Evaluation of Chlorophyll a Nuisance Thresholds and Targets for the Southwest Snake River and Brownlee Reservoir

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The Draft Snake River–Hells Canyon Total Maximum Daily Load (TMDL) identifies designated beneficial uses and water quality targets to support these uses (IDEQ and ODEQ 2001). Among these targets is a chlorophyll a concentration action level of 15 µg/L. Others (City of Boise 2001, Pilgrim et al. 2001) have evaluated this value to determine its applicability to the waters of the southwest Snake River and Brownlee Reservoir.

Enclosed are data and rationale for justification of chlorophyll a nuisance thresholds and targets for the southwest Snake River and Brownlee Reservoir. The objective was to evaluate the recreational use chlorophyll a nuisance thresholds and targets proposed by both City of Boise (2001) and Pilgrim et al. (2001) and make recommendations, if necessary, for revisions.

Evaluation of the Proposed Recreational Use Chlorophyll a Nuisance Thresholds and Targets

Pilgrim et al. (2001) proposed a user survey be conducted to define a chlorophyll a nuisance threshold for the southwest Snake River and Brownlee Reservoir. In the interim, however, data and recommendations from a user survey conducted on Lake Pepin, a Minnesota reservoir, is recommended. These data have defined a nuisance threshold of 40µg/L chlorophyll a. This translated into a mean growing season chlorophyll a target of 30 µg/L, based on site-specific data from the southwest Snake River. City of Boise (2001) used site-specific data from a reach of the Snake River that was determined to be "full support" of the recreational beneficial use. They determined a mean growing season chlorophyll a target of about 40 µg/L.

Idaho's Water Quality Standards and Wastewater Treatment Requirements do not specifically address chlorophyll a nuisance thresholds or criteria. The standards do, however, state 'surface waters of the state shall be free from excess nutrients that can cause visible slime growths or other nuisance aquatic growths impairing designated beneficial uses' and 'surface waters of the state shall be free from oxygen-demanding materials in concentrations that would result in an anaerobic water condition' (IDAPA 58.01.02 n.d.). Aquatic growths, primarily planktonic algae, in the southwest Snake River and Brownlee Reservoir have been shown to result in low dissolved oxygen concentrations in Brownlee Reservoir (Webb 1964, Harrison et al. 1999). Many researchers since Carlson (1977) have used chlorophyll a concentrations as a surrogate for algal biomass. The state of Oregon has established chlorophyll a guidance values of 10 µg/L for stratified lakes and15 µg/L for other lakes including reservoirs 'to identify water bodies where phytoplankton may impair the recognized beneficial uses' (OAR 340-041 n.d.). In general, both states have identified these waters as swimmable and fishable for salmonid fishes (IDAPA 58.01.02. n.d., OAR 340-041. n.d.).

The recommendations of City of Boise (2001) and Pilgrim et al. (2001) address the recreational beneficial use. It is important to note the Snake River and Brownlee Reservoir are also

designated for aquatic life uses (IDAPA 58.01.02. n.d., OAR 340-041. n.d.). These uses are likely more sensitive to chlorophyll a concentrations, found to be partially attributable to anaerobic water conditions (Webb 1964, Harrison et al. 1999), than the recreational use. The following discussion will therefore focus on chlorophyll a concentrations as the surrogate for evaluating nuisance aquatic growths in the southwest Snake River and Brownlee Reservoir that may result in anaerobic water conditions.

Chlorophyll a concentrations measured in the Snake River near Weiser, Idaho, increase in the spring, about March, and then decline again around October (Figure 1). These data are from Idaho Power Company. This period of March through October was selected to represent the "growing season."

Chlorophyll a concentrations during the growing season were queried from Idaho Power Company databases. These data were collated by dry (1989-1994), wet (1995-1999), and all years, depending on location. The mean concentrations for the Snake River and Brownlee Reservoir sampling reaches are shown in Table 1.

These data indicate a difference in mean growing season chlorophyll a concentrations between dry and wet years. Concentrations are higher during dry years likely due to less water. Chlorophyll a concentrations were higher in the Snake River during wet years. This phenomenon would also likely occur during dry years however no data existed to verify this hypothesis.

These data corroborate with those reported by other researchers. City of Boise (2001) reported a mean growing season chlorophyll a concentration of 26.1 µg/L for the Snake River between river miles 409 and 450. Pilgrim et al. (2001) reported "mean chlorophyll a concentration [for the Snake River between river miles 340 and 409] for May through September is about 30 µg/L based on 1995 through 2000 data." Neither, however, reported any concentrations for the other sampling reaches, for example Brownlee Reservoir.

