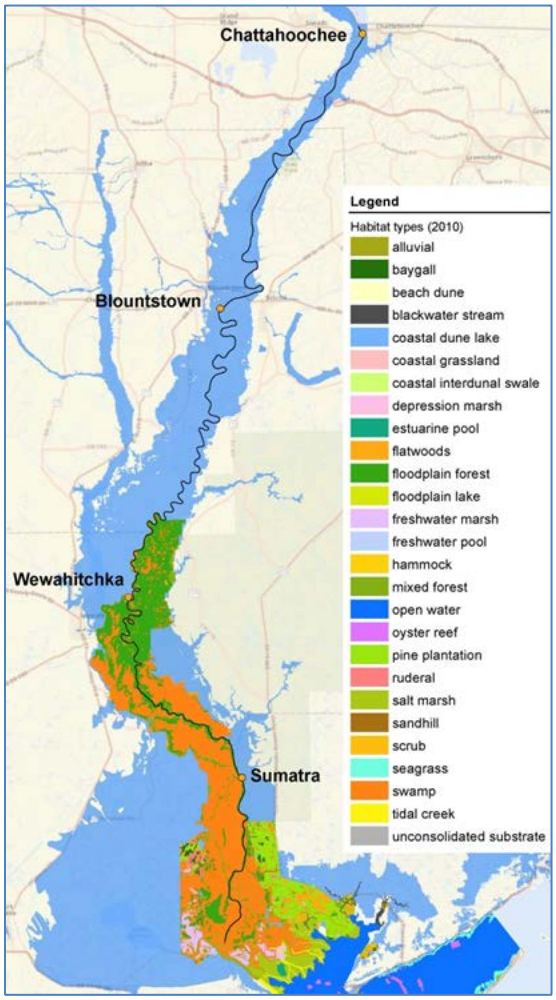
166. I compared the area of habitat inundated under a specified flow rate to the area inundated with incremental increases of 400 cfs and 1,000 cfs at the USGS Chattahoochee gage on the Apalachicola River. A 400 cfs value approximates the average difference that would be expected between the 1992 and 2011 consumptive use scenarios over an extended period of flow, while a 1,000 cfs value represents a conservative upper bound (95% confidence interval) of the average difference that would be expected between the 1992 and 2011 consumptive use scenarios over an extended period of flow. A 1,000 cfs also reflects the additional peak monthly flow that Florida's expert Dr. Sunding estimated could be achieved through various conservation practices.

167. I examined inundation for three predominant habitats in the floodplain, including alluvial (river channel, slough and creek), floodplain forest, and swamp. These habitat areas are shown in **Menzie Demo. 38**.

[46] Spatial inundation maps were created using LiDAR data from 2007, which were downloaded from the Northwest Florida Water Management District Public LiDAR Data Server (*http://nwfwmdlidar.com/*).

[47] Centralized Data Management Office (CDMO) website of National Estuarine Research Reserve (NERR) System. *http://cdmo.baruch.sc.edu/get/gis.cfm*

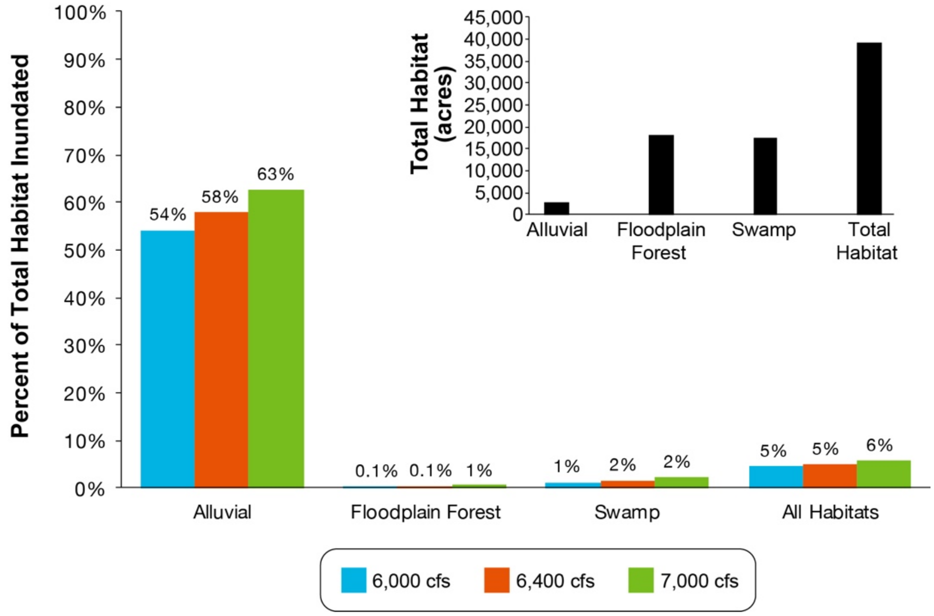
Menzie Demo. 38



Demo. 38. This figure shows the high-resolution land cover and habitat coverage map for the Apalachicola River and Floodplain below river mile (rm) 50. It relies on habitat data downloaded from the Centralized Data Management Office (CDMO) website of National Estuarine Research Reserve (NERR) System. *http://cdmo.baruch.sc.edu/get/gis.cfm*

168. I also considered the area of total habitat inundated, which includes all of the habitat types. Given the emphasis from Florida on the impact of incremental increases in flow at low flow rates, the results of the spatial analysis at a base flow of 6,000 cfs are provided in **Menzie Demo. 39**. The differences in acreages were calculated and expressed as a percentage of the habitat within the assessment area.

Menzie Demo. 39



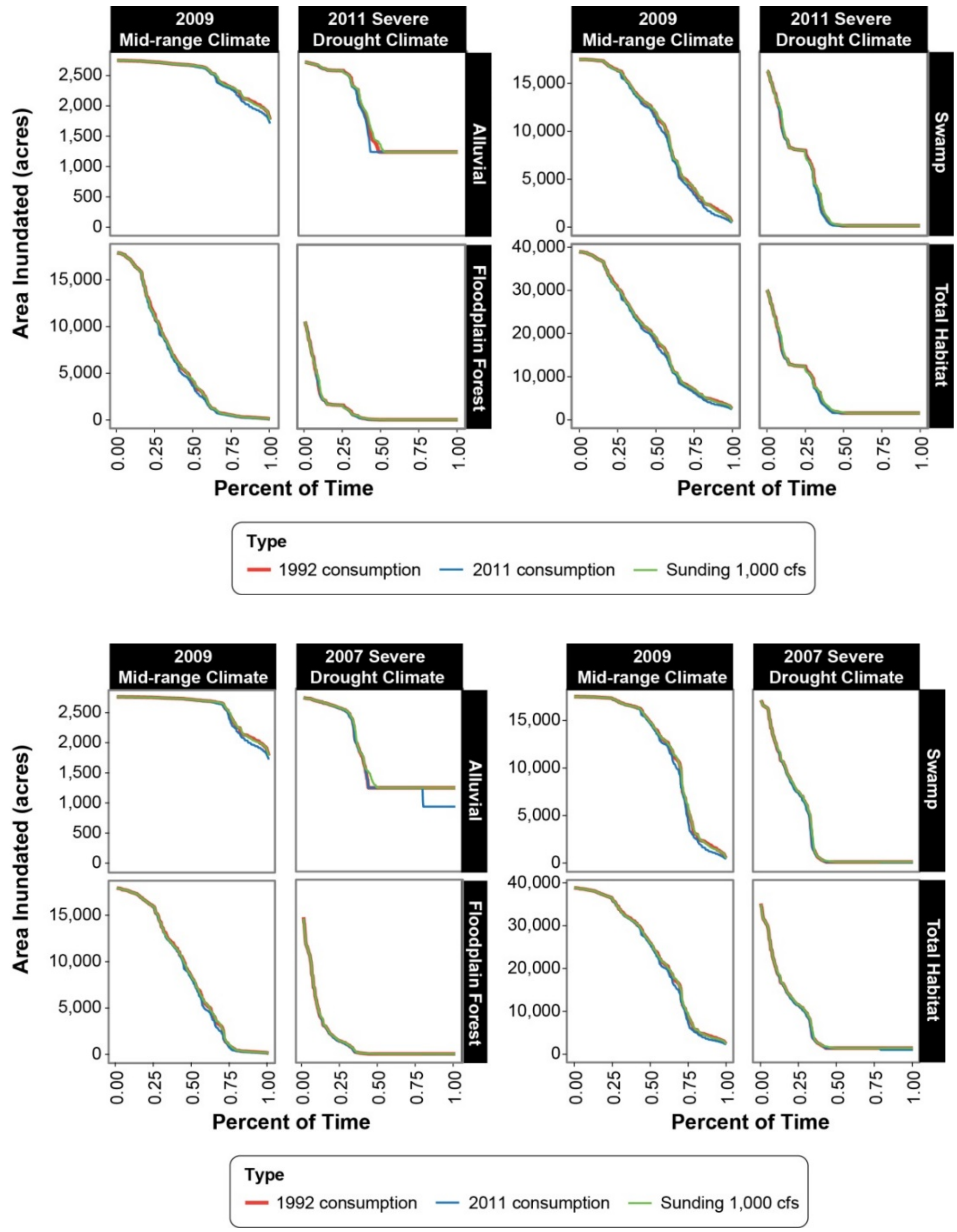
Demo. 39. This is Figure 30 from my Expert Report (GX-872), which shows the percent of total habitat inundated in three different habitat types with incremental increases in flow above 6,000 cfs. This figure relies on data used to develop my spatial model, including LiDAR data, USGS surface water elevations, and habitat data downloaded from the CDMO website of the NERR System. http://cdmo.baruch.sc.edu/get/gis.cfm.

169. At a low flow of 6,000 cfs, incremental increases in flow of 400 cfs and 1,000 cfs produce minimal increases in the percentage of habitat inundated by habitat type. At higher base flows of 10,000 cfs and 20,000 cfs, the spatial analysis shows that incremental increases in flow result in even smaller differences in the percent of inundated habitat.

LIDAR Analysis Method 2

170. The second approach I used focused on analyzing the impact of climate versus the impact of consumptive use. To that end, I compared inundated acreage exceedance plots in a recent PDSI-defined "mid-range" year (2009) and two recent PDSI-defined "severe drought" years (2007 and 2011) under different Georgia consumptive use scenarios (i.e., 1992 consumption , 2011 consumption, and "Sunding 1,000 cfs"). The flow rates for these scenarios were provided by Dr. Bedient, and the inundated acreage by habitat type was estimated using the same GIS spatial analysis based on LIDAR data and surface water elevations. This approach contrasts differences between consumptive use scenarios and climate conditions. The curves generated from this analysis are presented in **Menzie Demo. 40**.

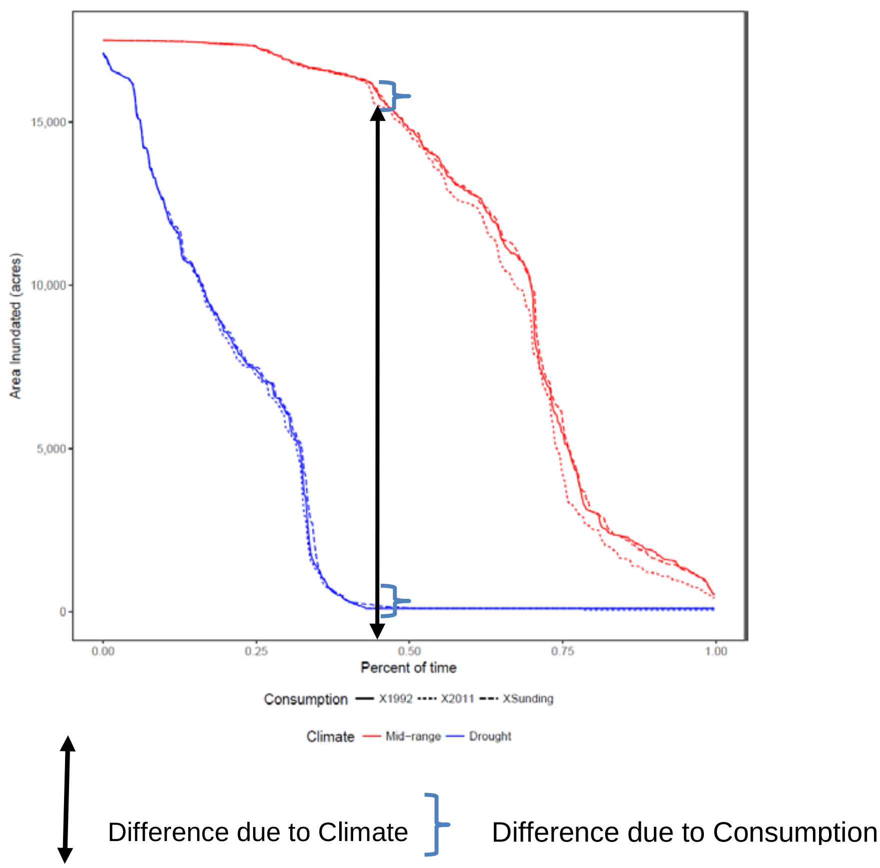
Menzie Demo. 40



Demo. 40. This figure was provided as Figures A-3 and A-4 in my Expert Report (GX-872), and shows the relative contribution of climate and Georgia's consumptive use of water on the average daily difference in inundated area, comparing the mid-range climate year 2009 and the severe drought years, 2007 and 2011 under three different consumptive use scenarios. This figure relies on flow data provided by Dr. Bedient as well as data used to develop my spatial model, including LiDAR data, USGS surface water elevations, and habitat data downloaded from the CDMO website of the NERR System.

