Developing a Site-Specific Dissolved Oxygen Standard for the Lower Saluda River

Fisheries and Wildlife and Water Quality
Resource Conservation Groups
Joint Meeting

December 7, 2005

Summary of DO Criteria and Standards

- Prior to the 1986 revision, the USEPA Criteria was a simple 5 mg/L minimum.
- This criterion was overprotective against acute mortality if rigorously applied.
- It was also potentially underprotective against chronic effects.
- In addition, states often used 5 mg/L as a daily mean value, allowing unacceptably lower true daily minima.

Criteria Improvement

- In the early 1980s EPA began developing new water quality criteria that included two numbers.
- One number protected against short-term lethal effects and the other protected against long-term chronic effects.
- A similar approach was needed to provide more adequate and scientific criteria for DO.

Key Features of the Latest EPA DO Criteria Approach

- The new DO criteria contained specific minima and long-term average concentrations for various habitats (e.g. cold-water fisheries).
- Growth was the most sensitive chronic effect and a 30-day moving average was recommended to protect growth.
- Monthly averages can be less protective by allowing continuous weeks of lower DO if they don’t all happen to fall within the same month.

Latest EPA Trout-Water Criteria

- For survival of trout: a minimum of 3 mg/L.
- For growth protection: a 6.5 mg/L 30-day average.
- For sensitive cold-water invertebrates: a 4 mg/L minimum.

Site-specific DO Criteria

- Because the 6.5 mg/L 30-day mean is based upon continuous exposure to various DO levels in lab tests, EPA sought a way to apply these data to real-world situations with variable DO levels.
- **EPA and TVA jointly developed a fish growth model that integrates the growth effects of variable DO, allowing site-specific chronic standards to be set that are both protective and realistic.**

Model Calibration

- This modeling approach was used to develop a site-specific chronic standard for the LSR.

- To apply the TVA/EPA model to the LSR, Site-specific trout growth data were needed.

2002- 2003 Trout Growth Study

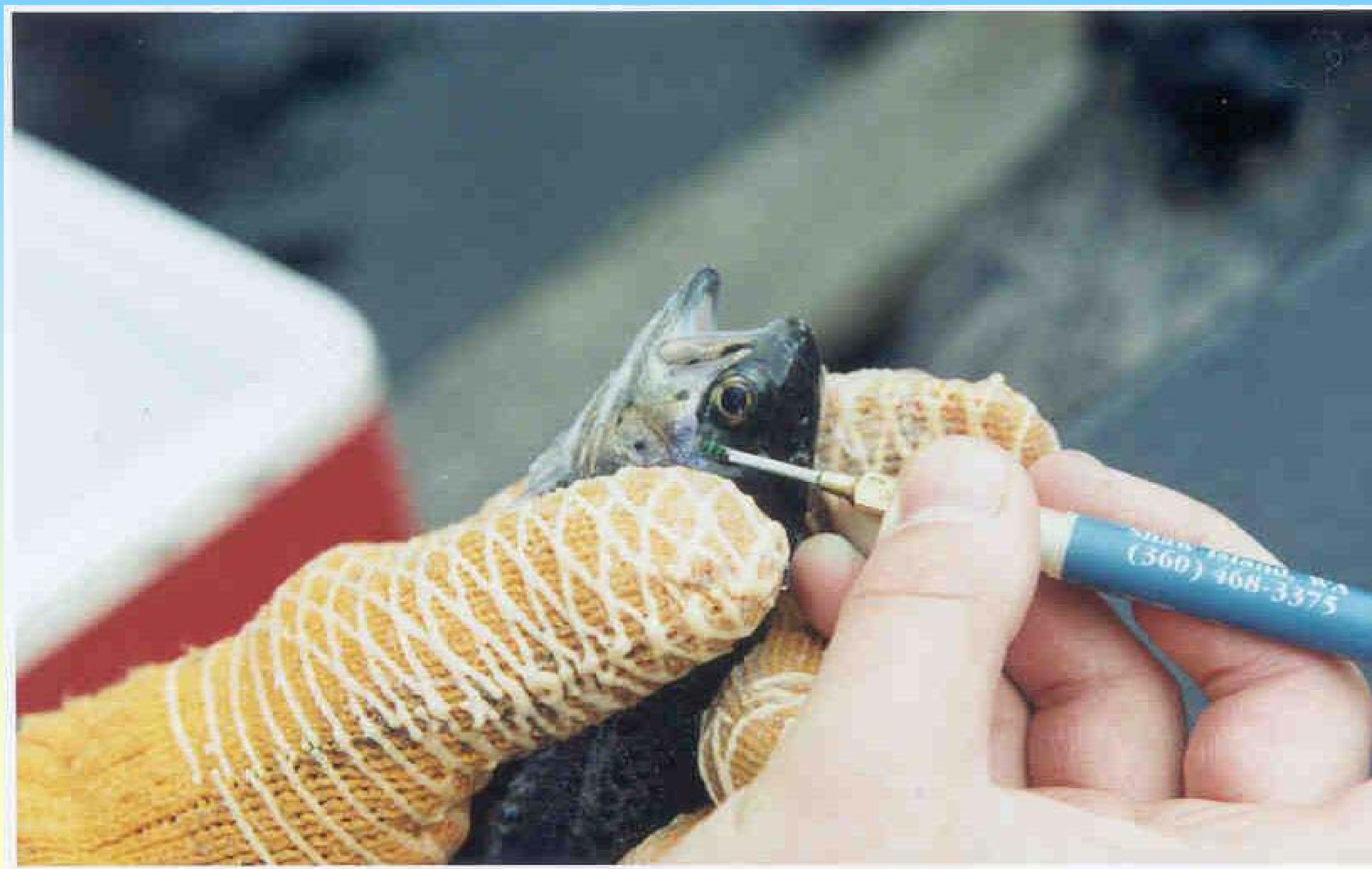
Objectives

- Provide site-specific trout growth data for the LSR
- Provide a food availability term for the bioenergetics model
- Provide general indication of the suitability of current conditions in the LSR

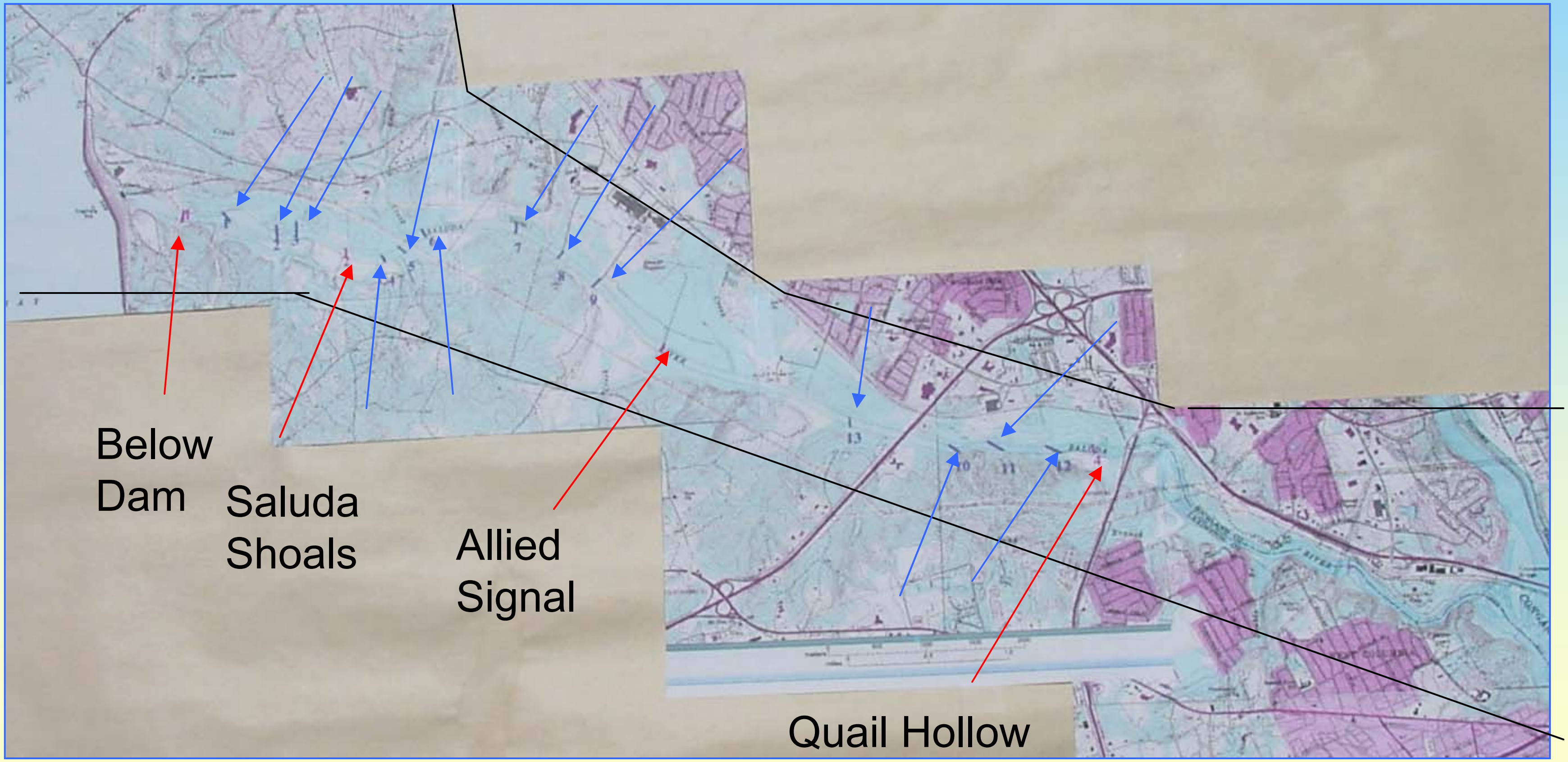
Field Methods

- Xxxxx rainbow trout were tagged at SCDNR's Walhalla Fish Hatchery
- Collaborative effort between Clemson University (USDA Coop Unit), SCDNR, SCE&G and Kleinschmidt

Vi-Alpha Tag Application



Release and Recapture Sites




N12WL


N12WL

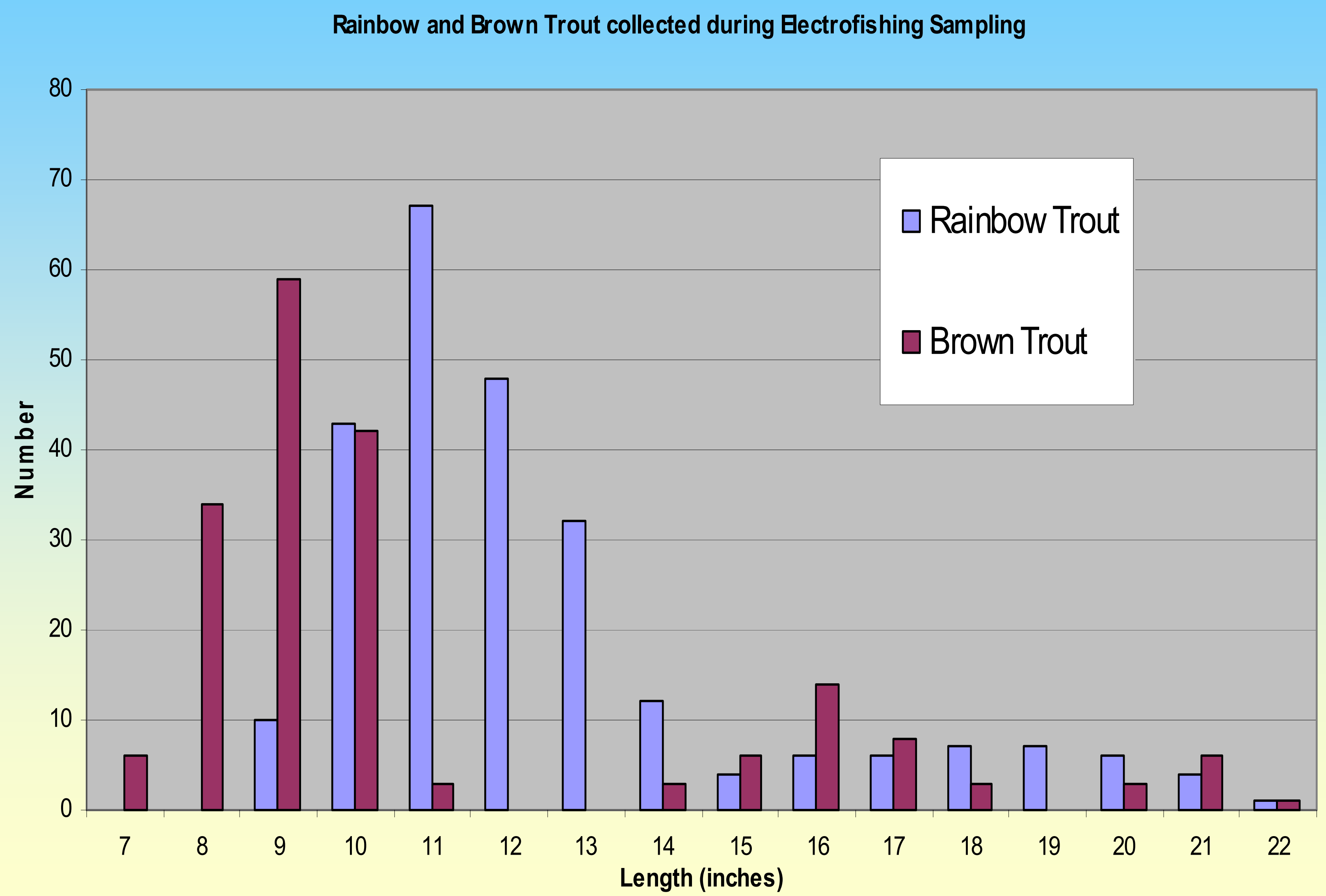
Recapture Results

- Fish collected in April, May and June through electrofishing and angler surveys

- Total of 111 fish recaptured

- Number of fish recaptured by stocking months

December	23
January	32
February	26
March	30


Rainbow and Brown Trout collected during Electrofishing Sampling
80
70
60
50
40
30
20
10
0
Number
Rainbow Trout
Brown Trout
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
Length (inches)

Additional Trout Fishery Information Collected

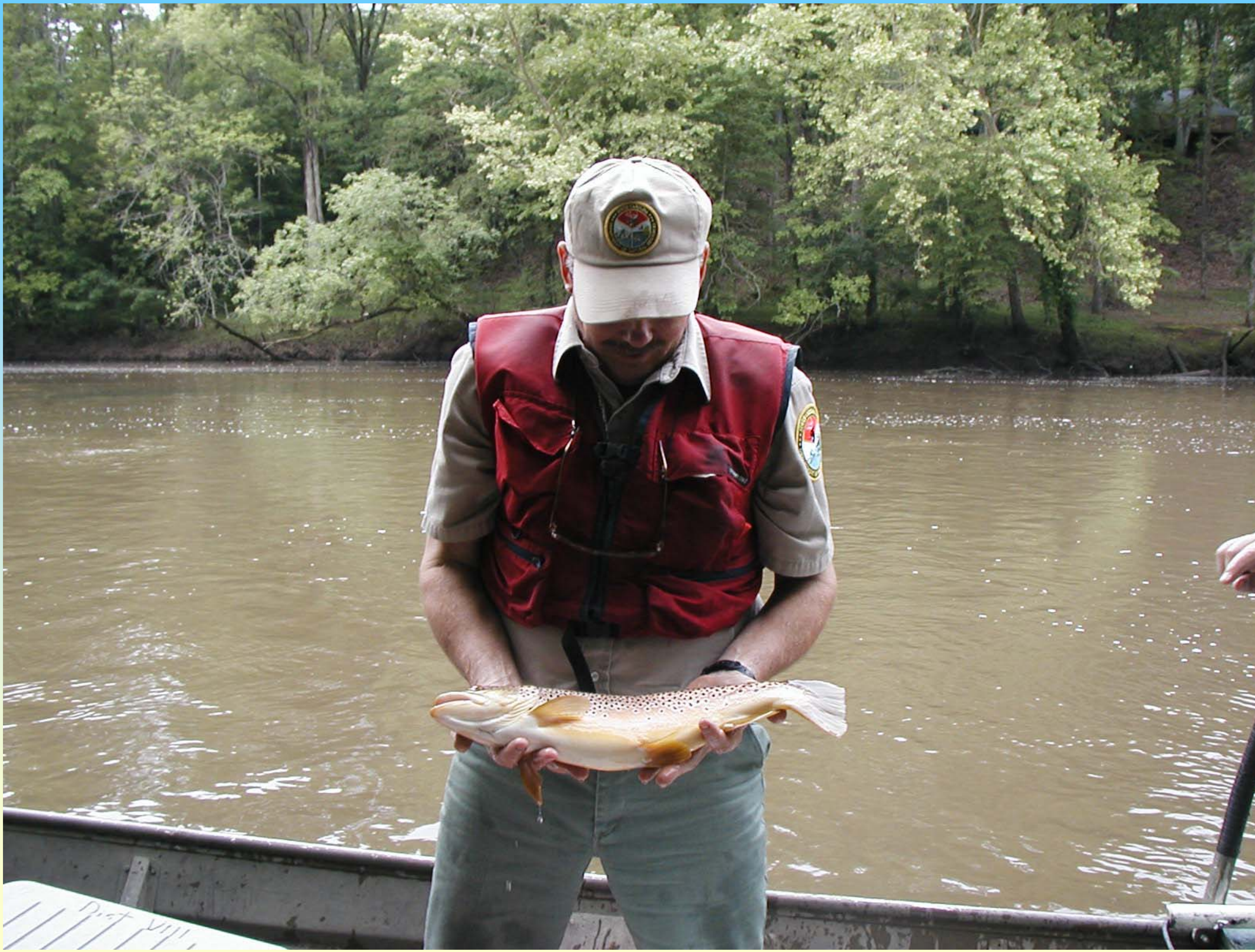
- Total of 441 trout collected during sampling

