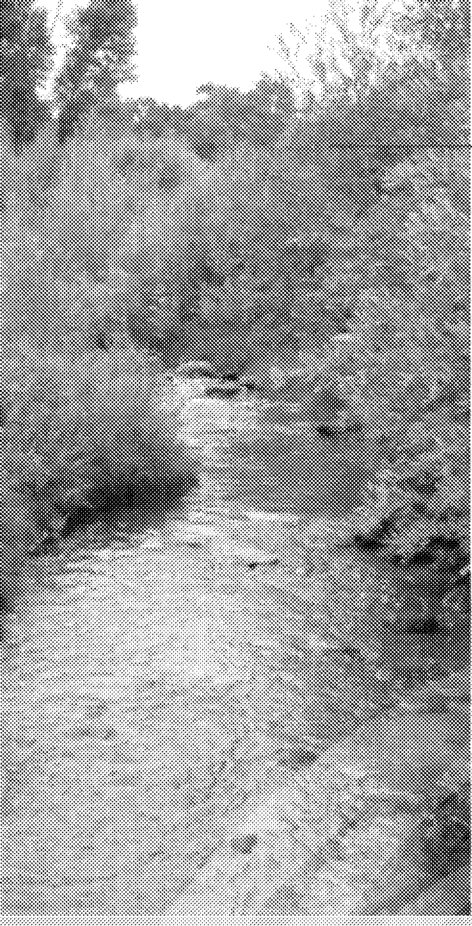


GEI Consultants

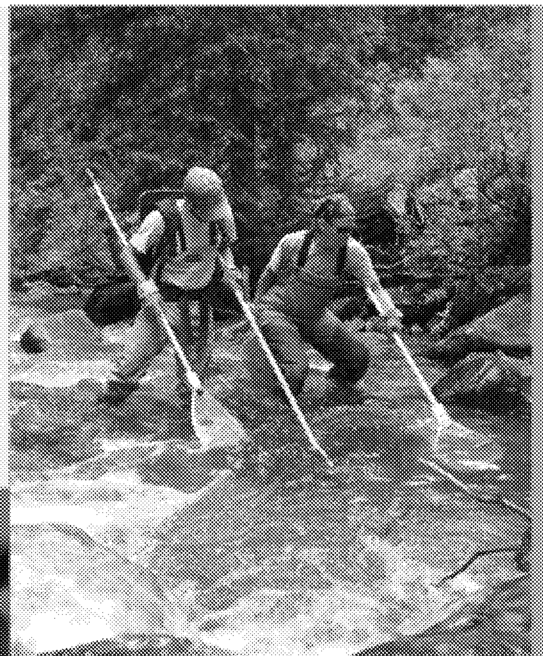
Consulting Engineers and Scientists

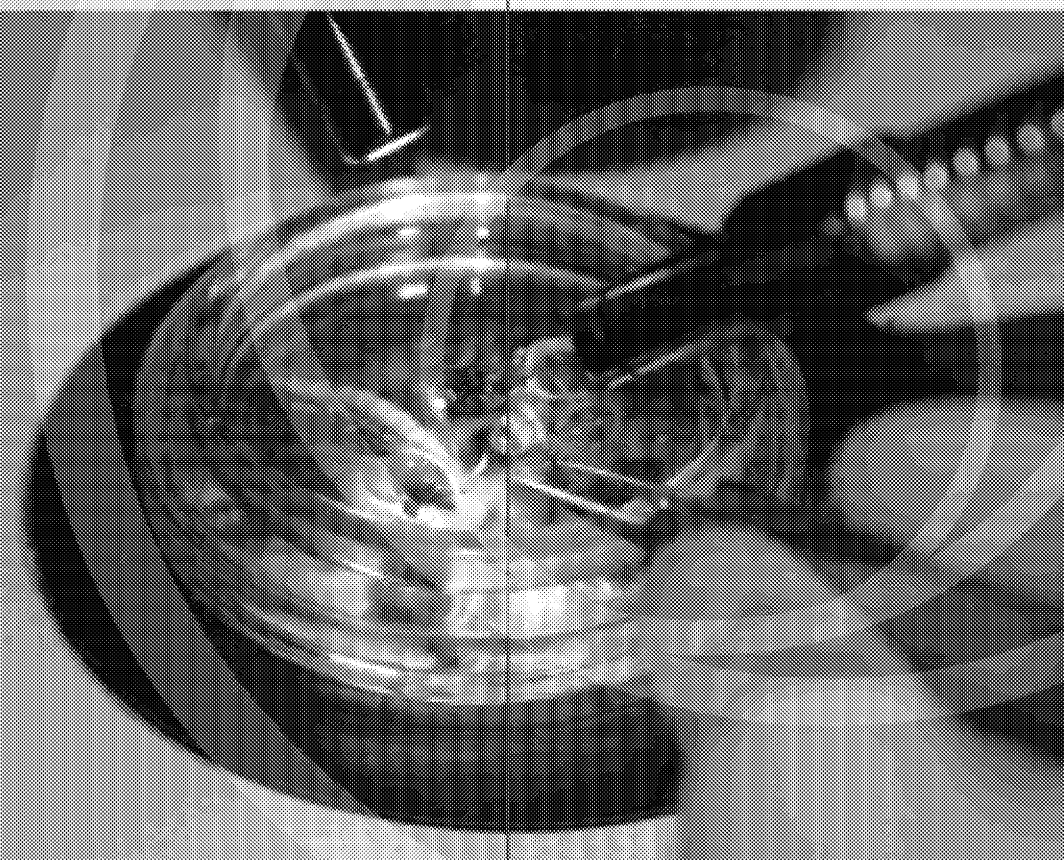
Review of EPA 2015 Draft Se Criteria Document

EPA 822-P-15-001

PREPARED ON BEHALF OF THE NATIONAL MINING ASSOCIATION

October 2015





Review of EPA 2015 Draft Se Criteria Document

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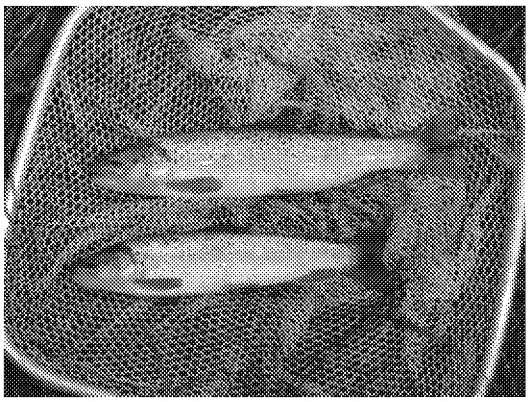

Submitted to:
Docket ID No. EPA-HQ-OW-2004-0019

Submitted by:
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Denver, CO 80237

October 2015

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Executive Summary

GEI Consultants, Inc. (GEI) toxicologists, water quality specialists, and regulatory strategists are recognized experts in water quality effects on aquatic life. In fact, our significant experience related to selenium (Se) spans over 20 years of study at sites throughout the U.S. and Canada. We frequently provide expert testimony and support for regulatory water quality hearings, environmental assessments, and ambient water quality standards development. Our personnel have served as invited experts for Se risk evaluation in aquatic environments for the Society of Environmental Toxicology and Chemistry, provided peer review for Se effects issues near coal mining sites in British Columbia (on behalf of the BC Ministry of the Environment), and provided technical review of Se issues for the North American Metals Council – Selenium Working Group, as well as other water quality issues for the National Mining Association (NMA). We have been involved with Se-related issues in waters throughout the U.S., including the collection of considerable water quality and biological data from a wide variety of waterbodies, evaluation of Se bioaccumulation trends, detailed Se source and fate identification, and development of site-specific Se standards. As such, we believe we can provide a unique perspective on this draft criterion and respectfully submit the following comments.

As stated in our prior review of the 2014 draft document, we commend EPA's effort in developing Se criteria that are generally consistent with the latest science regarding Se toxicity. We support the use of a fish-tissue based chronic criterion as the overriding criterion, as this is the most ecologically relevant measure of toxicity for Se. We also agree with the use of EC_{10}s rather than some other endpoint, as this is the more conservative approach. We also support EPA's conclusions regarding the timing of tissue data collection that samples collected within one year of each other are reasonable for acceptability.

We do have some concerns with several of the data decisions made by EPA in calculating the chronic tissue criterion concentrations. We have provided recommendations on revisions to the White Sturgeon, Bluegill and Brown Trout genus mean chronic values (GMCVs) or species mean chronic values (SMCVs). Should our recommendations be accepted, the result would be small, but significant, changes, with an egg/ovary criterion to 17.9 mg/kg, the whole-body criterion to 9.5 mg/kg, and the muscle criterion to 12.0 mg/kg. These revisions are based on our reanalysis of the studies, recalculation of conversion factors, or both.

We do not agree with the approach used to develop national water-column criteria. Our review provides discussion on why single nationwide standards are not appropriate and why site-specific water-column standards, calculated using EPA's Equation 18 from the criteria document, are a more scientifically justifiable approach. In addition, we provide an example of how limited the data set is, and how inclusion of additional data can make a substantial difference in the calculated water column criteria. Lastly, we would strongly recommend

EPA consider changing the paradigm for National Pollution Discharge Elimination System (NPDES) permitting such that direct use of tissue criteria would be possible. To our understanding, there is nothing in the Clean Water Act that would preclude this. By writing permits to the most defensible endpoint of tissues, EPA would eliminate the need for backing into water concentrations by methods that invariably add significant error and uncertainty.

There are several other components of the criteria that should be reevaluated by the EPA. The use of "never to be exceeded" frequency for the tissue criteria is inappropriate and not in line with standard criteria attainment requirements. We recommend clarification of tissue sampling requirements and use of an alternative approach such as the geometric mean of samples collected, with an allowable exceedance frequency of no more than once every three years on average – consistent with other criteria. Another issue that requires reevaluation is how to establish criteria for streams with no existing fish populations. The default by EPA is to use water-column criteria; however, we provide discussion of an alternative involving use of the chronic invertebrate data provided in the EPA document.