Pilgrim et al. (2001) reviewed the literature for nuisance thresholds and chlorophyll a standards (Table 2). They reported nuisance thresholds ranged from 20-30 µg/L chlorophyll a (Walmsey 1984) to > 40 µg/L (Heiskary and Walker 1995). Researchers suggested recreational uses could be adversely affected when the frequency of nuisance algal levels exceeded 25% (Smeltzer and Heiskary 1990). Chlorophyll a standards ranged from 10-15 µg/L for waters likely inhabitable by salmonids to 25-40 µg/L for other waters. It must be noted these other waters were not historically inhabited by salmonids. Additionally, Pilgrim et al. (2001) reviewed the literature for the effect of limited primary production on recreational fisheries. These data will be discussed later.

The proposed mean growing season chlorophyll a targets of between 30-40 µg/L (City of Boise 2001, Pilgrim et al. 2001) are within the range reported by others as being protective of waters

but appear to be toward the upper end of the range. In fact, their proposed mean growing season chlorophyll a targets are similar to, if not greater than, the current mean concentration of about 28 µg/L in the impaired waters [that is, Clean Water Act §303(d) listed waters] of the Snake River and Brownlee Reservoir. It appears the proposed targets may not be applicable due to the fact they may not be protective of all designated uses, particularly aquatic life, and do not appear to provide a mechanism to reduce the current chlorophyll a concentrations. Additionally, application of a user survey may not be the most advantageous approach to determine water quality thresholds needed to protect the aquatic life uses.

Alternative Chlorophyll a Nuisance Thresholds and Targets

I agree with City of Boise (2001) and Pilgrim et al. (2001) that a chlorophyll a target should accurately reflect the desired water quality and directly relate to the designated uses. User surveys have been used to these ends (Smeltzer and Heiskary 1990), however, more so for the recreational use. A methodology developed by Karr et al. (1986), based on data distributions, has been used extensively for biological measures and may be more appropriate for aquatic life uses.

The U.S. Environmental Protection Agency recommended this methodology to determine reference conditions and divergent levels, thus beneficial use support, from a random distribution of measures (USEPA 1998). Data from severely impaired sampling locations can be excluded from these analyses. They stated this methodology was most appropriate if minimal non-anthropogenic reference sites exist or can't be found and was especially relevant for reservoirs. The methodology consists of trisecting the range of the population distribution from the 95th percentile to the minimum possible measure. Values greater than the 95th percentile are considered reference or best attainable condition. Since higher chlorophyll a concentrations are indicative of lower water quality, the values less than the 5th percentile would be representative of reference or best attainable condition. The lower third of the distribution represents measures that do not deviate significantly from these conditions, whereas, the middle third represents those sites that deviate slightly. The upper third of the distribution, or the values between about the 63rd and the 95th percentiles represent those waters that deviate significantly and likely do not support the beneficial uses. Therefore, the break between the middle and upper thirds of the distribution represents the value at which beneficial uses are likely no longer supported and represents, in this case, a probable nuisance chlorophyll a threshold. It is noted the trisection of the data distribution may not accurately reflect desired water quality nor directly relate to the designated uses. It is an attempt to classify sites by their distribution from suspected reference or best attainable conditions.

The Idaho Department of Environmental Quality used a slightly different approach for the River Diatom Index due to a limited number of reference sites (Fore and Grafe 2000). (Diatoms are single-celled organisms important to the planktonic algae community.) They assigned index

categories based on the 75th, 50th, and 25th percentiles. A minimum threshold was not recommended. Therefore, using this approach in the case of chlorophyll a values, the 50th percentile would represent probable nuisance thresholds whereas values less than the 25th percentile would represent values that do not deviate significantly from reference or best attainable conditions.

Idaho Power Company growing season chlorophyll a concentration data distributions for impounded, unimpounded, and all waters of the Snake River are illustrated in Figure 2, Figure 3, and Figure 4, respectively. Generally values and thus percentiles are less in data distributions exclusive of the sampling sites located in the reach addressed by Pilgrim et al. (2001), which is from river mile 285 to 409, and represented as TMDL in the figures. As mentioned previously, exclusion of severely impaired sampling sites is acceptable in this approach. This reach has obviously higher chlorophyll a concentrations than other Snake River sampling reaches (Figure 5 and Figure 6). No sampling of unimpounded waters occurred in the TMDL reach of the Snake River during dry years.