253 Rainbow Trout: 225 – 550 mm (9 - 22 in)
188 Brown Trout: 175 – 550 mm (7 - 22 in)

37 Rainbow trout collected > 16 inches
35 Brown trout collected > 16 inches

SCDNR collected 24 in brown trout during standardized sampling in May 2003

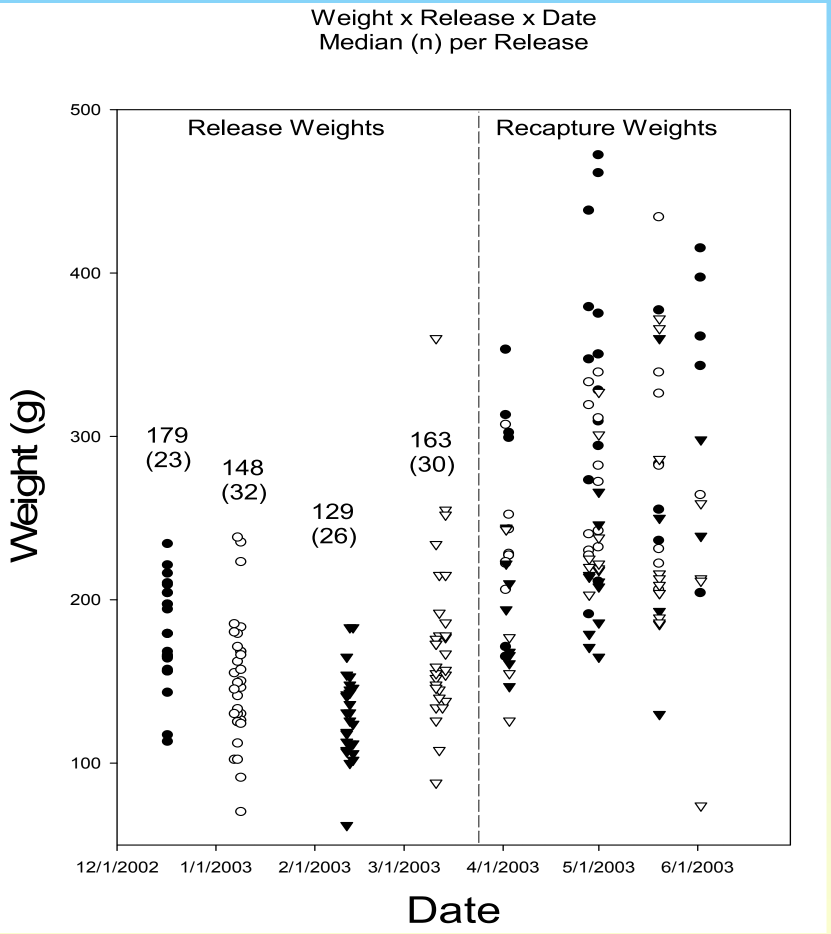

wildco
MODEL No. 118
1/8
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
1/10



General Observations

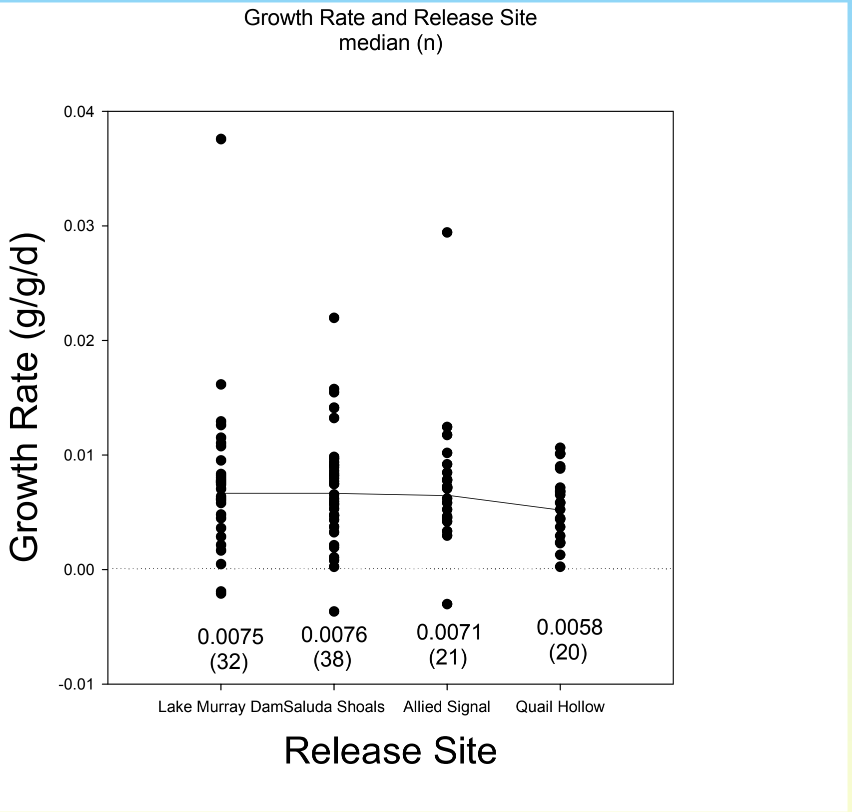
- Trout appear to be healthy
- Fish pressure for trout appears high
- Noticeable decline in trout numbers as striped bass moved in, especially small brown trout numbers
- Fisherman observed using rainbow trout as bait for Striped bass
- Movement of stocked trout limited but does sporadically occur
- Tagged Trout caught in Congaree River between Gervais Street Bridge and Railroad Trestle
- Trout appear to be feeding on Crayfish and Chironomids

Available Data from the Study



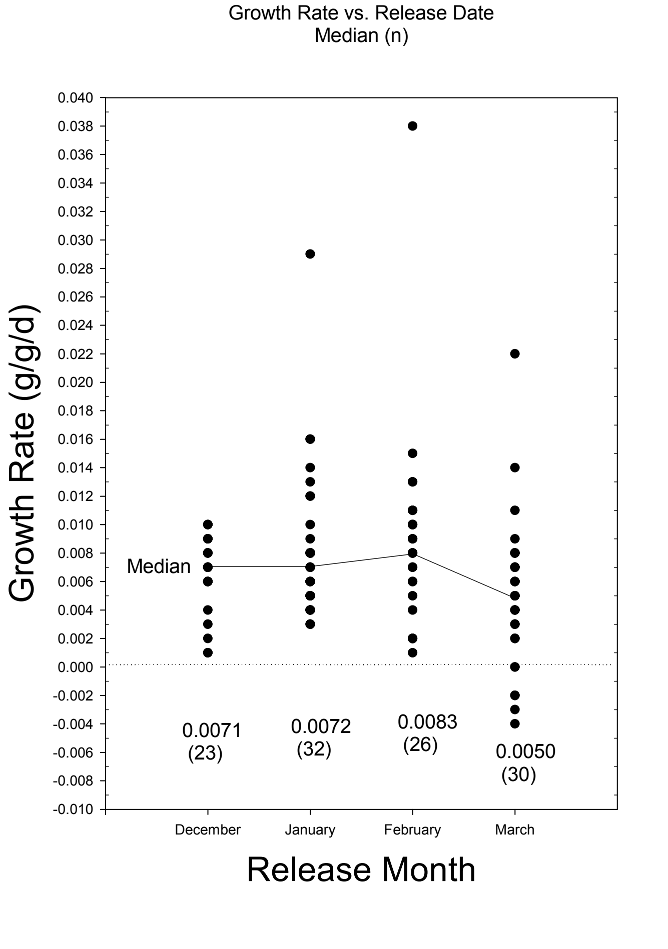
- A total of 111 fish were recaptured from the four releases.
- Detailed analysis of the data was needed to understand effects of size, movement in the stream, stocking site, stocking date and other factors.

Growth and Release Site



- Wide range in growth rate among individual fish at each sites
- Median growth rates similar among four sites, with but slightly lower at downstream site

Growth and Release Date



- Growth rates were similar between all release dates.
- Trout released in March grew at a slightly lower rate than other releases.

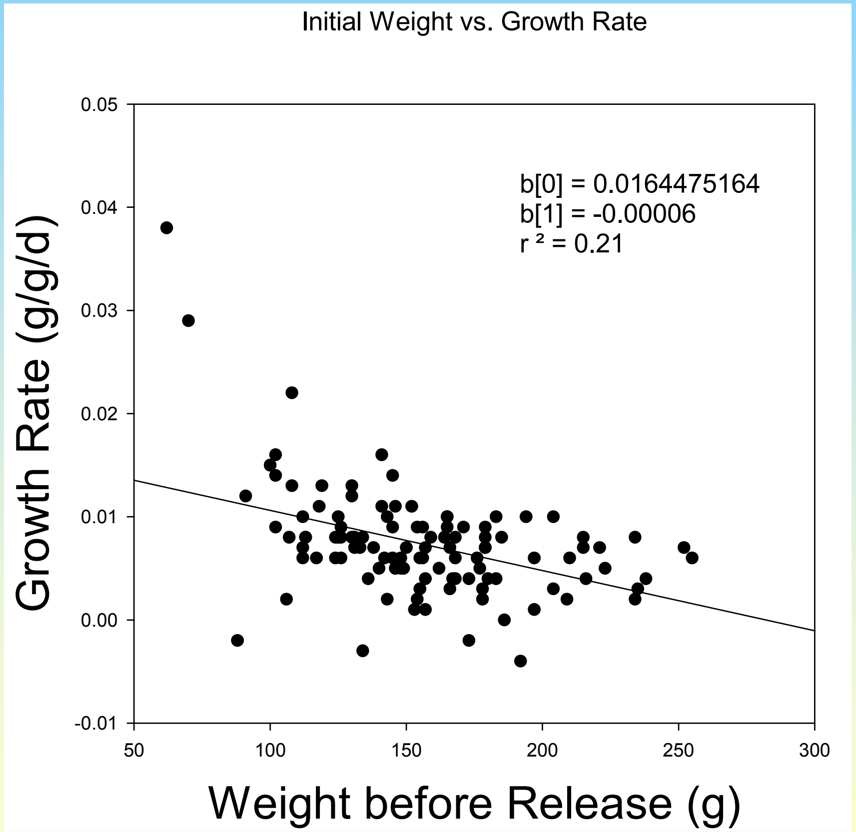
Median Growth Rates (g/g/d) by Site and Date of Release (n)

	Dec.	Jan.	Feb.	Mar.	All Months
Below Dam	0.0072 (2)	0.0070 (6)	0.0095 (11)	0.0048 (13)	0.0075 (32)
Saluda Shoals	0.0077 (11)	0.0083 (12)	0.0075 (9)	0.0063 (6)	0.0076 (38)
Allied Signal	0.0078 (6)	0.0065 (14)	No release	-0.0030 (1)	0.0071 (21)
Quail Hollow	0.0030 (4)	No release	0.0095 (6)	0.0055 (10)	0.0056 (20)
All Sites	0.0071 (23)	0.0072 (32)	0.0083 (26)	0.0056 (30)	0.0071 (111)

Factors with potential to influence growth in the study

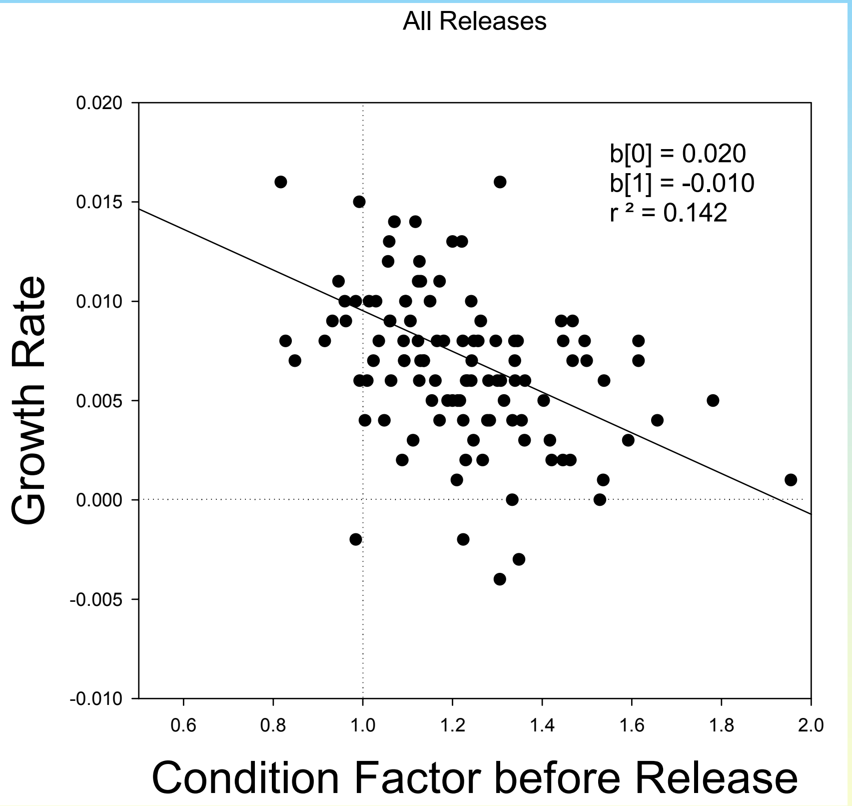
- Size of trout at release
- Condition of trout at release
- Location of recapture and possible residency
- Direction of movement after release (upstream or downstream)
- Distance traveled after release

Growth vs. Size at Release



- There was a slight tendency ($r^2 = 0.21$) of smaller fish to grow at a faster rate than larger fish.
- This is typical of fish with adequate rations.

Growth and Condition Factor

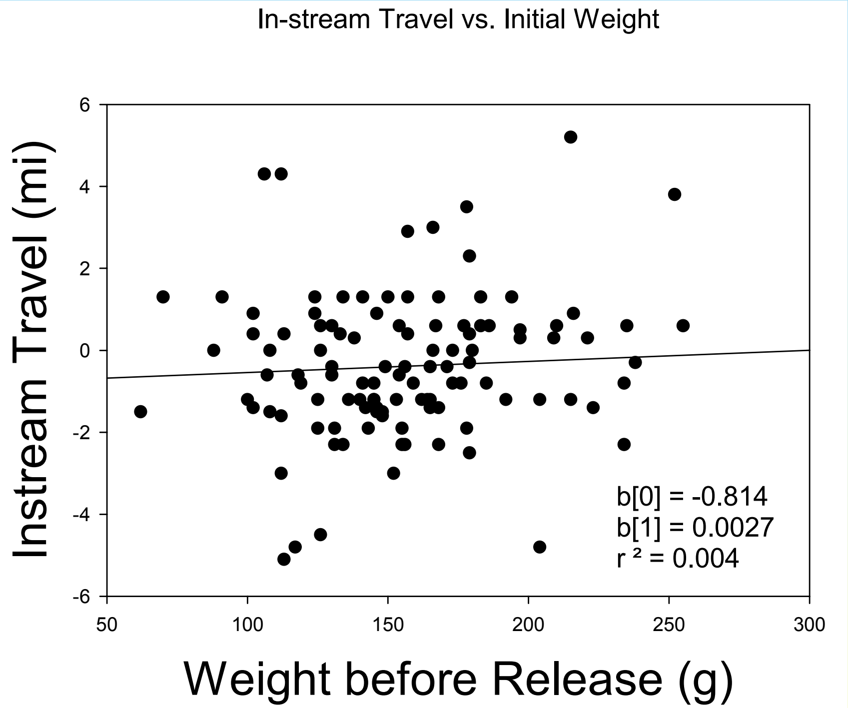


- There was also a tendency for higher growth rates for fish with lower initial condition factors.
- i.e., skinny fish grew faster than fat fish
- Effect of natural vs. hatchery environment

Summation of growth and size and condition at release

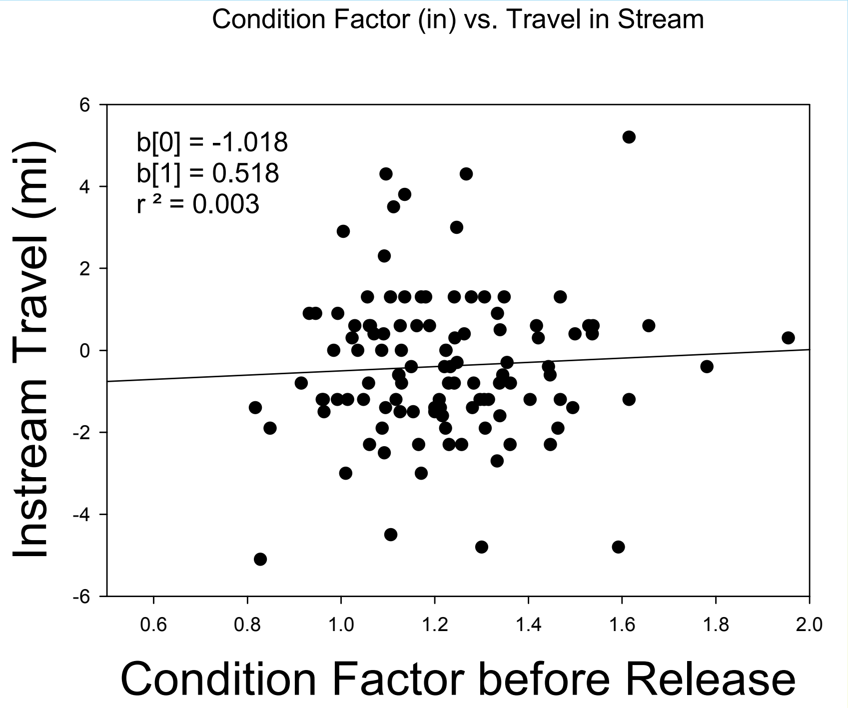
- Smaller fish grew a little faster than larger fish (both for initial weight and initial length)
- Fish with lower condition factors grew at a faster rate than fish with higher condition factors
- Condition factors tended toward a central value of about 1.1