Another topic that needs further consideration is providing discussion for how to use natural background Se concentrations to develop ambient based site-specific criteria (either tissue or water-based) where elevated concentrations are present unrelated to human-induced sources. EPA's discussion of site-specific standard development includes nothing on this issue (despite our raising this point last year) and needs further clarification.

We have some concern with the EC_{10} calculations used in the document such as the use of TRAP for all statistical analyses and we recommend EPA consider other options as well. We have also provided additional information regarding calculation of egg/ovary to whole-body conversion factors (CFs), which we used to revise the GMCVs and SMCVs discussed previously.

Overall, this document is a substantial improvement over pre-2014 Se criteria documents, and we look forward to the final draft document, with the hope our recommendations are taken into consideration.

1. Introduction

The EPA approach in the 2015 draft Se criteria document is more in line with standard water quality criteria development methodology (Stephan et al. 1985) than previous attempts at revising and updating the Se criteria, and includes a critical evaluation of 16 studies on various fish species and results in Se tissue thresholds for twelve fish species in ten genera. Criteria calculations follow recommendations by Stephan et al. (1985) and use the 5^{th} percentile calculation accounting for the relative sensitivities of all species in the data set. This approach results in more scientifically defensible criteria than the previous draft tissue criterion based on a single study.

We would like to acknowledge the extensive effort that EPA and others put into development of these updated chronic Se criteria and realize that considerable attempts were made to create a scientifically sound criteria document. However, it seems that even though a substantial number of interested parties provided written comments to the first draft of this criteria document in 2014, the majority of these comments do not appear to be addressed in the criteria, with no responses provided as to the reason why particular comments were not considered in the revision beyond responding to those provided by the peer reviewers. Having ecologically relevant water quality criteria based on current science is of great importance to the scientific and regulated community and we appreciate this opportunity to again provide our comments and recommendations on the 2015 draft Se criteria document.

2. Positives

As we stated in our review of the 2014 draft document, this document and the tissue-based criteria approach is a significant improvement over the 2004 draft criteria document (EPA 2004). We strongly support EPA's decision to develop Se criteria that are toxicologically and ecologically relevant.

The document is clearly laid out, follows standard protocols for water quality criteria development, and includes thorough descriptions of the steps used in development of the criteria. We are in support of the following core components of the 2015 draft criteria document (see Sections 2.1 through 2.4 below):

- Tissue-based standards,
- Use of EC_{10}s, and
- Timing of tissue data collection
- Exclusion of juvenile survival data

In addition, in Sections 3 and 4 of this review, we have provided several recommended revisions and considerations that we believe will make the 2015 draft criteria document even more scientifically sound.

2.1 Tissue-based Standards

As stated in our previous review, we strongly support the approach of a fish tissue-based Se chronic criterion approach (egg/ovary and whole-body) in the final document as the primary criterion. Fish tissue-based Se criteria are consistent with the latest scientific information regarding the toxicology of Se to aquatic life. Tissue-based criteria are the most ecologically relevant for Se, as they are based on the chronic toxicity pathway which includes bioaccumulation of Se through dietary exposure and incorporates such variables as chemical reaction rates and exchange rates between sediment, water, and organism (Brix and DeForest 2008, Chapman et al. 2009). In addition, we strongly urge EPA to consider how such tissue-based criteria can be directly incorporated into NPDES permitting, as discussed further later in this review.

2.2 Use of EC_{10}s

We agree with the use of EC_{10} values to develop the tissue-based Se criteria, as data allow. Use of EC_{10}s is more conservative and consistent with other recent approaches (e.g., DeForest and Adams 2011). In addition, for many of the studies, other endpoints (e.g., EC_{20}) may not be able to be determined based on the response curves observed in the data.

We also understand that not all available studies provide sufficient data to reliably calculate EC_{10} values. In general, we support the data decisions used by EPA for those studies, with the exception of the suggested modifications for specific studies and their data noted later in our review (Section 3.1).

2.3 Timing of Tissue Data Collection

We support EPA's conclusions that selenium measurements from samples collected at the same site within 1 year can serve as matched pairs of measurements, and feel the timing of tissue data collection will be an important component of implementing tissue-based criteria into NPDES permits and general 303(d) assessments. Allowance of appropriate sampling windows provides time for analysis of effluent data and potential follow-up tissue sampling. In addition, this large sampling window could be very important in ephemeral and intermittent aquatic systems where water may only be present during certain times of the year, resulting in limited time periods to conduct fish sampling.

2.4 Reliance on Maternal Transfer Rather Than Juvenile Survival Data

We would like to point out one additional point which we strongly agree with. We support EPA's decision to not rely on juvenile survival data, including overwinter survival, in developing the Se criteria. Although winter-stress may be a valid hypothesis, there are no data supporting its occurrence in the field (Janz 2008). Additionally, if other commenters have concerns with the exclusion of winter-stress data, we would recommend directing them to the Bluegill studies by Hermanutz et al. (1992, 1996), which included Bluegill exposed to year-round seasonal conditions in an outdoor test system, and thus include "winter stress" under natural conditions.

3. Key Issues and Recommendations

While the 2015 draft Se criteria are an improvement over previous criteria, there are some key areas of the criteria that we feel still need closer examination and revision. We presented many of these recommendations and revisions to these key issues in our review of the 2014 draft, but most appear not to have been addressed. We provide additional comments on these areas below, and a further discussion of new concerns on the 2015 draft.

3.1 Review of Toxicity Studies Used for Criteria Development

The 2015 draft Se criteria document includes reproductive toxicity study data for nine fish genera (Table 3.1, page 40). As noted previously, overall, we concur with most of the data usage decisions made by EPA. However, we would like to reiterate some of our comments and suggestions on the data that were used to develop the egg/ovary chronic criterion (and subsequently, the whole-body and muscle criteria), as well as provide new comments and suggestions. We believe incorporation of these suggested changes would result in an egg/ovary chronic criterion that is even more scientifically defensible and have greater consistency with EPA's other data-usage decisions used elsewhere in their document.

3.1.1 General

As with the 2014 review, we examined each of the data points deemed acceptable by EPA for use in the egg/ovary criterion calculation (Table 3.1, page 40) to determine if we saw any potential issues with EPA's use of the data.

We continue to have some concerns with the use of TRAP for all data analysis (described in Section 4.2), although we do understand the value in standardizing the calculation of chronic values from each study by using one statistical approach. However, many of the values calculated by TRAP differ considerably from those calculated by the study authors. We would recommend EPA consider comparing effects calculations using other standard toxicological statistical programs to better understand the variability among programs and any implications of their choice to use TRAP for the resulting criteria.

3.1.2 White Sturgeon

In the 2015 draft criteria document EPA included data from the Linville (2006) White Sturgeon study. These data were not included in the 2014 draft, but White Sturgeon is now the most sensitive species in the database. This study was a dietary exposure in which adult female sturgeon were fed a Se spiked diet, and effects on larvae were measured. Larval effects were observed for edema and deformities.

EPA calculated an EC_{10} for total deformities (edema + skeletal) of 16.3 mg/kg using TRAP. This value was calculated based on a partial dose response. When data from this study are analyzed, TRAP warns that data should only be used for "exploratory purposes." Due to the partial response in the data, the calculation is highly dependent on the initial guess used for the slope in TRAP. In fact, in Appendix C (EPA 2015), EPA shows how choice of initial slope can affect these calculations, with EC_{10} values ranging from 16.3 mg/kg to 19.1 mg/kg when using different slopes. EPA selected the most conservative value for use in criteria development, even while acknowledging there was no scientific reason one value was more valid than another (and, in fact, all calculated values were statistically identical).

Generally, use of an EC_{10} based on a partial response is not appropriate for national criteria development, especially when it results in a value becoming the "most sensitive" and thereby driving the final criterion. In fact, on page 33 of the 2015 draft criteria document EPA states that "an EC10 based on only one partial response would not ordinarily be included in the data set." A similar partial response was observed in the Fathead Minnow data from the GEI 2008 study; EPA excluded these Fathead Minnow data from the chronic dataset because of an "insufficient response." EPA's reasoning for using the White Sturgeon data that had only a partial response is that there are data that suggest that the federally-listed Green Sturgeon is also sensitive to selenium. The Green Sturgeon study consisted of effects on survival and percent body weight in juvenile sturgeon and is not comparable to the reproductive endpoints in all other studies used for criteria development. However, we realize that EPA is concerned with protecting any threatened or endangered species, and the criteria document states that the White Sturgeon serves as a surrogate for other sturgeon as well.

Although the White Sturgeon data are somewhat questionable, they are important data due to the threatened or endangered listings of other species of sturgeon. However, we do recommend revisions to the EC_{10} value used for criteria calculations. As stated previously, the EC_{10} is based on only a partial response, therefore when the threshold sigmoid nonlinear regression model in TRAP is used, several curves may be fit by varying the slope used in the calculation. In Appendix C of the 2015 EPA criteria document, four EC_{10} values have been calculated, all with the same goodness of fit. While EPA chose the most conservative value for use in criteria calculations, we recommend use of the geometric mean of the four EC_{10}s, as they are all equally valid. This results in an egg/ovary EC_{10} of 17.8 mg/kg dw for White Sturgeon (Table 2).

3.1.3 Bluegill

In the 2015 draft Se criteria document, EPA utilized three Bluegill studies in the derivation of the tissue-based criteria: Doroshov et al. (1992), Coyle et al. (1993), and Hermanutz et al. (1992, 1996). While we agree with the use of the Doroshov et al. (1992) and Coyle et al. (1993) studies, we have several concerns regarding the use of the Hermanutz et al. (1992, 1996) data.