Probable chlorophyll a nuisance thresholds interpreted from these data using the approach developed by Karr et al. (1986) and recommended by the U.S. Environmental Protection agency (USEPA 1998) are included in Table 3. These values approximate the 63rd percentile of the data distributions. It is obvious the effect of including the southwest Snake River and Brownlee Reservoir data. The chlorophyll a nuisance thresholds are on average about 50% higher when these data are included. It was determined these data are likely from severely impaired waters and were therefore removed from further analyses. Additionally, the mean growing season chlorophyll a concentrations are greater than the nuisance thresholds during dry years and less than during wet years. Chlorophyll a nuisance thresholds are higher in the southwest Snake River due to the higher chlorophyll a concentrations measured in this reach of the river. The Idaho Department of Environmental Quality approach used in the River Diatom Index selects the 50th percentile as a value to distinguish between values that deviate moderately to significantly from the reference or best attainable condition. Using this percentile, the average chlorophyll a nuisance threshold is about 9 µg/L. This is about 70% less than the average chlorophyll a nuisance threshold for unimpounded Snake River waters interpreted using the U.S. Environmental Protection Agency recommended methodology. It does not appear the River Diatom Index approach is applicable. Therefore, any further discussions will relate to chlorophyll a nuisance thresholds and targets calculated using the U.S. Environmental Protection Agency's methodology.

Other efforts have collected chlorophyll a data from reservoirs throughout the state. Milligan et al. (1983) surveyed 46 reservoirs and the Idaho Department of Environmental Quality sampled 36 as part of the Beneficial Use Reconnaissance Project (R. Steed, Idaho Department of Environmental Quality, unpubl. data). Both efforts targeted waters across the range of human influences. These data were collected near summer peak productivity (Figure 7). Using the U.S.

Environmental Protection Agency's methodology with these data, chlorophyll a nuisance thresholds are 21.1 µg/L and 33.4 µg/L, respectively. Our results best corroborate with those of the Idaho Department of Environmental Quality. These data will be used later to relate chlorophyll a concentrations with fishery management objectives.

Nuisance thresholds alone do not provide for a degree of certainty that the concentration will be protective of the beneficial uses. Site-specific data were evaluated to determine the frequency with which these thresholds would be exceeded (an example of these analyses is illustrated in Figure 8). The Idaho Department of Environmental Quality identified a level of ten percent in the Water Body Assessment Guidance (Grafe et al. 2000). Smeltzer and Heiskary (1990) stated that recreational uses would be protected at frequency exceedance levels up to 25%. I choose the 25% level to estimate mean growing season chlorophyll a concentrations that would be protective of designated uses and likely attainable in the southwest Snake River and Brownlee Reservoir. The alternative chlorophyll a nuisance thresholds and targets are included in Table 4. Chlorophyll a targets are lower in the southwest Snake River, even with higher nuisance thresholds, due to the greater variability in the data. A lower target must be set to ensure the nuisance threshold is not exceeded more than 25% of the time. Water-body and water-year specific chlorophyll a nuisance thresholds and targets may be appropriate, however, there were no data available from dry years for the southwest Snake River. This lack of data serves to underestimate, as mean growing season chlorophyll a concentrations are higher during dry years, chlorophyll a nuisance thresholds and targets. For this reason and simplicity, it may be more appropriate to combine the southwest Snake River and Brownlee Reservoir and years. It appears, giving these reasons, that a nuisance threshold of about 30 µg/L and a target between 15µg/L and 20 µg/L would be a reasonable alternative to assure that designated beneficial uses will be protected in the southwest Snake River and Brownlee Reservoir. These values are within the range reported by other researchers as nuisance thresholds (Table 2) and is similar to the chlorophyll a action level identified in the Draft Snake River-Hells Canyon Total Maximum Daily Load (IDEQ and ODEQ 2001).

