MONITORING THE EFFECTS OF RESERVOIR CREATION ON FEDERALLY LISTED FISH SPECIES IN THE SOUTHEAST

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Abstract. The proposal to construct a large off-stream public water supply reservoir on the floodplain of the Conasauga River raised concern for the aquatic community of the river, that includes twelve federally listed fish and mussel species. The primary function of the reservoir is to augment Conasauga River discharge during low flow periods by the release of water collected during periods of high flow. During the permitting process, concern was focused on potential aquatic macro-habitat modification issues such as the river's thermal regime, discharge regime, and water quality (dissolved oxygen and nutrient availability) and on issues related to availability of preferred habitats for species of special concern. In an effort to quantify any change to water quantity and quality, studies on the Conasauga River and an existing similar reservoir began in 1992.

In 1992, the Section 404 permit was granted for the proposed reservoir. The permit requires implementation of a water quality and biological monitoring program. The monitoring program includes collection of information relative to river temperature, discharge and water quality information and the collection of water quality information from an existing reservoir of similar design. In addition, the monitoring program includes the collection of fish distribution, habitat preference and micro-habitat availability information for the purposes of monitoring the distribution of fish species of special importance, to obtain additional information on the life history and habitat requirements of these species and to assess the availability of preferred habitats over time. The pre-operation phase of the monitoring program is nearing completion and the biological and water quality monitoring program has been in-place for two years. In this paper, the design of the monitoring program is introduced and some initial results of the pre-operation phase monitoring program are presented.

INTRODUCTION

Located approximately 10 miles northeast of Dalton, Georgia, the River Road Reservoir (Reservoir) is a 118 acre, 1.2 billion gallon, off-stream impoundment on the floodplain of the Conasauga River (Figure 1). The purpose of the 43 ft deep ring-dike storage reservoir is to augment the flow of the Conasauga River, the City of Dalton's primary water source, during periods of low flow (historically July to October) with water withdrawn from the river during the winter months (high flow period). The water added during low flow periods would be removed at the existing treatment facility 10 miles downstream.

The Conasauga River supports a unique aquatic community that includes twelve federally listed, and 20 state listed, fish and mussel species. Due to the special nature of this resident community, and pursuant to Section 7 of the Endangered Species Act and Section 404 of the Clean Water Act, the US Fish and Wildlife Service (USFWS) identified concerns associated with the project during the permitting process. These concerns, outlined in the USFWS Biological Opinion (USFWS 1990), were associated with possible alteration of macro-habitat conditions, specifically the river's thermal conditions, discharge regime, and certain water quality issues, that could adversely affect the ability of the river to support these species of special concern.

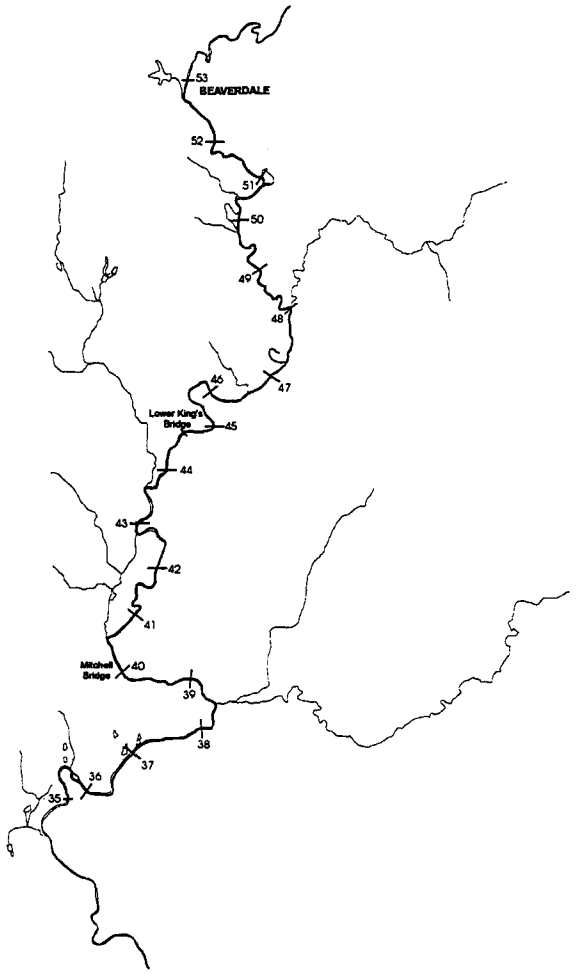

Figure 1. Study area on the Conasauga River showing river mile markers.