Size and movement after release



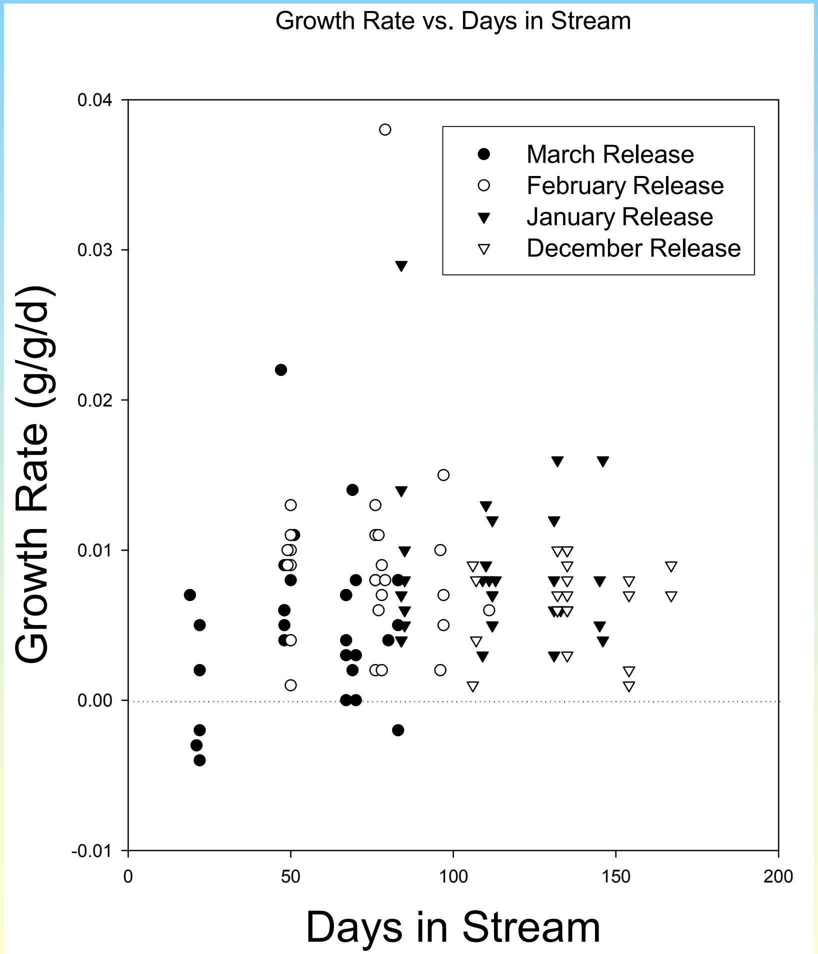
- There was no effect of size at release on distance or direction of travel after release
- Fish moved as much as five miles up- and down-stream
- No sampling below RM 3 (Quail Hollow)

Condition factor and movement after release



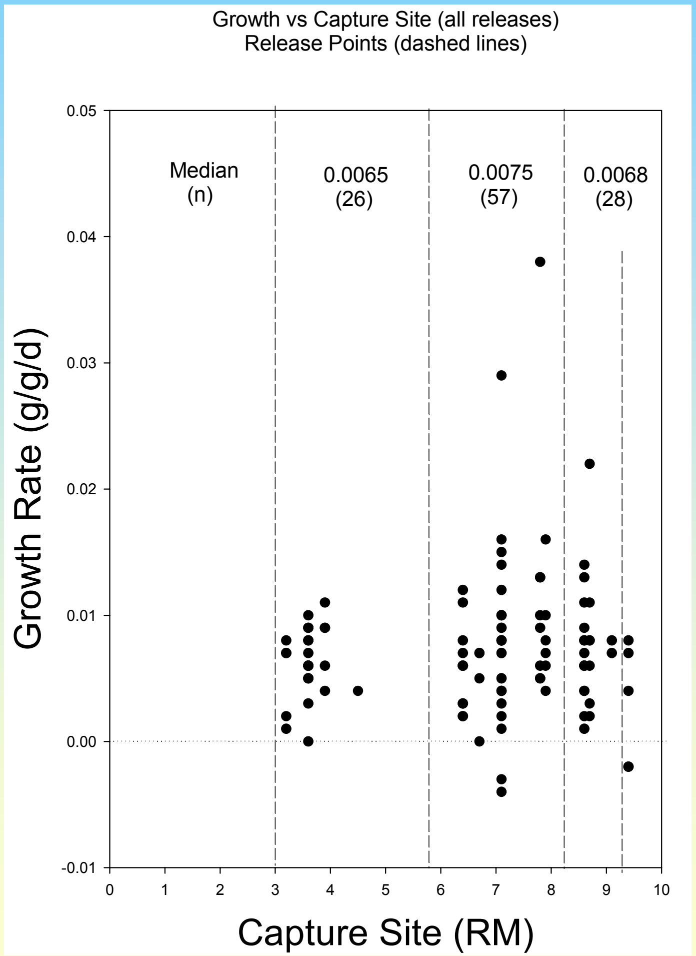
- There was no effect of condition factor on direction or distance traveled after release

Growth and time between release and recapture



- Except for the early recapture of fish from the March release, there was no clear relationship between time in stream and growth rate.
- All other releases were in the stream for 2 to 4 months before recapture

Growth and Recapture Site



- Fish recaptured between the two lowest release points showed slightly lower growth rates than fish in the upper four miles of the tailwater
- Upper areas see lowest DO levels

Decisions regarding bioenergetic model inputs

- There was a wide range of growth rates seen among the recaptured trout.
- Differences in growth rates were not greatly influenced by release site, release dates, size at release, condition at release, movement in stream, or recapture location.
- We decided to use the overall median growth rate from the study for determining general food availability for use in the bioenergetics model.

Saluda Tailwater Turbine Venting Model Calibration

Gary E. Hauser, P.E.
Loginetics, Inc.

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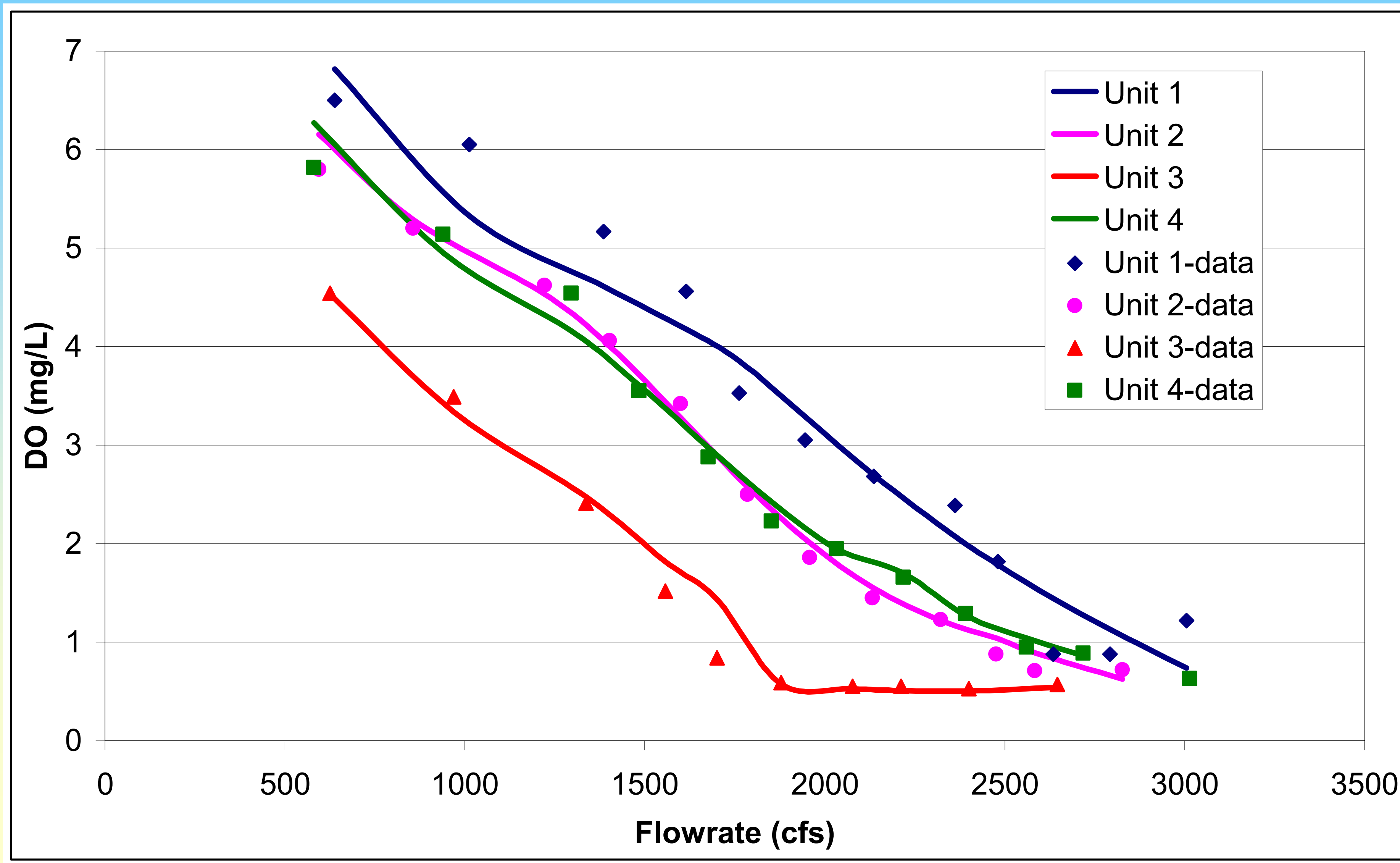
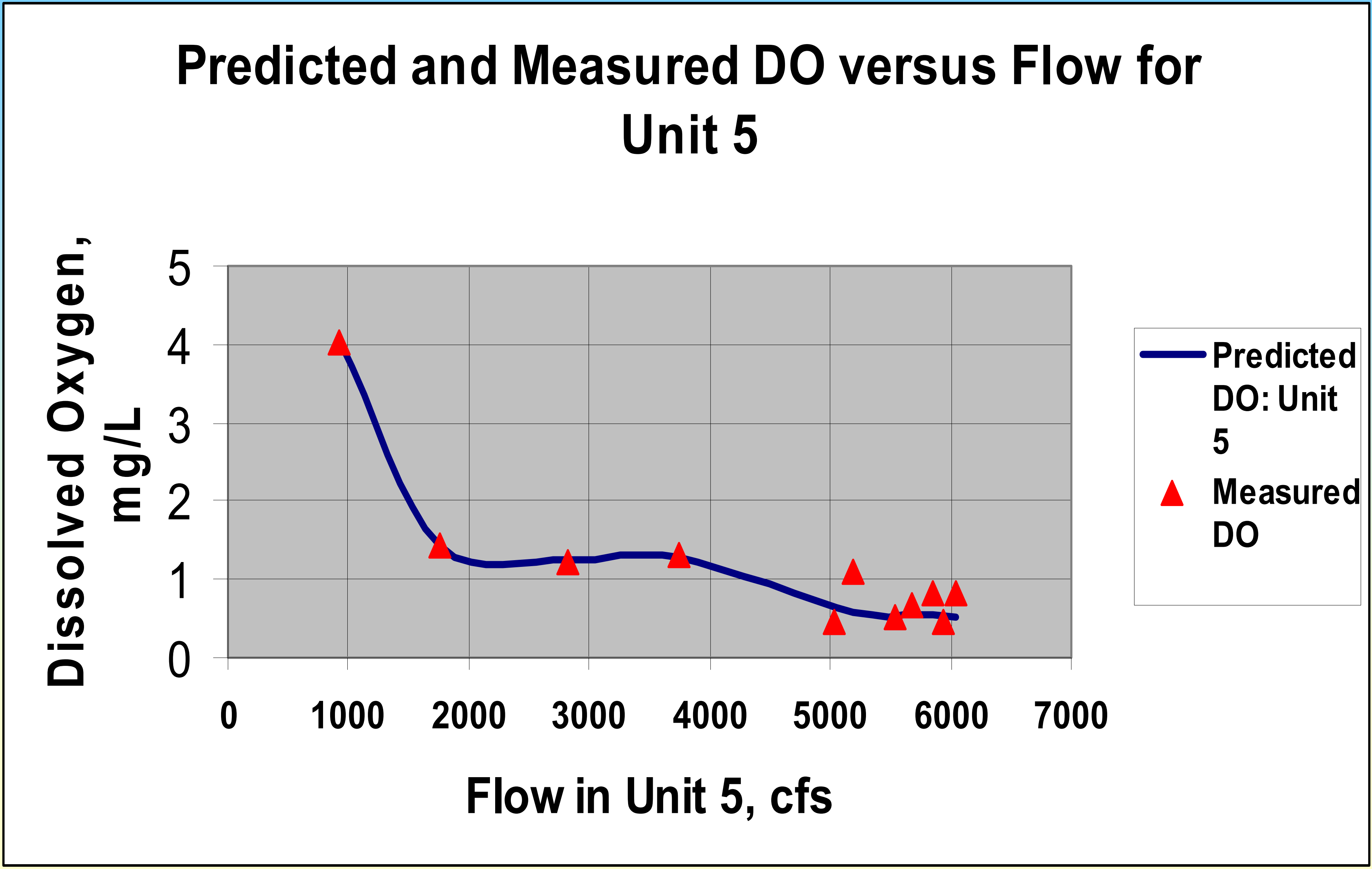
- MS Civil Engineering, University of Kansas, water resources engineering
- 23 yrs on TVA reservoir release improvements team, responsible for reservoir and tailwater modeling and minimum flow/aeration technologies, especially aerating weirs, at 30 hydroprojects for TVA and other utilities.
- 12 yrs as leader of WQ modeling team - TVA Engineering Laboratory.
- Co-developer of EPA-TVA bioenergetics model to predict fish growth in fluctuating temperature and DO regimes.
- Developer of hydrodynamic, water quality, and fish habitat models for TVA River Modeling System.
- Author of 100+ technical publications on aeration and modeling to resolve hydropower environmental problems.
- 2 patents on aerating weir technologies.

