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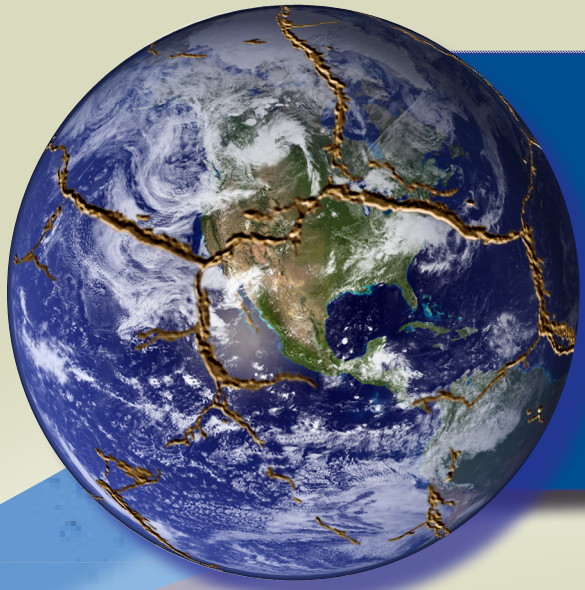
USGS Capabilities to Study the Impacts of Drought and Climate Change in the Southeastern United States



In the Southeast, U.S. Geological Survey (USGS) scientists are researching issues through technical studies of water availability and quality, geologic processes (marine, coastal, and terrestrial), geographic complexity, and biological resources. The USGS is prepared to tackle multifaceted questions associated with global climate change and resulting weather patterns such as drought through expert scientific skill, innovative research approaches, and accurate information technology.

The Southeastern United States embodies a treasury of natural resources from ancient mountains to the Coastal Plain. A "Region of Rivers," the Southeast is renowned for a remarkable diversity of amphibians, fishes, mollusks, crayfishes, and insects found nowhere else on Earth. Currently (2009), a steady increase in human population has led to the designation of the Southeast as one of the two fastest growing regions in the country.

Heightened concerns about the projected consequences of global climate change are justified by the occurrence of recent weather events, such as the severe drought in 2007. Summer temperatures are expected to increase substantially during the 21st century in the Southeast, and the effects of drought and climate change on factors such as rainfall and soil moisture are uncertain. Some climate models suggest the duration and frequency of droughts will intensify in this region during La Niña phases as atmospheric carbon dioxide (CO_2) increases. Global climate change could lead to more periods of severe drought conditions.

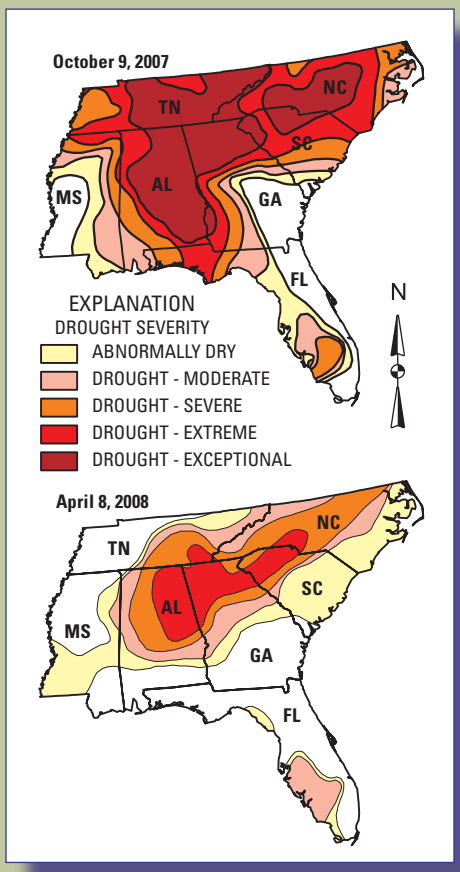
This fact sheet summarizes the USGS capabilities to provide the science necessary for managers to effectively allocate limited water resources.

