Effects of Reduced Summertime Stream Flows on Instream Habitat in the Lower Flint River Basin, Georgia, USA

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Abstract. The Lower Flint River and its tributaries in southwestern Georgia have experienced diminished summertime flows in recent decades as water extraction for agricultural irrigation has increased. We are conducting an instream flow assessment in one tributary watershed to predict effects of reduced stream discharge on the quantity and condition of instream habitat. Substrate elevation profiles were measured at several locations for two ecologically important stream habitats that are particularly susceptible to dewatering: shoals and coarse woody material. Analysis of these profiles in conjunction with water elevation-discharge relationships and historic discharge records dating back to the 1930s showed that reductions in summertime minimum flows below historic (pre-irrigation era) levels causes substantial habitat loss from dewatering; for example, most shoal habitat remained wet during extreme droughts in the past but dries under similar climate conditions today. Excessive shoal drying may also create temporary barriers to fish passage as thalweg depth can decrease to 15 cm or less. Habitat that remains inundated experiences reduced current velocity and increased temperature and periphyton cover. Studies are underway to assess biological responses to this habitat loss and change.

INTRODUCTION

Intensifying conflicts between human and environmental demands for water have raised awareness of the finite nature of water supplies in the southeastern U.S. These conflicts are evident in the ongoing disputes over water allocations among users within the Apalachicola-Chattahoochee-Flint (ACF) watershed. One aspect of this conflict centers on instream flows requirements to maintain habitat conditions that support freshwater and estuarine biota, in particular environmental requirements for maintaining minimum flows during droughts.

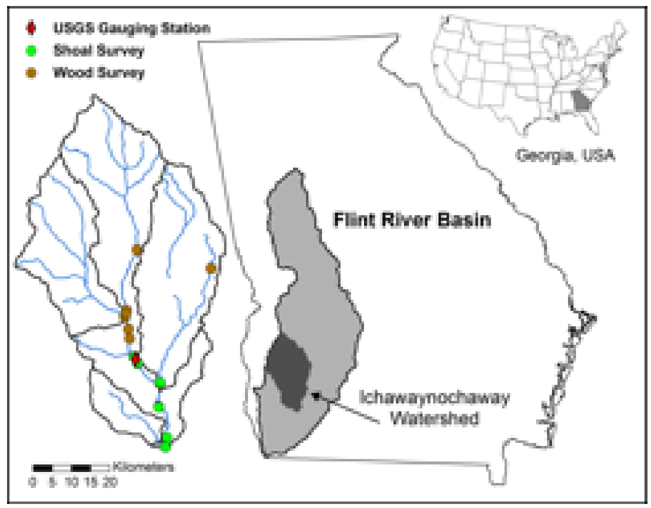

Figure 1: Location of Ichawaynochaway Creek watershed and study sampling stations within the Flint River Basin.

The Lower Flint River Basin (LFRB, Figure 1) is an agricultural region and a major water user within the ACF. Agricultural water use for irrigation expanded rapidly in this basin during the 1970s and is estimated to currently consume roughly 1 billion gallons of water per day during the 6-month growing season (April-September). Irrigation water is pumped directly from tributary streams and from the Upper Floridan aquifer, which is closely connected to surface water and supports stream baseflows. Current levels of agricultural pumping are associated with reduced summertime flows, particularly during periods of drought when groundwater levels are low and pumping rates are high (Georgia EPD 2006).

We are conducting an instream flow assessment in the Ichawaynochaway Creek watershed a major tributary basin to the LFRB to determine how changes in summertime flow regimes and reductions in minimum flows during droughts may affect stream ecological conditions. Here we report on the effects of flow alterations on the