171. The relative influence of climatic variation can be compared to that of water consumption by examining the degree to which the curves are influenced by each of these two factors. These relative influences are shown in **Menzie Demo. 41** as an example of how to compare the various curves. In the figure the red and blue curves represent two different years with different climatic conditions. For each of these years there are actually two plots – one a solid line and one a dotted line. These two red or two blue lines reflect the relative influence of the water consumption. As should be clear from the figure the big difference is associated with inter-annual climatic variation. Georgia's consumption of water is often indistinguishable and where there ar differences between the solid and dotted lines, those differences are very small.

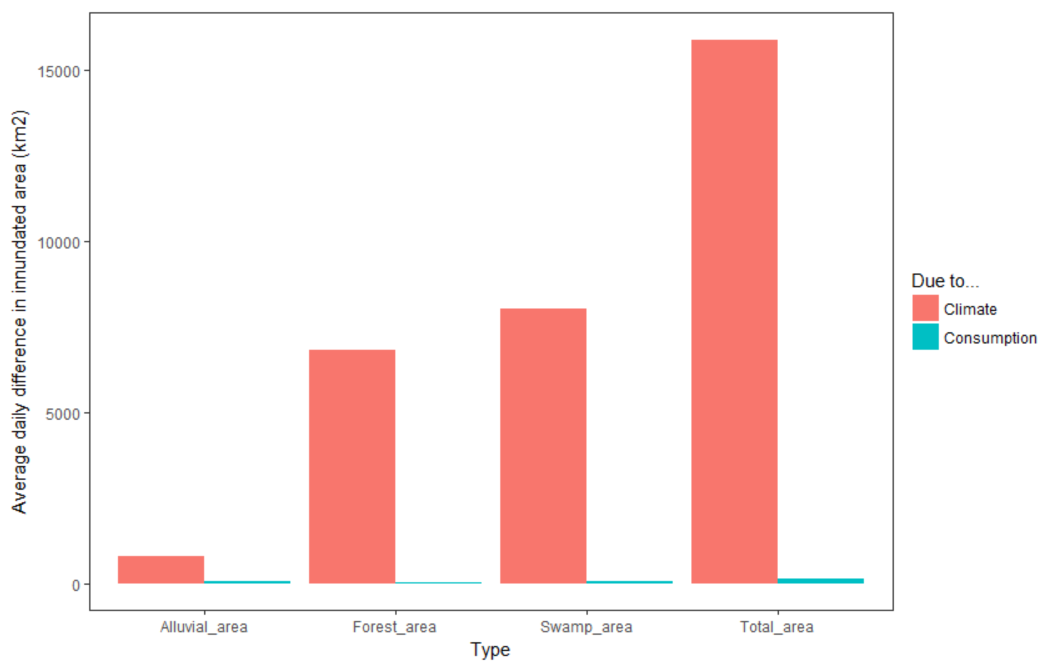
Menzie Demo. 41



Demo. 41. This figure shows how the contribution of climate to the average daily difference in inundated area can be determined by comparing the red and blue lines. The contribution of Georgia's consumptive use of water to the average daily difference in inundated area can be determined by comparing the dashed and solid lines within a color (i.e. within a climate year). It relies on data provided by Dr. Bedient as well as data used to develop my spatial model, including LiDAR data, USGS surface water elevations, and habitat data downloaded from the CDMO website of the NERR System.

172. **Menzie Demo. 41** demonstrates that the annual variation in inundation is driven primarily by climate and that Georgia's consumption of water has very little impact on inundation when compared to climate. By comparing the two climate curves from the same habitat areas, I have quantified the magnitudes of influence. This is illustrated in the bar chart below as Demo. 42. The red bars reflect the contribution of climatic variation and the blue bars show the influence of water consumption. It is clear that the differences between climate overwhelm the very small differences from consumptive use.

Menzie Demo. 42



Demo. 42. Relative contribution of climate and Georgia's consumptive use of water on the average daily difference in inundated area, comparing the mid-range climate year 2009 and the severe drought year, 2007.

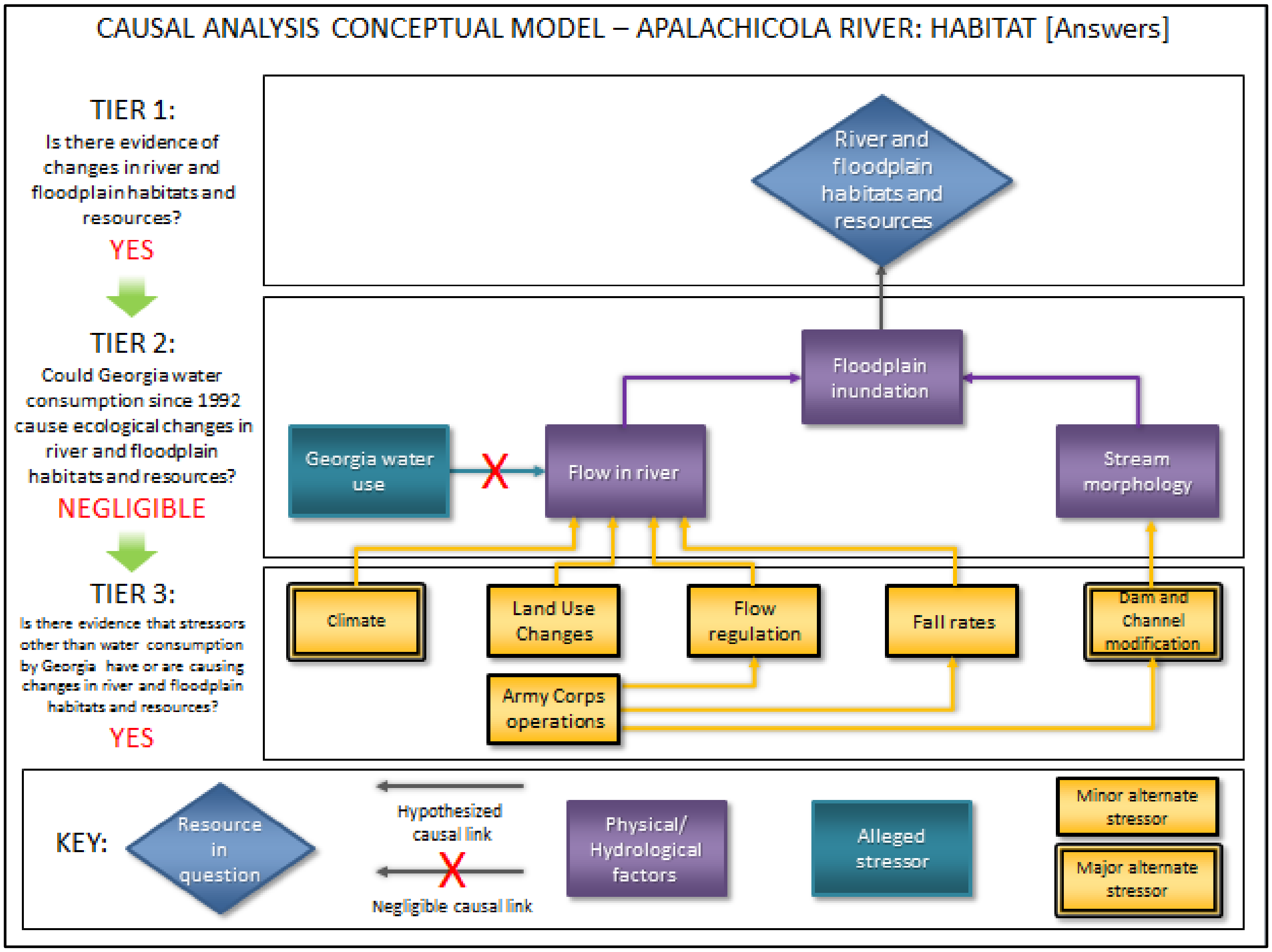
173. Based on the analyses conducted and data reviewed, I conclude that Georgia's consumptive use and influence on river flows are insufficient to cause the observed changes in floodplain forest composition. As documented by the USGS scientists, floodplain forest composition is most likely caused by historical changes in floodplain inundation. While river flow and floodplain inundation are related, Georgia's consumptive use of water results in at most minor changes in the frequency and extent of floodplain inundation. Consequently, Georgia's

consumptive use of water fails to satisfy the causal criterion for sufficiency under Tier 2. I will further characterize the relative contributions to changes in floodplain inundation of factors other than Georgia's consumptive use of water in my Tier 3 analysis.

(c) Tier 3— Is there evidence that stressors other than water consumption by Georgia have or are causing changes in river and floodplain habitat and resources?

174. Since Georgia's consumptive use of water cannot explain the observed changes in Floodplain forests, my Tier 3 causal analysis examines alternative stressors (other than Georgia's consumptive use of water) that could affect water level in the River and Floodplain. I found that channel modifications and the operations of the USACE, climate variation and droughts, and land use changes are stressors that have historically and currently affect water levels in the Apalachicola River. **Menzie Demo. 43**, which was discussed previously, is a conceptual model that identifies the factors influencing Floodplain inundation within the tiered framework of my analysis.

Menzie Demo. 43



Demo. 43. Results of the causal analysis for floodplain habitats presented within the conceptual model. The analysis showed that there were factors affecting river flows and inundation but that Georgia's consumption of water has a negligible influence.

Floodplain Inundation is Related to Water Levels

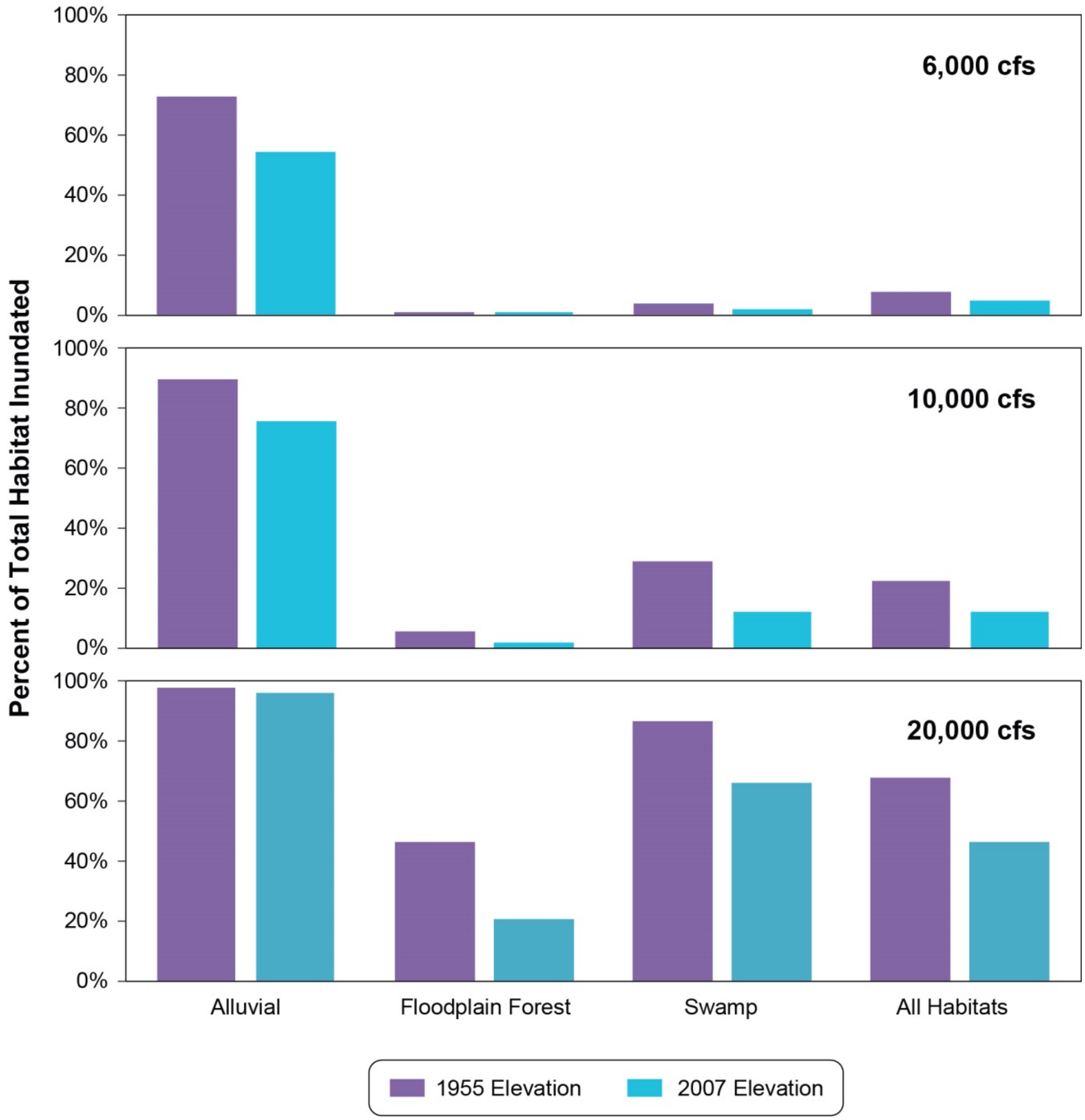
175. Changes in floodplain forest composition that have been detected since the late 1970s are likely linked to changes in the extent and duration of floodplain inundation. The duration and extent of floodplain inundation, in turn, is directly related to river stage, which is a complex function of upstream discharge, in-stream channel modification, downstream water usage, and climatic influences (e.g., precipitation and evaporation). There are many contributing causes to this phenomenon, but according to USGS's extensive studies, the primary driver of this trend is channel modifications.