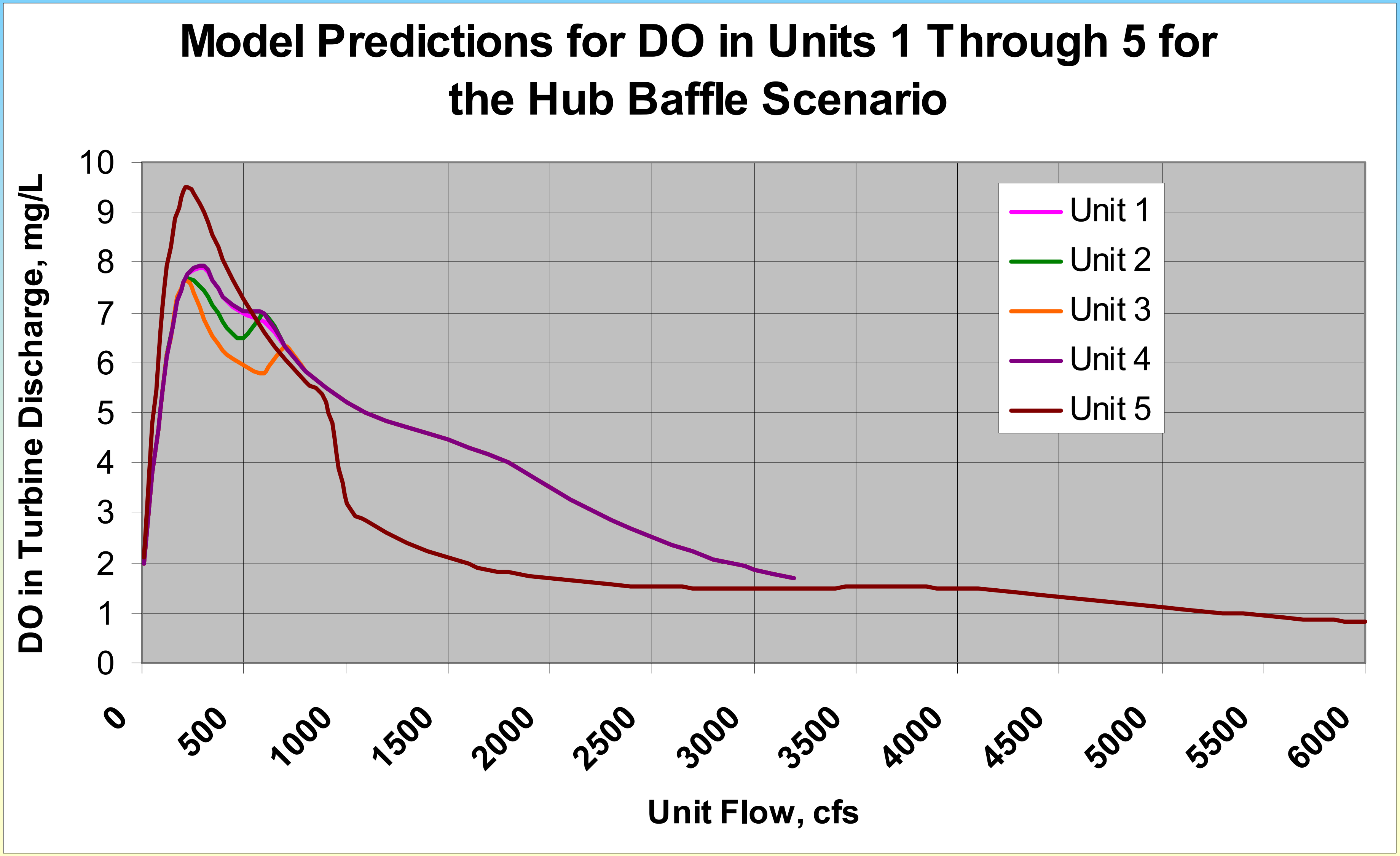
Turbine Venting Model Calibration



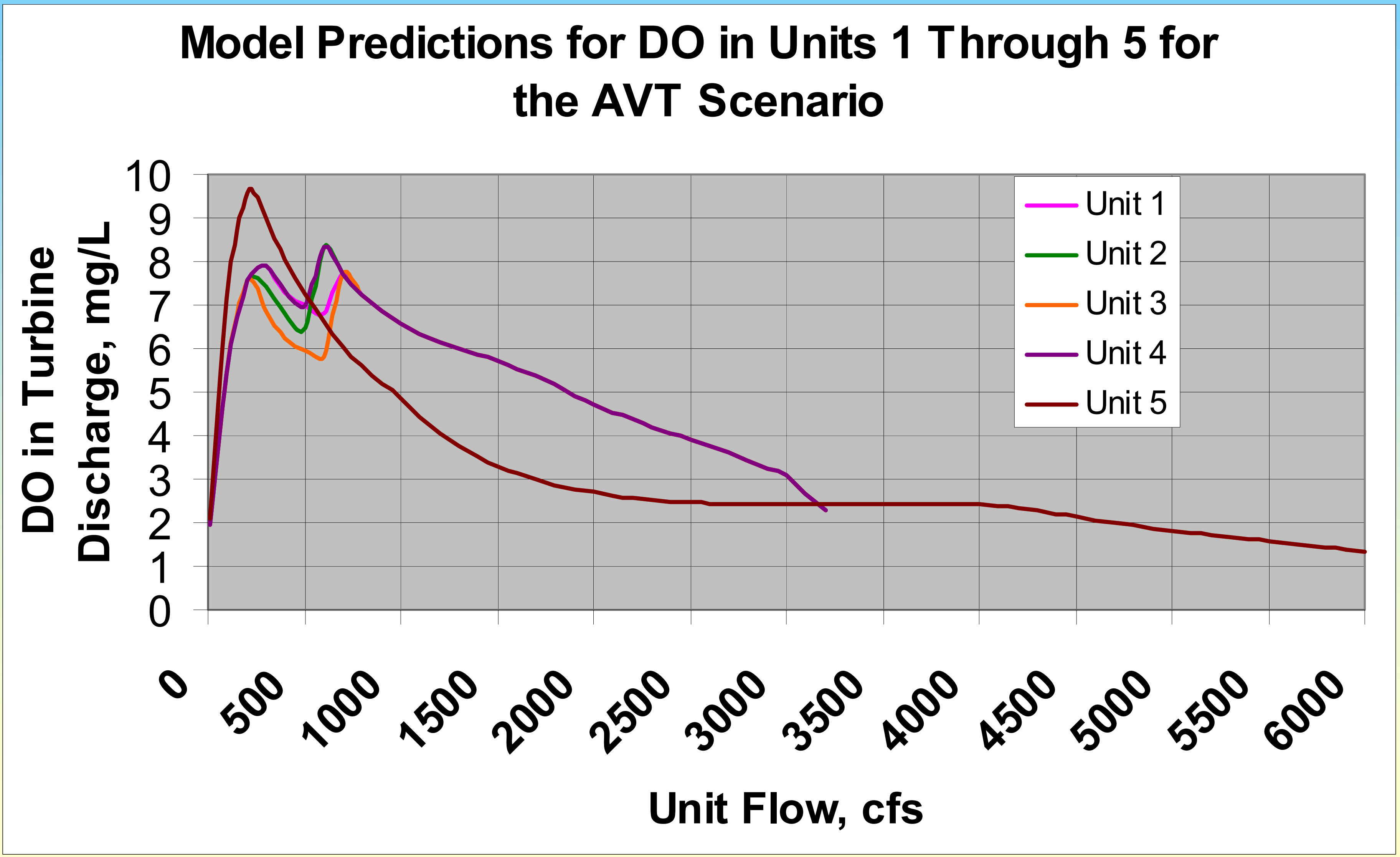
Turbine Venting Model Calibration



Turbine Venting Model DO Simulation



Turbine Venting Model DO Simulation

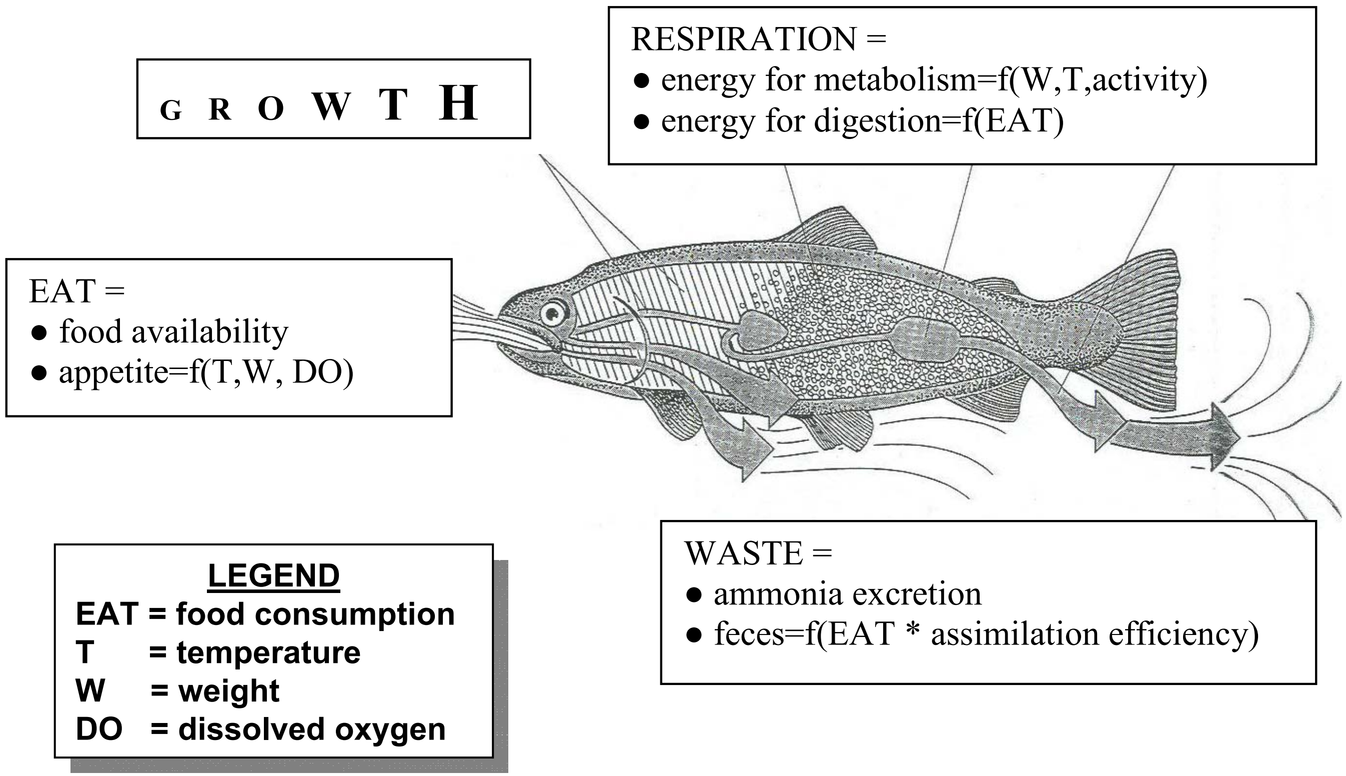


Saluda Tailwater Bioenergetics Model Calibration

Gary E. Hauser, P.E.
Loginetics, Inc.

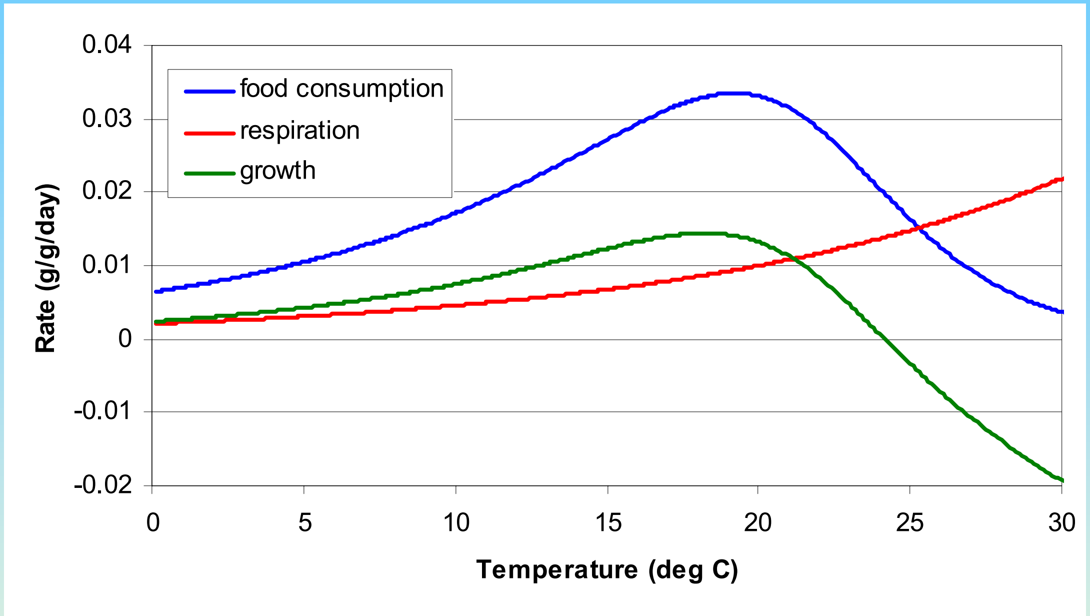
Overview of Bioenergetics Model Processes

Growth = Food Consumption - Waste - Respiration

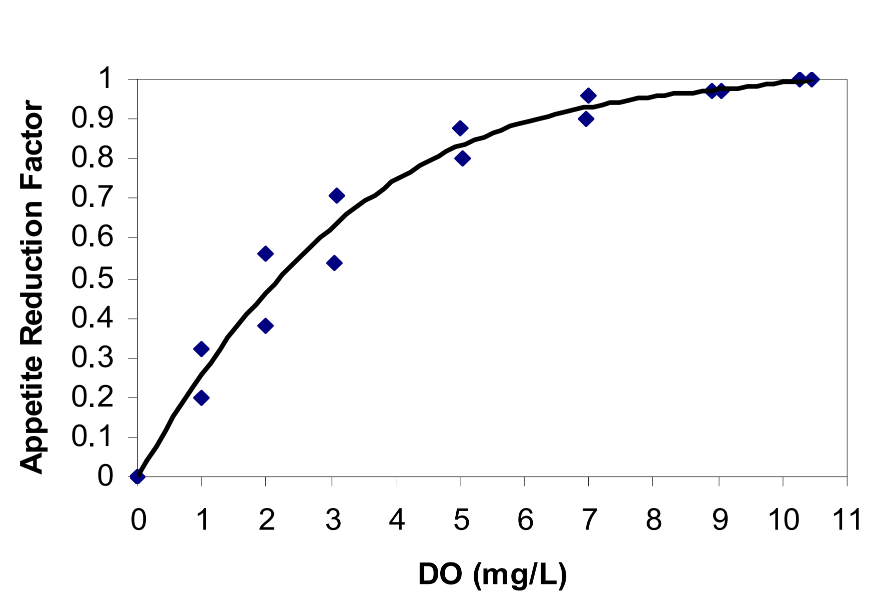


Bioenergetics Model Rainbow Trout Characteristics

RBT Food Consumption, Respiration = f (T)
Ref: From & Rasmussen (1984)



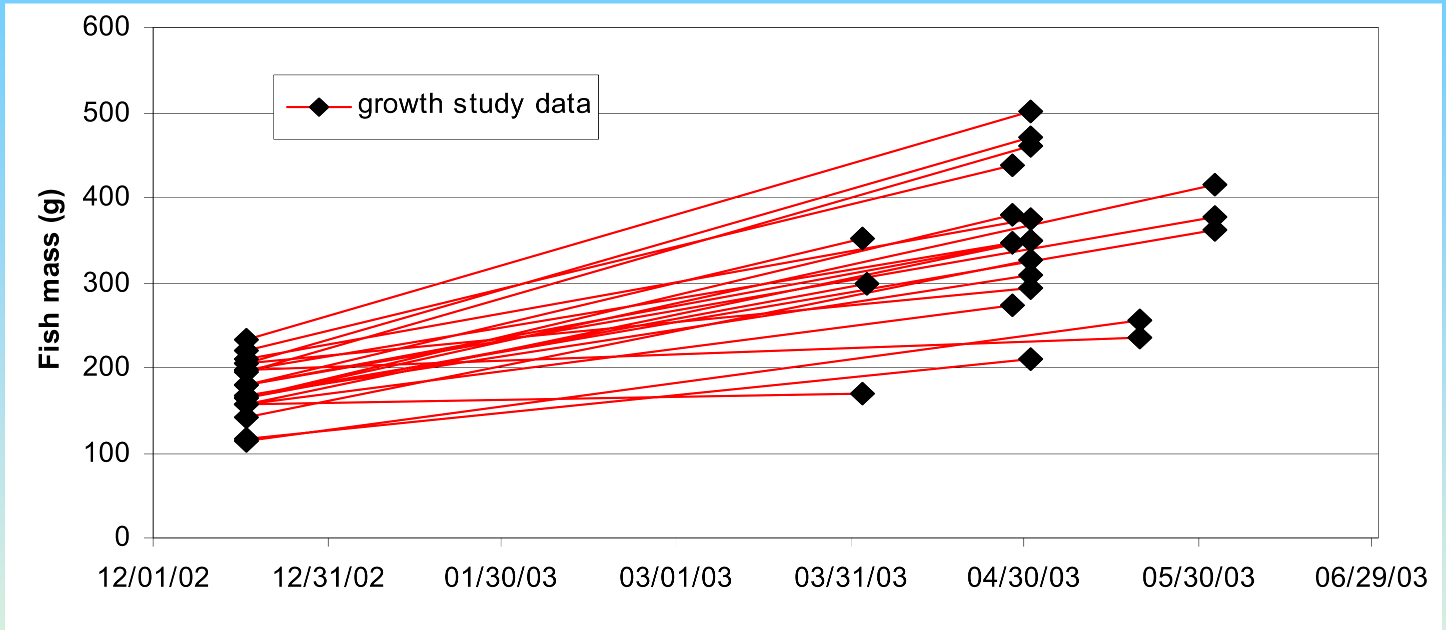
RBT Appetite = f (DO)
Ref: EPA-Duluth data



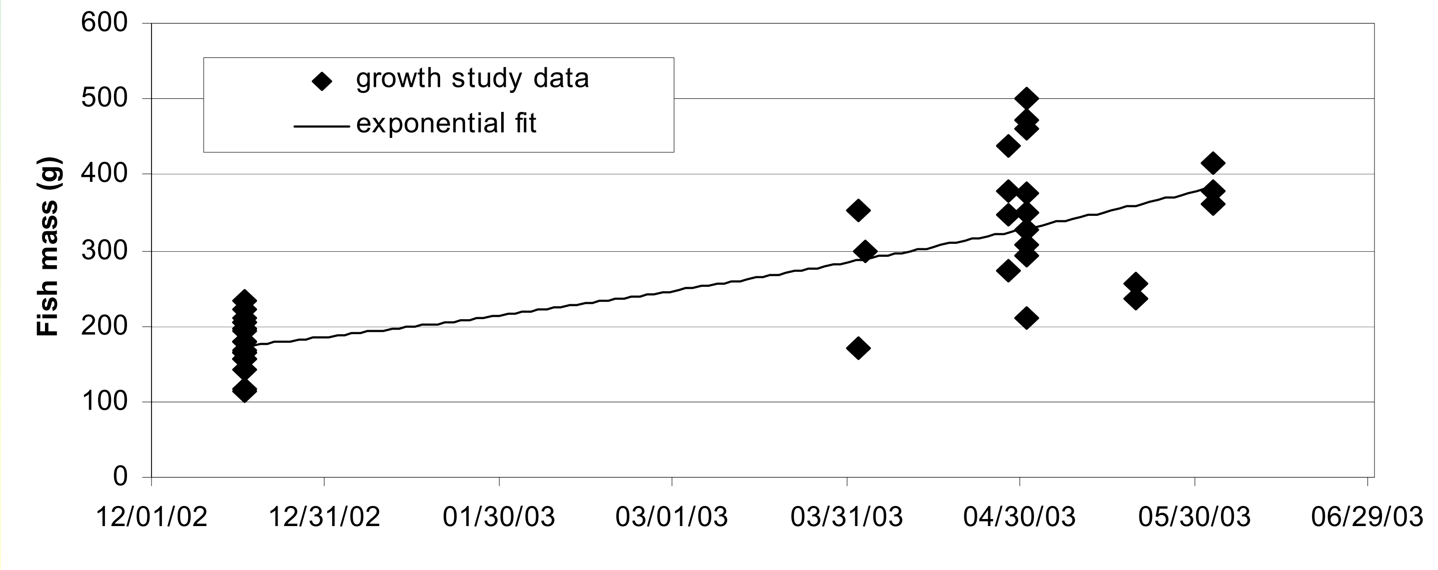
Calibration Process

- Calibrate tailwater model
- Run tailwater model: 1988-1989   2002-2003
- Run bioenergetics model for various food availability levels (fraction of appetite)
- Compare modeled vs measured growth
- Quantify food availability level that best matches growth study results

