Tailwater Fishery Management Using a Fish Bioenergetics Model

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Abstract

Water releases from TVA reservoirs exert great influence on downstream water quality. Analytical tools to quantify biological response to altered environmental conditions, such as dissolved oxygen and temperature, in tailwaters have been lacking. In this study, a fish bioenergetics model was coupled with one-dimensional dynamic flow and water quality models and used to simulate rainbow trout growth in tailwaters below Norris Dam, below South Holston Dam, and in aquaria studies with different DO treatments. The utility of this model for predicting growth responses to release improvements and dam operations was explored.

Introduction

Water released through turbines with deep intakes is often cold in temperature and low in dissolved oxygen. The low oxygen concentrations, combined with a cycle of wet-and-dry channel due to peaking operations, can severely limit aquatic life in a hydropower tailwater. Predicting the effects of such improvements has been virtually impossible, and post-mitigation evaluation of the effects on aquatic life has normally required years of intensive field studies.

To help evaluate mitigation efforts, a fish bioenergetics model was developed. An EPA version of the Cuenco model (Cuenco et al., 1985a,b,c) was coupled with TVA's one-dimensional dynamic flow and water quality models (Hauser, 1991),

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and the combined model was used to simulate fish growth patterns resulting from water quality and food availability patterns in real tailwaters and in aquaria studies. The model was also used to quantify fish growth responses to proposed operational and release improvement options.

Model Validation in Tailwaters and Aquaria

The bioenergetics model was used to simulate rainbow trout growth in the tailwater below Norris Dam under pre-and post-mitigation conditions. The model was reasonably accurate temporally, but was less successful spatially due to fish movement and non-uniform food distribution. Details of this study can be found in Shiao et al. (1992).

In 1992, tagged rainbow trout were released at three different times (March, April, and July) upstream and downstream of the labyrinth weir in the tailwater below South Holston Dam. Creeled data indicated that fish grew slightly better upstream of the weir, but can not be certain due to the scarcity of field data and greater fishing activity downstream of the aerating weir. Model predictions for the March and April releases followed the pattern in the captured fish weight data, but the July releases grew more slowly than the model predicted. Heavy fishing pressure below the weir reduced the number of bigger fish in the river and probably contributed to this apparent slower growth.

The aquaria rainbow trout study included seven DO treatments. Each aquarium held 10 four-inch rainbow trout that were fed a high protein trout chow at 3 percent initial body weight per day. Because trout and many other fish form hierarchies of dominance and submissiveness, the 3 percent ration was not shared equally. As a result, the model underestimated the growth of larger, more dominant fish and overestimated the growth of smaller, more submissive fish. On average, increase in body weight was about 15 percent with low DO (4 mg/L), 30 percent with cyclic DO (4-12 mg/L), and 50 percent with high DO (10-12 mg/L).

Scenario Simulations

The bioenergetics model was employed in 1988 to simulate rainbow trout in the Norris tailwater, with and without release aeration (turbine venting). Turbine venting is initiated at Norris Dam at Clinch River Mile (CRM) 79.9 when release DO drops below 4 mg/L. Simulated fish mass at CRM 79.7 and CRM 76.2 and DO with and without aeration is shown in Figure 1.

At the upstream reach, simulations showed that a 12.5-fold weight increase was realized with aeration comparing to a 7.5-fold increase without aeration, or 67 percent better growth performance with aeration. At the downstream reach, the difference in DO with and without aeration was smaller due to natural reaeration