EPA reported an egg/ovary EC_{10} of 12.68 mg/kg for the Hermanutz et al. (1992, 1996) studies. This value was derived through a reanalysis of the data using TRAP and combining results from Studies I and II (Hermanutz et al. 1992, 1996) – in other words, they actually combined data from studies conducted over two different years, a data usage practice rarely used in criteria development. EPA elected to exclude Study III and several streams from Study II because they were considered to be "recovering" streams and were no longer receiving aqueous Se dosing. However, fish in these streams were obviously exposed to dietary Se throughout the study, which is the same exposure route that was used in other studies considered acceptable by EPA, such as the Linville (2006) White Sturgeon study, the Doroshev et al. (1992) Bluegill study, and the CP&L (1997) Largemouth Bass study. It is unclear why these dietary studies were included in the criteria development and the "recovering" streams from Studies II and III, which showed no effects, were not.

In addition, we previously expressed several concerns about the results of Studies I and II and the resulting analysis:

- The studies were conducted 1 year apart, which resulted in significant variation in all of the measured water quality parameters between the two studies.
- There were differences in how EPA analyzed and used the data from the two studies in Appendix C (see pages C-107 and C-108 of the 2014 draft Se criteria document).
- There were differences in egg and larvae survival between Studies I and II (see pages C-107 and C-108 of the 2014 draft Se criteria document).
- The ovary Se concentrations resulting from the same water exposures were quite different. These variations raise concerns that differences in Se uptake, bioaccumulation, exposure, or other factors could have been occurring between Studies I and II.
- In Study I, geometric mean ovary Se concentrations were higher in the 10 µg/L exposure (17.71 mg/kg) than the 30 µg/L exposure (15.46 mg/kg). Related to the concerns discussed above, this unexpected result indicates there may have been an issue with study conditions that caused inconsistencies with Se uptake, bioaccumulation, or exposure.

Based on these concerns, as well as the omission of any data from Study III, we recommend the Hermanutz et al. (1992, 1996) data could be completely removed from the database used for criteria derivation altogether. If only the other two chronic values for Bluegill (20.75 mg/kg [Doroshov et al. 1992] and 24.55 mg/kg [Coyle et al. 1993]) are used, a Bluegill egg/ovary GMCV of 22.57 mg/kg would be appropriate, and show that the value EPA derived from the Hermanutz et al. studies would be an outlier.

3.1.3.1 Use of Only Egg Data from Bluegill Studies with Egg and Ovary Data Available

Both Doroshov et al. (1992) and Coyle et al. (1993) present tissue data for both ovaries and eggs. It is unclear why EPA only used egg data from these studies and did not include both egg and ovary tissues as an average value. On page 78 of the 2014 draft Se criteria document, EPA suggests that it is appropriate to use the average of egg and ovary concentrations when both tissues are reported when deriving CFs. We recommend EPA include data for both ovaries and eggs, or at the very least provide details about its preference for egg versus ovary tissues, as this information will be important to make sure future toxicity testing and criteria implementation include measurement of Se in appropriate tissues.

3.1.4 Brown Trout

In the 2015 draft Se criteria document, EPA utilized Brown Trout data from Formation Environmental (2011). During this study, a tank overflow accident occurred which resulted in the loss of several study fish. In the 2014 draft, EPA presented two approaches for dealing with this loss of these study organisms: 1) assume that all fry lost were dead or deformed ("worst case" assumption) and 2) assume that fry lost had the same rates of mortality and deformities as those not lost ("optimistic" assumption). In the 2014 draft, EPA chose to assume the "worst case" scenario and derived an egg/ovary EC_{10} of 15.91 mg/kg using the results from that scenario and the deformity alone endpoint. In the 2015 draft EPA acknowledged the uncertainty with how to best address the loss of fish, and decided to calculate an EC_{10} for survival only during the first portion of the test, prior to the accident. This resulted in calculation of an EC_{10} of 18.09 mg/kg egg dw for larval survival.

We still believe that all appropriate data from this study should be used and that the "optimistic" scenario should be considered, as it reflects what was observed in the remaining population (i.e., the fish not lost to overflow). EPA did not provide any reasons for why use of all data with the "optimistic" assumption is not a valid approach. As stated previously, throughout GEI's 25 years of conducting toxicity tests in our laboratory, we have observed that dead fish actually collect at the bottom of the aquarium not at the top, where fish would be more likely to be lost in an overflow event. Therefore, based on what has been observed in standard toxicity tests EPA should use their "optimistic" (i.e., what we consider to be realistic) assumption, and continue to use the entire data set that provides both survival and deformity information, rather than just using survival data from one portion of the test.

We also believe there is no valid reason to use the deformities endpoint alone when the combined survival and deformities endpoint is available. In fact, this is more in line with the EPA's previous approach in the 1999 ammonia criteria document where they used the combined survival and growth endpoint, termed "biomass." Additionally, there were no difficulties in using TRAP to fit the combined data, and these data and resulting graphs are provided in Appendix C, Figure 1 of the EPA 2015 draft Se criteria document. When these combined data are used, the EC_{10} for the "optimistic" assumption is 21.16 mg/kg for egg/ovary, which we recommend as an appropriate and protective Brown Trout chronic value.

3.2 Additional Fish Species

Another fish family used in development of the EPA criterion was Poeciliidae, which includes *Gambusia holbrooki* and *Gambusia affinis*. These fish are livebearers and were not included in development of the egg/ovary value, but were used as one of the values in the dataset, increasing the N used in calculations.

There are three additional fish species that could also be included to increase the number of values in the dataset. Although no valid reproductive studies have been conducted on these species, similar to the EPA decisions on invertebrates, field studies have demonstrated that these species are not sensitive to elevated selenium concentrations so they could be used to increase the N. Central Stonerollers (*Campostoma anomalum*), Red Shiner (*Cyprinella lutrensis*), and Sand Shiners (*Notropis stramineus*) were able to maintain successful reproducing populations (similar to their populations at low Se locations) with whole body tissue concentrations over 40 mg/kg dw in a study conducted near Pueblo, Colorado (GEI 2007). These data are also provided in Appendix E of the EPA 2015 draft criteria document (Table E-18). Because these species are insensitive to elevated selenium, they would not be in the top four most sensitive; however, they can be included in the total number of species. Inclusion of these fish species increases N from 15 to 18.

3.3 Derivation of Tissue Criterion Elements

3.3.1 Updates to Egg/Ovary Criterion

Implementing the data usage modifications discussed above (Section 3.1.1) results in changes to the criteria calculations. The following is a summary of our recommended modifications:

- Update the White Sturgeon SMCV to 17.8 mg/kg
  - Result of calculating the geometric mean of the four EC_{10}s calculated by EPA
- Update the Bluegill GMCV to 22.57 mg/kg
  - Result of excluding the Hermanutz et al. (1992, 1996) studies
- Update the Brown Trout SMCV to 21.16 mg/kg
  - Result of using all data (survival and deformity) with the "optimistic"/realistic assumption for addressing the issue of the fry lost during the study
- Include three additional fish species to increase N based on observed insensitivity to Se

The order and chronic values for the top four most sensitive species change as a result of the modifications to the White Sturgeon, Bluegill and Brown Trout GMCVs (Table 1). In addition, the sample size increases from N=15 to N=18. Using the data presented in Table 3, an updated egg/ovary criterion of 17.9 mg/kg can be derived using EPA criteria calculation methodology (Stephan et al. 1985; Table 2). We recommend EPA considers this recalculated criterion, as it is based on sound data for relevant species.

Table 1: Modified version of Table 3.2 of the 2015 draft Se criteria document following adjustments to chronic values for White Sturgeon, Bluegill, and Brown Trout based on review and analysis of study data. N=18. Asterisks indicate values that differ from those reported in the 2015 draft Se criteria document.

Rank	GMCV (mg Se/kg dw EO)	Species	SMCV (mg Se/kg dw EO)
9	56.22	Dolly Varden, *Salvelinus malma*	56.22
8	<34	Northern Pike, *Esox lucius*	<34
7	27	Desert Pupfish, *Cyprinodon macularius*	27
6	<23.85	Fathead Minnow, *Pimephales promelas*	<23.85
5	22.71	Cutthroat Trout, *Oncorhynchus clarki*	24.45
		Rainbow Trout, *Oncorhynchus mykiss*	21.1
4	22.57*	Bluegill Sunfish, *Lepomis macrochirus*	22.57*
3	21.16*	Brown Trout, *Salmo trutta*	21.16*
2	20.35	Largemouth Bass, *Micropterus salmoides*	20.35
1	17.8*	White Sturgeon, *Acipenser transmontanus*	17.8*

Table 2: Updated calculation of egg/ovary fish tissue-based Se criterion based on modifications in Table 2 (N = 14 genera, R = sensitivity rank in database).

Rank	Genus	GMCV	ln GMCV	(ln GMCV)^2	P = R/(N+1)	√P
1	*Acipenser*	17.80	2.8792	8.2898	0.0526	0.2294
2	*Micropterus*	20.35	3.0131	9.0787	0.1053	0.3244
3	*Salmo*	21.16	3.0521	9.3154	0.1579	0.3974
4	*Lepomis*	22.57	3.1166	9.7133	0.2105	0.4588
		Sum	12.0610	36.3972	0.5263	1.4101

Calculations:
Chronic Egg/Ovary Criterion

$$S^2 = \frac{\sum(\ln GMCV)^2 - (\sum \ln GMCV)^2/4}{\sum P - (\sum\sqrt{P})^2/4} = \frac{36.3972 - (12.0610)^2/4}{0.5263 - (1.4101)^2/4} = 1.0306 \qquad S = 1.0152$$

$$L = [\sum \ln GMCV - S(\sum\sqrt{P})]/4 = [12.0610 - 1.0152(1.4101]/4 = 2.6574$$

$$A = S(\sqrt{0.05}) + L = (1.0152)(0.2236) + 2.6574 = 2.8844$$

Final Chronic Value = FCV = e^A = **17.8927**

3.3.2 Updates to Whole-body Criterion

In Section 3.1.5.2 of the 2015 draft Se criteria document, EPA presents its approach for deriving a whole-body-based criterion. To develop whole-body chronic values, EPA translated the egg/ovary chronic values used to develop the egg/ovary criterion using egg/ovary to whole-body CFs (Table 3.5 of the 2015 draft Se criteria document). These converted values were then used to calculate a whole-body criterion of 8.0 mg/kg. EPA again used a sample size of 15, which included the three invertebrate-based values, the two assumed crustaceans, and *Gambusia*.