There is concern that the aquatic life uses may be adversely affected by limited primary production that is a lowering of the chlorophyll a concentration. Pilgrim et al. (2001) reviewed the literature and reported mean chlorophyll a concentrations should be between 20 µg/L and 60 µg/L to avoid adverse effects on the existing fishery. Most of these data are cited from studies conducted in southeastern U.S. waters. It must be noted these waters were dominated by warm water species while the southwest Snake River and Brownlee Reservoir are dominated by cool water adopted species. The Idaho Department of Environmental Quality surveyed lakes and reservoirs throughout Idaho as part of the Beneficial Use Reconnaissance Project. Chlorophyll a concentrations from these regional waters were related to Idaho Department of Fish and Game's fishery management objectives (Figure 9). It does not appear that mean growing season chlorophyll a concentrations of between 15-20 µg/L would negatively affect mixed fisheries in Idaho. Using the U.S. Environmental Agency's methodology, chlorophyll a concentrations less

than about 17 µg/L would likely be a threshold when mixed fisheries would begin to be adversely effected.

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Table 1. Growing season (March through October) mean chlorophyll a concentrations for the southwest Snake River and Brownlee Reservoir by dry, wet, and all years between 1991 and 1999.

	Mean Growing Season Chlorophyll a (µg/L)					
	Dry Years		Wet Years		All Years	
Sampling Reach	Mean	No.	Mean	No.	Mean	No.
Brownlee Reservoir	36.7	462	22.3	759	27.8	1221
Snake River-River Miles 409 > X < 335	NA	NA	28.7	165	28.7	165
Snake River/Brownlee Reservoir	36.7	462	23.4	924	27.9	1386

Table 2. Chlorophyll a concentrations applied for the protection of national waters.

Location	Chlorophyll a Concentration and Application	
Oregon (OAR 340-041 n.d.)	10 µg/L impairment guidance value for stratified lakes	15 µg/L impairment guidance value for other lakes and reservoirs
Southeastern US (Rashke 1994)	15 µg/L proposed mean growing season limit for water supply	25 µg/L proposed mean growing season limit for other uses
South Africa (Walmsey 1984)	10-20 µg/L for evident algal scums	20-30 µg/L for nuisance algal bloom condition
North Carolina (NALMS 1992)	15 µg/L standard for trout waters	40 µg/L standard for non trout waters
Lake Pepin (Heiskary and Walker 1995)	30 µg/L mean summer limit for aesthetics and recreation	> 40 µg/L mean summer limit for nuisance algal bloom condition

Table 3. Probable growing season (March through October) chlorophyll a nuisance thresholds for impounded, unimpounded, and all waters of the Snake River by dry, wet, and all years between 1989 and 1999.

	Chlorophyll a Nuisance Threshold (µg/L)					
	Dry Years		Wet Years		All Years	
Sampling Reach	Value	No.	Value	No.	Value	No.
Impounded Snake River with TMDL	56.6	1597	42.1	1826	48.1	3423
Impounded Snake River without TMDL	29.2	1135	26.6	1067	28.0	2202
Unimpounded Snake River with TMDL	31.0	406	38.9	674	35.5	1080
Unimpounded Snake River without TMDL	31.0	406	29.3	509	29.9	915
Snake River Waters with TMDL	53.4	2003	41.1	2500	46.2	4503
Snake River Waters without TMDL	29.9	1541	27.0	1576	28.4	3117

Table 4. Current mean growing season (March through October) chlorophyll a concentrations, nuisance thresholds (NUI), and targets (TAR) for the southwest Snake River and Brownlee Reservoir for dry, wet, and all years.

	Growing Season Chlorophyll a Concentration (µg/L)								
	Dry			Wet			All Years		
	Mean	NUI	TAR	Mean	NUI	TAR	Mean	NUI	TAR
City of Boise (2001)	NA						26.1	NA	39.6
Pilgrim et al. (2001)	NA						≈ 30	40	30
Brownlee Reservoir	36.7	29.2	14.2	22.3	26.6	14.0	27.8	28.0	14.4
Snake River	NA	31.0	NA	28.7	29.3	12.4	28.7	29.9	12.7
Brownlee/Snake	36.7	29.9	14.4	23.4	27.0	15.0	27.9	28.4	15.4