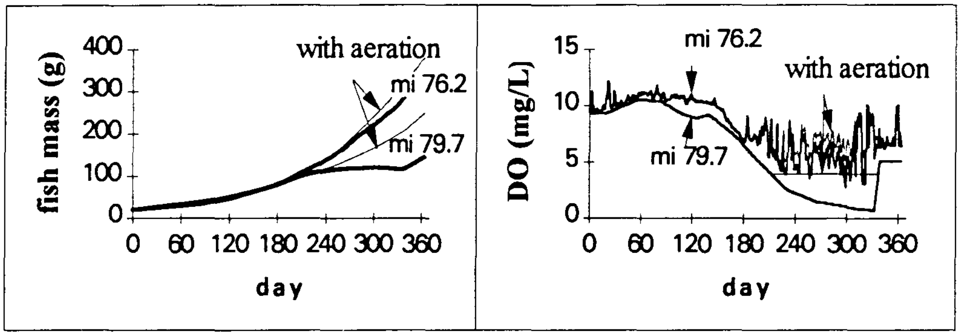

Figure 1. Model Simulation of Aeration Effect

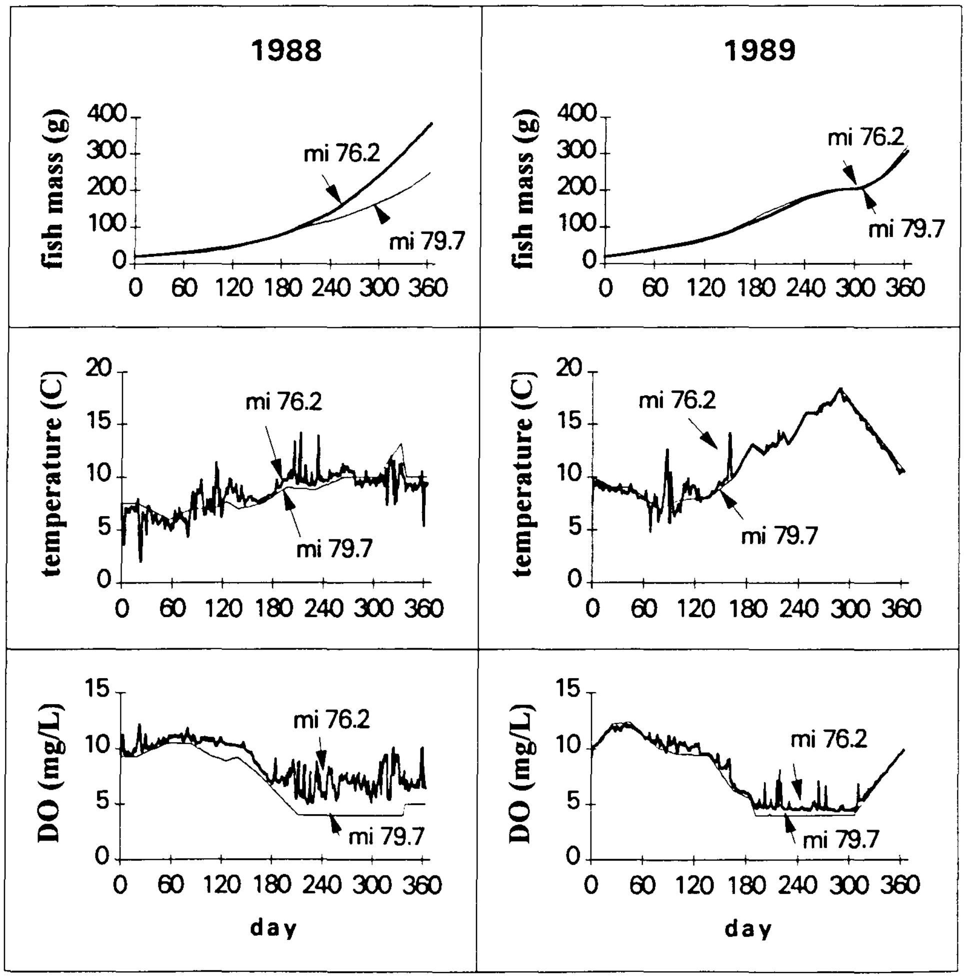

Figure 2. Model Simulations for Dry (1988) and Wet (1989) Years

of the water in both cases. Model results indicated about 10 percent better growth performance at the downstream location with aeration.

In Figure 2, the simulated fish body weight in a dry year (1988) is compared to that of a wet year (1989) along with the computed temperature and DO at the upstream and downstream reaches for the dry and wet years. In the dry year, releases from Norris Reservoir were low and changes in temperature and DO between the upstream and downstream reaches were much greater due to warming and aeration at the shallower depths. The simulated fish body weight was about 50 percent higher at the downstream reach than that at the upstream reach. In the wet year, more water was discharged from Norris Reservoir and temperature, DO, and growth at the downstream reach did not differ much from that at the upstream reach. Early wet-year temperatures were higher than the dry year, stimulating growth. Later wet-year temperatures became too warm, and DO was low enough at the downstream reach that growth was hampered relative to the dry year case.

Summary

In this study, a fish bioenergetics model was developed to simulate fish growth response to fluctuating temperature and DO in the tailwater below hydroprojects. As a planning tool, the model shows promise for interpreting data and distinguishing temperature and DO effects on fish growth. Applications of the model to other cool and warm water species in the tailwater, in addition to rainbow trout, need to be explored.

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