Also during review of the Section 404 permit application, the USFWS expressed concern related to the possible effects on the availability of preferred and critical habitats for species of special concern by the altering the present discharge regime of the river. Pursuant to these concerns, a program to monitor the biological effects of the reservoir was developed. The monitoring program focused on critically evaluating the impacts of the reservoir on the aquatic communities and habitats of the Conasauga River. The stated goal of the program was to obtain reliable, standardized, and quantitative information regarding the effects of reservoir creation and operation on the fish stocks and fish habitat in the Conasauga River with special emphasis on the federally listed fish species: the amber darter (*Percina antesella*) - endangered; the Conasauga logperch (*Percina jenkinsi*) - endangered; and, the blue shiner (*Cyprinella caerulea*) - threatened. With phase one of the monitoring program nearing completion, this paper discusses the development of the study design and program protocols to address the concerns identified by the USFWS and presents results of some of the baseline monitoring.

METHODS

Temperature Study

The principal concern expressed in the USFWS Biological Opinion was that the reservoir could induce changes in the temperature regime of the Conasauga River. Detailed information related to the existing river thermal regime needed to be collected and predictions made regarding the thermal changes expected by the proposed reservoir.

Information related to the existing river thermal and dissolved oxygen (DO) regime were collected at various points along the Conasauga River. In June, 1993, seven Onset Computer Corporation "Hobo" ® dataloggers were deployed at several stations along the Conasauga River. Three single channel datalogging thermographs were placed in a transect across the river at the proposed outfall of the River Road reservoir (River Mile (RM) 47.32), while four solitary thermographs were placed at sampling stations downstream at RM 47.13, RM 45.24 (Lower King's Bridge), RM 42.67 (Hwy. 286 Bridge), and RM 36.25 (treatment plant raw water intake). In addition, a single Hobo® thermograph was also placed in the air (hanging from a tree in shaded cover) on the bank of the Conasauga River near RM 36.25 to allow comparison of air and water temperatures. Logged data from the thermographs were downloaded monthly.

Information related to the predicted thermal regime of the reservoir was provided by studying a similar ring-dike reservoir (same depth but half the storage capacity) which had been in operation on the floodplain of the Conasauga River since 1990. The study of thermal characteristics of the existing reservoir, located about 10.5 miles downstream of the proposed River Road Reservoir, began in September 1992 with the collection of the first set of vertical temperature and dissolved oxygen (DO) profiles. The reservoir has been sampled periodically since 1992 in order to describe its characteristics relative to thermal conditions and stratification.

Water Quality Study

A water sampling program was instituted for the existing ring-dike reservoir. Water samples were periodically collected at several stations along the river, and samples of epilimnetic and hypolimnetic (if stratified) reservoir waters were collected (concurrently with temperature and DO profile measurement) and analyzed for various chemical parameters: total phosphorus, nitrate, nitrite, ammonia, biochemical oxygen demand, total suspended solids, volatile suspended solids, and pH. This sampling program has been conducted concurrent with the reservoir thermal regime study in order to describe the water quality conditions relative to nutrient availability in the existing reservoir.

Another concern was related to the potential change to the nutrient availability and DO levels in the Conasauga River. The USFWS predicted that water collected during high flows would be nutrient-enriched relative to the concentration of nutrients found in river water at lower discharge levels, and that releasing the stored nutrient-rich water into the nutrient-poor river would cause algal blooms, thereby increasing BOD and potentially dropping river DO levels below critical thresholds of some fisheries. Over time, this would change the aquatic community to the detriment of the protected species.