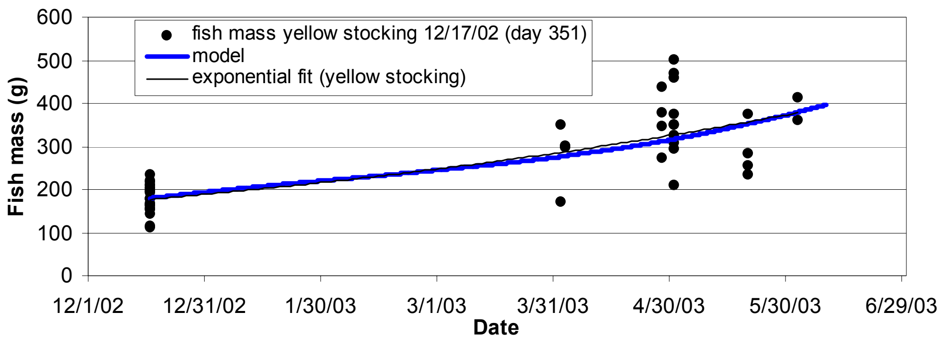
Use of 2002-2003 RBT Growth Data for Model Calibration

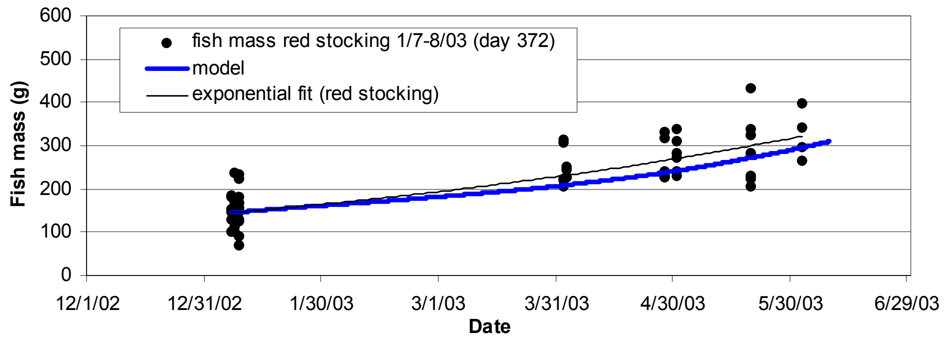


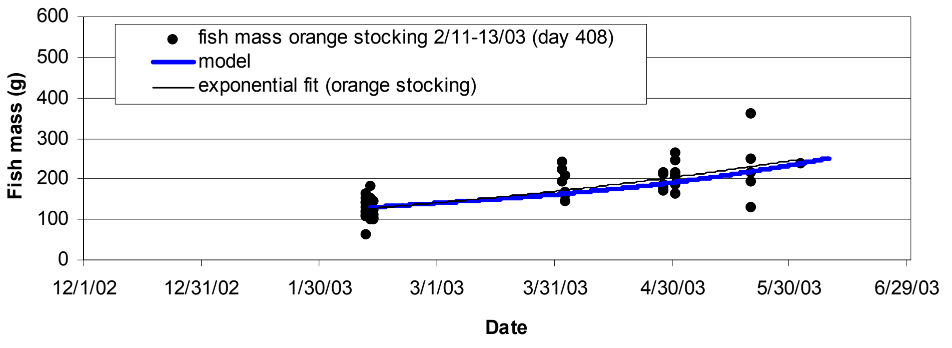
meaning of measurements

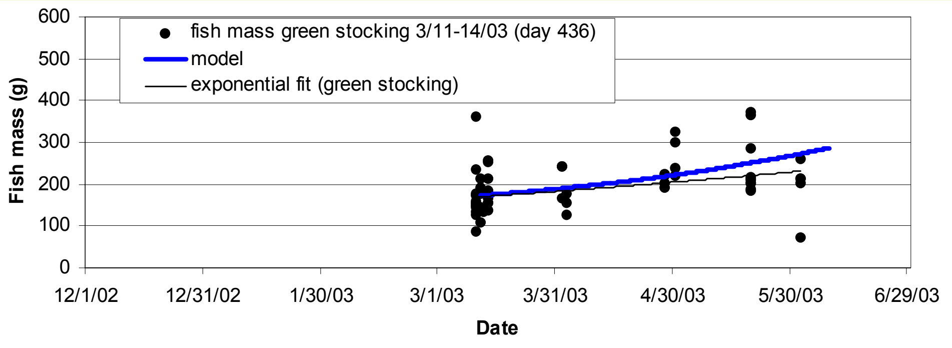


prepared for model calibration









Bioenergetics Model Calibration 2002-2003 Growth Study

Average growth = 0.67 in/mo

Food availability = 68% of maximum appetite

Growth Rate Comparison – SE Tailwaters

Dam	State	Length (mi)	Period	Start size (in)	T (deg C)	DO (mg/L)	Grow rate (in/mo)	Notes
various	KY	--	current				0.5	per KDFWR staff – BT, RBT
Wolf Creek	KY	50	Apr-Nov 1997 Apr-Nov 1998 Apr-Nov 1999 Apr-Nov 2000 Apr-Nov 2001 Apr-Nov 2002	7.5 8.2 8.2 7.0 7.4 7.7	9-27 9-27 9-27 9-27 9-27 9-27	3-10 3-10 3-10 3-10 3-10 3-10	0.52 0.48 0.49 **0.71** **0.69** 0.54	Dreves (2003) KDFWR - BT
Center Hill	TN	26	Mar-Jul 1997	9.4		4-7	0.51	Devlin (1999) TTU - RBT
Norris	TN	30	Jan-May 1975 Jan-May 1985 abv weir Jan-May 1985 bl weir Jan-May 1986 abv weir Jan-May 1986 bl weir	9.3 7.5-8.0 7.5-8.0 7.0-7.5 7.0-7.5	7-10 5-9 5-9 6-10 6-10	>8 >8 >8 8-10 8-10	0.62 0.48 0.30 0.38 0.43	1993 TVA data - RBT bioenergetics model report weights using CF=1.1; growth probably T limited
South Holston	TN	14	Mar-July 1992 July-Sep 1992 Mar-Sep 1992 1997 – Mar. stocking 1997 – Sep stocking 1997	4.72 7.64 4.72	6-8 6-8 6-8 <22 <22 <22	8-12 8-12 8-12 >6 >6 >6	0.58 **1.69** **0.90** 0.35 0.63 0.43	1992 TVA - RBT data Most growth in late summer/fall when the DO=12 mg/L T=8 C Bettoli, et al (TTU) - RBT Bettoli, et al (TTU) - RBT Bettoli, et al (TTU) - BT
Wilbur	TN		1998 – Mar stocking 1998 – July stocking				0.27 0.19	Bettoli, et al (TTU) - RBT
Saluda	SC	10	Nov 1988-Apr 89 **Dec 2002-Jun 2003**	6 (40g) 10 (150g)	10-18 8-15	0.5-12 4-12	0.25 **0.67**	Before aeration - RBT **Current aeration - RBT**

Growth Rate Comparison – Other Locations

Dam	State	Length (mi)	Period	Start size (in)	T (deg C)	DO (mg/L)	Grow rate (in/mo)	Notes
Sierra Nevada streams	CA		Avg 1987-1996 site #1 (fall-spring) Avg 1987-1996 site #2 (fall-spring) Avg 1987-1996 site #1 (summer) Avg 1987-1996 site #2 (summer)	Age 0 Age 0 Age 1 Age 1	Avg 7.2 Avg 10.2 Avg 14.9 Avg 18.1		0.44 0.54 0.20 0.06	Railsback and Rose (1999) - RBT

Saluda Tailwater Bioenergetics Model Application

Modeled Effects of Aeration Options on Trout Growth

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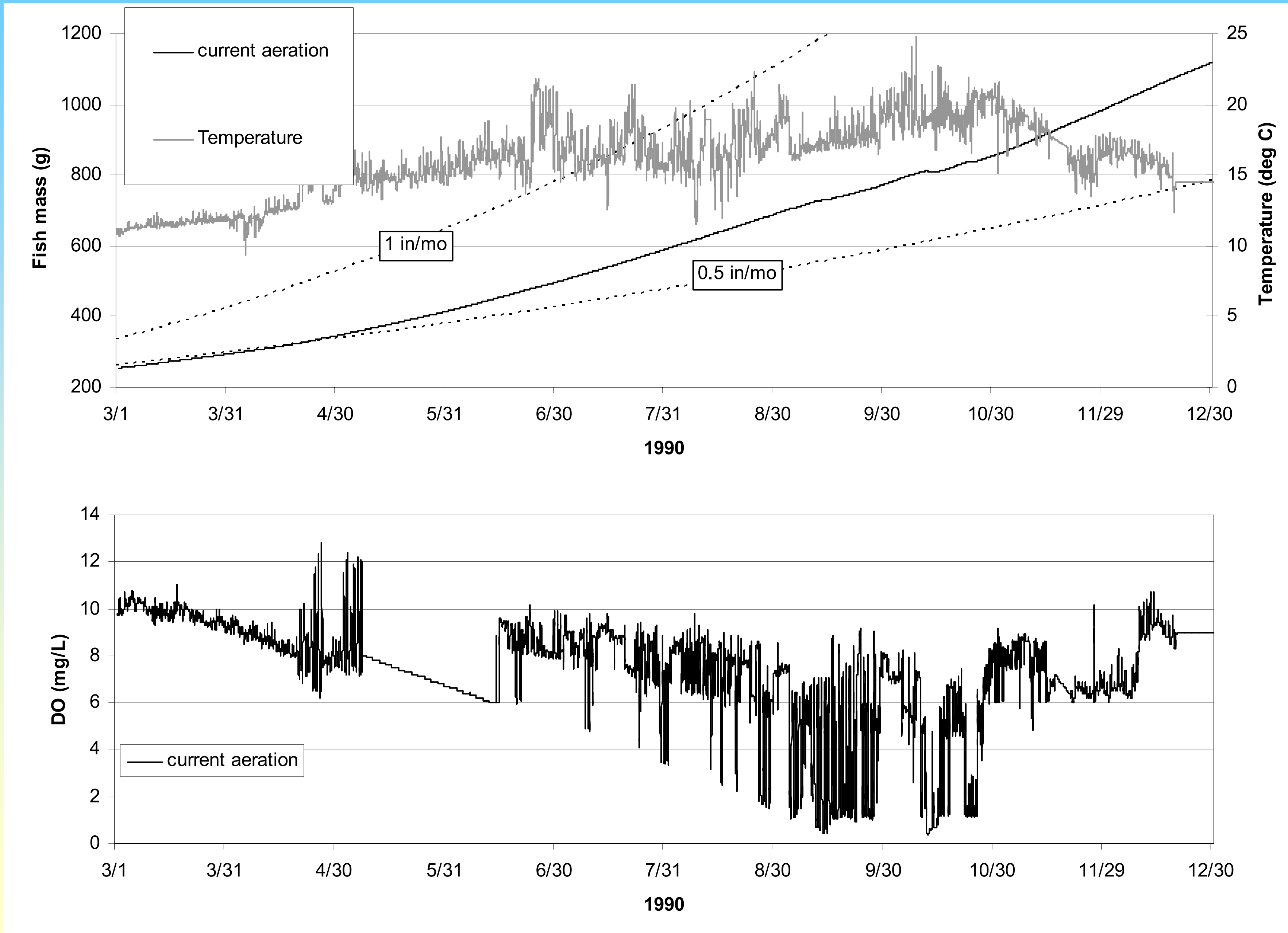
Notes on Growth Simulations For Various Aeration Options

- Used turbine venting model release DO results directly
    - no tailwater aeration or photosynthesis-respiration
- Used measured temperature at monitor d.s. of dam.
- Used 68% food availability for all cases
- Growth based on temperature, DO, food availability
    - Avoidance, predation, competition not simulated
    - Mortality not simulated – negative growth only (could have mortality or avoidance if exposed to DO < 2)

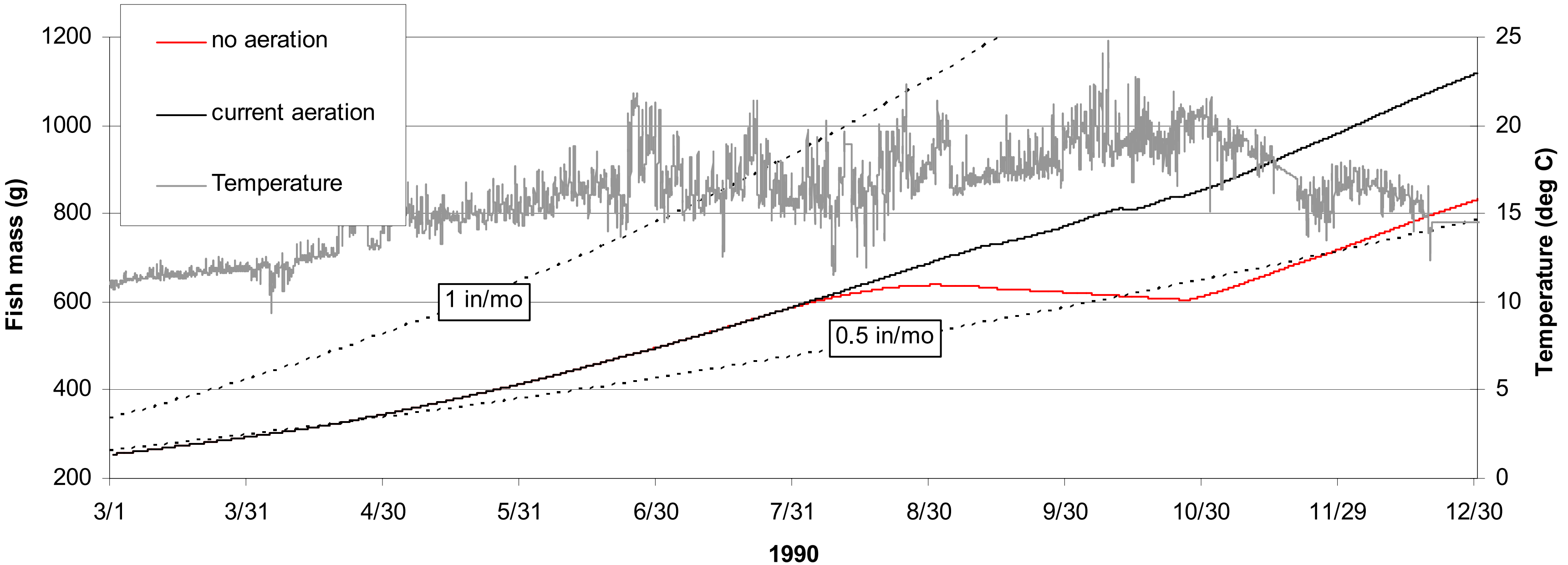
Aeration Scenarios

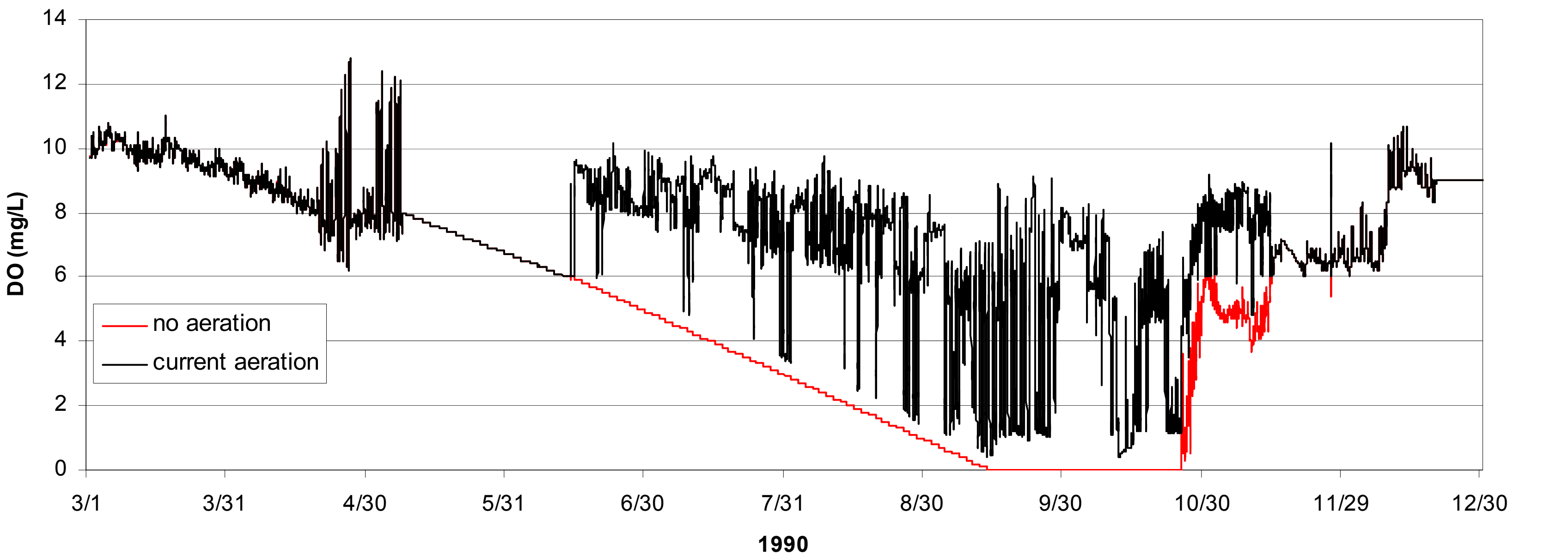
- No aeration
- Current aeration
- Hub baffles
- Auto - venting turbines (AVT)
- AVT with 4.0 mg/L minimum
- AVT with 6.0 mg/L minimum

1990 (wet year)