<u>Dam and Channel Modification has Caused A Major Reduction in Water Levels</u>

176. The USGS commissioned a number of studies analyzing what caused the observed changes in floodplain forests. Those studies concluded that the most significant factor was channel changes caused by the USACE. The USGS found that channel changes were primarily caused by the construction of the JWLD in 1954, and by dredging, widening, placement of dredge spoils, removal of woody debris, and straightening of the River by the USACE, which occurred over several decades. GX-88 (Light et al. 2006).

177. **Menzie Demo. 44** shows how channel changes have impacted floodplain inundation by showing the percent change in inundation caused exclusively by changes in the elevation of the riverbed between 1955 and 2007. The chart shows the impacts under three different flow rates – 6,000 cfs, 10,000 cfs, and 20,000 cfs. Declines in water level shown in Demo. 44 are most pronounced at flow rates of 10,000 and 20,000, which bracket Dr. Allan’s 14,100 cfs threshold of harm to Tupelo-cypress swamps. The results of my analysis of the impacts of channel modifications to floodplain inundation are consistent with those reported by Light et al., who found that an approximate 20% reduction in inundation has occurred at low flows as a result of channel geometry changes.

Menzie Demo. 44



Demo. 44. This figure shows the percent of total habitat inundated before channel modifications of the Apalachicola River (1955 Elevation) compared to the amount of total habitat inundated after channel modification (2007 Elevation). This figure relies on data used to develop my spatial model, including LiDAR data, USGS surface water elevations, habitat data downloaded from the CDMO website of the NERR System, and 1955 riverbed elevation models provided in GX-88 (Light et al. 2006).

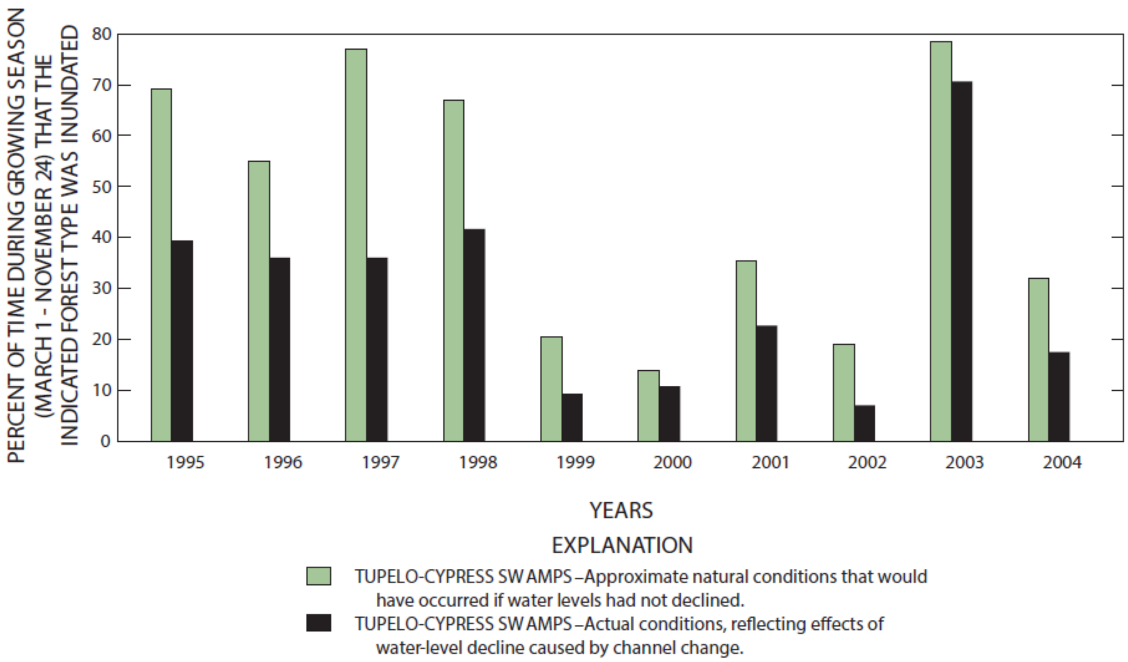
178. Swift Slough, which is a particular focus of Dr. Allan's metrics, provides a clear example of why channel modifications are necessary to consider as part of a causal analysis. As recently as 2006 Swift Slough was a perennial stream, supporting mussels and fish throughout the year; however, sediment deposition thought to be associated with high river flows in 2003 and 2005 increased the height of the mouth of the slough by 1.3 ft. This increased sill elevation means that far more water is now necessary at low flows since 2006 to overcome the increased height of the slough sill. In 2000, a flow of 5,000 cfs typically maintained a connection between Swift Slough and the Apalachicola River; however, since 2006, a flow of 5,600 cfs or more is necessary to maintain the slough's connectivity. The sediment deposition at the mouth of Swift Slough and the subsequent disconnection of Swift Slough were not caused by Georgia's consumptive use of water. The movement of sediment in the channel that resulted from accumulated dredge spoils and natural variations in flow redistributed the sediment and adversely impacted the connectivity of Swift Slough with the Apalachicola River. As such, attributing recent "harm events" in Swift Slough to Georgia's consumptive use of water overlooks the important physical changes to the geomorphology of the channel that are a primary cause of the impacts that Dr. Allan describes in the slough during low flows.

179. The blockage of Swift Slough provides a relatively inexpensive option for restoration. Periodic clearance of this blockage would permit water to more easily enter the slough. This could be a routine maintenance activity that offsets the sedimentation that has been occurring on the river.

180. The USGS has studied how historical channel modifications have impacted the duration of inundation for a specific point in the river: a Tupelo cypress swamp near Porter Lake in the middle reach of the River. The USGS used historical flow rates from 1995 to 2004 and compared how that swamp would have been inundated under the pre-dam channel levels with the actual inundation of the swamp under current channel modifications. In the absence of channel modifications, Tupelo cypress swamps would have been inundated approximately 47% of the growing season between 1995 and 2004 at this site. But after changes in riverbed morphology caused by the construction of the JWLD, that Tupelo cypress swamp was only inundated approximately 29% of the growing season. Thus, channel modifications alone reduced

inundation by 18% of the growing season. These effects of channel modifications on water level decline are shown in **Menzie Demo. 45**.

Menzie Demo. 45



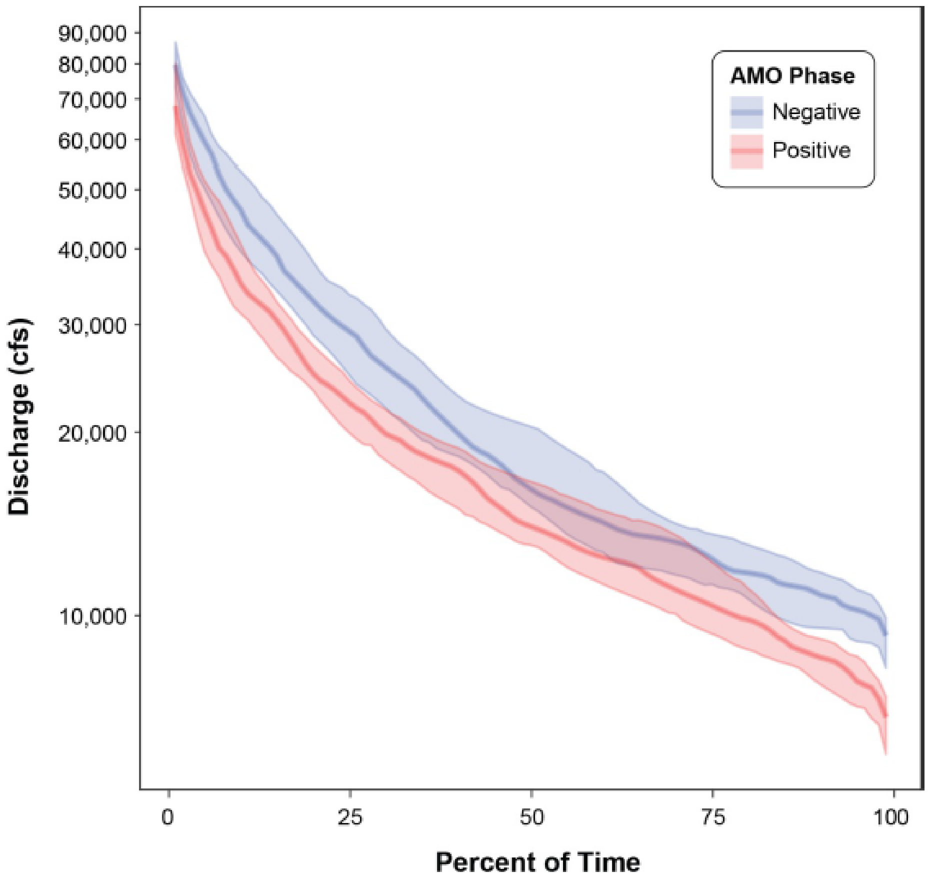
Demo. 45. This figure shows the effects of water-level decline caused by channel modifications on the duration of inundation during the growing season (March 1 – November 24) in Tupelo cypress swamps near Porter Lake, 1995–2004. It is a reproduction of Figure 25 of GX-88 (Light et al. 2006).

Climatic Variation and Droughts Have Caused Declines in Water Levels

181. As I described in my Tier 2 analysis, climate has a strong impact on the level of inundation. Since the late-1990s, the ACF Basin has experienced a number of severe droughts. Researchers have found that these severe droughts may be linked with a long-term climate oscillation called the Atlantic Multidecadal Oscillation (AMO). The AMO is a long-duration change in the surface temperature of the Atlantic Ocean, with a periodicity of 20 – 40 years. Researchers have observed that in northern Florida, the negative phase of the AMO generally corresponds with higher river flow and that low flows (< 10,000 cfs) happen significantly more frequently in AMO positive years than in AMO negative years. **Menzie Demo. 46** compares the exceedance curves of discharge at Chattahoochee for AMO positive and AMO negative years. Unlike the exceedance curves comparing consumptive use scenarios, these two curves show

significant differences (beyond the 95% confidence interval), demonstrating that there is a strong correlation between AMO phase and discharge—especially at low flows.

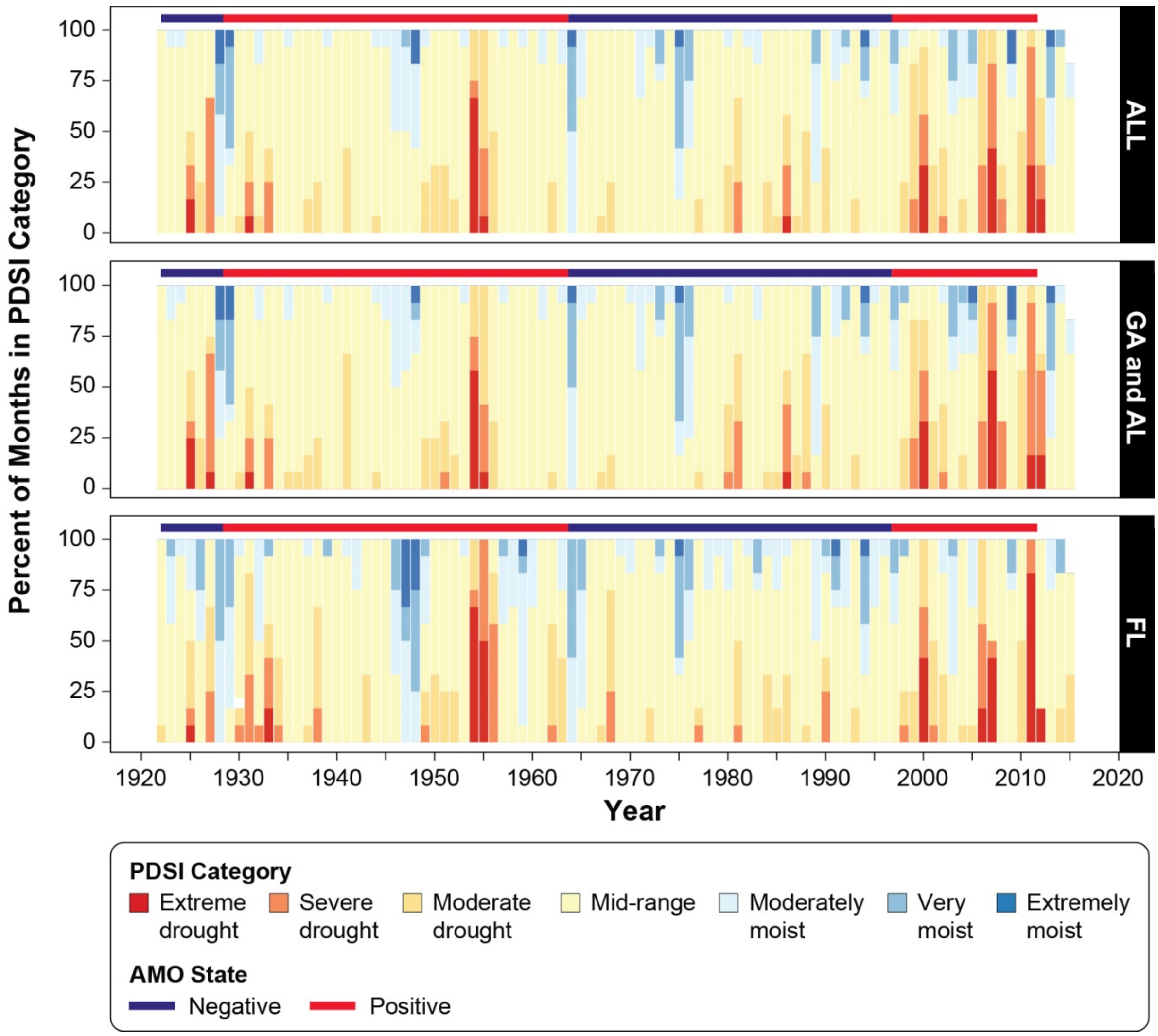
<u>Menzie Demo. 46</u>



Demo. 46. This is Figure 34 from my Expert Report (GX-872), which shows the daily flow duration in AMO positive and AMO negative years between 1920 and 2015. This figure relies on data from NOAA (http://www.esrl.noaa.gov/psd/data/timeseries/AMO/) characterizing the directionality of the AMO and flow rate data from the USGS Chattahoochee gage.