As we previously commented, in the past EPA has used regression-based CFs (e.g., Bluegill CF from EPA's 2004 draft Se criteria document). However, in the 2015 draft Se criteria document, EPA developed CFs based on the median of available matched egg/ovary and whole-body Se data. We believe a more appropriate method would be to use regression-based egg/ovary to whole-body translators when appropriate (i.e., when the regression relationship had an R^2 value >0.70). We translated the egg/ovary database to whole-body and derived an updated whole-body criterion (Table 3 and Table 4). For *Oncorhynchus*, individual CFs were used to translate each species individually (*O. mykiss* and *O. clarkii*), but an overall regression using data for both species was used to convert the *Oncorhynchus* egg/ovary GMCV to a whole-body GMCV of 14.99 mg/kg (Table 6). In addition, as discussed in Section 4.3.1, we corrected and updated the median-based CFs based on our review of EPA's data and addition of our data; these updates were incorporated here. Many of these recommendations, which are based on data EPA had in 2014 or were provided in our earlier review in 2014, were not used, with no reasons provided.

The whole-body criterion should also be adjusted as a result of our updates to the White Sturgeon, Bluegill, and Brown Trout egg/ovary chronic values.

Incorporating our modifications to the egg/ovary to whole-body translators, updated toxicity values for White Sturgeon, Bluegill, and Brown Trout, and increasing the sample size from 15 to 18 results in an updated whole-body criterion of 9.55 mg/kg which can be derived using EPA criteria calculation methodology (Stephan et al. 1985; Table 7). We recommend EPA considers this recalculated criterion with regression-based CFs in place of median-based conversion factors when possible, as it is based on sound data for relevant species.

Table 3: Modified version of Table 3.5 of the 2015 draft Se criteria document following adjustments to conversion factors and chronic values for White Sturgeon, Bluegill, and Brown Trout recommended by GEI Consultants, Inc. Asterisks indicate egg/ovary values that differ from those reported in the 2015 draft Se criteria document.

Rank	Taxon	EO Chronic Value	EO/WB Regression[a] or Median-based CF	Calculated WB Repro Chronic Value	Basis for EO/WB Ratio (from Appendix B)
8	*Salvelinus*	56.22	y=0.9617x+5.5021	59.57	Regression-based Dolly Varden (includes M/WB conversion)
7	*Esox*	34	y=0.9426x-1.4953	30.55	Regression-based Northern Pike (includes M/WB conversion)
6	*Cyprinodon*	27	1.21	22.31	Median Desert Pupfish EO/WB from EPA 2014
5	*Pimephales*	23.85*	1.40	17.04	Median Fathead Minnow EO/WB (from GEI Consultants, Inc. 2008)
4	*O. mykiss*	21.1	y=0.6582x-0.0949	13.79	Regression-based Rainbow Trout (includes M/WB conversion)
	O. clarkii	24.45	2.32	10.54	Modified median Cutthroat Trout (includes M/WB conversion)
	Oncorhynchus	22.71	y=0.5731x+1.9711	14.99	Regression-based Rainbow Trout and Cutthroat Trout (includes M/WB conversion)
3	*Salmo*	21.16*	1.45	14.59	Median Brown Trout EO/WB
2	*Micropterus*	20.35	y=0.4384x+2.161	11.08	Regression-based Centrarchidae (Bluegill, smallmouth bass, green sunfish) EO/WB
1	*Lepomis*	22.57*	y=0.4239x+1.2392	10.81	Regression-based Bluegill EO/WB
	Acipenser	17.8	1.694	10.51	Median White Sturgeon EO/M (1.330) x median fish M/WB (1.274)

Table 4: Updated calculation of whole-body fish tissue-based Se criterion based on modifications recommended by GEI Consultants, Inc., including use of EO/WB regressions (N = 18 genera, R = sensitivity rank in database).

Rank	Genus	GMCV	ln GMCV	(ln GMCV)^2	P = R/(N+1)	√P
1	*Acipenser*	10.51	2.3523	5.3334	0.0526	0.2294
2	*Lepomis*	10.81	2.3805	5.6666	0.1053	0.3244
3	*Micropterus*	11.08	2.4051	5.7847	0.1579	0.3974
4	*Salmo*	14.59	2.6803	7.1842	0.2105	0.4588
		Sum	9.8183	24.1690	0.5263	1.4101

Calculations:
Chronic Whole-body Criterion

$$S^2 = \frac{\sum(\ln GMCV)^2 - (\sum \ln GMCV)^2/4}{\sum P - (\sum\sqrt{P})^2/4} = \frac{24.1690 - (9.8183)^2/4}{0.5263 - (1.4101)^2/4} = 2.3707 \qquad S = 1.5397$$

$L = [\sum \ln GMCV - S(\sum\sqrt{P})]/4 = [9.8183 - 1.5397(1.4101]/4 = 1.9118$

$A = S(\sqrt{0.05}) + L = (1.5397)(0.2236) + 1.9118 = 2.2561$

Final Chronic Value = FCV = e^A = **9.5457**

3.3.3 Updates to Muscle Criterion

In Section 3.1.5.3 of the 2015 draft Se criteria document, after presenting its approach for developing the egg/ovary criterion, EPA presents its approach for deriving a muscle-based criterion. To develop muscle chronic values, EPA translated the egg/ovary chronic values used to develop the egg/ovary criterion using egg/ovary to muscle CFs (Table 3.7 of the 2015 draft Se criteria document). These converted values were then used to calculate a muscle-based criterion of 11.3 mg/kg. EPA again used a sample size of 15, which included the three invertebrate-based values, the two crustaceans and *Gambusia*.

As a result of our recommended updates to the White Sturgeon, Bluegill, and Brown Trout egg/ovary chronic values, the muscle criterion will also need to be adjusted.

Incorporating our suggested modifications results in several changes in the top four most sensitive species of the muscle-based toxicity database (Table 5). In addition, the sample size increases from N=15 to N=18 as a result of the additional fish species discussed previously. Using the data presented in Table 6 an updated muscle criterion of 11.96 mg/kg can be derived using EPA criteria calculation methodology (Stephan et al. 1985). We recommend EPA considers this recalculated criterion, as it is based on sound data for relevant species.

Table 5: Modified version of Table 3.7 of the 2015 draft Se criteria document following adjustments to chronic values for White Sturgeon, Fathead Minnow, Bluegill, and Brown Trout based on review and analysis of study data. Asterisks indicate values that differ from those reported in the 2015 draft Se criteria document.

Rank	Taxon	EO Chronic Value	EO/M Ratio	Calculated Muscle Repro Chronic Value	Basis for EO/M Ratio (from Appendix B)
	Salvelinus	56.22	1.264	**44.478**	Median Dolly Varden EO/M
8	*Cyprinodon*	27	0.95	**28.421**	Median Desert Pupfish EO/WB divided by median fish M/WB
7	*Salmo*	21.16*	1.135	**18.643***	Median Brown Trout EO/
6	*Esox*	34	1.875	**18.133**	Median Northern Pike EO/M
5	*Micropterus*	20.35	1.187	**17.144**	Median Micropterus EO/M
4	*Lepomis*	22.57*	1.375	**16.415***	Median Bluegill EO/M
3	*Pimephales*	23.85	1.59	**15.0**	Median Cyprinidae EO/M
2	*Acipenser*	17.8	1.33	**13.383**	Median White Sturgeon EO/M
	O. mykiss	21.1	1.916	11.013	Median Rainbow Trout EO/M
1	*O. clarkii*	24.45	1.805	13. 546	Median Cutthroat Trout EO/M
	Oncorhynchus	22.71	1.86	**12.214**	Using geomean of species ratios yields geomean of SMCVs

Table 6: Updated calculation of muscle fish tissue-based Se criterion based on modifications to Table 8 (N = 18 genera, R = sensitivity rank in database).

Rank	Genus	GMCV	ln GMCV	(ln GMCV)^2	P = R/(N+1)	$\sqrt{P}$
1	*Oncorhynchus*	12.214	2.5026	6.2629	0.0526	0.2294
2	*Acipenser*	13.383	2.5940	6.7288	0.1053	0.3244
3	*Pimephales*	15.0	2.7081	7.3335	0.1579	0.3974
4	*Lepomis*	16.415	2.7982	7.8299	0.2105	0.4588
		Sum	10.6028	28.1551	0.5263	1.4100

Calculations:
Chronic Muscle Criterion

$$S^2 = \frac{\sum(\ln GMCV)^2 - (\sum \ln GMCV)^2/4}{\sum P - (\sum\sqrt{P})^2/4} = \frac{28.1551 - (10.6028)^2/4}{0.5263 - (1.4100)^2/4} = 1.7159 \qquad S = 1.3099$$

$L = [\sum \ln GMCV - S(\sum\sqrt{P})]/4 = [10.6028 - 1.3099(1.4100]/4 = 2.1889$

$A = S(\sqrt{0.05}) + L = (1.3099)(0.2236) + 2.1889 = 2.4818$

Final Chronic Value = FCV = e^A = **11.9634**

3.4 Derivation of Protective Water Column Concentrations

3.4.1 Use of Probability Distribution of Water Column Concentrations

As stated previously, we do not agree with the general approach used to derive the two default water column concentrations meant to be protective of fish-tissues. Table 3.13 on page 82 of the 2015 draft Se criteria document presents site-specific data for 20 lentic and 33 lotic species-site combinations and includes site-specific enrichment factors (EF), species-specific whole-body to egg/ovary conversion factors (CF), and composite trophic transfer function ($TTF^{composite}$) values based on expected trophic levels at the site.