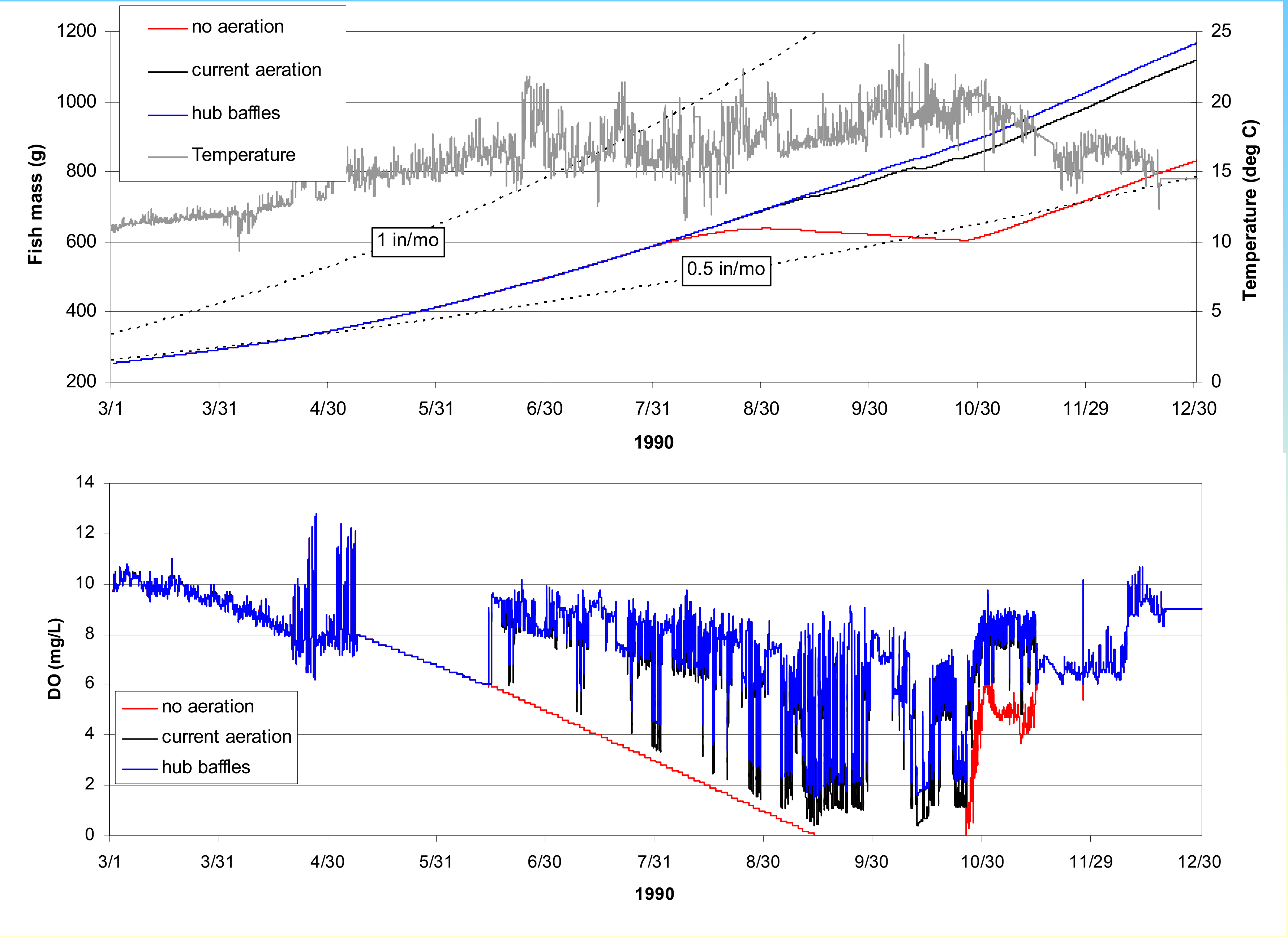


1990 (wet year)

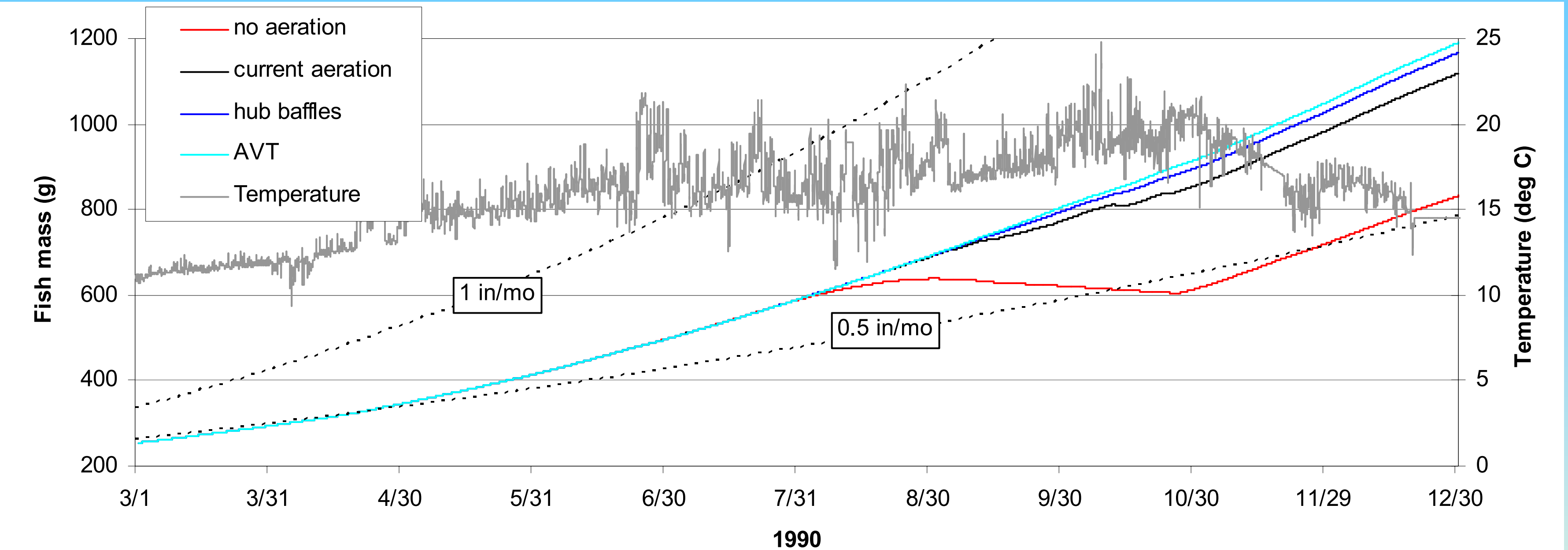


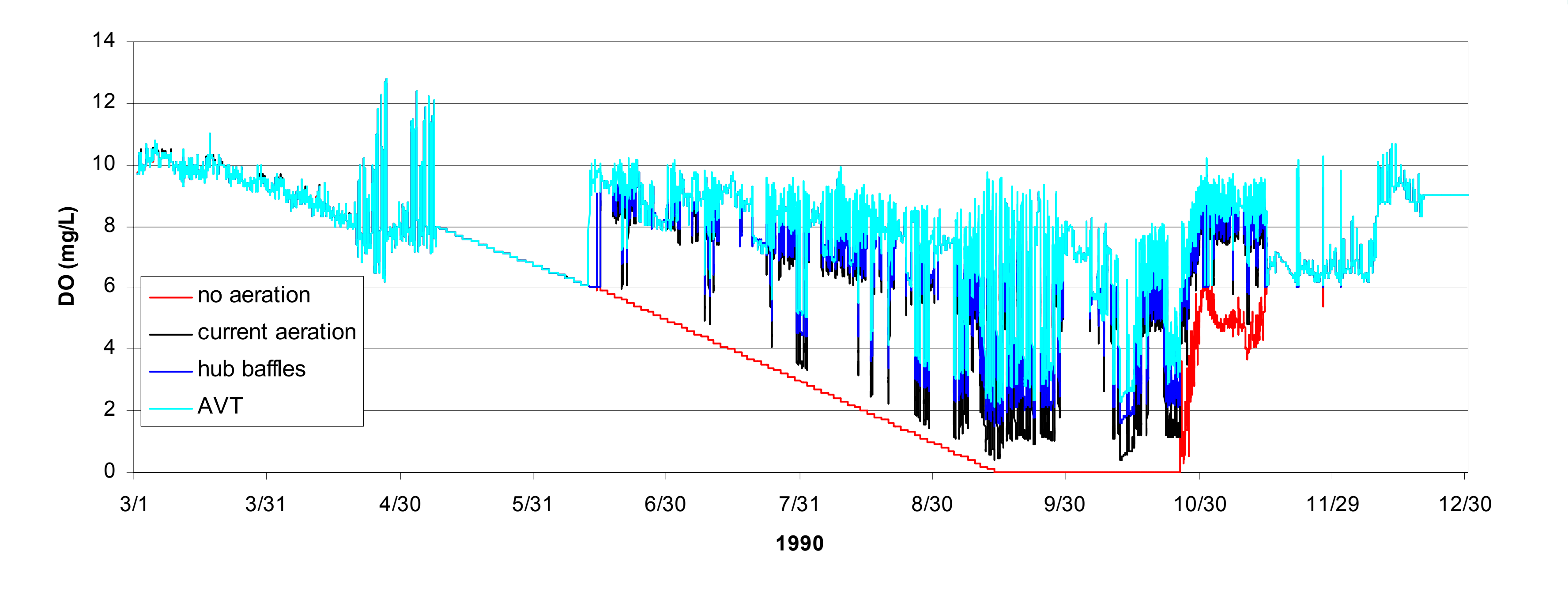


1990 (wet year)

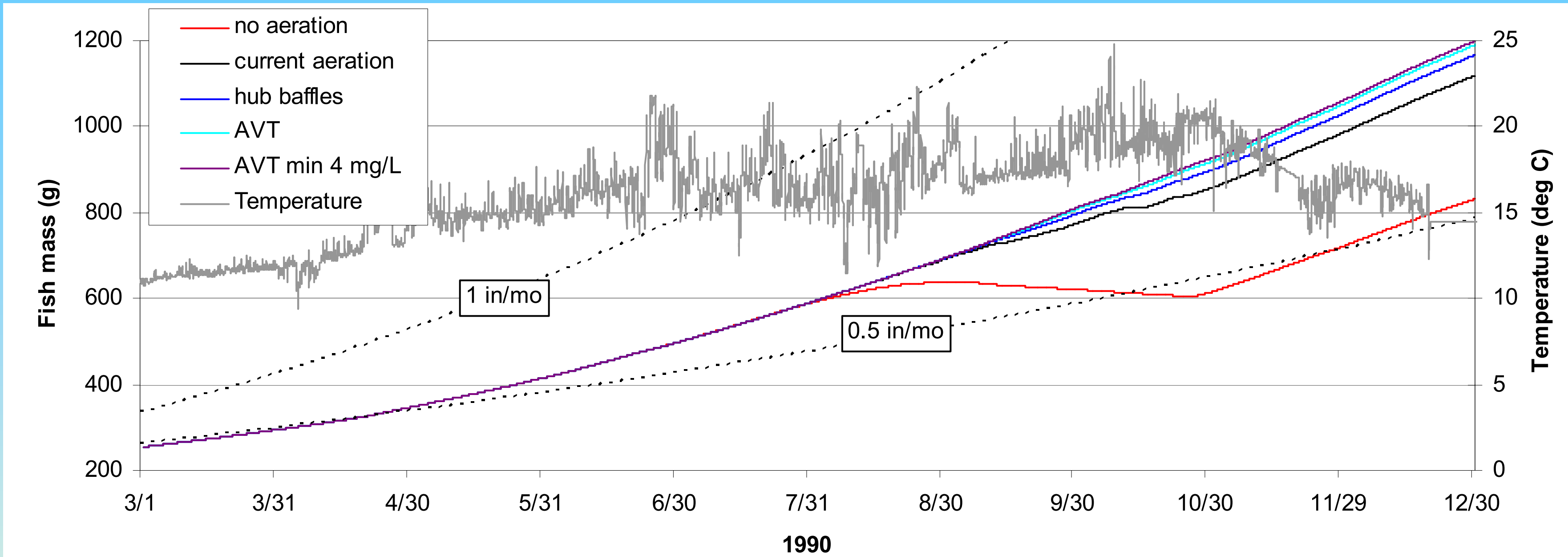


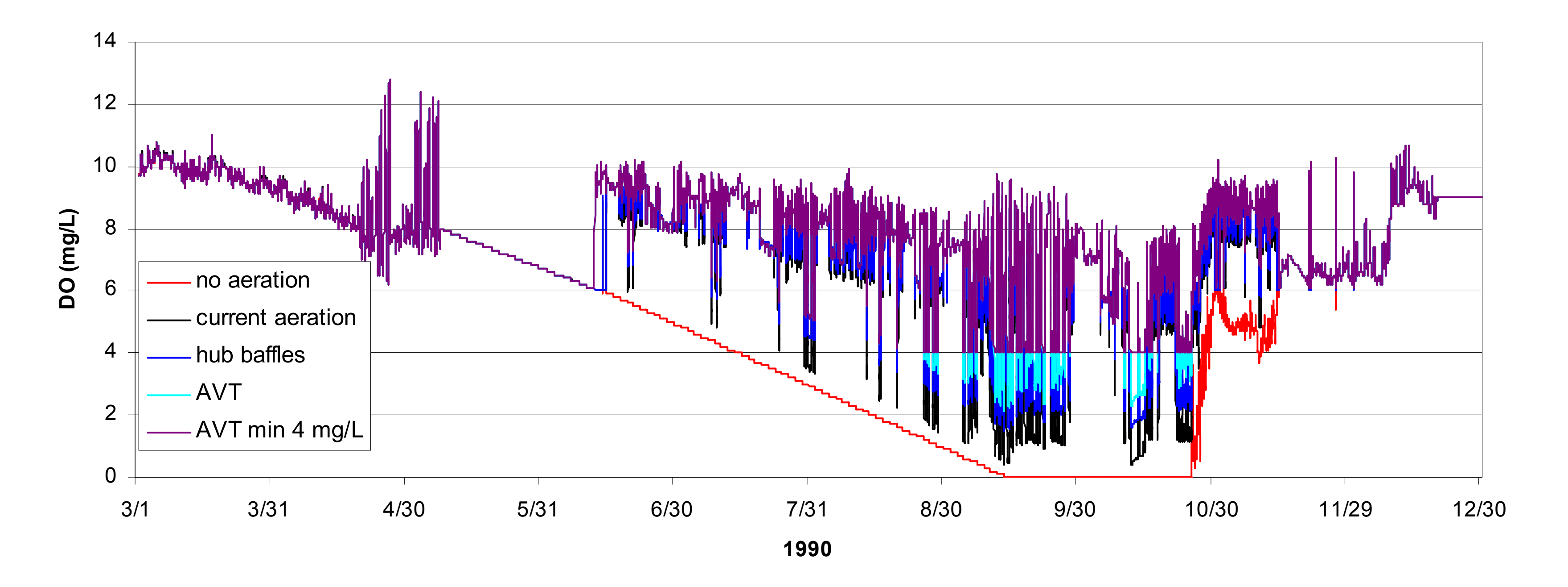
1990 (wet year)



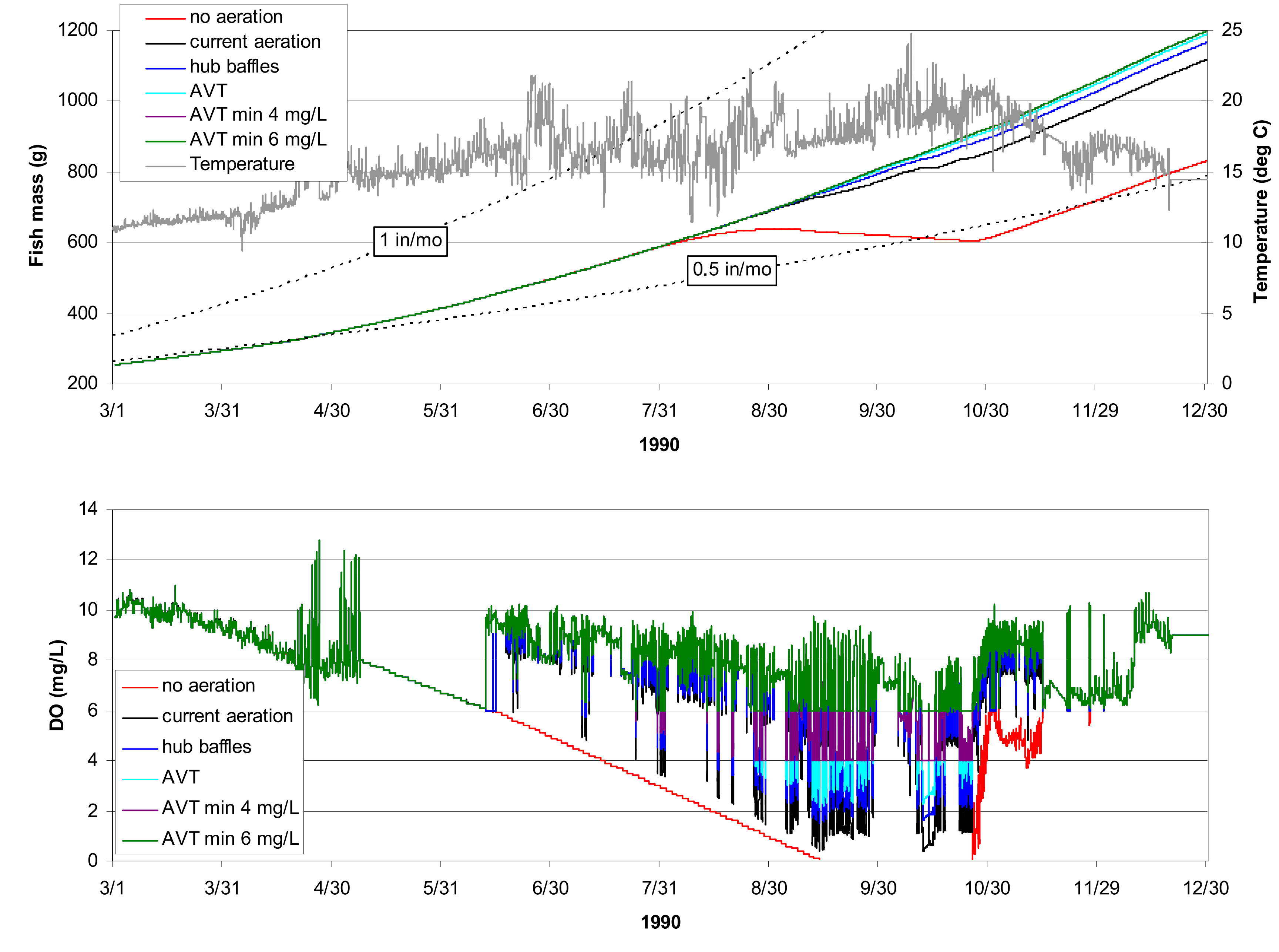


1990 (wet year)