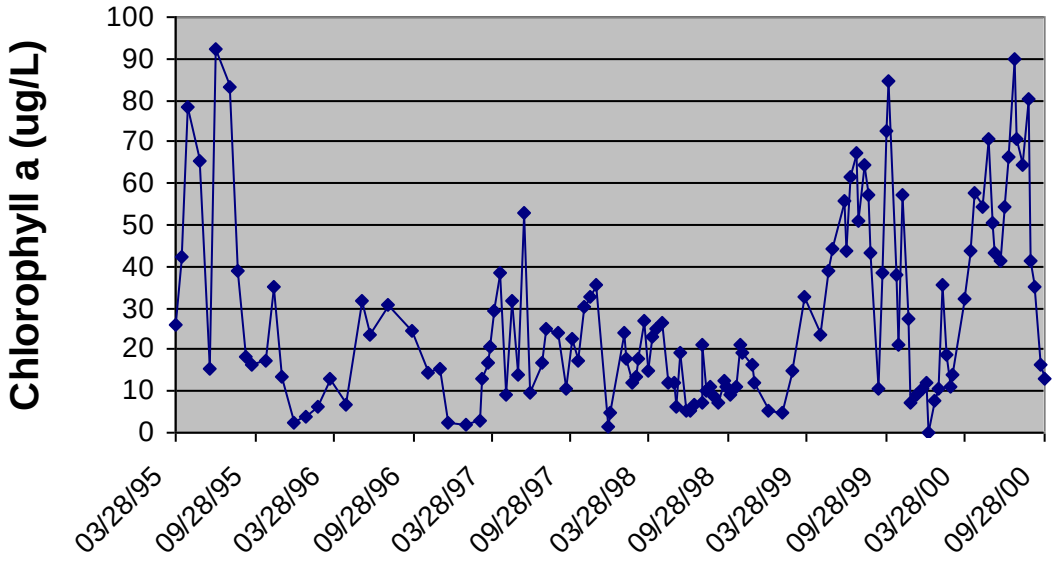

Figure 1. Chlorophyll a concentrations for the Snake River near Weiser, Idaho, 1995-2000.

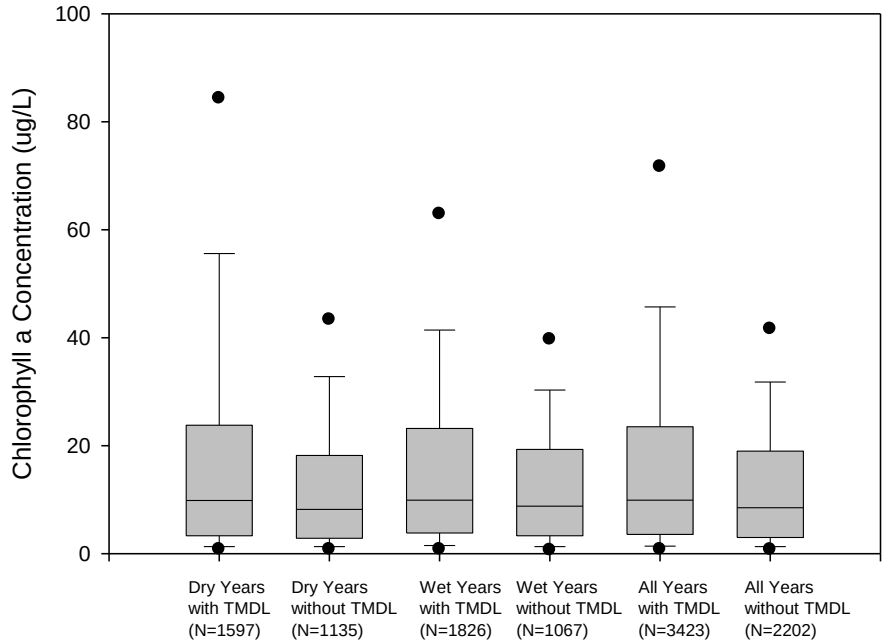

Figure 2. Growing season (March through October) chlorophyll a concentration distributions (circular symbols represent the 5th and 95th percentiles) for Idaho Power Company data from impounded waters of the Snake River, 1989-1999.