182. **Menzie Demo. 47** shows how the AMO phase correlates with the historic droughts in the region. The AMO Phase was positive from approximately 1948-1963, and has been positive since about 1996. The AMO Phase was negative from approximately 1963 through 1996. Demonstrative X shows months of drought according to the Palmer Drought Severity Index (PDSI) data computed by NOAA. This data is also consistent with the AMO Phase, showing severe droughts when positive (1950s and three major droughts since 1999), and very few droughts when AMO phase is negative.

Menzie Demo. 47

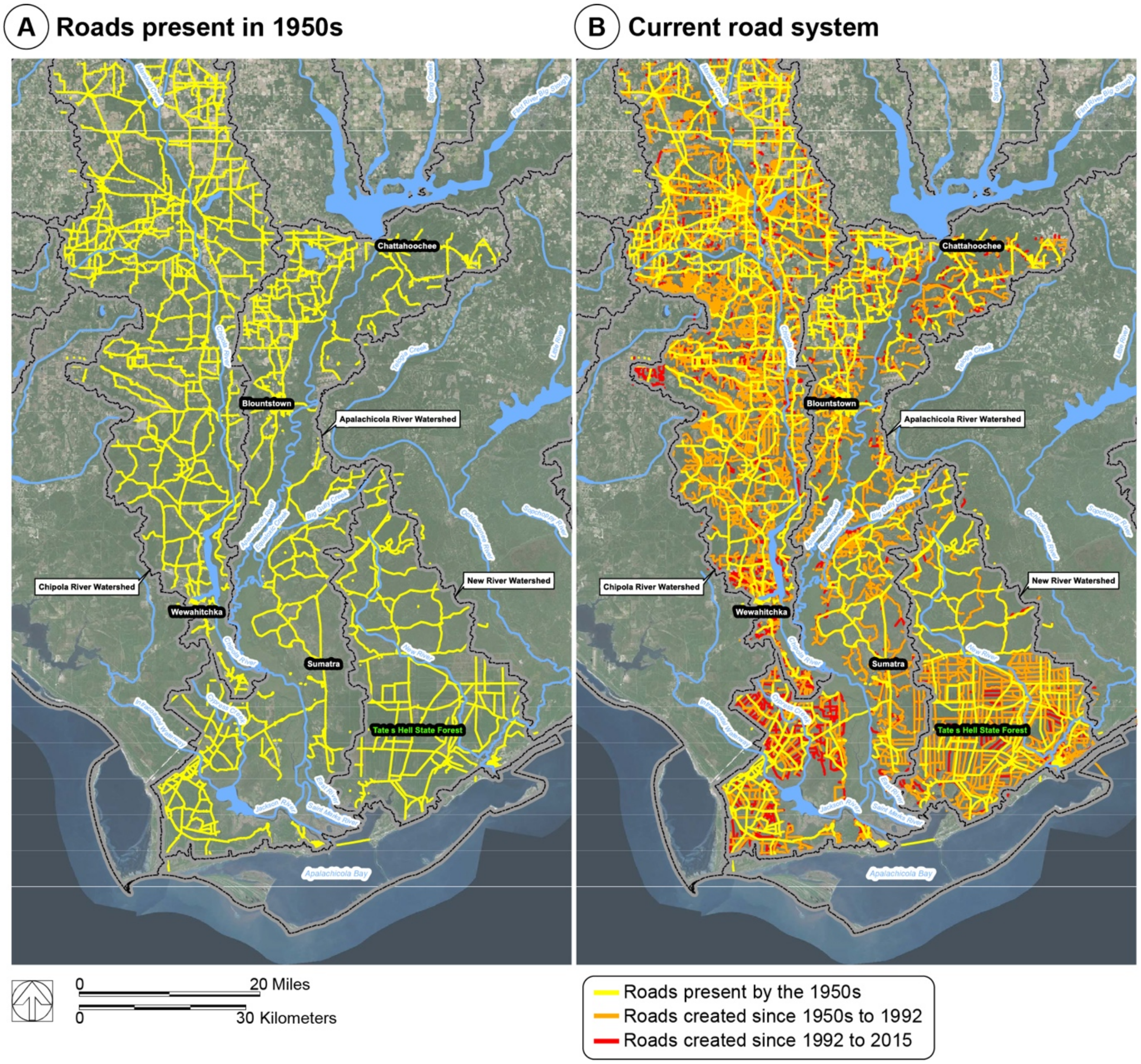


Demo. 47. This is Figure 7 from my Expert Report (GX-872), which shows the percent of months in each year that fall into each of the seven Palmer Drought Severity Index (PDSI) categories. The upper ACF Basin represented by counties in Georgia and Alabama is differentiated from those in Florida to examine regional differences in drought severity. The AMO phase (positive or negative) is plotted at the top of each PDSI chart. This figure is an adaption of Figure 7 in my Expert Report (GX-872). It relies on data from NOAA: GX-1153 (http://www.ncdc.noaa.gov/temp-and-precip/drought/historical-palmers/) and GX-1149 (http://www.esrl.noaa.gov/psd/data/timeseries/AMO/).

Land Use Changes have an Impact on Floodplain Inundation

183. Land use changes in the Apalachicola River Basin may also affect river level. I analyzed land use changes in the Apalachicola River Floodplain by reviewing topographic maps of the area. Of particular note is the interruption of floodplain habitat by the addition of a crisscrossing network of roads since the 1950s.

<u>Menzie Demo. 48</u>



Demo. 48. This is Figure 4 from my Expert Report (GX-872), which shows how the network of roads in the Apalachicola Basin has increased from 1950s (A) to the present (B). It relies on data from the following sources: [http://ufdc.ufl.edu/aerials and 1954/1957 historic topo maps](http://ufdc.ufl.edu/aerials); https://www.census.gov/geo/maps-data/data/tiger-line.html; *and* http://www.dot.state.fl.us/planning/statistics/gis/.

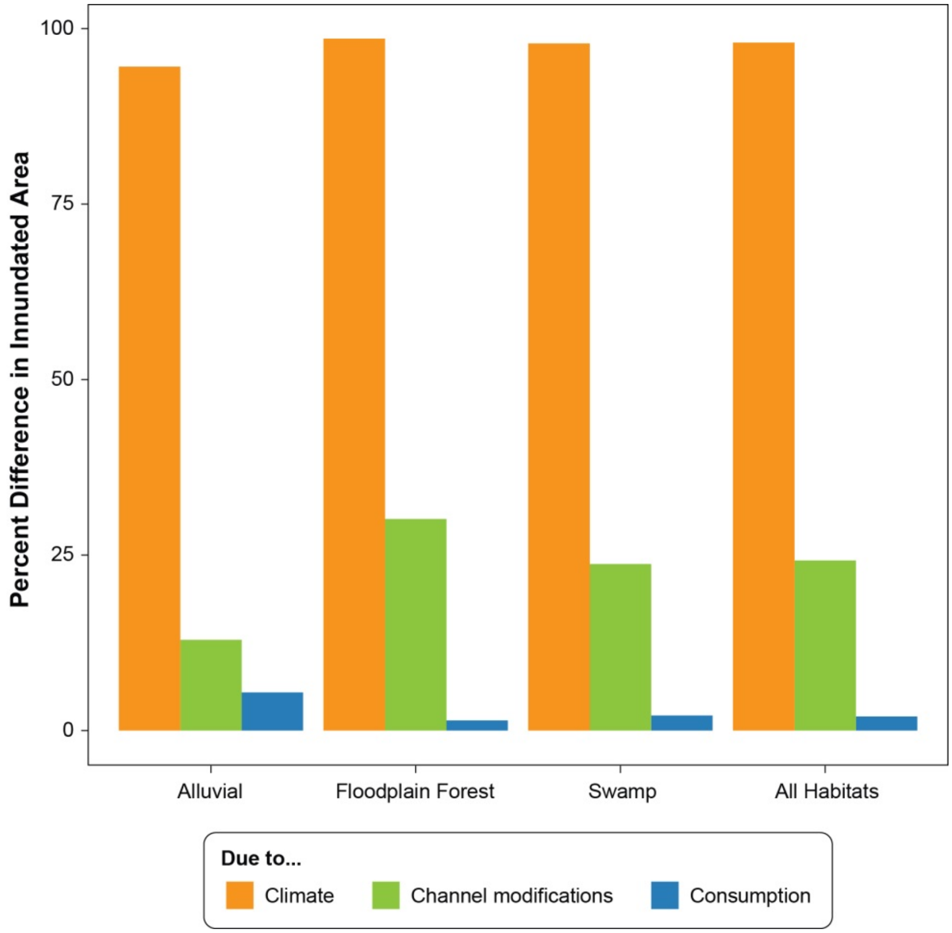
184. I personally observed how the raised roads that intersect the floodplain can impede or delay the connectivity of flow by creating a barrier between wetland forest areas. By impeding the flow of water through the floodplain, these roads inhibit water from reaching floodplain habitats. I found that land use changes may also affect river level, but considering the major impacts of climate and channel change, I do not classify it as a major stressor.

Menzie Demo. 49

Demo. 49. This is Figure 33 from my Expert Report (GX-872), which shows how a raised road in the Apalachicola floodplain interrupts the hydrological connectivity of two areas of floodplain forest, with forest on one side of the road having standing water and the other side having no standing water. This figure is based on photographs that I personally took on April 18, 2016 on Route 22 near Wewahitchka, FL.

185. To understand the relative contribution of different possible causal factors to changes in the inundation of the Apalachicola River and Floodplain, I compared the percent change in inundated acres of floodplain due to channel modifications and climate variation with those resulting from a change in Georgia's consumptive use of water between 1992 and 2011. **Menzie Demo. 50** clearly demonstrates that climate is the most significant factor affecting the extent of floodplain inundation. Channel modifications resulting from the USACE operations since 1955 have also contributed to substantially greater changes in floodplain inundation. Both of these causal factors dwarf the negligible influence of Georgia's consumptive use of water.