The final water quality criteria selected for lotic and lentic systems were based on Figure 3.96, page 84 of the 2015 draft Se criteria document. This figure is a probability distribution of the water column concentrations for lentic and lotic sites after being translated from the final egg/ovary tissue criterion (data from EPA Table 3.13). As we stated in our previous review, it appears this figure and the choice of a 20th percentile were used as if these represented sensitivity distribution curves, in which protectiveness can be predicted based on selecting a certain percentile value from the curve. However, these are not sensitivity distribution curves – in fact, as we pointed out last year, each value on these curves is a translated water concentration value that was specifically calculated to be protective of the egg/ovary tissue criterion. ***Therefore, each and every point on this graph (and those values in the far-right column of Table 12) is protective of the egg/ovary criterion based on the site-specific parameters at that site (given site-specific EF, CF, TTF)***.

Thus, the analysis by EPA actually demonstrates that water concentrations that are protective of the tissue criterion can range from 0.23 µg/L to 50.4 µg/L for lentic sites, and 1.2 µg/L to 40.6 µg/L for lotic sites, depending on the site-specific factors used in Equation 18. By selecting a 20th percentile value to use as the water column criteria, as EPA did, 80% of the sites in Table 3.13 would be overprotected, and 20% of the sites would be underprotected, resulting in a water column criterion that is wrong virtually 100% of the time – with the exception being the particular sites that fell right on the 20th percentile lines.

We believe there are a number of valid approaches to translate an egg/ovary criterion to a water column value, such as Equation 18 or a bioaccumulation factor (as discussed later), but only if the proper data are used in the equations. The key is to properly characterize the base of the food chain, which for lotic systems includes incorporating sediment and/or periphyton data, rather than relying on suspended particulate Se data. Other modeling approaches that also capture the various aspects of the system could also be used to translate a water column criterion.

In addition, the dataset used to derive EPA's water column values is very limited, especially when considering this is supposed to be the basis for a national criterion. Using additional data from several GEI projects (and other GEI updates previously discussed in this document), we recalculated the lotic water column value using EPA's method and derived a value of 4.2 µg/L. Paired data from GEI projects were available for 47 additional sites, which more than doubles the database used by EPA. Protective values for these lotic sites range from 1.18 µg/L to 81.03 µg/L. While we still believe this method for calculating a nationwide water column value is over-conservative, this recalculation demonstrates how additional data can substantially affect the final value. If EPA intends to use this method to calculate a nationwide water column value, there should be more effort put into collecting site-specific data to include in the database, and not just relying on a few published literature values, most of which were data collected more than 20 years ago.

In addition, we also concur with comments provided by (API 2015) regarding the counterintuitive results calculated when using constant EFs and TTFs. We would agree that the alternative approaches they provide for these calculations would result in more appropriate protective water column criteria.

3.4.2 Intermittent-exposure Element

The intermittent exposure component of the water column-based criterion attempts to address pulses of elevated Se concentrations that could contribute to chronic effects. The equation to calculate the intermittent exposure criterion seems to be an oversimplification as it is essentially just a rearrangement of the equation to calculate a 30-day average concentration. A more appropriate way to determine limits for short-term elevated pulsed Se exposures would be to use a scientifically-based biokinetic model as discussed in Appendix G of the 2014 draft Se criteria document, and described in more depth in DeForest et al. (in press). We have also provided further recommendations on calculation of this element in our previous review (GEI 2014a).

3.5 Recommendations for "Never to be Exceeded" Frequency

Although it is inherent in the way this document was written that the burden to determine how a tissue-based standard will be implemented will be left to the States, we would like to comment on the "instantaneous" and "never to be exceeded" language that is presented in relation to the proposed tissue standard.

Generally, the term "never to be exceeded" requires substantive clarification to make clear what is expected – an issue that cannot wait for some future undetermined "implementation guidance" document. The way the language is written currently suggests that a single fish tissue sample with a concentration above the criteria (egg/ovary, whole-body, or muscle) would result in non-attainment – a result that is in direct contradiction to the data used to develop the criterion, which are based on EC_{10}s calculated from means of treatments. However, other alternatives could be employed (as discussed in our previous review) to ensure that a single fish would not be used to determine attainment. We also support the very detailed analysis of this issue contained in last year's comments by NAMC-SWG (2014).

3.6 Concerns with Primacy of Water Column Values

We also have serious concerns with Footnote 3 of the proposed criterion. Footnote 3 outlines two scenarios in which water column values have primacy over fish tissue values – "fishless waters" and waters with "new or increased inputs of selenium until equilibrium is reached." Specifically, Footnote 3 states:

> Water column values are based on dissolved total selenium (includes all oxidation states, i.e., selenite, selenate, organic selenium and any other forms) in water. Water column values have primacy over fish tissue values under two circumstances: (1) "Fishless waters" (waters where fish have been extirpated, or where physical habitat and/or flow regime cannot sustain fish); and (2) New or increased inputs of selenium until equilibrium is reached.

While we understand the concerns EPA is seeking to address with respect to these two scenarios, we think that the proposed language, when taken in conjunction with the anti-backsliding provisions of the CWA, the requirements of the National Pollutant Discharge Elimination System (NPDES) permitting process for establishing water quality-based effluent limits (WQBELs), and state antidegradation regulations could in some instances effectively nullify the fish tissue approach all together. While EPA considers this an "implementation" issue, it is in fact the language of the criterion itself that will cause the issue and it cannot be rectified with implementation guidance. However, we think that there are ways to address EPA's intent in the criterion document that will allow state programs to maintain the primacy of the fish tissue values in permits without compromising the quality of downstream waters or waters with new or expanded selenium discharges.

The CWA's anti-backsliding provision provides that "a permit may not be renewed, reissued, or modified…to contain effluent limitations which are less stringent than the comparable effluent limitations in the previous permit." CWA Sec. 402(o). While there are listed exceptions to the anti-backsliding requirements, many state agencies and their NPDES permit writers construe these exceptions narrowly and generally interpret anti-backsliding to mean that permits cannot be modified or renewed with less stringent WQBELs than those contained in the previous version. Additionally, certain anti-backsliding exceptions for WQBELs are tied to both attainment and antidegradation regulations, which may cause additional issues with their application in some state programs.

As written, with respect to new or expanded discharges, the criterion would require a permit writer to put WQBELs based on the proposed water column criteria into NPDES permits during the months or even years that it takes for the receiving water to reach "equilibrium."[1]

[1] Importantly, Footnote 1 explains that the egg/ovary criterion element "overrides any whole-body, muscle, or water column element when egg/ovary concentrations are measured, except in [the situations outlined in Footnote 3]," and Footnote 2 states that the fish whole body or muscle criterion element "overrides any water column element when both fish tissue and water concentrations are measured, except in [the situations outlined

Due to the conservative estimates used to derive the water column concentrations, it is possible that in many instances a post-equilibrium discharge limit derived from a fish tissue concentration-based effluent limit will be higher than one based on the water column value. However, because a discharger's permit will already contain the more stringent limitation, even after equilibrium is reached a discharger may only be allowed to have a limitation based on a fish tissue concentration put into their permit if that limitation would be more stringent than the one based on the water column value. In other words, there will likely be instances in which a fish tissue-based effluent limitation will not be permissible if states adopt the criterion as proposed despite the fact that such a limitation would represent the best available science and reflect the EPA's intent as we understand it. This same analysis applies to existing discharges where states may choose to first apply a WQBEL based on the proposed water column criterion where data regarding fish tissue and fish egg ovary selenium concentrations may be scarce, not collected during permit renewal, or otherwise unavailable at the time of permit renewal.

While for some states programs this may not pose an issue (and we support such states' interpretation of anti-backsliding), and for others implementation guidance *may* be able to address this issue by fitting the criterion into one of the anti-backsliding exceptions, it is unclear if that will be legally possible, and regardless it would not matter because as a practical matter dischargers would have already had to install control technologies to treat to the more stringent water column-based limit despite the fact that such controls are not necessary to protect aquatic life. In more extreme cases, dischargers may not be able to get a permit at all based on Footnote 3 due to elevated natural background levels of selenium, despite the fact that certain levels of selenium could be discharged safely as demonstrated by the fish tissue concentrations, because permit writers would be inappropriately basing their calculations on the water column number. Because of this, we make two recommendations. The first is deleting Footnote 3 as written, and instead including a provision for new or expanded discharges whereby limitations are derived from fish tissue concentrations but compliance cannot be tested until the appropriate amount of time has elapsed for the receiving water to reach equilibrium (i.e., a bioaccumulation study special condition requirement). The second is renaming the water column "criteria" as water column "thresholds," as was done in Kentucky's recently approved selenium water quality criteria revision. This would clarify EPA's intent to allow fish tissue concentrations to have primacy over the water column values.

With respect to "fishless waters," Footnote 3 will likewise lead to situations in which dischargers must install expensive control technologies or not be able to discharge selenium at all despite the fact that such requirements are not necessary to protect aquatic life. We

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in Footnote 3]." Therefore, when read together, Footnotes 1-3 make clear that, with respect to "fishless waters" and waters with new or increased selenium inputs until equilibrium is reached, the water column element must be used as the applicable water quality criterion. Permit writers must therefore, based on this language, use the water column values to derive applicable water quality-based effluent limitations.

understand that EPA is required under the CWA to protect downstream waters when deriving water quality criteria. However, a scientifically defensible approach to "fishless waters" that EPA should provide to states as an option in the criterion is the derivation of a site-specific criterion that takes into account the sensitivity of the macrobenthos in the receiving water to protect the receiving water's attainable uses (i.e., to protect the receiving water's macrobenthic communities), while protecting downstream waters through determination of the flow rate of the receiving water into the nearest fish-containing water and ensuring that the fish tissue standard is being met in the downstream fish populations. Such a criterion would ensure that both in-stream and downstream aquatic life are protected without arbitrarily assigning overly-protective water column-based limitations to permittees. We therefore again recommend deleting Footnote 3 as written, and instead including a provision for "fishless waters" that allows for the development of site-specific criteria that protect the attainable use of in-stream macrobenthos as well as downstream fish populations through application of the tissue-based criterion (see additional discussion in Section 3.6.1).