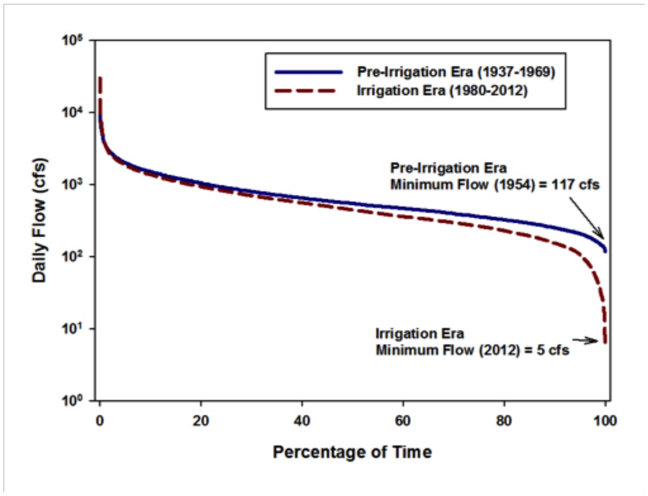

Figure 2: Comparison of flow duration curves for the pre-irrigation and irrigation periods of record at USGS gauging station 02353500 in the Ichawaynochaway Creek watershed (see Fig. 1 for location).

dewatering of key instream habitats known to support high secondary production and biodiversity and are especially susceptible to dewatering at low stream flows.

METHODS

Watershed Description

The Ichawaynochaway watershed drains 2900 km2 in the LFRB (Fig. 1) and spans two distinct geologic formations that determine channel geomorphology and habitats. Stream reaches in the upper portion of the watershed flow through a sand-sandstone geology and have low-gradient, sinuous channels with broad floodplains and a sandy stream bottom typical of many Southeastern Coastal Plain streams. Coarse woody material is abundant and provides a stable substrate that supports considerable instream productivity (Benke and Wallace 1990). Lower watershed reaches are incised into limestone bedrock and are higher gradient, constrained channels with coarse substrate including cobble, boulders, and bedrock. Shoals are a common feature in these reaches and are known to support a diverse fauna and high secondary production (Marcinek et al. 2005).

Agricultural irrigation water is derived primarily from groundwater pumping in the lower watershed and from surface-water withdrawals in the upper watershed. A comparison of historical (pre-irrigation era) and contemporary (irrigation era) streamflow duration curves illustrate how current levels of water use within the watershed have increased the frequency of extreme low flows (Fig. 2)

Field Methods

Twelve stream reaches were selected for surveying, including 6 reaches (wood surveys) in the upper watershed and 6 reaches (shoal surveys) in the lower watershed. Examples of these habitats are shown in Figs. 3 and 5.

During the peak of the recent drought (July 2012), habitat elevation profiles were generated by standard surveying methods using a tripod-mounted level and a surveyor's rod. These profiles were based on approximately 100-150 measurements of channel bottom elevation in individual shoals and elevation ranges of approximately 100-200 pieces of coarse (> 10 cm mean diameter) woody material in individual stream reaches. A staff gauge was installed at each site and elevation measurements were tied to this gauge in order to predict habitat inundation as a function of stream stage.

Data Analysis

Regression relationships between discharge at a long-term (1937-present) USGS gauging station in Ichawaynochaway Creek (see Fig. 1) and water stage at surveyed stream reaches were used to generate inundation-discharge relationships for habitats at each site. These relationships allowed us to estimate minimum flows and corresponding habitat inundation in each reach during the historical (1954) and recent (2012) droughts of record, which were similar in their duration and intensity.

RESULTS AND DISCUSSION

Site Discharge Relationships

Site-USGS discharge relationships could be generated for all stream reaches, allowing us to predict historical patterns of habitat inundation using USGS discharge records. All shoal reaches were either in close proximity to or downstream of the long-term USGS gauging station. Strong log-log relationships ($r^2 \geq 0.912, p < 0.001$) between reach stage and USGS discharge were generated for each of these reaches. Reaches sampled for wood were located varying distances upstream of the USGS station. Strong linear relationships ($r^2 \geq 0.875, p < 0.001$) between reach stage and USGS discharge were generated for each of these sites. Differences in stage-discharge relationships (log vs. linear) between the two habitat types may be due to differences in reach geomorphology. Shoal cross-sections are somewhat triangular in shape such that a steady decrease in discharge causes an accelerating decline in stage. By contrast, wood reaches tend to be rectangular in cross section such that declining discharge causes a proportional reduction in stage.