A water sampling program involving the existing reservoir and the Conasauga River began in July 1994. The purpose of the program was threefold: to allow comparison between river and reservoir DO levels; to determine if nutrient concentrations in the river at higher flows are greater than their concentrations at lower river flows; and, if so, to determine whether water collected at high flow then stored would remain nutrient-enriched relative to the nutrient levels observed in the river during lower flows. Water samples were collected at various points on the Conasauga River and from the existing reservoir about once per month.

Biological Effects Monitoring

The thermal and water quality studies described above were implemented in an effort to make predictions regarding potential adverse effects from the creation and operation of the proposed off-channel reservoir. A biological monitoring program was also initiated, the intent of which was to identify realized effects on the aquatic communities or habitats. The biological monitoring program comprised several components including monitoring of fish community, aquatic habitats, benthic aquatic invertebrate communities and mussel community distribution. As the focus of this paper is on the potential effects to fish communities, only the methods used in fish community and aquatic habitat sampling are described.

Fish Community Monitoring

The identified species of special concern in the Conasauga River are generally located in areas of shallow riffles with coarse substrata comprised of loose gravel and cobble. Concern has been identified that the availability and suitability of these shoal habitat areas could be affected by the further manipulation of river discharge regimes. The fish community monitoring program focused on sampling in these habitat types at numerous stations along the river in order to document changes in fish communities spatially and temporally. Due to the endangered nature of several fish species within the river reach, non-destructive techniques of fish sampling were necessary. Fish collection was conducted by kick-seining and sweep-seining techniques. Both techniques utilize a short (3 by 1 m) seine net. Kick-seining involves the sampling of a defined area (6 m^2) of riffle or

shallow run habitat of the river by the disturbance of the river substrata by two individuals kicking while two others hold the net in-place downstream of the disturbed area. Sweep-seines involve the hauling of the seine net through a recorded area in pool or deep run habitats which are deeper and/or more placid in nature.

Shoal sites were sampled throughout the eighteen mile study reach. At each shoal sampled, numerous kick and sweep-seines hauls (up to 100 in total) were conducted per shoal. In order to identify seasonal and between year variability, baseline (i.e. pre reservoir operation) sampling was conducted in the spring and fall of 1995; and, spring and fall of 1996.

Detailed Habitat Description

In an effort to describe the availability of habitat types within the areas of the river sampled and to obtain a better understanding of the life-history requirements of species of special concern, a habitat description protocol was developed. The system of codes was implemented during the fish inventory work on the Conasauga River. The codes were used to classify the habitats within each area sampled (seine haul or kick seine) and were also used during habitat mapping of each shoal sampled. It was important that the number of codes be limited for the purpose of practicality, but was sufficient to establish habitat preferences and habitat availability information on an individual species basis. The coding system used is presented in Table 1.

In addition to the general habitat types described in Table 1, additional habitat parameters that could influence the suitability of habitats for species of special concern were identified. These habitat parameters included the presence of aquatic vegetation and the mobility of the stream bed. In order to identify the presence of these habitat parameters, a descriptor was used for aquatic vegetation (j - *Justicia americanum*; p - *Podostemum ceratophyllum*; m - *Myriophyllum sp.*) and another for stream bed mobility (+ easily movable when agitated, which may provide interstitial cover for small fish, - especially embedded or "paved" minimizing the use of interstitial space for occupancy). The code for a certain area of aquatic habitat included the basic stream habitat type code plus specific cover descriptors; for example, the code A1j+ would be used to describe a shallow riffle or run in an area with coarse movable substrate adjacent to or within *Justicia*.