Concerning a related issue, we also note that EPA guidance limits the terms of compliance schedules to five years, as do many state permitting programs based on EPA's guidance. Because in some situations where selenium levels are being decreased based on the new criterion it may take longer than 5 years for corresponding fish tissue concentrations to decrease, NMA recommends including a provision in the criterion stating that longer compliance schedules may be needed with respect to bioaccumulants. Although again this could be considered an "implementation" issue, because it is a facet of the criterion that could directly conflict with existing state water quality programs – thereby limiting states' ability to adopt it – it is necessary to adopt language in the criterion itself that addresses this concern.

3.6.1 Recommendation for Invertebrate Tissue Criterion

In cases where fish populations are not present due to flow limitations the aquatic life to be protected are the macrobenthos. In EPA's analysis of invertebrate data, the most sensitive species had a GMCV of 24.2 mg Se/kg dw wb. All other effect concentrations for invertebrates for which chronic data were available were substantially higher than 24.2 mg/kg. Therefore, based on these data, an invertebrate Se tissue concentration of 24.2 mg/kg dw would be protective of these invertebrates and an appropriate tissue-based criterion for fishless waters.

4. Other Issues and Considerations

The previous sections highlighted specific recommendations for revisions to the document and criteria. In this section we present other issues which we believe need reconsideration. While we may not have specific recommendations on these issues, we feel they do need to be reexamined to ensure the science supporting the decisions made to develop the Se criteria are solid.

4.1 Background Selenium Sources and Occurrences

EPA provides some discussion of Se sources in Section 3.1 of the 2014 draft selenium criteria document. EPA discusses natural Se deposits and highlights areas where Se deposits have been brought to the surface through mining activities and where irrigation in the western United States may cause leaching from high Se soils. However, in addition to human-induced/ irreversible activities that may contribute to elevated Se in surface waters, there are also natural processes that may leach Se into groundwater, and consequently into surface waters, that were not discussed in the draft criteria document. We provided more in depth information on this topic in our previous review (GEI 2014a).

4.1.1 Incorporation of Background Conditions into Site-specific Criteria

Appendix K of the 2015 draft Se criteria document, which describes methods for deriving site-specific criteria, does not discuss inclusion/consideration of data from reference or background sites. This is especially critical at sites with background levels of Se that would be considered elevated, comparatively speaking. In Appendix A, Examples 1-6 include calculation of site-specific criteria that includes background Se concentrations of 5.0 µg/L. Working through the calculation results in a site-specific water column criteria that are always lower than the original background concentration. It is unclear how these calculations could be applied to sites with naturally elevated background Se and result in a Se criterion that would be appropriate for that site.

As discussed in Section 4.1 of this review, ambient site-specific criteria may be appropriate in many parts of the country containing underlying geology with elevated Se levels. This naturally elevated Se may lead not only to elevated water concentrations, but also to naturally elevated fish tissue concentrations, resulting in the need for not only site-specific water column criteria but also a need for an approach that acknowledges there could be site-specific tissue criteria. In our previous review a more in depth discussion of this issue was provided along with specific examples (GEI 2014a).

4.2 Use of TRAP versus Other Statistical Methods

As mentioned previously, we continue to have some concern with the exclusive use of TRAP for determination of all EC_{10} values used in criteria development. TRAP may work well with certain data sets, but may pose problems for analysis of others. We provided additional discussion of the potential issues in our previous review (GEI 2014a).

In many of the studies provided in the 2015 draft Se criteria document, the EC_{10} values calculated by EPA differed from the original values determined by the study authors and those calculated by DeForest and Adams (2011). EPA should provide a list of all parameters and "Initial Guesses" on slopes used for analyses.

4.3 Additional Discussion of Tissue Criterion Elements

4.3.1 Conversion Factors

As part of our previous review, we conducted an evaluation of the conversion factors (CFs) developed by EPA in the 2014 draft Se criteria document wherein we reviewed all of the data used and corrected values where mistakes were found. A detailed evaluation of this issue is also presented by NAMC-SWG (2014).

In addition to reviewing EPA's data and calculations, we also compiled matched tissue data from studies conducted by GEI to supplement the CF database (GEI Appendix A, 2014). We also used the matched egg/ovary, whole-body, and muscle Se data provided in the 2014 draft Se criteria document, which was further updated by GEI as described above, and developed regression-based CFs (Table 9; GEI Appendix A). When the regression has a relatively high goodness of fit (i.e., when R^2 is at least 0.70), we recommend using the regression equation in place of the median (or geometric mean) ratios, as the regression better predicts tissue concentrations, particularly at the high and low ends of the spectrum. Where the strength of the regression is not as high (e.g., creek chub, Fathead Minnow, mountain whitefish), it may be more appropriate to use the median or geometric mean CF to represent the central tendency of the relationship. As shown in Section 3.3.2, we used the regression-based CFs where appropriate to translate the updated egg/ovary criterion database for these species to whole-body for the purposes of deriving the updated whole-body criterion. For the remaining species, we used the updated and new median ratio-based CFs.

4.4 Derivation of Water Column-based Criterion Elements

In Section 3.2 of the 2015 draft Se criteria document, EPA derives an equation to be used to translate the egg/ovary tissue criterion into a water column criterion. The result is Equation 18 on page 63:

$$C_{water} = \frac{C_{egg-ovary}}{TTF^{composite} \times EF \times CF}$$

Where:

C_{water} = Concentration of selenium dissolved in water (µg/L)
$C_{egg/ovary}$ = Selenium concentration in the eggs or ovaries of fish (µg/g)
$TTF^{composite}$ = Product of all trophic transfer functions
EF = Enrichment function (L/g)
CF = Whole-body to egg/ovary conversion factor (dimensionless ratio)

There are several components of this equation that require further analysis and consideration.

4.4.1 Discussion of Trophic Transfer Functions (TTF)

4.4.1.1 Importance of Site-specific TTFs

Ranges of TTFs can vary widely due to site-specific factors. To demonstrate this in our previous review (GEI 2014a), we reviewed data in Appendix B of the 2014 draft Se criteria document and compiled information on the ranges of TTFs for each species with data derived from field studies. We also verified the median TTF values and found several errors in Tables 9 and 10 on pages 76 and 77 of the 2014 draft, these errors still remain in the 2015 draft and should be fixed. Additionally, we recalculated TTF's including additional data that were submitted for addition to the TTF database in our previous review, but were not incorporated in the 2015 draft. These values are included in Table 7 (below) and the corrections are shown in bold with the incorrect values shown as strikeouts.

Table 7: TTF median ratios from Table 3.10 and 3.11 in the 2015 draft Se criteria document and calculated ranges and geomean ratios. Italicized values are lab-based TTF values; other TTFs are from field data. Strikeouts indicate EPA calculation errors. Revised values and species added to the database are shown in bold. Invertebrate and fish groups are indicated with orange and blue shading, respectively.

Common Name	Scientific Name	TTF Median Ratio
Crustaceans		
Amphipod	*Hyalella azteca*	~~1.22~~ **1.06**
Copepod	Copepods	*1.41*
Crayfish	Astacidae	1.46
Waterflea	*Daphnia magna*	*0.74*
Insects		
Dragonfly	Anisoptera	~~1.97~~ **0.89**
Damselfly	Coenagrionidae	~~2.88~~ **1.30**
Mayfly	*Centroptilum triangulifer*	2.38
Midge	Chironomidae	1.90
Water boatman	Corixidae	1.48
Mollusks		
Asian clam	*Corbicula fluminea*	*4.58*
Zebra mussel	*Dreissena polymorpha*	*4.00*
Annelids		
Blackworm	*Lumbriculus variegatus*	*1.29*
Other		
Zooplankton	Zooplankton	2.01
Bluehead sucker	*Catostomus discobolus*	1.04
Cypriniformes		
Common Carp	*Cyprinus carpio*	**1.29**
Creek Chub	*Semotilus atromaculatus*	**1.02**
Red Shiner	*Cyprinella lutrensis*	**1.34**
Redside Shiner	*Richardsonius balteatus*	**0.77**
Fathead Minnow	*Pimephales promelas*	**1.26**
Flannelmouth Sucker	*Catostomus latipinnis*	1.06
Longnose Sucker	*Catostomus catostomus*	0.90
Sand Shiner	*Notropis stramineus*	**1.60**
Blacknose Dace	*Rhinichthys atratulus*	**0.71**
White Sucker	*Catostomus commersonii*	**1.04**
Cyprinodontiformes		
Mosquitofish	*Gambusia* sp.	**0.97**
Northern Plains Killifish	*Fundulus kansae*	1.27
Western Mosquitofish	*Gambusia affinis*	1.25
Esociformes		
Northern Pike	*Esox lucius*	2.04
Gasterosteiformes		
Brook Stickleback	*Culaea inconstans*	**1.79**

4.4.1.2 Use of Composite TTFs

The composite TTF is the product of the TTFs that represent dietary pathways of Se exposure for a given species within an aquatic system. As we commented in our previous review, the $TTF^{composite}$ approach would require prey item-specific consumption rate/frequency data (ideally site-specific) to best characterize exposure. Species-and site-specific dietary preference data are likely not available for many combinations of organisms. In those scenarios, assumptions will need to be made for each prey item, introducing additional and potentially unrealistic uncertainty to derive a TTF composite value.

For more accurate analysis of a specific aquatic system, the best approach is to collect and analyze tissue and water samples to measure actual Se concentrations rather than making assumptions and using highly uncertain composite TTFs.

4.4.2 Enrichment Factors (EF)

Pages 74 of the 2015 draft Se criteria document state that "The single most influential step in selenium bioaccumulation occurs at the base of the aquatic food webs (Chapman et al. 2010)" and "The availability of selenium measurements from particulate material was limited." Given these statements and how critical it is to generate valid Enrichment Factors (EF), EPA should consider inclusion of an uncertainty discussion related to the particulate material Se data and how representative the calculated EF values may (or may not) be to all sites. Additional data to add to the EF database from GEI studies are were included in Appendix A of our previous review. These additional data were not incorporated into the 2015 draft; therefore, calculated EF values for GEI studies are shown in Appendix A.