Availability and Management of Water

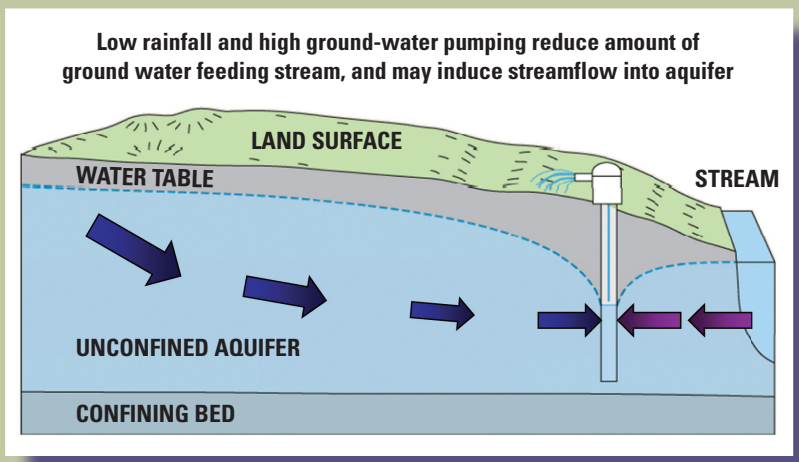
Drought conditions directly affect streamflows, surface-water levels, ground-water levels, and ground-water/surface-water exchanges that sustain river and spring flows. For example, extreme droughts have greatly reduced daily flows, cutting them to nearly half of the normal dry season flows for portions of the Chattahoochee and Flint Rivers in Georgia, and the Apalachicola River at Chattahoochee, Florida. These drought-related water flow and level declines, in turn, affect the economy and environment throughout the Southeast. During extreme drought conditions, there is insufficient water to meet demands for drinking water and irrigation, to provide adequate power generation, to support healthy populations of fish and other aquatic organisms, and to maintain floodplain forest and wetland habitats.

As flows decline in streams during droughts, pollutants and other contaminants become more concentrated causing a decline in water quality. Coastal environments are also harmed by drought. For example, sufficient freshwater inflows are required for maintenance of low-salinity waters in estuarine areas. If freshwater flows are insufficient to create brackish conditions, then downstream fisheries in estuarine areas such as Apalachicola Bay are negatively impacted.

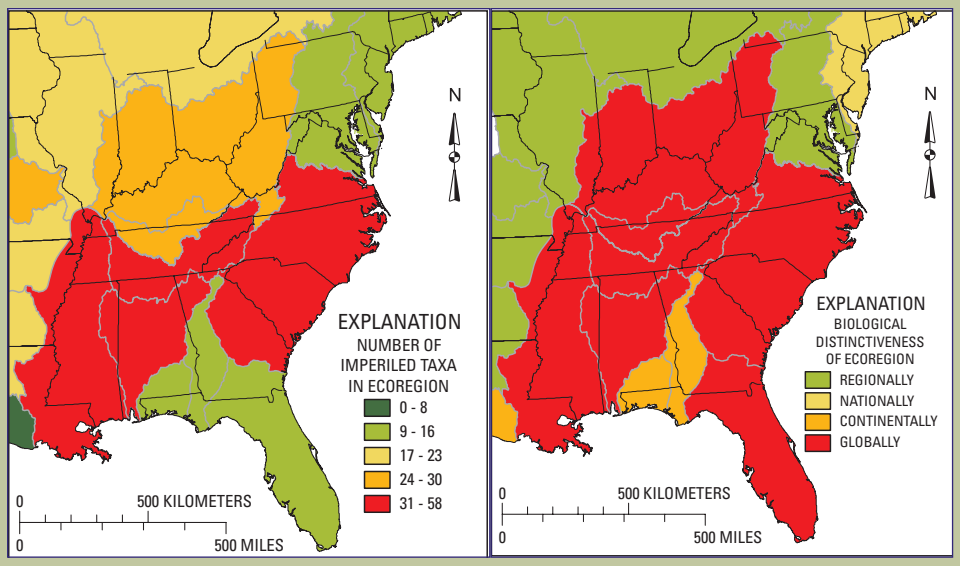
The USGS has a long history of working cooperatively with other Federal, State, and local agencies to provide important science and data concerning water availability and drought. For example, the USGS currently operates over 1,600 streamgaging stations in the Southeast that report data in real time, and hundreds more that provide surface-water, ground-water, and water-quality data at daily and monthly intervals. USGS geographers and hydrologists have also compiled water withdrawal information and documented changes in water use patterns in various areas of the Southeast. USGS hydrologists



Drought in the Southeastern United States in 2007 and 2008.