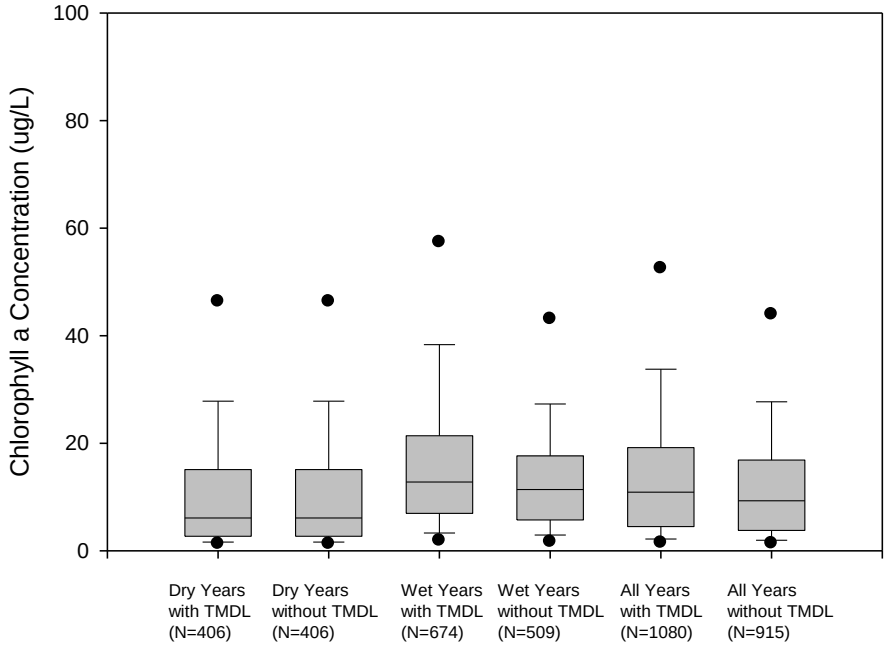

Figure 3. Growing season (March through October) chlorophyll a concentration distributions (circular symbols represent the 5th and 95th percentiles) for Idaho Power Company data from unimpounded waters of the Snake River, 1989-1999.

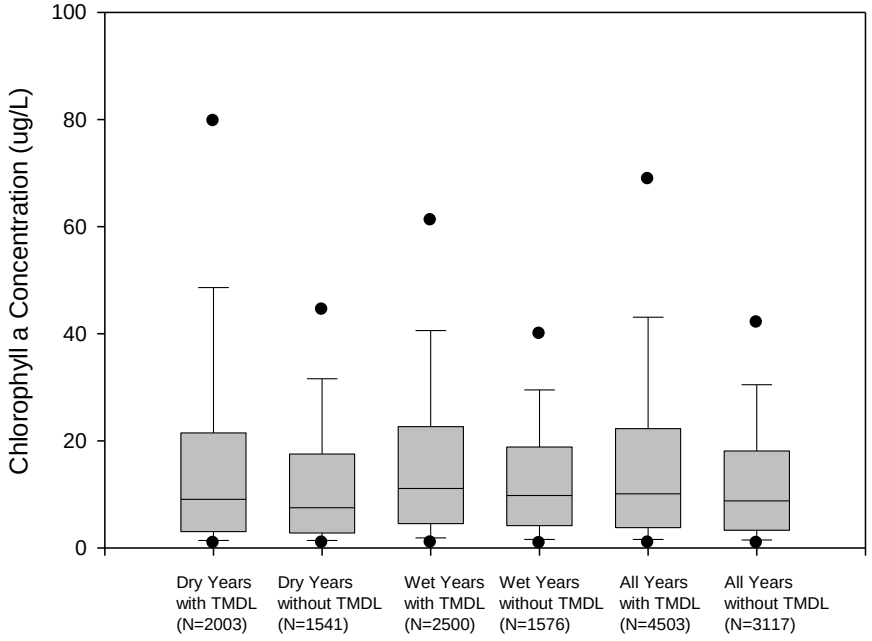

Figure 4. Growing season (March through October) chlorophyll a concentration distributions (circular symbols represent the 5th and 95th percentiles) for Idaho Power Company data from all waters of the Snake River, 1989-1999.