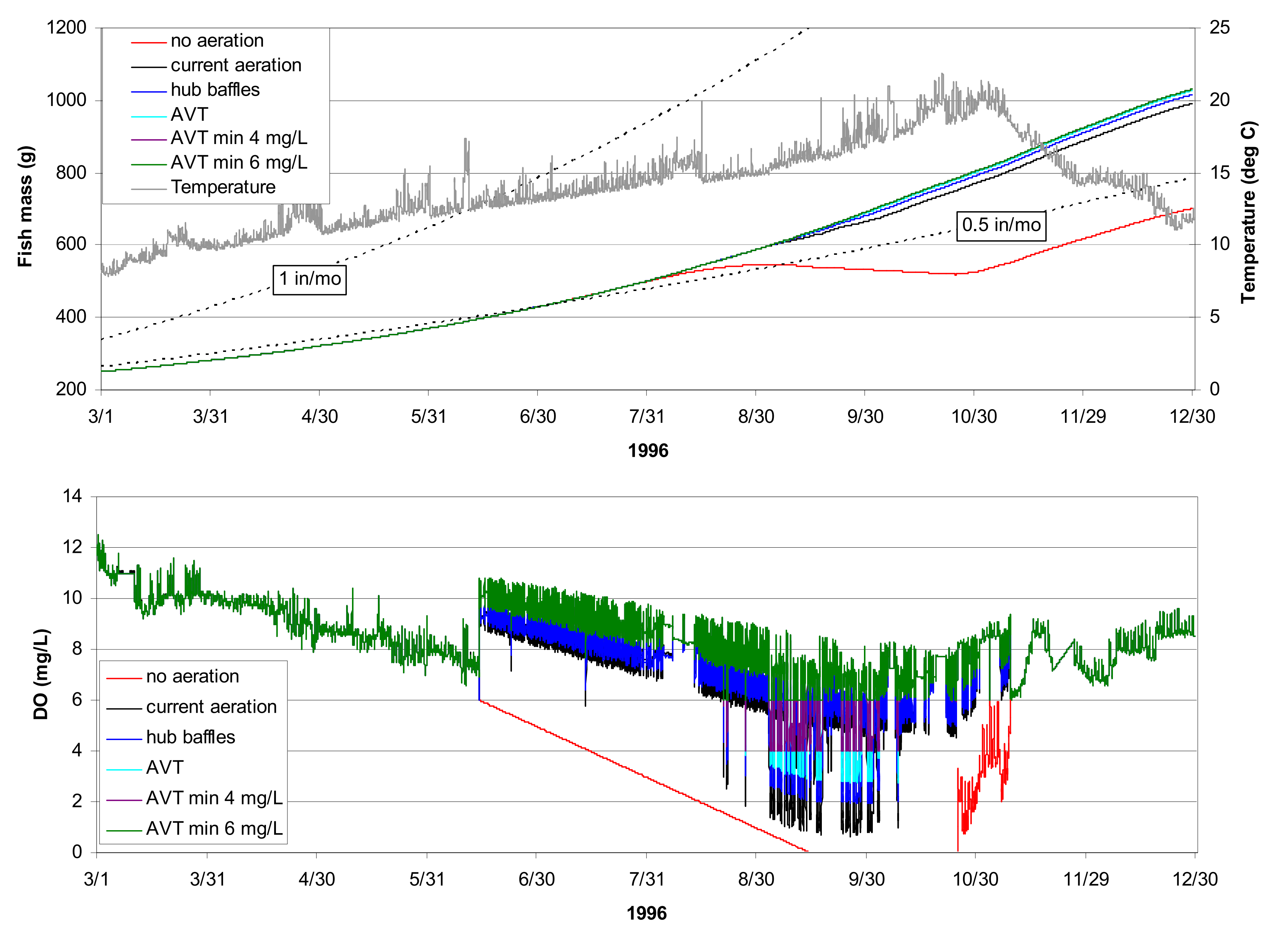




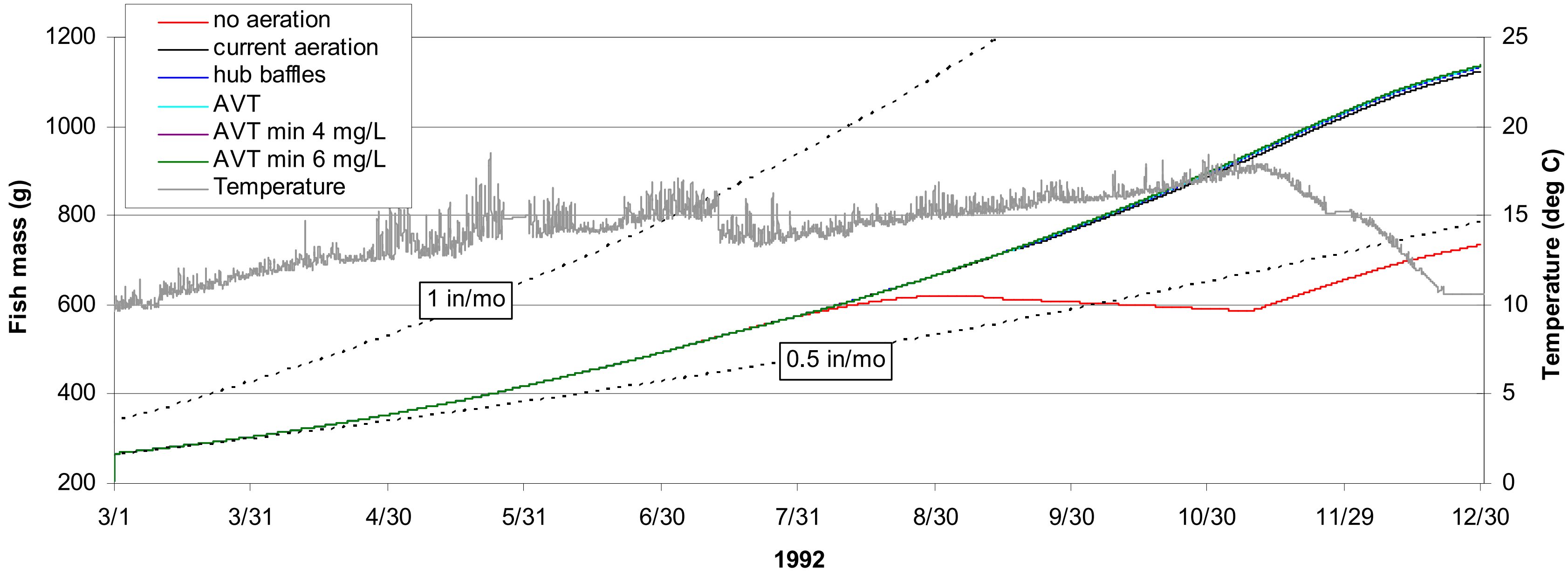
1990 (wet year)

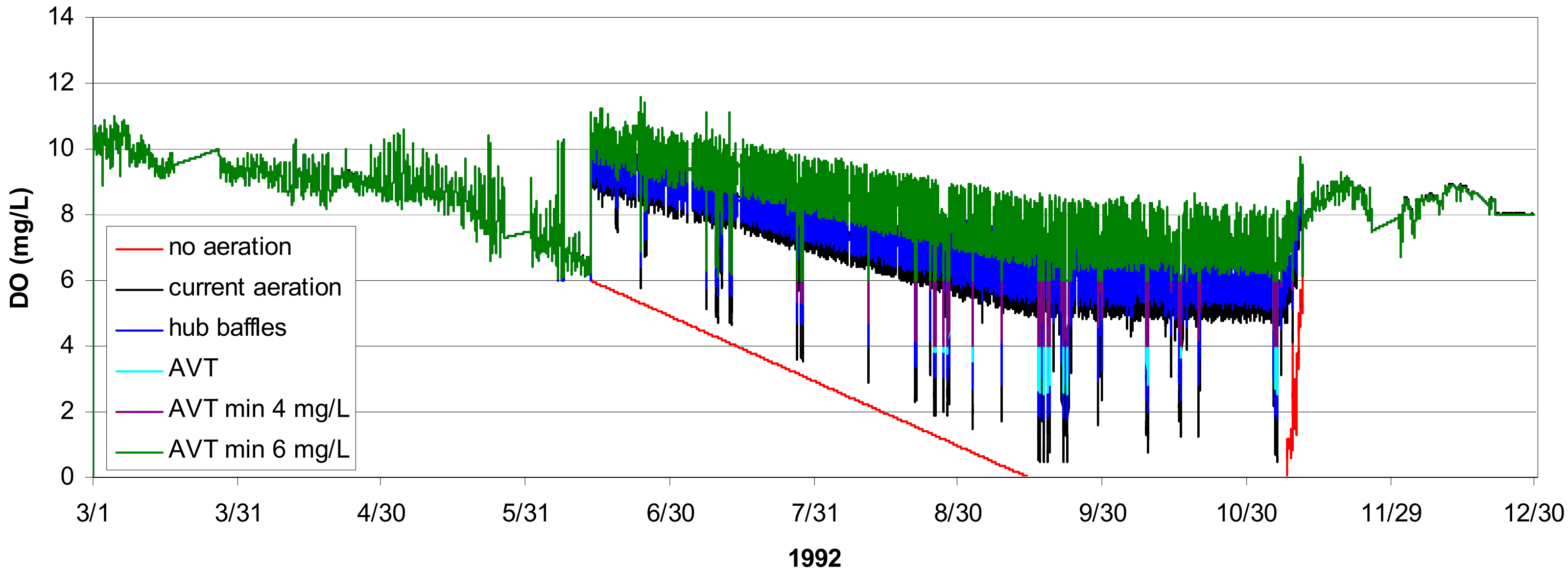


1996 (mod. wet year)

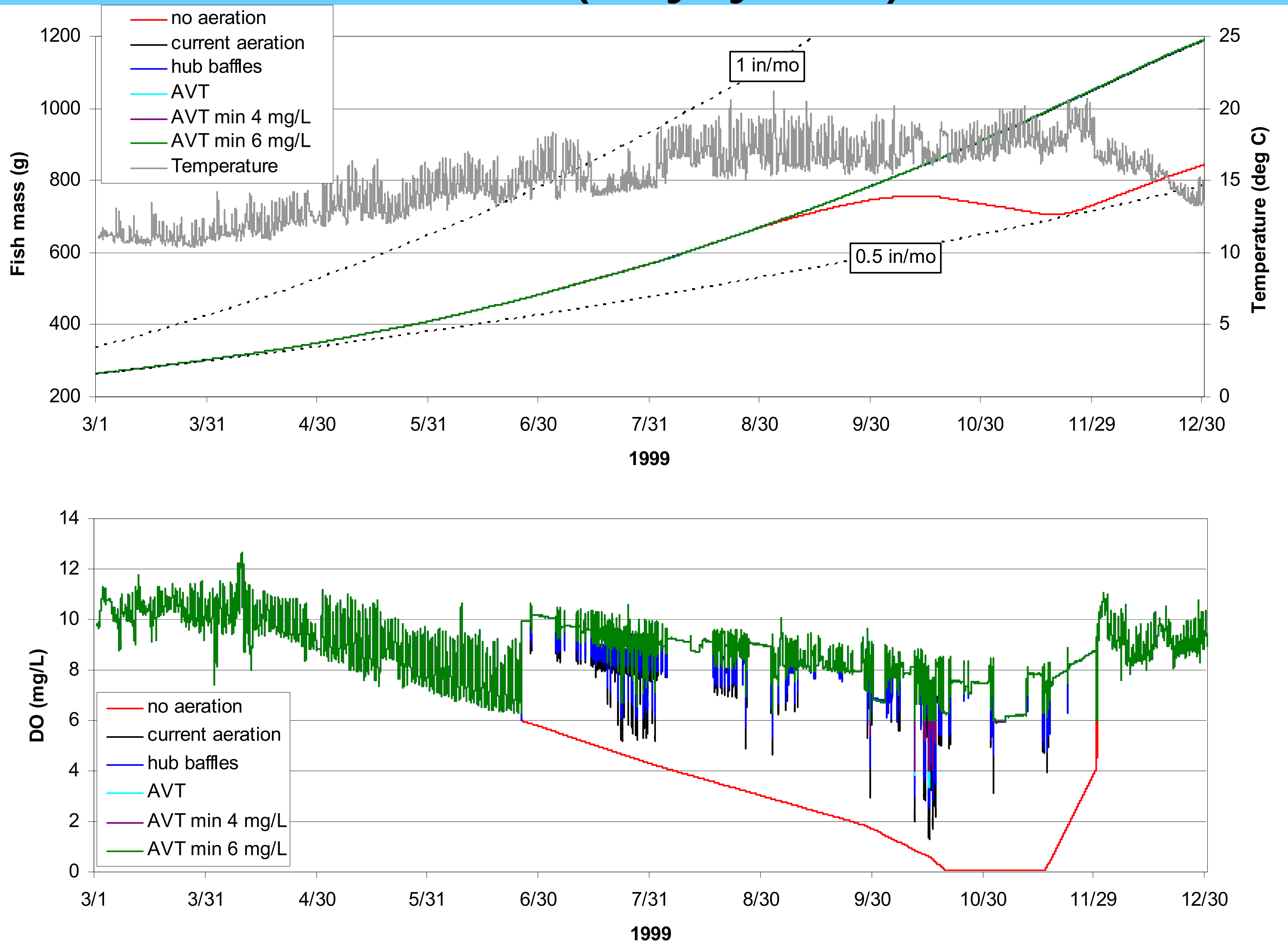


1992 (avg year)





1999 (dry year)

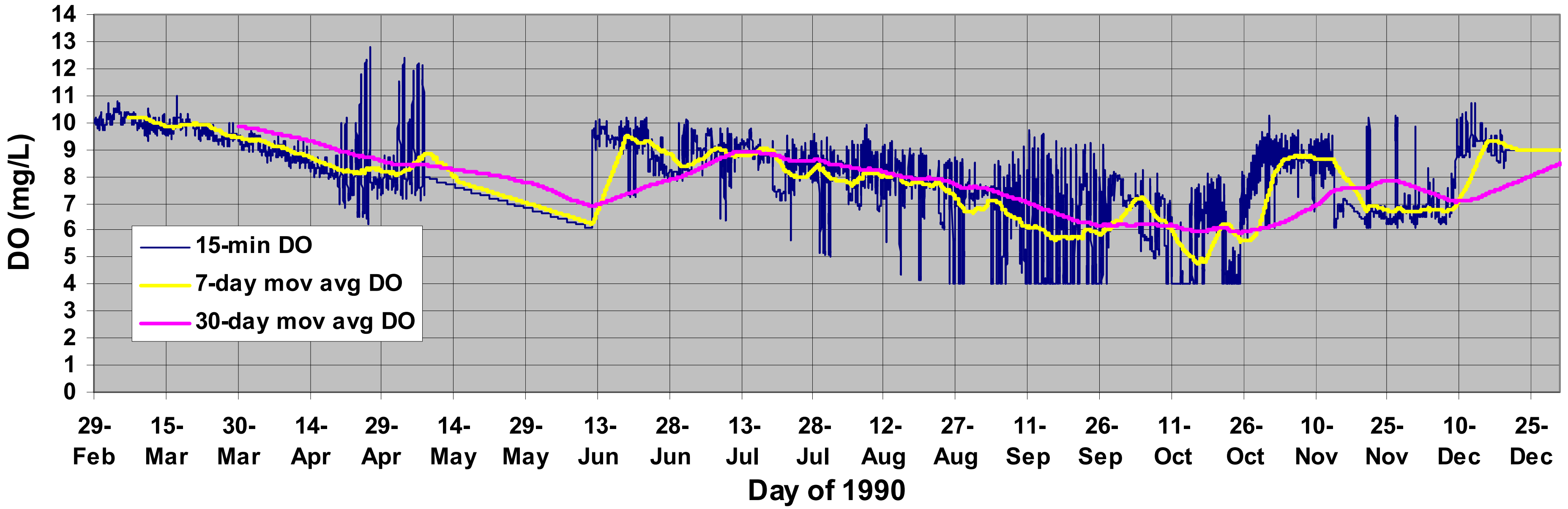


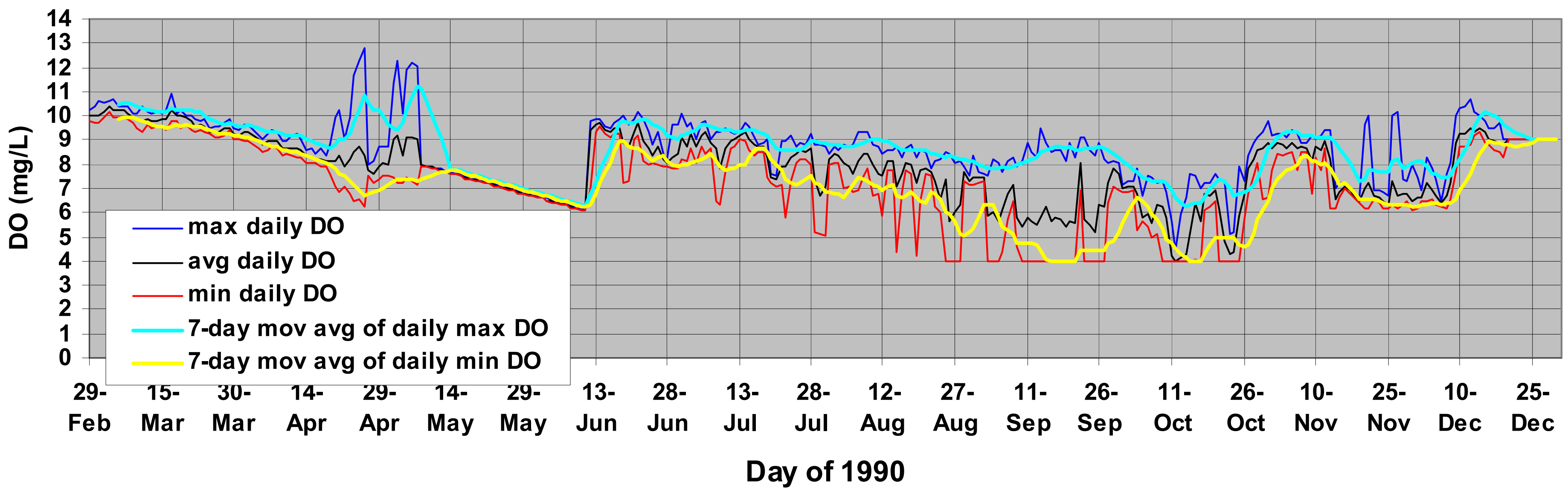
Results of the Study and Considerations for Setting The Site-Specific Standard for DO