Relation among low rainfall, ground-water pumping, and streamflow.



Imperilment and biodiversity in the Southeast (American Fisheries Society Endangered Species Committee; Abell and others, 2000).

also use these data to develop models to predict how increased water withdrawals, drought, and other stresses could affect water levels, streamflows, water quality and availability, and floodplain habitats. USGS scientists and technicians can provide the science and data necessary to gain a better understanding of drought-related effects on (1) ground- and surface-water quality and quantity, (2) water use, (3) rates and patterns of net precipitation (rainfall minus evapotranspiration) to the land surface and recharge to aquifers, (4) chemical transport and transformation in the unsaturated zone (between land surface and the water table), and (5) salinity intrusion.

Southeastern Biodiversity and Imperilment

Freshwater and floodplain habitats are essential for the survival of a very diverse group of animals—from salamanders to minnows. The Southeast is an area of great freshwater biodiversity compared to other temperate regions of the world. However, many animals in the Southeast are imperiled, meaning species are federally listed as endangered, threatened, or considered to be likely candidates due to their habitat conditions. More imperiled fishes occur in the freshwater ecoregions of the Southeast than anywhere else in the country. Recent severe droughts compound the stresses on aquatic habitats and species already imperiled. Without proper foresight and management, much of the aquatic biodiversity in the Southeast may be lost.

From bottom-dwelling invertebrates to amphibians, fishes, and alligators, USGS scientists are experts in studying a wide variety of aquatic organisms vulnerable to drought. Furthermore, USGS has a long history of reliably monitoring water quality and quantity, mapping natural resources, and modeling hydrologic, geological, and biological processes. Because of its integrated multidisciplinary approach, the USGS is uniquely qualified to address scientific questions that cross traditional research boundaries.

Invasive Species

Invasive non-native animals and plants can often tolerate a wide range of environmental conditions, thus they are better able to thrive in rapidly changing habitats than many native species. In a struggle for survival, non-native species may outcompete native species under drought conditions. Nearly 40 percent of the native fishes in North America are considered imperiled. The presence of invasive fishes and other invasive aquatic organisms is considered one of the main factors that has contributed to the decline and imperilment of these native fishes. Two examples of invasive species now established and threatening the Southeast are the flathead catfish and red shiner. The flathead catfish can reach 4 feet in length, weigh 100 pounds, and prey upon native fish. The red shiner, a small fish transplant from the Mississippi River basin, is abundant in some small streams and commonly hybridizes with native shiners.

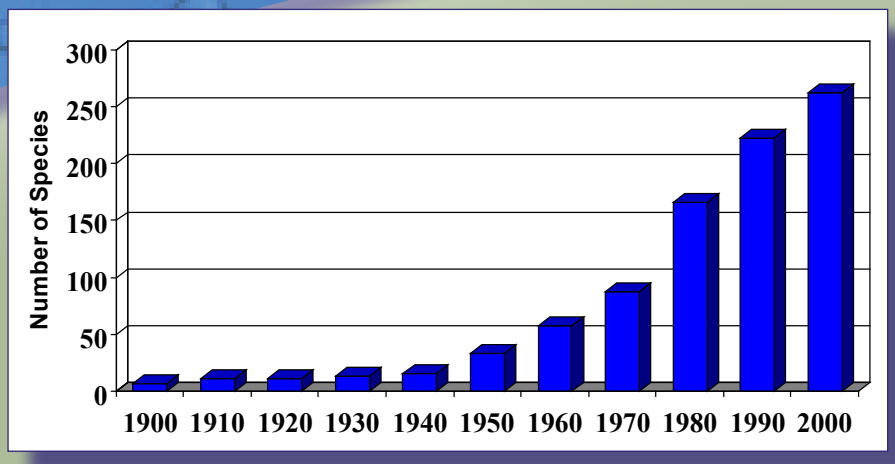
The USGS has a long-standing commitment to documenting and understanding the effects of invasive animals and plants, as well as providing natural resource managers with control information. USGS researchers are investigating a wide range of issues, for example, invader-native species interactions, invader influence on ecosystem structure, and long-term ecological consequences of invasive species. On a national level, the USGS maintains the Nonindigenous Aquatic Species database, which includes a georeferenced history of documented aquatic introductions across the United States. This database currently contains over 73,000 records, many of these from the Southeast. The database allows users to perform space and time analyses of species occurrences, and distribution mapping. Because the database tracks the dispersal of non-native species, it functions as an early warning system when adjacent drainages or regions are newly invaded.