4.4.3 Classification of Aquatic Systems – Lotic vs. Lentic

It is known that bioaccumulation of Se is significantly different in lentic and lotic systems (Adams et al. 2000). EPA differentiates between system types using EFs and residence time. As discussed in our previous review, this makes sense in theory, however, the resulting data have substantial overlap, indicating the differences are not that clear. It would be more appropriate to develop site-specific criteria rather than create artificial groupings of waterbody types that mask the site-specific differences so important to ensuring attainment of the tissue criterion.

4.5 Site-specific Criteria

4.5.1 Deriving Site-specific Water Concentration Values from the Egg/Ovary Criterion

Appendix K of the 2015 draft Se criteria document describes a methodology to derive site-specific criteria using a mechanistic modeling approach. However, Appendix K seems to simply be a more detailed presentation of information presented in the main text. It does not describe the process or data requirements that a state or tribe would need to follow/generate in order to have their site-specific criteria considered by EPA. In our previous review we discussed several questions and concerns that should be addressed to enable states and tribes to appropriately develop site-specific criteria (GEI 2014a).

5. Conclusions

Overall, the 2015 draft Se criteria document, including the tissue-based criteria approach, is a significant improvement over the 2004 draft criteria document. We strongly support EPA's decision to develop tissue-based Se criteria that are toxicologically and ecologically relevant. While we support the overall approach and core of the 2015 draft Se criteria document, we have several recommended revisions and considerations that, if considered by EPA, could significantly improve the scientific validity of the document and resulting Se criteria.

5.1 Reevaluation of Acceptable Studies

We reviewed all of the reproductive toxicity study data deemed acceptable by EPA in the 2015 draft Se criteria document. Data were presented for ten fish genera. Overall, we concur with most of the data usage decisions made by EPA, but have comments and suggestions on some of the data that were used to develop the egg/ovary chronic criterion (and subsequently, the whole-body and muscle criteria).

Specifically, we had comments on usage of specific White Sturgeon, Bluegill and Brown Trout data in the criteria calculations.

- White Sturgeon – We recommend using the geometric mean of all the EC10s calculated by EPA, as the goodness-of-fit is equal for all curves, therefore all EC10s are equally appropriate. The recommended egg/ovary EC_{10} value, which is equivalent to the SMCV, is 17.8 mg/kg.

- Bluegill – We have concerns about the data used from the Hermanutz et al. (1992, 1996) studies. We recommend rejecting data from all Hermanutz studies. Using only data from the other two studies, the updated Bluegill egg/ovary GMCV is 22.57 mg/kg, with an accompanying whole-body value of 10.58 mg/kg using regression-based CF.

- Brown Trout – We recommend using the Brown Trout EC_{10} calculated under the "optimistic"/realistic assumption for dealing with the lab accident that resulted in loss of study organisms in the Formation Environmental (2011) study. The recommended EC_{10} value, which is equivalent to the SMCV, is 21.16 mg/kg, with an accompanying whole-body value of 14.59 mg/kg based on updated CFs.

- We developed regression-based CFs for translating between egg/ovary and whole-body. When the regression relationship is strong, we recommend using regression-based CFs instead of median ratio-based CFs.

Incorporation of these suggested changes results in updated egg/ovary, whole-body, and muscle chronic criteria that are even more scientifically defensible and consistent with EPA's other data-usage decisions (Table 13).

5.2 Other Considerations

As stated in our review of the 2014 criteria document (GEI 2014b), we agree that any fish tissue collected is representative of accumulation over time and could be considered an "instantaneous" measurement of the current conditions. However, we believe the use of the term "instantaneous" leads to some confusion regarding the tissue sampling requirements. We support the thorough discussion of this topic in the NAMC-SWG 2014 review and agree that there will be natural variability in the tissue samples collected, and a single sample may be over- or under-representative of site conditions. The best way to represent environmental conditions is to average the tissue samples in some manner. We recommend replacing "instantaneous" with "seasonal average" in the tissue criterion requirements.

Another issue that requires reevaluation and clarification is how to establish criteria for streams with no existing fish populations. The default approach is to use water-column criteria; however, an alternative states could be provided is the use of the chronic invertebrate data provided by EPA to develop invertebrate tissue-based site-specific criterion and associated protective water-column criteria.

Another topic that needs further consideration is the use of natural background Se concentrations to develop ambient based site-specific criteria. We have provided discussion of how this has been successfully done in Colorado in our previous review (GEI 2014a), and how it should be considered on a case-by-case basis nationwide. EPA's discussion of site-specific standard development is lacking and needs further clarification.

Finally, we have also provided additional field data for CFs, trophic transfer functions, and enrichment factors for EPA to incorporate and improve their database (GEI 2014a, Appendix A).

5.3 Discussion of Final Criterion

As stated above, we strongly support EPA's decision to develop tissue-based Se criteria that are toxicologically and ecologically relevant. The tissue-based criteria, including our recommended modifications and updates, reflect the best science and are protective of fish.

EPA also derived nationwide lentic and lotic water column-based criteria to supplement the tissue-based criteria. However, as discussed in Section 3.3 it is not possible or appropriate to derive a single nationwide standard for water column-based criteria for only two water body types (lentic or lotic), and such an effort is not supported by EPA's own analysis. While we agree that use of Equation 18 or other approaches could be used to translate a water column criterion from the egg/ovary criterion, this type of modeling should only be done with the appropriate site-specific data and not rely on default generalized model parameters. In addition, as noted earlier, we strongly urge EPA to evaluate direct use of tissue-based criteria in NPDES permitting, which would obviate the need for the back-calculation to a water value, thus eliminating the potential errors and uncertainty that arise in such calculations.

Regarding implementation of the tissue-based criteria, the use of "never to be exceeded" frequency is inappropriate and not in line with standard criteria attainment requirements. We recommend clarification of tissue sampling requirements and use of an alternative approach such as the geometric mean of samples collected, with an allowable exceedance frequency of no more than once every 3 years on average.

Based on the results of our analysis, we recommend updating the proposed egg/ovary, whole-body, and muscle chronic criteria to include our suggested changes (Table 8). In addition, because nationwide water column-based criteria cannot not be derived reliably, we advise EPA to only recommend water column-based criteria be developed on a site/state/region-specific basis (Table 8).

Table 8: Revision of Table 4.1 from the 2015 draft Se criteria document, including our revisions and recommendations.

Media Type	Fish Tissue		Water Column[3]	
Criterion Element	**Egg/Ovary[1]**	**Fish Whole-Body or Muscle[2]**	**Monthly Average Exposure**	**Intermittent Exposure**
Magnitude[4]	17.9 mg/kg	9.5 mg/kg whole-body or 12.0 mg/kg muscle (skinless, boneless filet)	n/a	Site-specific
Duration	Seasonal average	Seasonal average	30 days	Site-specific
Frequency	Not more than once in 3 years on average	Not more than once in 3 years on average	Not more than once in 3 years on average	Site-specific

1. Overrides any whole-body, muscle, or water column elements when fish egg/ovary concentrations are measured.
2. Overrides any water column element when both fish tissue and water concentrations are measured.
3. Water column values are based on dissolved selenium in water.
4. Magnitude is the geometric mean of tissue samples collected.

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Appendix A Supplemental Data

Revised EPA Table 3.11 with updated TTFs from Table B-7 using additional data provided by GEI

Common Name	Scientific Name	AE	IR	ke	TTF
Cypriniformes					
Bluehead Sucker	*Catostomus discobolus*	-	-	-	1.04
Longnose Sucker	*Catostomus catostomus*	-	-	-	0.9
White Sucker	*Catostomus commersonii*	-	-	-	~~1.18~~ 1.04
Flannelmouth Sucker	*Catostomus latipinnis*	-	-	-	1.06
Common Carp	*Cyprinus carpio*	-	-	-	~~1.34~~ 1.29
Red Shiner*	*Cyprinella lutrensis*	-	-	-	1.34
Redside Shiner*	*Richardsonius balteatus*	-	-	-	0.77
Creek Chub	*Semotilus atromaculatus*	-	-	-	~~1.12~~ 1.02
Fathead Minnow	*Pimephales promelas*	-	-	-	~~1.57~~ 1.26
Sand Shiner	*Notropis stramineus*	-	-	-	~~1.83~~ 1.6
Blacknose Dace*	*Rhinichthys atratulus*	-	-	-	0.71
Cyprinodontiformes					
Mosquitofish	*Gambusia sp.*	-	-	-	~~0.86~~ 0.97
Western Mosquitofish	*Gambusia affinis*	-	-	-	1.25
Northern Plains Killifish	*Fundulus kansae*	-	-	-	1.27
Esociformes					
Northern Pike	*Esox lucius*	-	-	-	2.04
Gasterosteiformes					
Brook Stickleback	*Culaea inconstans*	-	-	-	~~1.69~~ 1.79
Perciformes					
Black Crappie	*Pomoxis nigromaculatus*	-	-	-	2.67
Bluegill	*Lepomis macrochirus*	-	-	-	1.48
Green Sunfish	*Lepomis cyanellus*	-	-	-	~~1.27~~ 1.12
Largemouth Bass	*Micropterus salmoides*	-	-	-	~~1.27~~ 1.41
Smallmouth Bass*	*Micropterus dolomieu*	-	-	-	0.83
Striped Bass	*Morone saxatilis*	0.375	0.335	0.085	1.48
Walleye	*Sander vitreus*	-	-	-	1.82
Yellow Perch	*Perca flavescens*	-	-	-	1.42