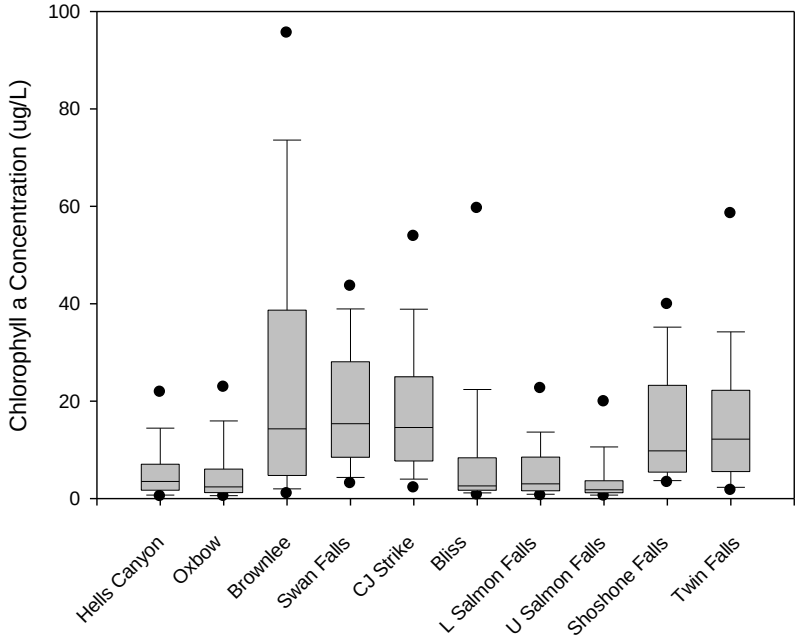

Figure 5. Growing season (March through October) chlorophyll a concentration distributions (circular symbols represent the 5th and 95th percentiles) for Idaho Power Company data from discrete reservoirs of the Snake River, 1989-1999.

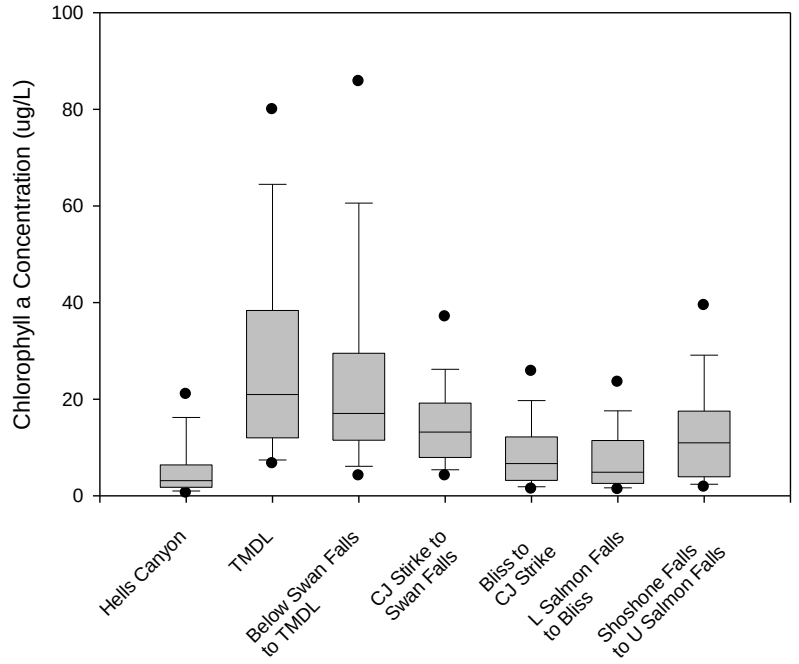

Figure 6. Growing season (March through October) chlorophyll a concentration distributions (circular symbols represent the 5th and 95th percentiles) for Idaho Power Company data from discrete unimpounded reaches of the Snake River, 1989-1999.

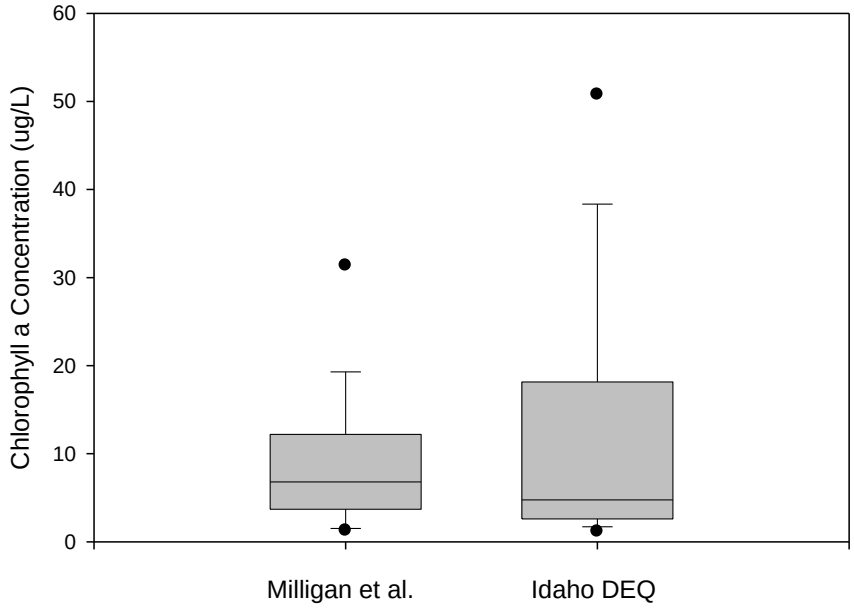

Figure 7. Chlorophyll a concentration distributions (circular symbols represent the 5th and 95th percentiles) for Idaho reservoirs during peak productivity collected by Milligan et al. (1983) and the Idaho Department of Environmental Quality (R. Steed, Idaho Department of Environmental Quality, unpubl. data).