Table 1 Habitat Type Coding System

Code	Depth	Substrata	Code Current Velocity / Habitat Description
A1	<20 cm	coarse (gravel to small cobble)	medium to swift / riffle or shallow run
A2	<20 cm	fines (silts, sand, some gravel)	medium to low / riffle or shallow run
A3	<20 cm	fines (silts and sand)	slow / backwater
B1	20-50 cm	coarse (gravel to small cobble)	medium to swift / riffle or shallow run
B2	20-50 cm	fines (silts, sand, some gravel)	medium to low / riffle or shallow run
B3	20-50 cm	fines (silts and sand)	slow / backwater
C1	>50 cm	coarse (gravel to small cobble)	medium to fast / deeper run
C2	>50 cm	fines (silts, sand, some gravel)	medium to low / off thalweg run
C3	>50 cm	fines (silts and sand)	slow / backwater

RESULTS

Thermal Study Results

A continuous thermogram (48 minute sampling interval) of the Conasauga River was recorded from June 11 to November 7, 1993. Results of the thermal regime study indicate that there was no apparent vertical or horizontal variations in temperature in the river. This was to be expected as the river is shallow, relatively turbulent and thoroughly mixed in most areas.

Data collected by the thermographs from all stations on the Conasauga River indicate similarity in thermal trends between stations, i.e., the river temperatures were similar at all locations at a given time, and the pattern of temperature change with time varied little from location to location (Figure 2). However, there was considerable variation in water temperature at a station both diurnally and seasonally. Daily temperature fluctuation is suspected to result from the amount and angle of insolation, and ambient air temperatures.

For the period June 12 - November 6, 1993, the diel temperature variation, $T_{max} - T_{min} = \Delta_T$, at each temperature monitoring station ranged from 1.0 °F to 7.2 °F. A frequency distribution of Δ_T for stations at RM 47.32 indicates that from June 12 to November 6, 1993, the majority of days experienced a fluctuation of 4 °F or greater (Figure 2).

Water temperatures in the surrogate reservoir were shown to be dependent on depth and time of year. Primarily in response to solar radiation, the reservoir experiences a slow warming progression throughout the summer; the depth to the thermocline increases, the hypolimnion warms slowly, and the overall volume of the hypolimnion decreases. By mid- to late summer, the temperature DO profile of the reservoir shows a relatively uniform profile with high DO (9.5 to 10 mg/L) and moderate temperature (80 - 82°F) for most of the water column (Figure 3).

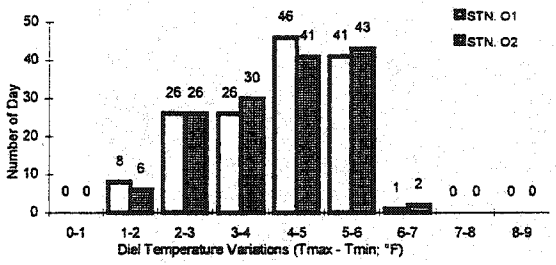

Figure 2. Frequency distribution of Diel temperature variations, Stations 0-1 and 0-2, June 12-Nov. 6, 1993.

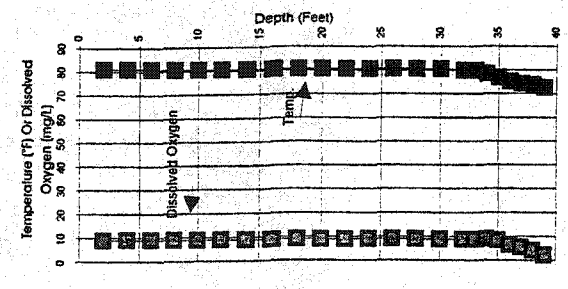

Figure 3. Conasauga Reservoir temperature and DO profiles on Sept. 2, 1992.

Water Quality Study Results

A well-defined vertical temperature and DO gradient was present in May 1993 when water temperatures ranged from about 72 °F at the surface to 50 °F at the bottom (Figure 4). The thermocline was located at a depth of about 20 feet and the entire water column was well oxygenated. In contrast, in September of 1992 the temperature of the water column from the surface to the thermocline at a depth of about 34 feet was approximately 81 °F (Figure 4).