At least 70 non-native aquatic animal and plant species have been documented in a single southeastern drainage, the Apalachicola-Chattahoochee-Flint (ACF) drainage. Several amphibians, various invertebrates (for example, freshwater jellyfish, copepods, crayfish), 44 transplanted and foreign fishes, one mammal (the South American nutria), and almost 20 species of invasive aquatic plants have been documented as occurring in the drainage. The Asian swamp eel entered the ACF drainage in about 1989; it is an air-breathing fish that preys on native animals. The Asian clam exists throughout the drainage, yet the extent to which it competes with native imperiled clams and mussels is unknown.

Contaminants

Contaminants that may be present in the aquatic environment can be adversely affected by drought conditions. Lower rainfall amounts may result in increased *concentrations* of contaminants (and dissolved naturally occurring constituents) in ground water, streams, rivers, and lakes, posing an increased threat to aquatic organisms. These concentration increases could occur as a result of lower dilution capacity in rivers and lakes, and increased concentrations of chemical residues transported to ground and surface waters during first-flush rainfall events. Also, increased temperatures and lower water levels may alter biogeochemical transformation processes and potentially accelerate transformation of chemicals to degradational products, some of which can be more toxic than the parent chemicals. Adverse ecological impacts associated with "emerging contaminants" (including pharmaceuticals, pesticides,

Asian swamp eel
(Photograph by the USGS)



Cumulative number of fish species introduced into the Southeast by decade, 1900-2000.

Flathead catfish
(Photograph by the USGS)

and other synthetic chemicals) from municipal wastewater treatment facilities could increase as a result of drought and reduced dilution capabilities of streams and lakes. These impacts (which include disruption of endocrine functioning, growth, and sexual development) could increase, extend further downstream, and persist over longer periods during times of drought. Changes in aquatic community structure following reduced flows and water levels can impact organisms higher in the food chain with broader effects reaching into ecosystems. Understanding the effects of contaminants on aquatic species during times of drought is critical for assessing potential risks to human health from drinking-water sources and through the food chain, and for prioritizing contaminants for further human-health research.