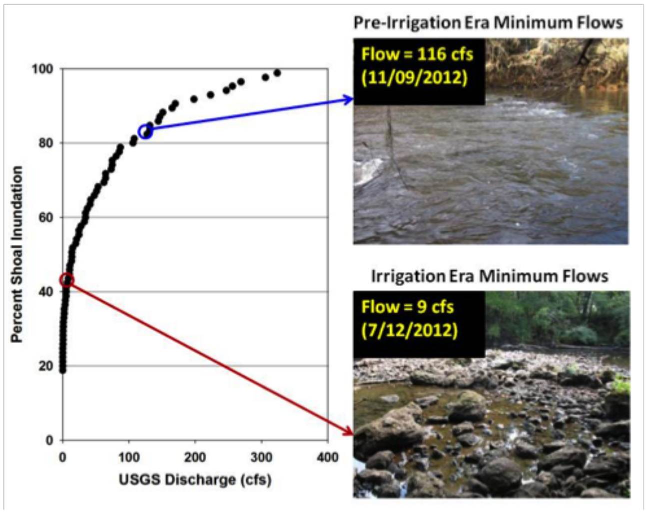

Figure 3: An example of a discharge-inundation relationship for a shoal. Pictures at right show degree of habitat inundation at discharges similar to minimum flows during the pre-irrigation and irrigation periods of record.

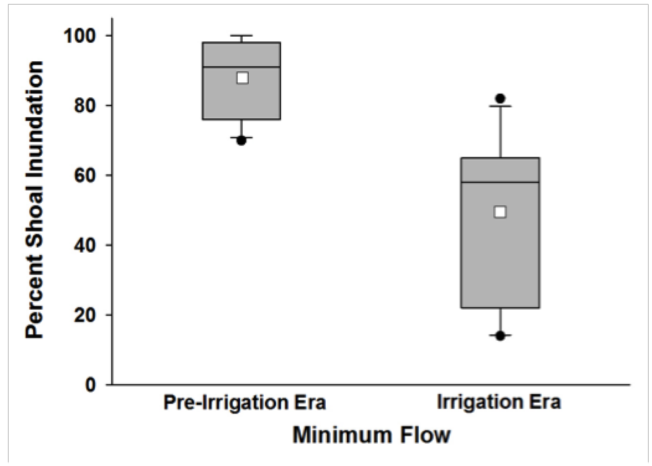

Figure 4: Box plots showing range of predicted shoal inundation in the lower Ichawaynochaway watershed at minimum stream flow recorded during the pre-irrigation and irrigation periods of record. Boxes and lines are median, 10th, 25th, 75th, and 90th percentiles. White square within box is the mean and black circles are outliers.

Shoal Inundation. Discharge-inundation relationships were generated for 15 shoals across 6 lower watershed reaches. A representative example of these relationships is shown in Fig. 3. The curvilinear shape of this relationships shows that the rate of shoal dewatering accelerates as stream discharge declines. In this example, we estimated that 82% of the shoal remained inundated at the minimum stream flow during the 1954 drought (117 cfs) whereas only 43% of this habitat was inundated at the minimum flow during a drought of similar duration and severity in 2012 (5 cfs).

A signed rank test was used to test for differences in habitat inundation across all 15 shoals between historical and recent minimum discharge at the USGS gauge. This test revealed that significantly ($p < 0.001$) more shoal habitat was inundated during the 1954 drought (mean percent inundation = 88%) than during the 2012 drought (mean percent inundation = 50%) (Fig. 4).

Wood Inundation. Discharge-inundation relationships were generated for the 6 upper watershed reaches where wood was surveyed. A representative example of these relationships is shown in Fig. 5. The shape of this relationship is less curvilinear than for shoals, indicating that the rate of wood dewatering is proportional to the decline in discharge. In this example, we estimated that 66% of the shoal remained inundated at the minimum stream flow during the 1954 drought (117 cfs) whereas only 32% of this habitat was inundated at the minimum flow during a drought of similar duration and severity in 2012 (5 cfs).

A signed rank test revealed that significantly ($p < 0.001$) more wood habitat was predicted to be inundated during the 1954 drought (mean percent inundation = 60%) than during the 2012 drought (mean percent inundation = 24%) (Fig. 4).