Since the inception of the water sampling program, DO levels measured in the epilimnion of the existing reservoir, or throughout the water column when unstratified, are almost always at, or slightly above, 100 percent saturation (all DO measurements have been taken during daylight hours). Generally, hypolimnetic water in lakes and reservoirs is rarely saturated with respect to DO, and anoxic conditions typically develop prior to fall turnover; the deeper and more productive a water body, the more profoundly anoxic the hypolimnion can become. However, DO levels measured in the Conasauga Reservoir's hypolimnion during the summer and fall months over the past 3 years generally decrease with depth as expected, but anoxic conditions (<0.5 ppm DO) have very rarely been detected. Further, when low hypolimnetic DO concentrations have been measured, the thickness of the water column with DO below 2 ppm is generally less than 2 feet. It is expected that the relatively shallow depth of this, and the proposed, ring-dyke reservoir (about 40 feet) combined with low productivity, seem to minimize the development of a significant thickness of anoxic water.

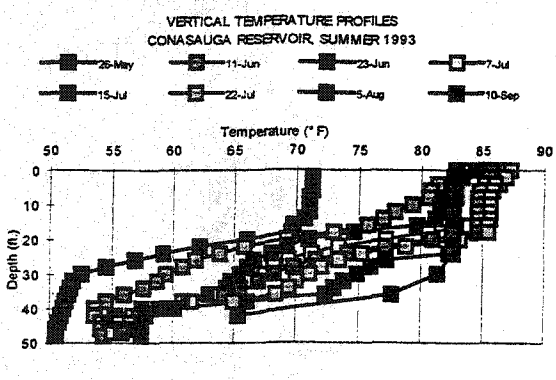

Figure 4. Temperature profiles of Conasauga Reservoir, summer 1993.

DO levels measured in the Conasauga River are usually at 100 percent saturation or within 1.0 ppm of saturation. DO was measured in transects across the river at various stations along a nine mile reach. As observed during the concurrently performed temperature transects, no apparent difference in DO concentration was observed in the water column (≤ 0.1 ppm in a 9 foot water column) nor was there a substantial difference from top to bottom of the study reach where DO ranged from 10.2 to 10.0 ppm. This was expected since the river is shallow, appears turbulent and thoroughly mixed.

During increased discharge periods in the winter and early spring, nutrient and suspended solid concentrations in the Conasauga River can be considerably higher than in the Conasauga Reservoir. However, these relatively elevated levels were not observed to persist into the summer and fall months. In fact, during this period, reservoir water quality was generally better than river water quality in terms of lower concentrations of total phosphorus and total suspended solids.

Fish Community Sampling

The fish community sampling results from the spring and fall of 1995 and 1996 underscore the diversity within the fish community of the Conasauga River. Figure 5 provides a summary of the number of species present at select shoals on the Conasauga River. In general, there does not appear to be a clear trend in fish community diversity along the Conasauga River. Fish community structure downstream of the proposed reservoir (situated at approximately river mile 47.32) did not appear to be reduced to that found in sampling of fish communities upstream. However, there was considerable variability identified within a shoal between sampling periods.

Similarly, there does not appear to be an identifiable trend in the distribution of species of special concern along the Conasauga River based on the pre-operation monitoring results (Figure 6). This would indicate that habitats within the shoals selected on the Conasauga River upstream and down-stream of the proposed reservoir do not vary significantly with respect to their ability to support these identified species of special interest.

DISCUSSION

The potential biological effects of reservoir operation on the Conasauga River include modification of water quality, thermal conditions and flow regimes. Monitoring programs are now in-place to measure possible effects and allow for modification to reservoir operations as necessary to minimize impacts as specified in conditions of the Permit. Concerns about release of low DO water are lessened by observations of a deep thermocline in the surrogate reservoir during summer and fall, in which case well oxygenated epilimnetic water would be released into the river when river discharge is augmented. To further allay this concern a Parshall flume (cascading system) was incorporated into the design of the release structure to maximize DO concentrations in the released water. Temperature change scenarios were developed using empirical relationships, which indicate that during periods of reservoir releases, absolute changes in river temperature can be minimized with restricted release of stored reservoir water. Of course, the absolute change in river temperature will be dependent on the volume of water released, the current discharge of the Consauga River, and the temperature differential