Menzie Demo. 50

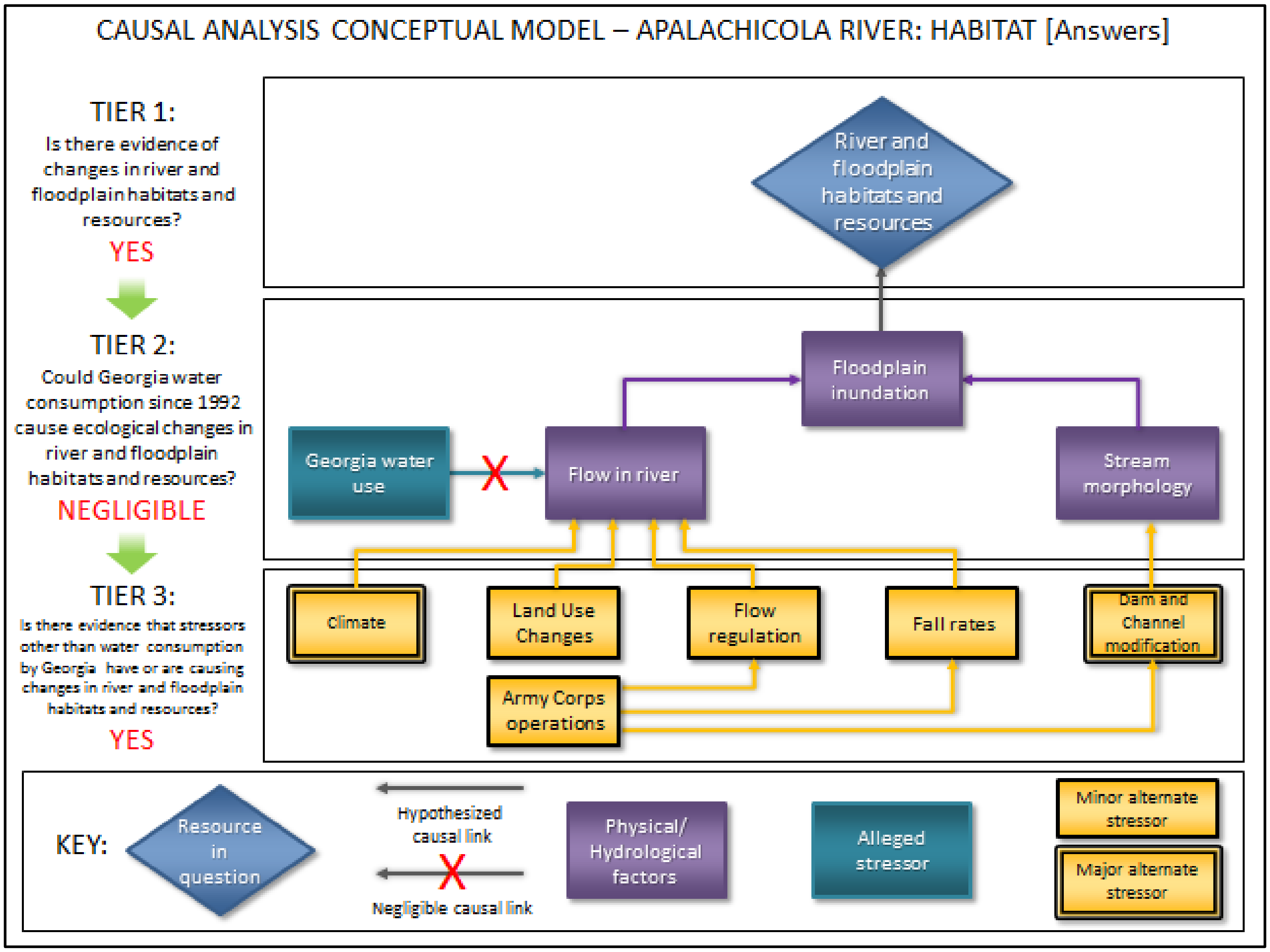


Demo. 50. This figure shows the relative contribution of climate, channel modifications, and Georgia's consumptive use of water to changes in floodplain inundation. It relies on flow data provided by Dr. Bedient and data used to develop my spatial model, including LiDAR data, USGS surface water elevations, and 1955 riverbed elevation models provided in Light et al. (2006).

(d) Conclusion

186. Based on the analyses conducted and data reviewed, I conclude that historical channel modifications and climate shifts are the primary stressors that have resulted in a decline in water level in the Apalachicola River, which in turn caused the observed changes in floodplain forest composition. My conclusions are consistent with other authorities who have looked into this issue. USGS scientists concluded that channel modifications have been "the most serious anthropogenic impact that has occurred so far in the Apalachicola River and floodplain."

Menzie Demo. 51



Demo. 51. This figure shows the results of my tiered causal analysis of changes to River and Floodplain habitats and resources within the conceptual model framework presented previously. It demonstrates that channel modifications that have altered the stream morphology and climate, which has impacted river flow are the major causal factors affecting the River and Floodplain habitats and resources.

II. Georgia's Water Use is Not Harming Endangered Sturgeon

(a) Sturgeon Habitat Needs

187. Gulf Sturgeon are known to occur in the main channel of the Apalachicola River. Although the Gulf Sturgeon population is relatively small, studies suggest that it has been slowly increasing. The 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.

188. Gulf sturgeon are known to occur in the main channel of the Apalachicola River. The population is reported to be relatively small, but slowly increasing. Gulf sturgeon use rivers for 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, more rarely, for inter-river movements. Currently, the primary spawning site in the Apalachicola River for this species is at Race Shoals (rm 105).

189. According to the USFWS there is approximately five-times more Gulf sturgeon habitat in the Flint River located above the JWLD; however, the Flint River habitat has been unavailable to the species since the dam was finished in 1957. The USACE has worked in recent years to manage the locks associated with the dam to promote more Gulf sturgeon passage beyond the dam. However, even when the JWLD navigation lock is open, there is a large sill approximately 30 feet high along the bottom of the lock where it meets the bottom of the Apalachicola River. Gulf Sturgeon remain on the bottom of the river and do not swim vertically up the sill to pass into the lock and into Lake Seminole on their own. Thus, the JWLD remains a permanent impediment to Gulf Sturgeon accessing habitat in the Flint and Chattahoochee Rivers.

(b) Tier 1 — Is there evidence of "adverse" change for Gulf Sturgeon?

190. The first step of the causal analysis framework was to determine whether there is evidence of downward changes in Gulf sturgeon populations in the River over time. The answer to this question, by default, is yes, because otherwise, this species would not be classified as a T&E population. Considering that Gulf sturgeon were listed as a T&E species in the 1990s, there is clear evidence that the populations of these species were on the decline at the time they were listed. However, the USFWS recently affirmed that Gulf Sturgeon populations are stable and may be slowly increasing in the Apalachicola River. JX-168 (2016 BIOP).

(c) Tier 2 — Is there evidence that freshwater flow and, more specifically, flow variation related to Georgia's consumption of water since 1992, are a significant contributor to change for Gulf sturgeon?

191. Changes in flow below specific levels in the River, or quick fall rates, have been documented as causing detrimental effects to the Gulf sturgeon. For example, from 1990 to 2000, the USACE periodically scheduled navigation windows in the Apalachicola River to

support navigation. Navigation windows were created by increasing river flow downstream of the JWLD to increase the depth of the navigation channel for discrete periods of time (days to weeks); periods of lower flow preceded and followed the navigation windows. Flow management to maintain navigation windows resulted in wide swings in river flow and fall rates, which were alleged to have harmful effects on fish spawning and mussel populations (Senate Report).

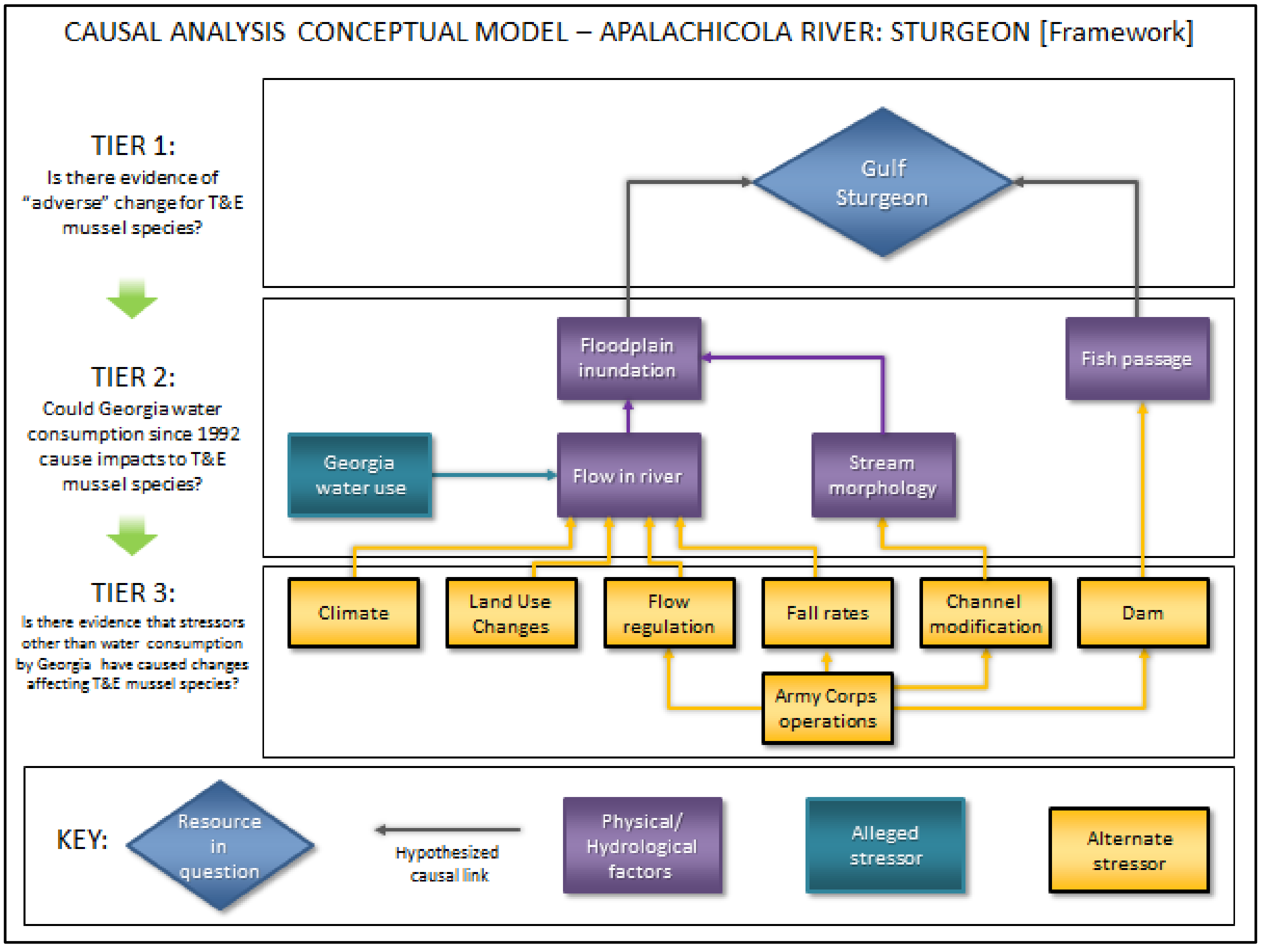
192. The USACE has worked with the USFWS since the 1990s to develop flow management procedures to minimize effects on federally protected Gulf sturgeon.

193. I examined floodplain inundation patterns associated with varying flows in the River. That analysis shows that, while there can be large flow variations and associated inundation events that result from annual and seasonal variations, the contribution of Georgia's water consumption to these variations is minor for the low flow periods that would be of potential concern to Gulf Sturgeon that use the river as habitat. Given that I agree with the opinion reached by USFWS, and I have demonstrated the small influence associated with water consumption by Georgia on flows into Florida, I conclude that water consumption by Georgia since 1992 does not pose a threat of harm to Gulf sturgeon in the river.

(d) Tier 3 — Is there evidence that stressors other than water consumption by Georgia have or are a significant contributor to change for Gulf Sturgeon species?

194. My Tier 3 causal analysis examines alternative stressors (other than Georgia's consumptive use of water) that could affect water level in the River and Floodplain or otherwise adversely affect Gulf sturgeon populations in the River. As above, I identified channel modifications, the JWLD and other operations of the USACE, climate variation and droughts, and land use changes as stressors that have historically and currently affect water levels and fish passage in the Apalachicola River. A conceptual model of the interaction of these factors with river flow and T&E Gulf sturgeon are shown in **Menzie Demo. 52** and described below.

Menzie Demo. 52



Demo. 52. This figure shows a conceptual model of my tiered causal analysis of changes to Gulf sturgeon, including Georgia's consumptive use of water and alternative causal factors that were considered.