CONCLUSIONS AND FUTURE WORK

We continue to analyze and expand this data set, but our current findings allow us to reach the following general conclusions:

- Increased agricultural water demand over the past several decades is associated with an increased frequency of extreme low flows in Ichawaynochaway Creek and a more than 20-fold reduction in the minimum flow compared to the pre-irrigation era.
- This reduction in minimum flow translates into a substantial decrease in the amount of instream habitat that is available for growth and propagation of aquatic organisms.
- The extent of shoal dewatering may also reduce connectivity between stream reaches by limiting movement of fish and other aquatic organisms that are sensitive to depth or other hydraulic factors.

Future instream habitat surveys during low flows will include measurements of water velocity, temperature, and dissolved oxygen and periphyton cover. Preliminary measurements indicate that all of these parameters are altered under extreme low flows. We have also begun quantifying

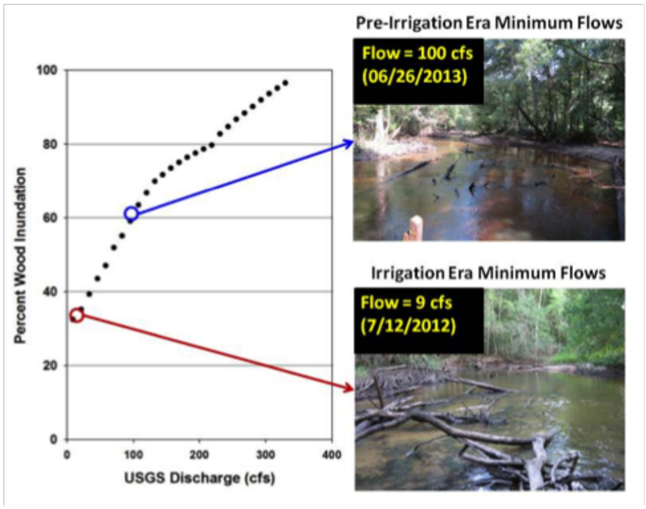

Figure 5: An example of a discharge-inundation relationship for coarse woody material in the stream channel. See Figure 3 for picture details.

fish and invertebrate responses to reductions in stream habitat availability and condition in order to assess the immediate and longer-term effects of extreme low flow events on biotic integrity.

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REFERENCES

Benke, A.C. and J.B. Wallace. 1990. Wood dynamics in Coastal Plain blackwater streams. Canadian Journal of Fisheries and Aquatic Sciences 47: 92-99.

Georgia EPD. 2006. Flint River Basin Regional Water Development and Conservation Plan. Georgia Department of Natural Resources, Environmental Protection Division, Atlanta, GA.

Marcinek, P.A., P.J. Gagnon, M.C. Freeman, C. Straight, M.D. Merrill, and B.J. Freeman. 2005. Ecological Importance and Conservation Status of Southeastern River Shoal Habitat. Report submitted to the U.S. Fish and Wildlife Service, Atlanta, GA. University of Georgia and U.S. Geological Survey, Athens, GA.

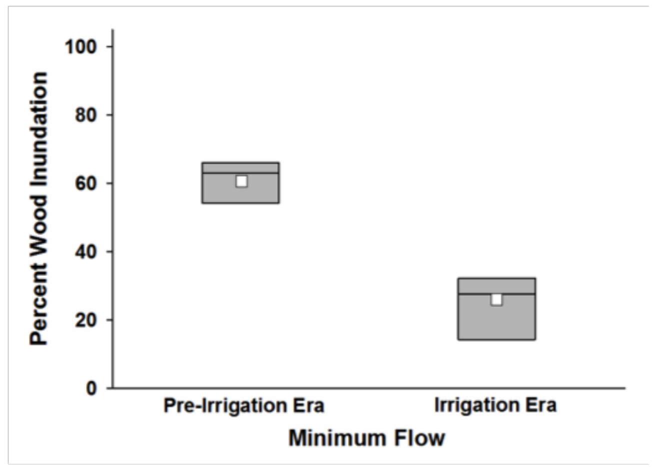

Figure 6: Box plots showing range of predicted wood inundation in the lower Ichawaynochaway watershed at minimum stream flow recorded during the pre-irrigation and irrigation periods of record. See Figure 4 for details.