Jim Ruane

Reservoir Environmental Management, Inc

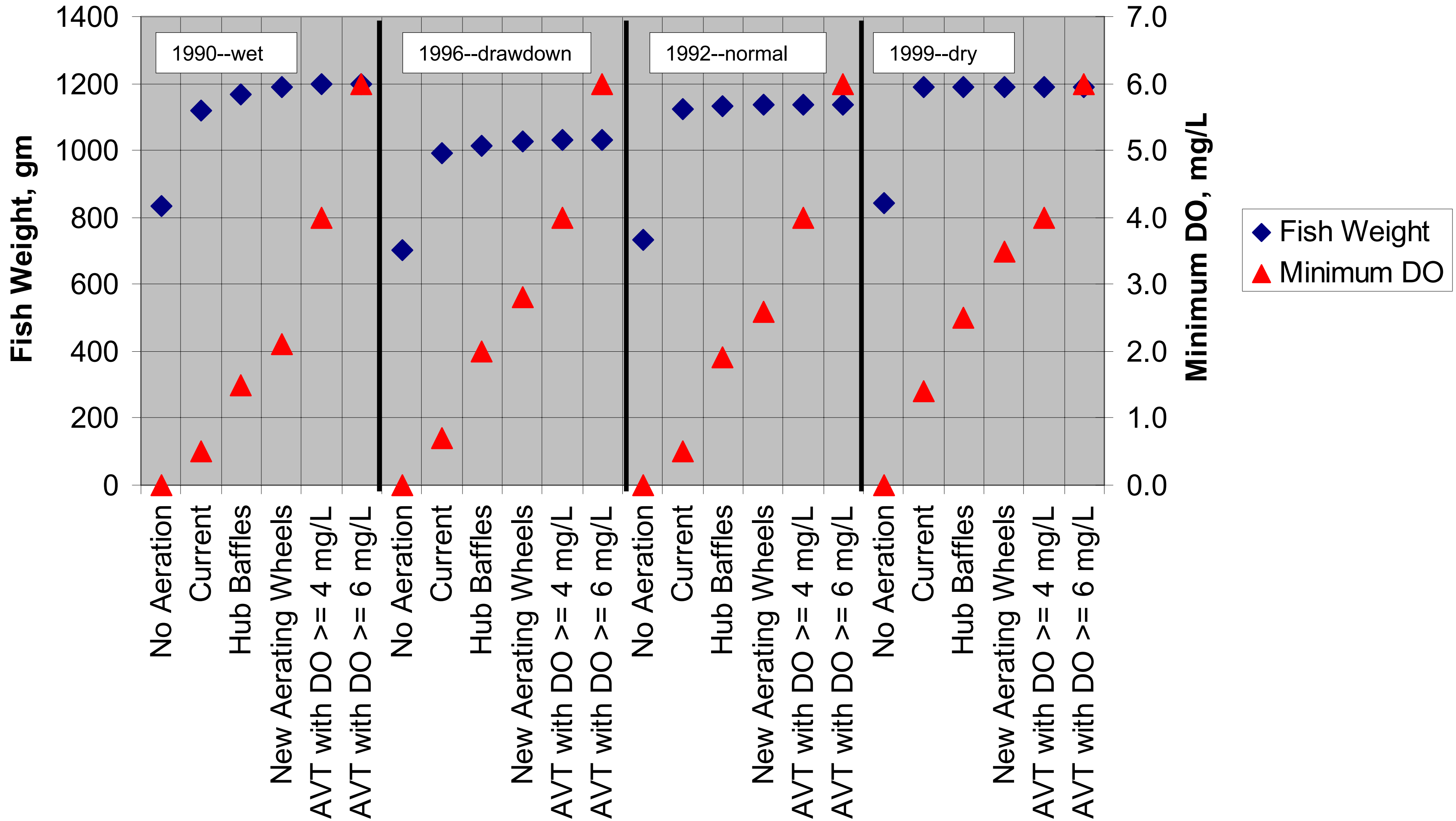
- I will present the results from the previous sections and compare the results of the fish modeling to DO metrics that summarize the DO conditions to which the fish were exposed in the fish model.
- The DO metrics presented here focus on those that might be considered for setting a site-specific standard. In considering regulatory DO standards it is important to set DO thresholds which are intended to be met or exceeded under defined conditions. Hence most of the discussion in the section regarding DO metrics will focus on the minimum values of each of the metrics.



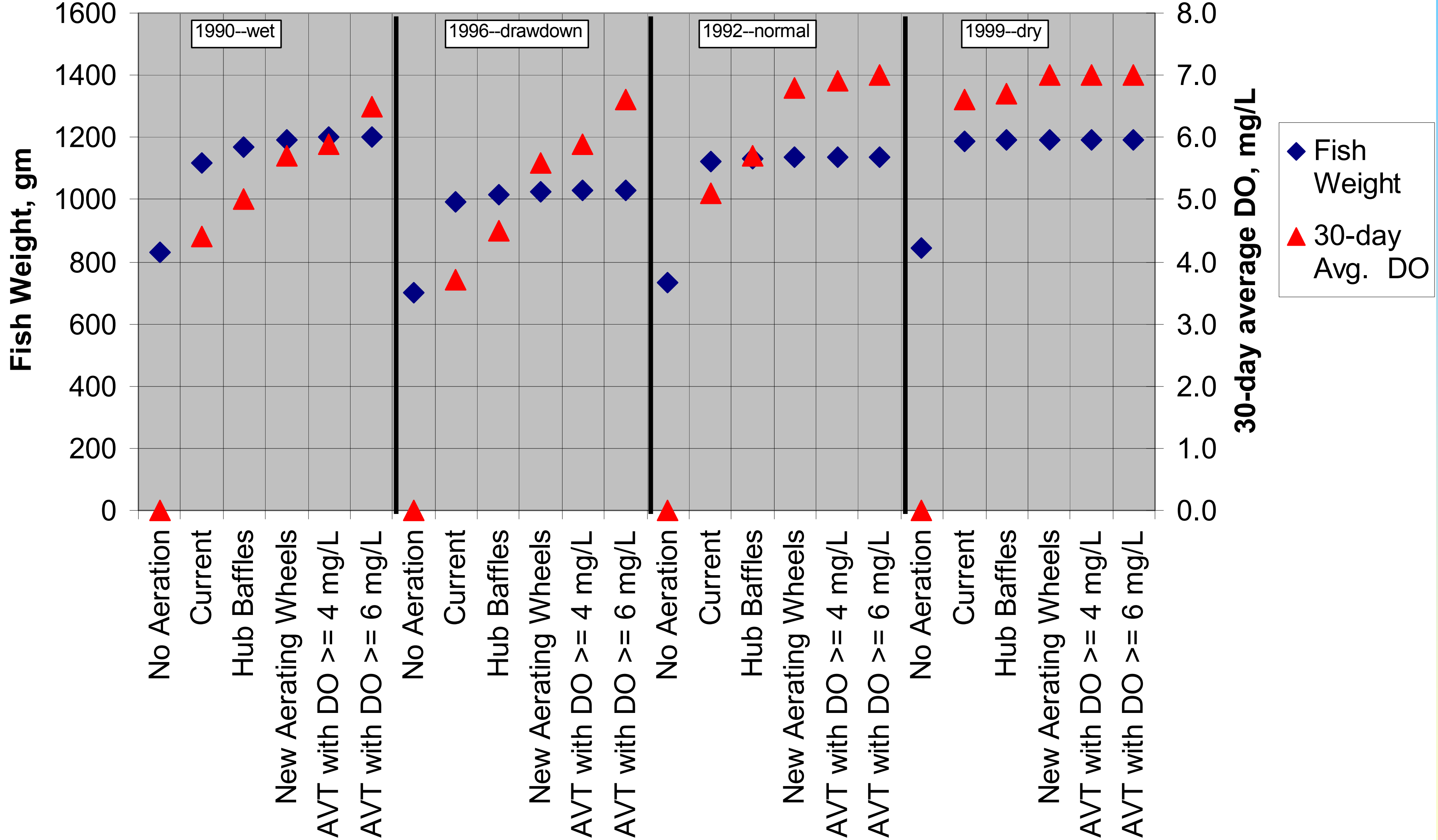


AVT Scenario with 4 mg/L Minimum DO

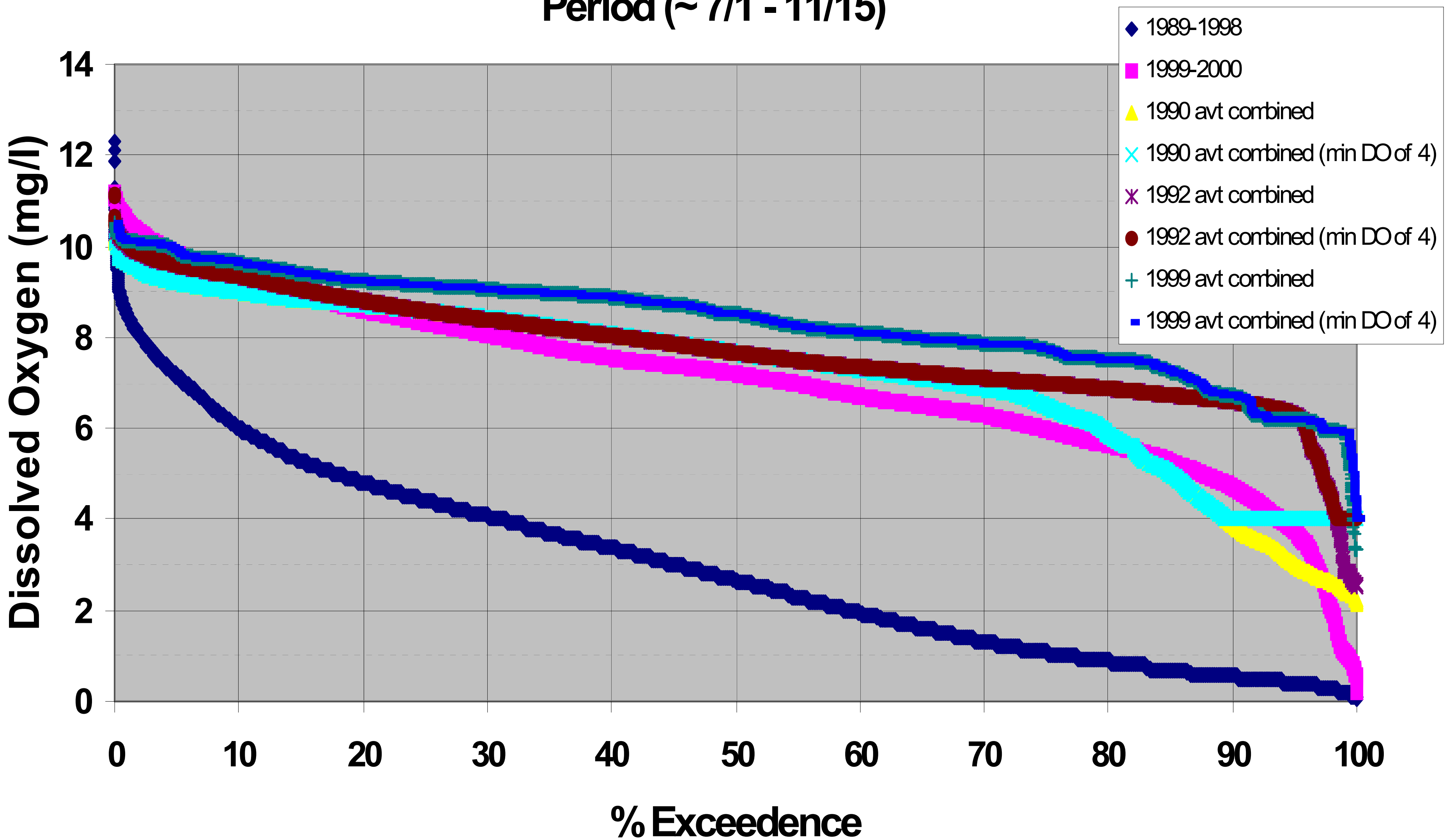
Year-End Fish Weight and Minimum Daily DO Levels Observed for Each Year For the Aeration Scenarios Considered



Year-End Fish Weight and Minimum 30-day Average DO Levels Observed for Each Year For Various Aeration Scenarios



Percent of Time that Various Dissolved Oxygen Concentrations Would be Exceeded in Saluda Hydro Tailwater - for the Low DO Period (~7/1 - 11/15)



Current Conditions

- Current conditions of the fishery and invertebrate food supply are excellent by comparison to other southeastern hydropower tailwaters, even though DO concentrations have periodically dropped to about 1 mg/L during high flows.
- These fishery conditions can be attributed in large part to SCE&G aeration practices over the past 4 years, in conjunction with drought conditions that have occurred over this same period of time.

Current Conditions, cont.

- The most critical DO conditions occur during high flows. When special drawdowns of Lake Murray occur, especially in wet years, more water has been released during the time of year when DO in the discharges was at its lowest levels. Under these conditions (2 of the last 14 years), low DO occurred more frequently and for longer durations.
- Fish modeling indicates that the current aeration practice would result in good growth, i.e., 0.67 inches/month and year-end fish lengths of about 18 inches and weights of over 2 pounds.
- However, with additional aeration, small increases in growth might occur and mortality and avoidance would be less likely.

At least two DO metrics are needed for the site-specific standard:

1. one to protect against acute toxicity, and
2. one to ensure suitable fish growth.

These metrics should be selected to protect designated uses, as well as allow Saluda Hydro to operate as cost-efficiently as possible.

DO Metric for Acute Toxicity

- DHEC has specified that the minimum be no less than 4 mg/L, and this value is consistent with the EPA criteria for trout waters. (This EPA criterion was set in order to protect insect species that may be more sensitive than trout. EPA suggested a minimum value of 3 mg/L to avoid trout mortality.)
- The trout growth study on the LSR indicates that the 4 mg/L minimum DO is more than sufficient to provide for food supply and protect the trout against mortality.
- Considering that SCDHEC has set 4 mg/L as the minimum DO level, SCE&G has no practical alternative but to consider proposing 4 mg/L as the minimum DO level.

DO Metric For Growth

- The 30-day average DO metric was significantly better than any other metric for being correlated to fish growth, based on a comparison using the other DO metrics (daily average and 7-day average)
- Regression coefficients were determined for the relationships between year-end fish weight and the DO metrics, and R-square values were significantly higher for the 30-day average,
- Average DO metrics for shorter periods like daily and 7-day average fell below 5 mg/L intermittently for brief periods in 1990 and 1996 even when minimum DO was 4 mg/L

DO Metric For Growth, cont.

- An approach using the 30-day average, which best protects fish growth, is recommended in the EPA criteria document.

- Although a 30-day average differs from the daily average DO currently used by SC for most waters of the state, it is more protective as a growth metric when proposed along with a minimum DO standard.

- The 30-day average is more protective because it is a higher level of DO over a longer period of time, which is more important to growth.

Considerations for Setting the Standard

- A 30-day average of 5.5 mg/L can be used with immeasurable differences in weight or length relative to that attainable with a minimum DO of 6 mg/L.
- “Immeasurable” is defined to be 14 grams, 0.5 ounces, or 1/16 inches less than growth achieved using a minimum DO of 6 mg/L.
- The mean difference in year-end fish size with a 30-day average DO of 5.5 mg/L versus a minimum DO of 6 mg/L from all four years was 6 grams, 0.22 ounces, and 1/32 inches.
- Difference in growth in 1990 was also determined to be immeasurable: 12 grams, 0.45 ounces, and 1/16 inches.

More than any other metric, the 5.5 mg/L 30-day average satisfies both DHEC/EPA/DNR objectives for the trout put-grow-and-take use designation and SCE&G's objectives for cost-effective compliance in terms of capital costs, operational costs, and "operator difficulty" for complying with the target DO.

Site-Specific Considerations for Saluda Hydro

- The primary reason that a 5.5 mg/L, 30-day average DO is sufficient for the LSR: low DO values only occur an average of about 1 % of the time.
- DO is low when flow is high (about 10,000 cfs or more). Fishing experience is not likely to be impacted during low DO conditions since fishing is not as prevalent at high flows
- The 30-day average generally requires continuous monitoring. This is difficult to measure and maintain for point source dischargers on unregulated streams, but it is relatively easy to measure for hydropower discharges since continuous monitors are routinely installed.
- The 30-day average provides important flexibility needed for operations of a large hydropower project where the entire river passes through the project, i.e., the hydropower project is challenged to “treat” a whole river that discharges as much as 18,400 cfs, or almost 12,000 MGD or about 200 times the size of the wastewater discharge from the City of Columbia.