195. In the 2016 BIOP (JX-168), it identifies threats and potential threats to the Gulf sturgeon as:

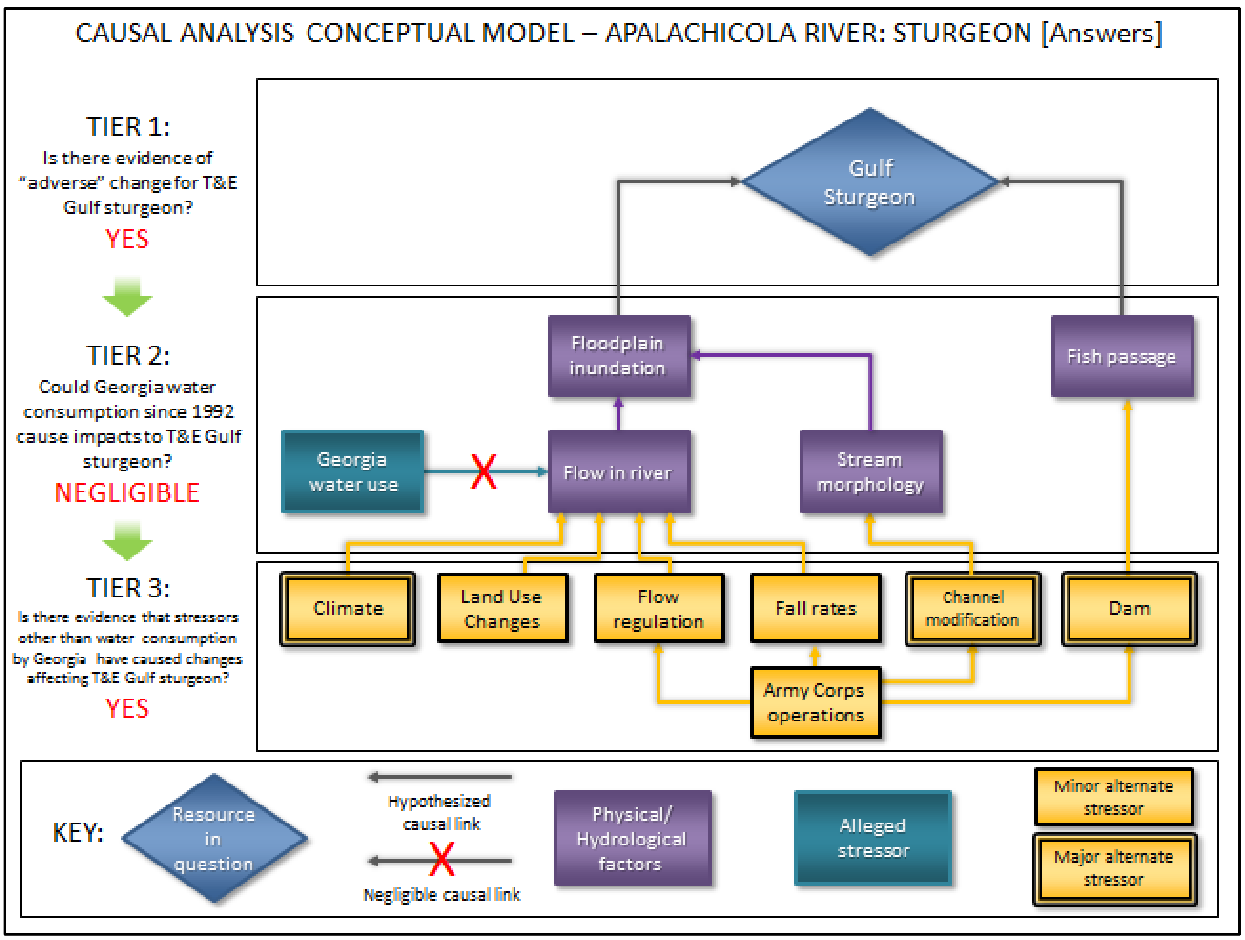
- construction of dams,
- modifications to habitat associated with dredging,
- dredged material disposal,
- de-snagging (removal of trees and their roots) and other navigation maintenance activities;
- incidental take by commercial fishermen;
- poor water quality associated with contamination by pesticides, 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.

196. The USFWS did not include "consumptive use" among the threats to the Gulf sturgeon.

197. Based on my review of the information presented in the 2016 BIOP (JX-168) and the 5-year review, incremental water consumption by Georgia since 1992 is at most a negligible cause of changes in Gulf Sturgeon populations.

Menzie Demo. 53



Demo. 53. This figure shows the results of my tiered causal analysis of changes to Gulf sturgeon populations within the conceptual model framework presented previously. It demonstrates that actions by the USACE, including channel modifications that have altered the stream morphology, fall rates, and construction of the JWLD have impacted river flow, stream morphology, and fish passage, which can all negatively affect Gulf sturgeon populations. Climate is an additional significant causal factor affecting flow in the River.

III. Threatened and Endangered Mussel Populations Are Stable or Improving

(a) Habitat Needs of Freshwater Mussels

198. While the Apalachicola River is home to a number of freshwater mussel species, the focus of my evaluation was on whether effects of consumptive use of water by Georgia could have an adverse effect on T&E mussels in Florida, specifically the Chipola slabshell, purple bankclimber, and fat threeridge. I focus on T&E species because of their special status. I consider these T&E species as sensitive sentinel aquatic organisms that can be used to evaluate if flow conditions, as a result of Georgia's consumptive water use, are harming other less sensitive aquatic organisms in the Apalachicola River Basin. I evaluated specific information on habitat needs for these species, followed by a tiered causal analysis of the relationship between flow (including operation of the JWLD), habitat availability, and survival of T&E mussels in the River.

199. The T&E mussel species of the Apalachicola River watershed reside in the main channel of the rivers and some of the interconnected backwater sloughs. Each species, however, shows slightly different habitat preferences.

200. The fat threeridge inhabits the main channel of rivers in slow to moderate current, but it has also been found in some of the interconnected backwater sloughs of the Apalachicola River (e.g., Swift Slough). The species is found in a variety of substrates, including gravel and cobble, as well as a mixture of sand, silt, and clay. The most abundant populations are found in moderately depositional areas along bank margins at depths of approximately 1 m. However, recent research into the distribution of the species has found that the Fat Threeridge inhabits waters as deep as 8.5 m within the River.

201. The purple bankclimber also inhabits river channels. It prefers deeper water (>3 m) in the main River channel; however, it has been found at depths in the Apalachicola River as shallow as 0.5 m. Mussels are parasitic during one stage of their life cycle, and the Gulf sturgeon is the primary host fish for purple bankclimber. This is explains why most purple bankclimbers in the Apalachicola River are found at Race Shoals — the primary spawning area for the Gulf Sturgeon.

202. The Chipola slabshell lives in slow to moderate currents of the River in sandy sediments mixed with silt, clay, and occasionally gravel. The Chipola Slabshell occurs in the main channel of the Chipola River but not the main channel of the Apalachicola River. There has been no observed mortality of Chipola Slabshell during low flow events in recent droughts. JX-72 (USFWS 2012 BIOP).

(b) Tier 1 — Is there evidence of "adverse" change for T&E species?

203. The first step of the causal analysis framework was to determine whether there is evidence of downward changes in T&E mussel populations in the River. T&E classification is tied to the declining status of the population of the species, as defined in the Endangered Species ACT (ESA). Considering that each species was listed as a T&E species in the 1990s, there is clear evidence that the populations of these species were on the decline at the time they were listed. Under my causal analysis this alone requires further analysis under Tier 2—however that does <u>not</u> imply that there has been additional population-level harm since their listing.

204. For example, a mortality event of mussels in the Apalachicola River is generally precipitated by a series of predictable events that are not solely related to river flow. Many species of mussels move in response to water levels. When water levels have been elevated for a relatively long period of time, mussels will move to occupy riverbed elevations that are higher than the elevations where they are typically found. Then, when water levels naturally drop, the mussels must move down the riverbed slope to avoid becoming stranded. If the decline in water levels is too fast and/or the slope of the riverbed is too shallow, the mussels cannot move quickly enough to keep pace with the falling water levels, and could become stranded. When this sequence of events happens, which is not uncommon, individual mussel mortality occurs. However, for such cyclical mortality events to be significant to mussel populations, they need to be of a sufficient magnitude to impact productivity or threaten population viability.

205. The 2012 BIOP (JX-72) explained that there were significant mortality events during low flow events in 2006-2007, 2010, and 2011. Despite these events, the USFWS found that the populations of these mussels are generally stable or increasing:

206. *<u>Chipola Slabshell</u>* — No evidence of any harm from low flows (JX-72, 2012 BIOP).

207. *Fat Threeridge* — Population stable and increasing and may be as high as 16.5 million (JX-168, 2016 BIOP). Based on new population data, the USFWS is considering downlisting this species (related docs).[48]

208. *Purple Bankclimber* — There is considerable uncertainty around population estimates for purple bankclimber. (JX, 168 2016 BIOP) Past studies have found the species population was stable, but the USFWS currently considers this species to be declining over the short term (JX-168, 2016 BIOP). The USFWS attributes the recent decline to drought. Dr. Allan noted that the purple bankclimber population is centered at Race Shoals, an area where it is "simply too difficult to separate the channel erosion issues from the flow issues." Allan Dep. Tr. 236:10-237:5.

(c) Tier 2 — Is there evidence that freshwater flow and, more specifically, flow variation related to Georgia's consumption of water since 1992 are a significant contributor to change for T&E mussel species?

209. Water level is important to T&E mussel species, but water level alone does not cause any harm. Rapid changes in flow, or quick fall rates, have been documented as causing detrimental effects to the T&E mussel species of the River.[49] Since the 1990s, the USACE has worked with the USFWS to develop flow management procedures to explicitly minimize effects to federally protected species in the River. The USACE's procedures require that the flow rate of the Apalachicola River below the JWLD will generally not be less than 5,000 cfs. In addition, the fall rates of water in the channel must be kept within limits that allow mussels to move in response to changes in river stage. These operational requirements are independent of the level of consumptive use and have recently been reaffirmed by the USFWS in their 2016 BIOP to not jeopardize the continued existence of the T&E mussel populations and to not destroy or adversely modify habitat critical to the species. For this reason, changes in consumptive use patterns by Georgia are expected to have a negligible effect on low flow conditions and maximum fall rate within the River, and thus to have a negligible effect on T&E mussel species.

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[48] GX-602 (USFWS. 2013b. Information Memorandum for the Regional Director. From: Leopolda Miranda, ARD ES. Subject: Potential to Downlist the Endangered Fat Threeridge Mussel. June 10, 2013).

[49] GX-24 (Senate Report 107-338. 2002. Restore the Apalachicola River Ecosystem (RARE) Act of 2002).

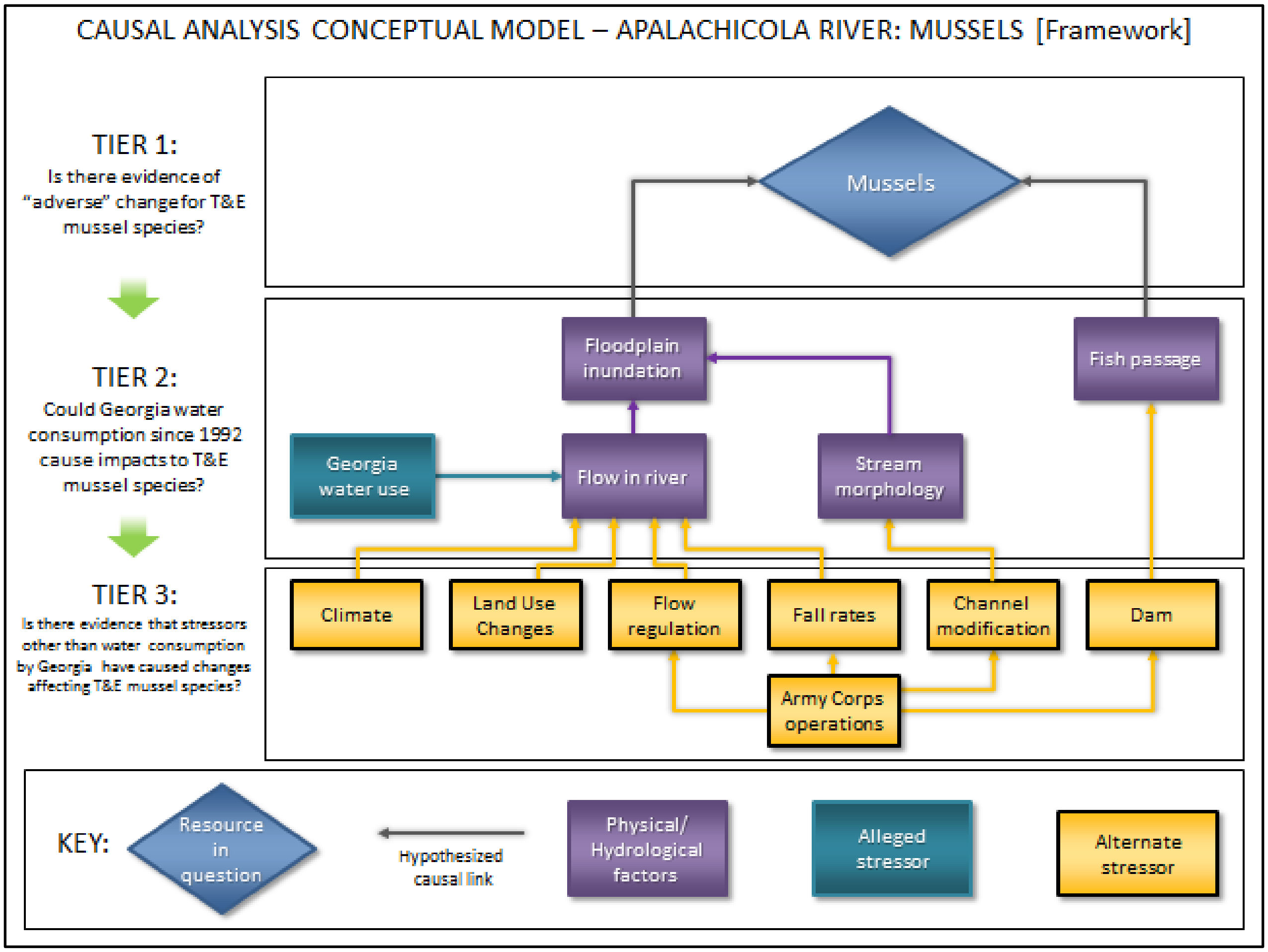
210. As explained above, floodplain inundation—specifically inundation of alluvial habitat where mussels live—is not substantially affected by Georgia's consumptive use.

211. Given that the USACE maintains flows to protect these species regardless of consumptive use — and that consumptive use does not significantly change inundation patterns, I conclude that Georgia's consumptive use has a negligible impact on T&E mussels.

(d) Tier 3 — Is there evidence that stressors other than water consumption by Georgia have or are a significant contributor to change for T&E mussel species?