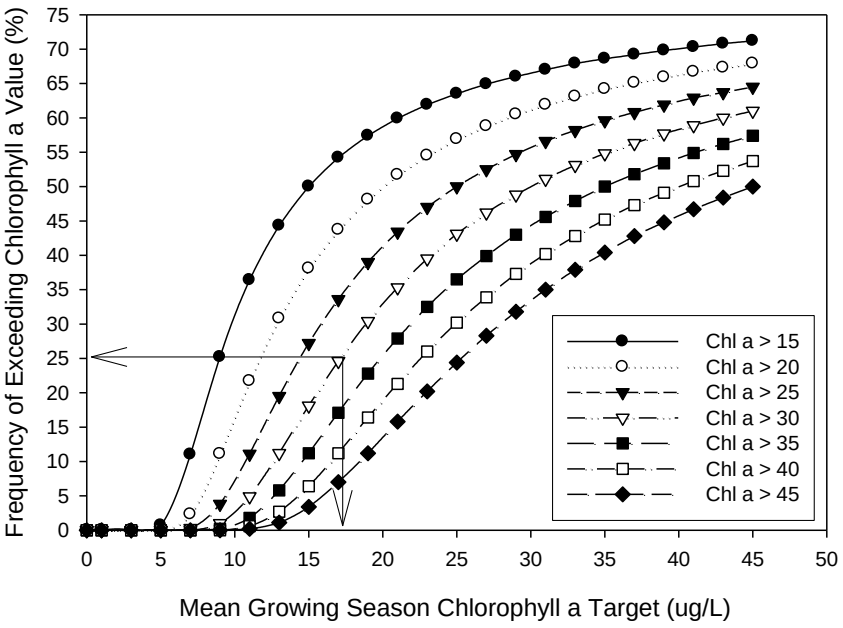

Figure 8. Predicted percent occurrence of exceeding chlorophyll a concentrations based mean growing season chlorophyll a targets and nuisance thresholds.

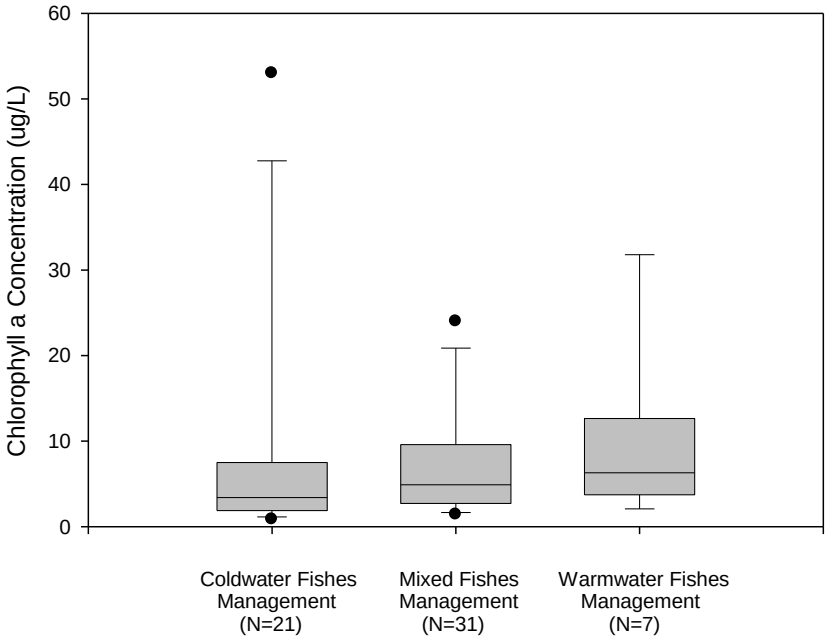

Figure 9. Summer chlorophyll a concentrations related to Idaho Department of Fish and Game's fisheries management.