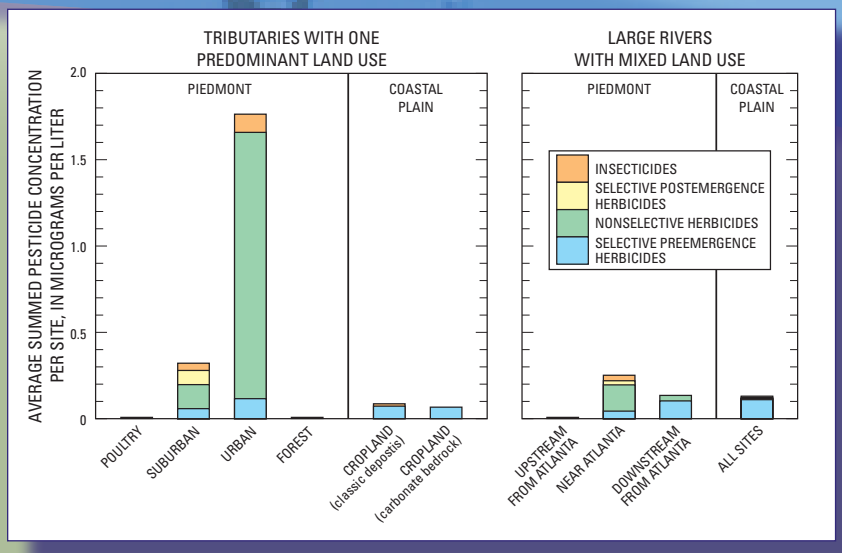
USGS scientists have the capability and resources to investigate the influence of drought on the environmental risks of contaminants. The USGS is the lead federal agency for measuring long-term ground-water levels, streamflow, and water quality; developing water-quality sampling protocols; understanding the processes associated with contaminant occurrence, transport, and fate in water resources; and in field evaluations of contaminant effects on biota and ecosystems. The USGS water-quality laboratories are national leaders in methods development and analytical capabilities, and can assess a broad spectrum of contaminants at parts-per-billion and parts-per-trillion concentrations necessary to evaluate ecologic effects and temporal trends. USGS researchers are among the first to document endocrine disruption in biota, the occurrence of emerging contaminants in water, and their effects on biota. USGS scientists continue to serve in advisory capacities to other federal agencies and policymakers to address these issues.

Iconic Species

Iconic species serve as the "canary in the coal mine" for indicating the health and stability of an ecosystem. Iconic species are unique, readily recognizable, and considered to have intrinsic, aesthetic, or economic value to people. In the aquatic habitats of the Southeast, such species include the alligator, oyster, manatee, striped bass, and Gulf sturgeon. The effects of drought upon these aquatic species mirror the observed effects on most of the other native inhabitants of southeastern aquatic ecosystems; many are in trouble. Whether their declines are a result of overfishing, collisions with watercraft, or loss of habitat, these species are harmed further by habitat changes caused by drought and reduced water availability.

The following combination of physical and ecological expertise and data enables the USGS to place the present populations of iconic species and drought-affected habitats into a historical ecological context and provide scientifically based alternatives to managers:

- Gulf Sturgeon—More than two decades of scientific research; compilation and management of an Apalachicola River Gulf sturgeon mark-recapture population database containing 22 years of data.
- Manatees—Three decades of scientific research encompassing population modeling, satellite telemetry monitoring, genetics, integrated hydrology/manatee models, and development of decision support tools; management of the interagency manatee photo-identification database containing over 30 years of data.
- Alligators, Oysters, Food and Game Fish—Four decades of scientific research on the habitats, ecology, and effects of ecosystem restoration on these iconic species.
- Water Level and Streamflow Monitoring—More than 100 years of monitoring hydrologic conditions throughout the Southeast; providing the physical data necessary to best determine the effects of drought on iconic species.



Relation between pesticide type, concentration, land use, and site location for the Apalachicola-Chattahoochee-Flint Rivers basin (Frick and others, 1998).

West Indian manatee (Photograph by the USGS Sirenia Project.)

Apalachicola Icons: Oysters and Sturgeon

No species is a more recognizable icon of the Apalachicola River ecosystem than the oyster, yielding $200 million in revenue to the local economy. Oysters require a delicate balance of fresh and salt water to thrive. The integrity of the Apalachicola River ecosystem is critical to the oyster and to people who depend on this species for their livelihood. Oysters and sturgeon are used by several resource agencies and public interest groups as hallmarks of the overall health and stability of rivers and estuaries.

The sturgeon is a large iconic fish in several major U.S. river systems. When drought reduces springtime water levels, sturgeon spawning grounds over 150 kilometers inland can become dry and no spawning can occur. Along the Gulf Coast, impassable shoals and bars can prevent Gulf sturgeon from migrating upstream to spawn under drought conditions. During less severe droughts, stagnant river flow may provide insufficient dissolved oxygen for developing eggs and larvae. Additionally, pooled nutrients may stimulate massive algal blooms along the river bottom, prohibiting access to sand habitats where sturgeon and other bottom fish must feed.