212. Since the USACE operations are explicitly designed to protect these species and Georgia's consumptive use has a negligible impact on floodplain inundation, I considered alternative stressors to T&E mussels in Tier 3. I identified channel modifications, the JWLD and other operations of the USACE, climate variation and droughts, and land use changes as stressors that have historically and currently affect water levels in the Apalachicola River. I noted earlier in my testimony that blockage of sloughs has occurred as a result of sedimentation arising from dredge material piles and upriver sources; this is the case for Swift Slough. This blockage can only be overcome with greater flow. (Removal of the blockage would alleviate the problem to some extent and allow inundation to occur at lower flows). Another cause of harm to these mussels occurs when fish species upon which mussels depend for successful reproduction cannot pass through the JWLD (such as Gulf sturgeon). A conceptual model of the interaction of these factors with river flow and T&E mussels are shown in **Menzie Demo. 54** and described below.

Menzie Demo. 54



Demo. 54. This figure shows a conceptual model of my tiered causal analysis of changes to T&E mussel species, including Georgia's consumptive use of water and alternative causal factors that were considered.

213. Quick decreases in river stage (fall rates or down-ramping rates) caused by flow management practices of the USACE or extreme weather events have been documented to adversely affect the T&E mussel species in the Apalachicola River. When river flows drop more quickly than mussels can move in response, the mussels can become stranded and die.

214. The USACE used to manage the JWLD to maintain a navigation channel. Flow management to maintain navigation windows resulted in wide swings in river flow and fall rates, which were alleged to have harmful effects mussel populations. GX-24 (Senate Report 107-338, Restore the Apalachicola River Ecosystems (RARE) Act of 2002). The USACE has suspended this process, and since then the T&E mussel populations are now generally stable or increasing.

215. The USFWS has also explained that water level can harm T&E mussels when water levels rise—allowing mussels to move higher in elevation—and then decreasing quickly causing mussels to be stranded and die. Extreme weather events and natural flow variation—high-flow conditions for extended periods of time, followed by low-flow conditions as a result of drought—have been documented to adversely affect T&E mussel species in the Apalachicola River. The historical naturally occurring periodic changes between wet and dry periods likely set up conditions for mortality events for mussels that become stranded within sloughs in the system. So, some fraction of the populations has always been vulnerable to these oscillations. Because the main portion of the populations of T&E species reside in the river itself, these periodic naturally-occurring losses alone were insufficient to compromise the long-term viability of the populations.

(e) Conclusion

216. The T&E mussel populations are generally stable or increasing over the long term. One species—the fat threeridge—may even soon be delisted. This suggests that the flow regime since the 1990s (which includes Georgia's consumptive use) has not harmed these species populations or adversely impacted their habitats. To the extent the purple bankclimber populations are declining over the short term, the USFWS concluded that it is most likely caused by drought.

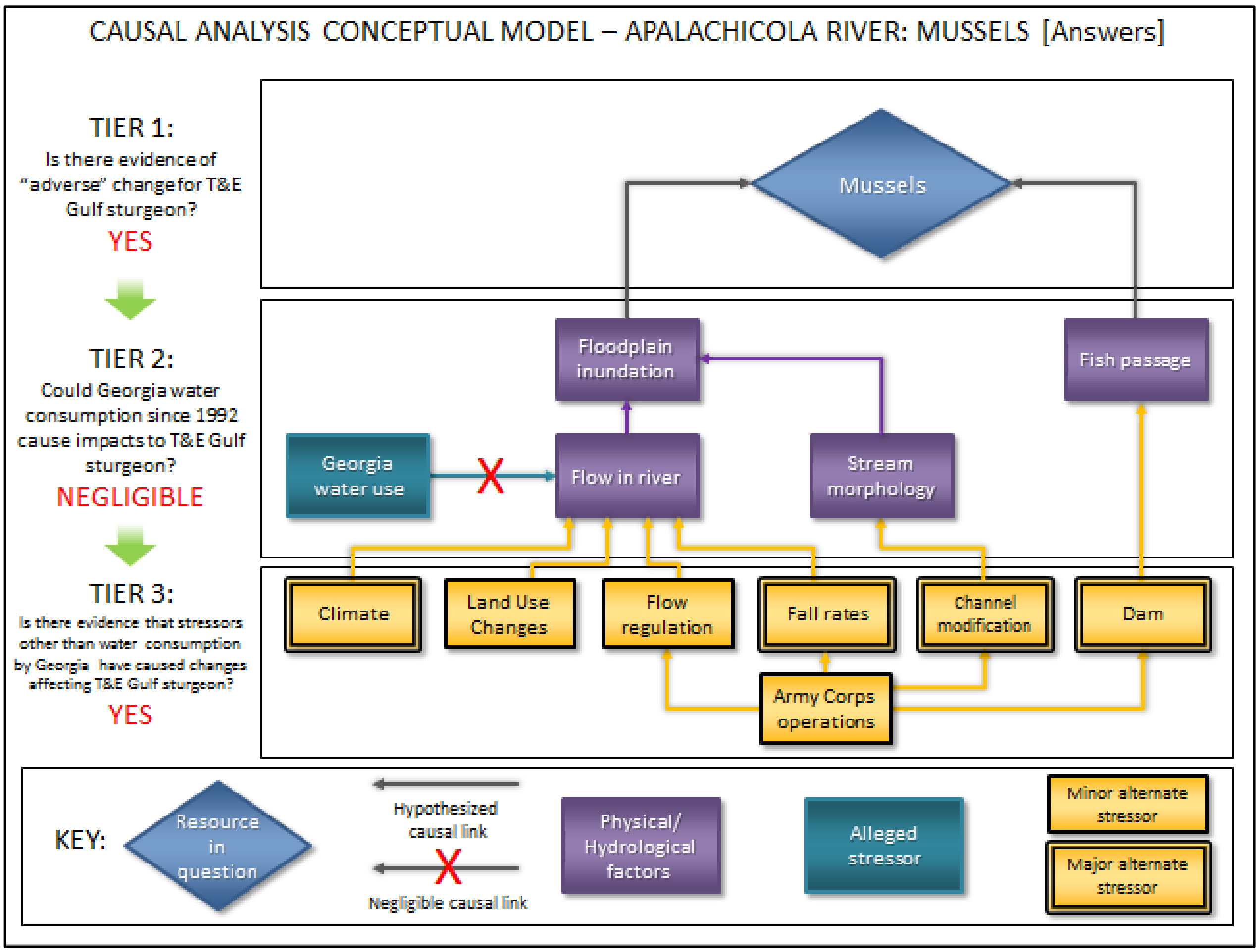
217. My conclusion is consistent with the findings of the USFWS. In 2012, USFWS issued a biological opinion on USACE operations currently in force and found that USACE's management of flow conditions (i.e., flow rates and fall rates) in the Apalachicola River below the Woodruff Dam should minimize the potential for adverse effects to T&E populations and habitat in the Apalachicola River under most circumstances. JX-72 (USFWS 2012 BIOP). I agree with this opinion and looking at the updated population estimates, the USFWS was correct.

218. The USFWS recently issued an updated biological opinion on proposed USACE operations. The USFWS again found that USACE's proposed management of flow regime in the Apalachicola River should minimize the potential for adverse effects to T&E populations and habitat in the Apalachicola under most circumstances. JX-168 (2016 BIOP). It also found that

T&E species populations are generally stable or increasing. JX-168 (2016 BIOP). I also agree with this opinion.

219. Based on my own review of the information presented in the USFWS Biological Opinions, and an independent evaluation of the effect of Georgia's consumptive use on low flow conditions in the Apalachicola River, I concur with the USFWS that the flow regime (including Georgia's consumption) has a negligible effect on the T&E species.

Menzie Demo. 55



Demo. 55. This figure shows the results of my tiered causal analysis of changes to T&E mussel populations within the conceptual model framework presented previously. It demonstrates that actions by the USACE, including channel modifications that have altered the stream morphology, fall rates, and construction of the JWLD have impacted river flow, stream morphology, and fish passage, which can all negatively affect mussel species. Climate is an additional significant causal factor affecting flow in the River.

IV. Dr. Allan Fails to Perform a Scientifically Defensible Causal Analysis of the Apalachicola River and Floodplain Ecosystem

220. Florida's expert, Dr. Allan, claims that Georgia's consumptive use has harmed the ecosystem and specific species in the Apalachicola River and Floodplain. There are two fundamental errors with Dr. Allan's analysis. His definition of "harm" is overly broad and unverified, and he fails to conduct a proper causal analysis. Dr. Allan's metrics analyzed 'modeled estimates of harm' — not actual harm. His metrics are designed to indicate when optimal flows are not met, not whether any organism is actually harmed. In fact, he has little-to-no empirical data to verify that any species was actually harmed when his modeled metrics hypothesized that harm occurred. Dr. Allan also conducts no causal analysis. He attributes "significant harm" to mussels, fish, and trees due to Georgia's water consumption, relying entirely on the report of Florida's expert, Dr. Hornberger, as the basis for a causal link. While he admits that other factors have influenced the system, he fails to conduct any investigation whatsoever to determine the relative impact of those factors.

(a) Riverine Habitats are Robust and Have Evolved under a Variable Flow Regime

221. Dr. Allan's analysis assumes that because the Apalachicola ecosystem responds to changes in flow that this makes it "vulnerable" and "highly sensitive." But this is not the case. The Apalachicola River and floodplain form a dynamic, complex ecosystem that have evolved and adapted to changes in flow and inundation. Over hundreds of years, the Apalachicola River experienced broad fluctuations in climate, and more recently, man-made modifications to the natural course of the river flow. Through this time, the River and Floodplain have continued to adapt due to the resilience of ecosystem.

222. The animal and plant species of the Apalachicola River and Floodplain have evolved to accommodate and thrive under various flow conditions. As described previously, the hydrological regime of this region varies widely within a year and, importantly, between years due to natural climate variations. This type of variation drives natural selection in the habitat to favor species that are adaptive and resilient. Many are "r-selected" species, which means they have evolved to have many offspring, each of which has a relatively low probability of surviving to maturity. These species also have small bodies and reach reproductive maturity quickly.

Because of those adaptations, these species can quickly colonize large areas that are flooded under the year-to-year variability in the historical flood regime.

223. Organisms have also adapted to summer conditions in the River and floodplain—when the combination of abundant organisms, high temperatures, and low flows can create hypoxic and anoxic conditions in certain parts of the floodplain. Fish like the Longnose gar and Spotted gar have developed the ability to breathe air through an organ similar to the human lung, while other fish can utilize the thin surface layer of water that becomes more oxygenated. Plants have also adapted to low flow conditions. Many plant species utilize structural mechanisms, such as restricting the root structure to the upper layers, developing air spaces between the roots to help increase oxygen availability, or developing "knees" that protrude out of the anoxic zone to help with gas exchange to the root system (e.g., bald cypress). Other species like the Ogeechee Tupelo have the ability to store starch during the flooding season that can be used as a water reserve during the drought season. As even Florida's experts recognized, "Like many dynamic river-floodplain systems, the Apalachicola River has a changing and complex relationship with its floodplain forests and sloughs, which alters seasonally and year to year with changing flows."[50] This variable flow is vital to the health of the ecosystem and a key factor explaining the high biological diversity of the area.

(b) Dr. Allan's harm metrics are not evidence that any harm has actually occurred.

224. Dr. Allan developed a series of resource-specific metrics to assess the frequency of "harm" to specific biological populations in the River and Floodplain. Dr. Allan claims that the flow rates and durations that he chose correspond with periods when organisms could die or be otherwise harmed due to insufficient habitat extent or quality. Dr. Allan bases these thresholds on water levels at specific points in the River that correspond to known habitat for a given resource. He uses published and unpublished data to support his selection of seasonal time periods and duration of low flows sufficient to cause "harm."

225. But Dr. Allan's harm metrics only consider flow rate and duration. They fail to consider other important factors related to flow that can affect the incidence of harm to river and

[50] FX-796 (Kondolf Expert Report, at 2).

floodplain resources. Whether mussels are harmed by a particular flow rate depends on upon the preceding flow rate, the slope of the bank where the mussels are located, and the rate at which the river level declines, or fall rate. If the fall rate is sufficiently slow and the bank slope sufficiently steep, mussels can actually avoid becoming stranded by moving down slope with the falling water level. Fall rates are similarly important to fishes that use the floodplain. If the fall rate is sufficiently slow, fishes can avoid becoming stranded on the floodplain during low flow periods. Therefore, a specific flow rate is not alone an indication of whether "harm" to individual resources is likely.

226. There is no evidence that any modeled "harm" identified under Dr. Allan's metrics has actually resulted in real-world harm. Dr. Allan's analysis suggests that during the last 16 years there should have been massive harm to mussel populations (up to 13/16 years, including 8/16 years with "maximum mortality" in the main channel), floodplain fish populations (up to 13/16 years), young of the year Gulf sturgeon (up to 7/16 years), and Tupelo cypress swamps (up to 13/16 years). However, with the exception of a handful of documented, drought-related mussel mortality events and a shift in floodplain forest composition (caused by channel changes over the past 30 years and climate variation as described above), Dr. Allan provides no evidence of real-world harm that consistently correlate with his metrics. He presents no evidence that any populations are decreasing. Indeed, the USFWS has just recently confirmed that many of these species have populations that are stable and increasing—like fat threeridge mussles and Gulf Sturgeon. JX-168 (2016 BIOP). This suggests that Dr. Allan's metrics show harm when there is no evidence that any occurred and are thus ecologically meaningless.