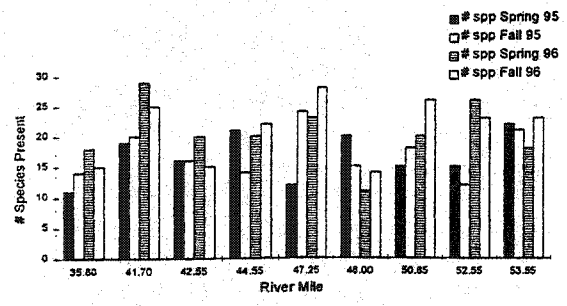

Figure 5. Fish species captured at select shoals along the Conasauga River.

between reservoir and river waters. The realized change in river temperature will be monitored through operational phases.

As with most rivers, the Conasauga River experiences diurnal fluctuations in temperature. Continued monitoring will assess whether the operation of the reservoir changes the frequency of large temperature fluctuations or the duration of large temperature shifts. These types of thermal regime changes could have detrimental biological effects on the resident aquatic biota (*e.g.* emergence of fall insects, development time or growth rate of juvenile fishes and insects, fall cues for reproductive development in fishes). The data collected during the project permitting phase supports the assertion that the River Road Reservoir will not adversely affect water quality in the Conasauga River (Golder 1994). For the duration of reservoir operation, a water quality monitoring program incorporating stations in the reservoir, in the outfall structure, and two permanent water quality monitoring stations on the Conasauga River, one upstream and one downstream, will monitor water quality parameters to ensure that the baseline conditions observed in the river are maintained.

All of the predictions made regarding the anticipated changes in river thermal and water quality regimes indicate that conditions in the Conasauga River should not be substantially erature will be dependent on the volume of reservoir water altered. The thermal mixing study and ongoing monitoring of water quality and temperature regimes in the river will test the predictions made. However, the most important criterion on which to assess realized impact will be the abundance and distribution of the sensitive species of special concern within the Conasauga River. The biological monitoring study which has been established will enable changes in the distribution or abundance of these sensitive species so that reservoir operations can be adjusted, if necessary, to protect this important river and the valuable resource it supports.

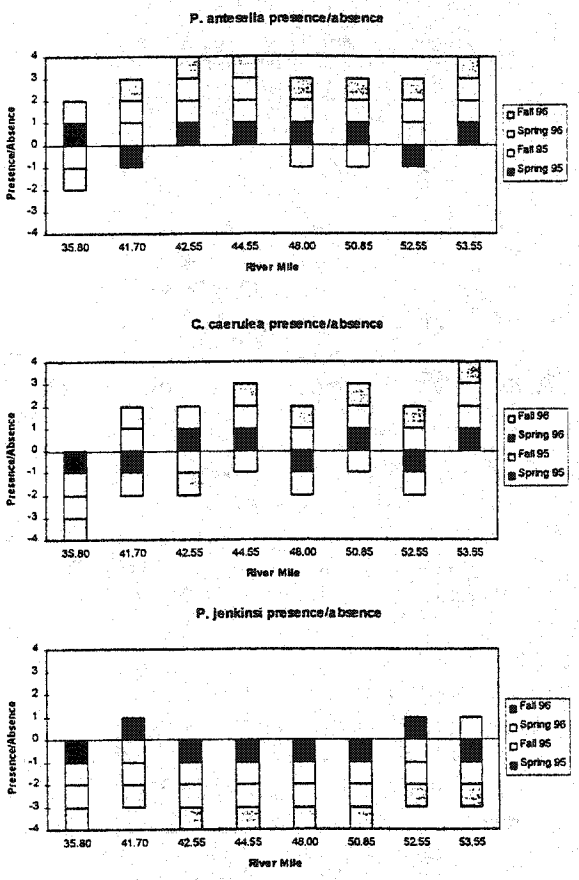

Figure 6. Presence / absence of listed fish species at selected shoals along the Conasauga River.

ACKNOWLEDGMENT

The authors wish to recognize Dalton Utilities continuing support in developing and implementing this Conasauga River monitoring program.

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