Gulf sturgeon
(Photograph by Oscar Sosa, ©2007)

Drought effects extend beyond the freshwater reaches of rivers. Diminished freshwater input results in salinity intrusion into coastal bays and estuaries, eliminating the low and mid-salinity regions critical to sturgeon, oysters, and a host of other species. In late 2007, for example, highly saline water penetrated the entire Apalachicola Bay estuary, as well as the lower reaches of the Apalachicola River.

As critical zones where rivers mix with the ocean, estuaries provide essential feeding grounds for sturgeon and oysters, both of which are harmed by reduced freshwater input. Specifically, juvenile Gulf sturgeon are jeopardized because they feed exclusively in estuaries, and oysters face a dual threat because their larvae require reduced salinities to settle and renew the oyster bars. Neither will be able to persist long under multi-year drought conditions that eliminate the food-rich brackish zone, depriving early juvenile sturgeon of estuarine food and preventing the oyster and many other estuarine-dependent species from repopulating.

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Integrated Science

The integrated nature of USGS scientific research enhances the ability of its scientists to address the complex biological, hydrological, and physical interrelationships that characterize the Southeast. Some of the capabilities of USGS scientists include:

- Research on fish and wildlife distribution, population dynamics, and ecology;
- Understanding the impacts of environmental stressors, such as invasive species and contaminants;
- Water monitoring and research;
- Image analysis and interpretation;
- Development of models and adaptive management strategies to answer complex management questions; and
- Evaluation of ecosystem-level questions regarding land use, water use and allocation, and the effects of changing land use on animals, plants, and ecosystems.

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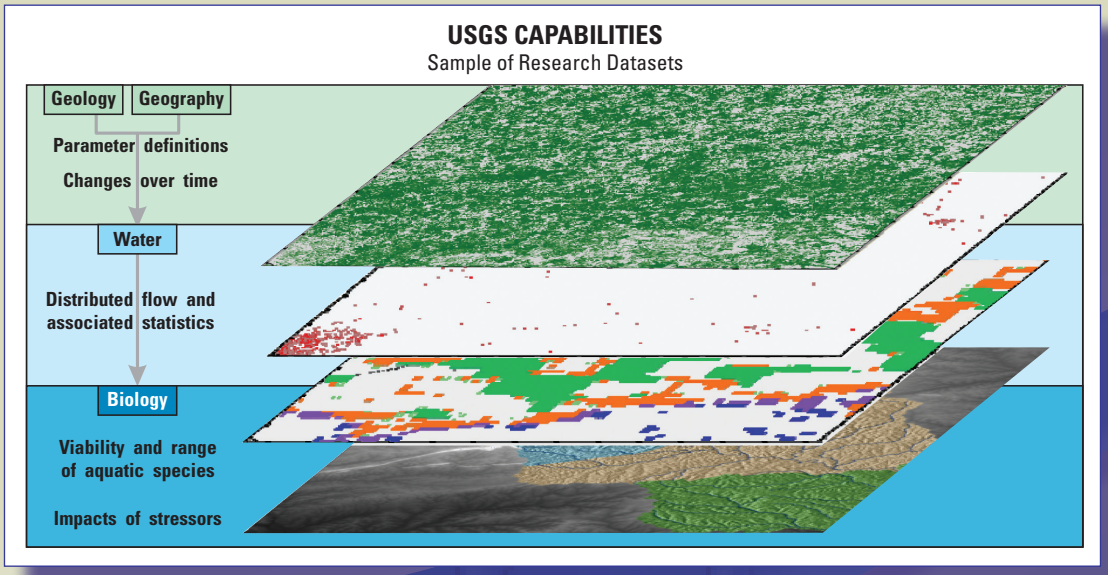
For further information on drought in the Southeast and USGS Science, please visit this website: *http://fisc.er.usgs.gov/southeastdrought/*



USGS disciplines enhance research capabilities for determining long-term effects on complex systems.

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