(c) Dr. Allan's analysis assumes Georgia's Consumptive Use is the cause of all harm

227. Dr. Allan's interpretation of his analysis ignores all other influences in the River and assumes that any harm identified by his metrics is caused by Georgia's consumptive use alone.

Historic Baseline

228. Dr. Allan chose a 16-year period in the 1940s and 1950s before the Dam was built as a baseline for comparison to the most recent 16 years. Dr. Allan's baseline not only represents a period when there was little consumption by Georgia but also a very different hydrological regime. Dr. Allan's choice of a baseline predates all the development that has occurred in the floodplain and surrounding areas, all the modifications of the River, and the entire history of damming and reservoir operations. Given that Dr. Allan recognizes these as important factors, the choice of a baseline that excludes all of these stressors is clearly inappropriate without additional analysis to distinguish the effects of multiple stressors.

229. Some of Dr. Allan's metrics also show dramatic modeled harm for this early period. For example, more than half of these early years show harm to floodplain fishes and mussels. Dr. Allan has no evidence that any harm actually occurred in the early years. The fact that his metrics show much harm before any dam operations or meaningful consumptive use provide further evidence that they are ecologically meaningless.

230. Dr. Allan selects his historical period to include a severe drought; however, one drought in the historical time period is hardly comparable to the repeated severe droughts that have occurred in the recent period. Because the underlying drought conditions between Dr. Allan's historical and recent periods are substantially different, his interpretation that the more frequent incidences of "harm" predicted by his metrics in the recent period are due to Georgia's consumptive use is unsubstantiated. His analysis is confounded by the differences in climate, which I have shown have a substantial influence on floodplain inundation.

Unimpaired Flows

231. Dr. Allan also relies on outputs from Dr. Hornberger's Precipitation-Runoff Modelling System (PRMS) model. It is my understanding that outputs from this model are highly uncertain and not appropriate estimates of Georgia's consumptive use as Dr. Allan uses them here. Another Georgia expert, Dr. Bedient, provides further details on the errors with the PRMS model and outputs in his testimony.

Remedy Scenario

232. Dr. Allan also relies on outputs from Dr. Hornberger to analyze the impact of a "remedy scenario." It is my understanding that this remedy analyzes the impact of draconian cuts to Georgia's consumptive use including a cut of 50% of all agricultural water use, 50% reduction in small impoundments, and 100% reduction of interbasin transfers. I also understand that this scenario relies on outputs from the seriously flawed Lake Seminole model that assumes all water conservation shows up in Apalachicola flows.

233. Despite the serious flaws with this scenario, it still shows that even extreme cuts to Georgia's consumptive use will have little-to-no impact on Dr. Allan's harm metrics. For example, the Remedy provides less than 3 additional days per year of inundation under all of Dr. Allan's floodplain forest metrics. The extreme Remedy provides only 4 additional days per year of Gulf sturgeon access to "optimal" feeding areas under one metric.

(d) Dr. Allan mischaracterizes my causal analysis of T&E resources

234. In his direct testimony, Dr. Allan incorrectly asserts that my approach to considering population-level harm would only detect "harm if there is a threat of populations going extinct." He characterizes this as "equating biological harm with jeopardy of extinction" and criticizes my reliance on the USWFWS BIOPs to support my opinion that Georgia's consumptive use of water has a negligible effect on T&E species in the River and Floodplain.

235. First, it is clear that Dr. Allan does not fully understand how the USFWS considers whether an action will "jeopardize" T&E species. In the most recent 2016 BIOP, the USFWS defines "Jeopardize the continued existence of" to mean "engag[ing] 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 (emphasis added)." JX-168 (2016 BIOP). Dr. Allan also fails to recognize that the USFWS BIOP also considers whether a proposed action will cause "destruction or adverse modification" of habitat that has been designated as critical to conservation of the species. Dr. Allan is correct that the BIOP determines that thousands of mussels will die during low flow periods. However, the conclusions regarding *survival and recovery* and *critical habitat* preservation that the USFWS arrive at *after* their comprehensive

analysis supports my opinion – that losses of individual organisms (even thousands of organisms if that number represents a very small fraction of the overall population) can and will occur, but these losses do not result in population "tipping points." Survival and recovery of populations occurs despite these events. And, as I note earlier, these events have likely occurred throughout the history of the system. This is an important distinction between my approach, which is consistent with the population-based approach of the USFWS, and Dr. Allan's approach that predicts harm to individual resources without validation that such harms consistently affect the resources and without an analysis of the population consequences of his predicted, ambiguous "harm."

(e) Dr. Allan Ignores All Stressors Except for Georgia's Consumptive Use

236. Dr. Allan admits that other factors have impacted the ecosystem in the Apalachicola River, but he failed to investigate any of them. For example, Dr. Allan admits that "the channel has changed over the years due to both human and natural causes," but he then inexplicably states, "I do not believe that channel erosion is relevant to assessing harm to the River." Allan Written Direct Testimony ¶ 85. This position is especially inappropriate when Dr. Allan relies heavily on investigations by Helen Light and various other authors to show that there has been a shift in floodplain forest composition, but at the same time he chooses to ignore that those same investigators conducted a causal analysis and found that ***channel changes*** were the primary cause of the shift. For example, Light, et al. (GX-88) explains:

> "Water-level declines in the river have substantially changed long-term hydrologic conditions in more than 200 miles of off-channel floodplain sloughs, streams, and lakes and in most of the 82,200 acres of floodplain forests in the nontidal reach of the Apalachicola River. . . . Water-level decline *caused by channel change* is probably the most serious anthropogenic impact that has occurred so far in the Apalachicola River and floodplain."

237. Dr. Allan also dismisses the influence of weather and climate, and, in fact, fails to mention it at all in his direct testimony. Dr. Allan has written extensively that climate is one of the factors that affect key aspects of a river's hydrology, channel shape, and chemistry. The effects of changing climate to rivers are not limited to physical changes. Dr. Allan also notes in his work published prior to this case that climate change can affect the ecosystem and food web, with effects including the accrual and loss of benthic algal biomass, the global decline of

amphibians, threats to fish populations, and even a potential increase in biological productivity. Despite a significant body of his own work describing the critical impact of weather and climate on riverine ecosystems, Dr. Allan dismisses the influence in his expert report with a single line: "*climate change has not been the cause of the historically increased stresses in the ecosystem*." FX-790 (Allan Expert Report, at 84).

238. In short, Dr. Allan has not conducted the causal analysis work necessary to support his opinions that harmful conditions are the result of Georgia's consumption of water. He erroneously assumes that his modeled harms actually correlate with real-world harm and assumes that Georgia's consumption is the sole cause. He either misses important and more plausible alternative explanations for ecological changes, or he simply dismisses them without providing any scientifically valid reason. Instead, Dr. Allan erroneously presumes that any of his modeled harms are caused by Georgia's cogood nsumptive use of water.

CONCLUSION

239. The Apalachicola Bay and River Floodplain is an ecosystem that has historically been sustained, and in fact has thrived, through multiple periods of natural variability, including periods of drought, changes in flow, and extreme conditions. My robust causal analysis shows that Georgia's incremental consumption of freshwater has had a minor incremental influence on salinity in Apalachicola Bay, and any salinity changes are dwarfed by natural variability. As a result, Georgia's incremental consumption of freshwater has negligible biological effects on oysters, benthic invertebrates, fish, and other estuarine organisms in the Bay. The ecological productivity of the Bay is sustained even at low flows. In addition, my robust causal analysis shows that water consumption by Georgia has had a minor effect on freshwater flows and thus a minor influence on inundation patterns during low-flow periods since 1992. Consequently, water consumption by Georgia has had little-to-no influence on floodplain habitats.

LIST OF EXHIBITS CITED

- **GX-07**: This exhibit is a true and accurate copy of a 1998 study published by the United States Geological Survey ("USGS"), authored by Darst, M.R., H.M. Light, and J.W. Grubbs, titled "Aquatic habitats in relation to river flow in the Apalachicola River floodplain." Experts in my field regularly rely on such studies, and I relied on it in forming my opinions.

- **GX-24**: This is a true and accurate copy of Senate Report 107-338, Restore the Apalachicola River Ecosystems (RARE) Act of 2002, from the U.S. Senate Committee on Environment and Public Works. Experts in my field regularly rely on such reports, and I relied on it in forming my opinions.

- **GX-88**: This exhibit is a true and accurate copy of a 2006 study published by the United States Geological Survey, authored by H.M. Light, et al., titled "Water-level decline in the Apalachicola River, Florida, from 1954 to 2004, and effects on floodplain habitats." Experts in my field regularly rely on such studies, and I relied on it in forming my opinions.

- **GX-351**: This exhibit is a true and accurate copy of a publication by the Apalachicola Estuarine Research Reserve ("ANERR") titled "ANERR Fall 2011 Oyster Catcher,", available at http://apalachicolareserve.com/news-fll11.php. Experts in my field regularly rely on such publications, and I relied on it in forming my opinions.

- **GX-352**: This exhibit is a true and accurate copy of a 2011 study published by the Florida Fish and Wildlife Conservation Commission ("FFWCC") titled "Seagrass integrated mapping and monitoring for the State of Florida: Mapping and monitoring report no. 1." Experts in my field regularly rely on such studies, and I relied on it in forming my opinions.

- **GX-393**: This exhibit is a true and accurate copy of ANERR 2000-2012 Monthly Trawl Data and associated salinity data, as transformed and produced with the expert report of Dr. Kenneth Jenkins, Florida's former fisheries expert in this case. Experts in my field regularly rely on such data, and I relied on it in forming my opinions.

- **GX-872**: This exhibit is a true and accurate copy of the expert report I submitted in this case.

- **GX-975**: This exhibit is a true and accurate copy of the ANERR SAV Monitoring Database, available at http://cdmo.baruch.sc.edu/get/gis.cfm. Experts in my field regularly rely on such data, and I relied on it in forming my opinions.

- **GX-976**: This exhibit is a true and accurate copy of ANERR 2014-2015 Monthly Trawling Surveys conducted by the Florida Department of Environmental Protection ("FDEP"), available at http://www.dep.state.fl.us/coastal/sites/apalachicola/science/trawling.htm. Experts in my field regularly rely on such data, and I relied on it in forming my opinions.

- **GX-988**: This exhibit is a true and accurate copy of 1972-1984 Livingston Trawl Data (filename "BioticData.mdb"), as transformed and produced with the expert report of Dr. Kenneth Jenkins, Florida's former fisheries expert in this case. Experts in my field regularly rely on such data, and I relied on it in forming my opinions.

- **GX-1061**: This exhibit is a true and accurate copy of 1998-2014 Fisheries Independent Monitoring Trawl Data (filename "Apalachicola_FIM_data.mdb"), as transformed and produced with the expert report of Dr. Kenneth Jenkins, Florida's former fisheries expert in this case. Experts in my field regularly rely on such data, and I relied on it in forming my opinions.

- **GX-1092**: This exhibit is a true and accurate copy of a database maintained by the FFWCC, which tracks the occurrence of harmful algal blooms across the state, available at http://myfwc.com/research/redtide/monitoring/databse. Experts in my field regularly rely on such data, and I relied on it in forming my opinions.

- **GX-1102**: This exhibit is a website link to PDSI drought reconstructions generated from published tree ring chronologies for the United States, as reported in the North American Drought Atlas, A History of Meteorological Drought (http://northgeorgiawater.org/conserve-http://iridl.ldeo.columbia.edu/SOURCES/.LDEO/.TRL/.NADA2004/.pdsi-atlas.html). Experts in my field regularly rely on such data, and I relied on it in forming my opinions.

- **GX-1149**: This exhibit is a website link to the NOAA Atlantic Multidecadal Oscillation Index, available at http://www.esrl.noaa.gov/psd/data/timeseries/AMO/. Experts in my field regularly rely on such data, and I relied on it in forming my opinions.

- **GX-1153**: This exhibit is a true and accurate copy of a website link to the NOAA Palmer Drought Index (http://www.ncdc.noaa.gov/temp-andprecip/drought/historical-palmers/), which is an index maintained by the United States Fish and Wildlife Service, National Oceanic and Atmospheric Administration. Experts in my field regularly rely on such data, and I relied on it in forming my opinions.

- **GX-1159**: This exhibit is a true and accurate copy of the LiDAR data maintained by the Northwest Florida Water Management District, available at http://nwfwmdlidar.com/. Experts in my field regularly rely on such data, and I relied on it in forming my opinions.

- **GX-1252**: This exhibit is a true and accurate copy of a 2012 study published by the FDEP titled "Site-specific information in support of establishing numeric nutrient criteria in Apalachicola Bay." Experts in my field regularly rely on such studies, and I relied on it in forming my opinions.

- **GX-1254**: This exhibit is a true and accurate copy of a 2014 study published by the FFWCC titled "Summary report for Franklin County Coastal Waters in Seagrass, integrated mapping and monitoring report no. 1.1." Experts in my field regularly rely on such studies, and I relied on it in forming my opinions.