Common Name	Scientific Name	AE	IR	ke	TTF
Salmoniformes					
Brook Trout	*Salvelinus fontinalis*	-	-	-	~~0.88~~ 0.97
Brown Trout	*Salmo trutta*	-	-	-	1.44
Mountain Whitefish	*Prosopium williamsoni*	-	-	-	1.38
Cutthroat Trout	*Oncorhynchus clarkii*	-	-	-	1.07
Rainbow Trout	*Oncorhynchus mykiss*	-	-	-	1.19
Westslope Cutthroat Trout	*Oncorhynchus clarkii lewisi*	-	-	-	1.2
Scorpaeniformes					
Mottled Sculpin	*Cottus bairdi*	-	-	-	1.38
Sculpin	*Cottus sp.*	-	-	-	1.29
Siluriformes					
Black Bullhead	*Ameiurus melas*	-	-	-	~~0.91~~ 0.87
Channel Catfish	*Ictalurus punctatus*	-	-	-	0.73

Notes:
* Additional species added to the database

Revised EPA Table 3.12 with updated conversion factors for use in back calculating water column vaues using additional data provided by GEI

Common Name	Scientific Name	E/O to WB CF Median Ratio
Acipenseriformes		
White Sturgeon	Acipenser transmontanus	1.69
Cypriniformes		
Bluehead Sucker	*Catostomus discobolus*	1.82
Flannelmouth Sucker	*Catostomus latipinnis*	1.41
White Sucker	*Catostomus commersonii*	~~1.41~~ 1.38
Common Carp	*Cyprinus carpio*	1.92
Razorback Sucker	*Xyrauchen texanus*	~~1.42~~ 1.45
Roundtail Chub	*Gila robusta*	2.07
Fathead Minnow*	*Pimephales promelas*	1.4
Creek Chub*	*Semotilus atromaculatus*	1.99
Esociformes		
Northern Pike	*Esox lucius*	~~2.39~~ 2.41
Perciformes		
Bluegill	*Lepomis macrochirus*	2.13
Green Sunfish	*Lepomis cyanellus*	1.45
Smallmouth Bass	*Micropterus dolomieu*	1.42
Salmoniformes		
Brook Trout	*Salvelinus fontinalis*	~~1.38~~ 1.4
Dolly Varden	*Salvelinus malma*	1.61
Brown Trout	*Salmo trutta*	1.45
Rainbow Trout	*Oncorhynchus mykiss*	~~2.44~~ 2.46
Cutthroat Trout	*Oncorhynchus clarkii*	~~2.30~~ 2.32
Mountain Whitefish	*Prosopium williamsoni*	~~7.39~~ 7.42

Notes:
* Additional species added to the database.

Revised EPA Table 3.13 (lotic data only) with CFs, TTFs and revised back calculated water column values using updated values from Tables 3.11 and 3.12, and including additional GEI data

Reference	Site	Species	Site Type	EF[a]	CF[b]	TTF[composite-c]	Cwater[d]
Butler et al. 1991	Uncompahgre River at Colona	Rainbow Trout	Lotic	0.63	~~2.44~~ 2.46	2.44	~~4.21~~ 4.73
Butler et al. 1993	Spring Cr. at La Boca	Speckled Dace	Lotic	0.18	~~2.00~~ 1.96	~~2.78~~ 2.41	~~15.89~~ 21.05
Butler et al. 1995	Hartman Draw near mouth, at Cortez	Fathead Minnow	Lotic	0.15	~~2.00~~ 1.40	~~2.77~~ 2.69	~~19.13~~ 31.69
Butler et al. 1995	McElmo Cr. at Hwy. 160, near Cortez	Speckled Dace	Lotic	0.90	~~2.00~~ 1.96	~~2.78~~ 2.41	~~3.16~~ 4.21
Butler et al. 1995	McElmo Cr. downstream from Alkali Cyn.	Speckled Dace	Lotic	0.37	~~2.00~~ 1.96	~~2.78~~ 2.41	~~7.73~~ 10.24
Butler et al. 1995	McElmo Cr. downstream from Yellow Jacket Cyn.	Fathead Minnow	Lotic	0.12	~~2.00~~ 1.40	~~2.77~~ 2.69	~~23.79~~ 39.61
Butler et al. 1995	McElmo Cr.upstream from Yellow Jacket Cyn.	Speckled Dace	Lotic	0.10	~~2.00~~ 1.96	~~2.78~~ 2.41	~~29.77~~ 37.89
Butler et al. 1995	Navajo Wash near Towaoc	Speckled Dace	Lotic	0.20	~~2.00~~ 1.96	~~2.78~~ 2.41	~~14.52~~ 18.95
Butler et al. 1995	San Juan River at Four Comers	Speckled Dace	Lotic	0.26	~~2.00~~ 1.96	~~2.78~~ 2.41	~~10.85~~ 14.57
Butler et al. 1995	San Juan River at Mexican Hat Utah	Common Carp	Lotic	0.29	1.92	~~1.70~~ 1.64	~~16.72~~ 19.60
Butler et al. 1995	Woods Cyn. Near Yellow Jacket	Fathead Minnow	Lotic	0.40	~~2.00~~ 1.40	~~2.77~~ 2.69	~~7.05~~ 11.88
Butler et al. 1997	Cahone Canyon at Highway 666	Green Sunfish	Lotic	0.20	1.45	~~2.44~~ 2.16	~~22.81~~ 28.58
Butler et al. 1997	Mud Creek at Highway 32, near Cortez	Fathead Minnow	Lotic	0.07	~~2.00~~ 1.40	~~2.77~~ 2.69	~~40.60~~ 67.90
Casey 2005	Deerlick Creek	Rainbow Trout	Lotic	2.24	~~2.44~~ 2.46	2.44	~~1.19~~ 1.33
Casey 2005	Luscar Creek	Rainbow Trout	Lotic	0.33	~~2.44~~ 2.46	2.44	~~8.15~~ 9.04
GEI 2013*	GC-1	Red Shiner	Lotic	0.88	1.96	2.33	4.44
GEI 2013*	SC-1	Fathead Minnow	Lotic	0.96	1.4	2.69	4.98
GEI 2013*	SC-2	Red Shiner	Lotic	0.50	1.96	2.33	7.83
GEI 2013*	SC-3	Red Shiner	Lotic	0.52	1.96	2.33	7.535
GEI 2013*	SC-4	Sand Shiner	Lotic	0.67	1.96	2.48	5.46
GEI 2013*	SC-6	Red Shiner	Lotic	0.06	1.96	2.33	67.67
GEI 2013*	SC-8	Fathead Minnow	Lotic	0.21	1.4	2.69	22.32
GEI 2013*	SC-9	Red Shiner	Lotic	0.33	1.96	2.33	11.83
Formation 2012	Crow Creek - 1A	Sculpin	Lotic	0.80	~~1.63~~ 1.69	2.80	~~4.33~~ 4.73
Formation 2012	Crow Creek - 3A	Sculpin	Lotic	0.81	~~1.63~~ 1.69	2.82	~~4.24~~ 4.64
Formation 2012	Crow Creek - CC150	Sculpin	Lotic	1.04	~~1.63~~ 1.69	2.69	~~3.46~~ 3.79
Formation 2012	Crow Creek - CC350	Sculpin	Lotic	1.16	~~1.63~~ 1.69	2.75	~~3.02~~ 3.32
Formation 2012	Crow Creek - CC75	Sculpin	Lotic	1.19	~~1.63~~ 1.69	2.63	~~3.09~~ 3.38
Formation 2012	Deer Creek	Sculpin	Lotic	1.55	~~1.63~~ 1.69	2.68	~~2.32~~ 2.55

Reference	Site	Species	Site Type	EF[a]	CF[b]	TTF[composite-c]	Cwater[d]
Formation 2012	Hoopes Spring - HS	Sculpin	Lotic	0.24	~~1.63~~ 1.69	3.51	~~11.25~~ 12.57
Formation 2012	Hoopes Spring - HS3	Sculpin	Lotic	0.54	~~1.63~~ 1.69	2.39	~~7.54~~ 8.21
Formation 2012	Sage Creek - LSV2C	Sculpin	Lotic	0.45	~~1.63~~ 1.69	2.83	~~7.63~~ 8.32
Formation 2012	Sage Creek - LSV4	Sculpin	Lotic	0.69	~~1.63~~ 1.69	2.67	~~5.21~~ 5.75
Formation 2012	South Fork Tincup Cr.	Sculpin	Lotic	1.32	~~1.63~~ 1.69	2.85	~~2.56~~ 2.82
Hamilton and Buhl 2004	lower East Mill Creek	Sculpin	Lotic	1.32	1.96	2.02	~~3.03~~ 3.43
GEI Unpublished*	C-BCR2	Green Sunfish	Lotic	0.76	1.45	2.16	7.5
GEI Unpublished*	C-CC1	Green Sunfish	Lotic	0.64	1.45	2.16	8.9
GEI Unpublished*	C-CC2	Green Sunfish	Lotic	0.54	1.45	2.16	10.5
GEI Unpublished*	C-CF1	Green Sunfish	Lotic	1.48	1.45	2.16	3.87
GEI Unpublished*	C-CLF1	Green Sunfish	Lotic	0.65	1.45	2.16	8.86
GEI Unpublished*	C-CLF2	Green Sunfish	Lotic	0.80	1.45	2.16	7.18
GEI Unpublished*	C-HC1	Creek Chub	Lotic	0.78	1.99	1.4	8.19
GEI Unpublished*	C-LF1	Creek Chub	Lotic	0.07	1.99	1.4	91.8
GEI Unpublished*	C-LFWOC1	Longnose Dace	Lotic	0.06	1.96	2.41	60.1
GEI Unpublished*	C-LMF1	Creek Chub	Lotic	0.53	1.99	1.4	12.19
GEI Unpublished*	C-SC1	Smallmouth Bass	Lotic	0.50	1.42	2.36	10.66
GEI Unpublished*	C-TF1	Green Sunfish	Lotic	0.30	1.45	2.16	18.83
GEI Unpublished*	C-WOC1	Green Sunfish	Lotic	0.09	1.45	2.16	67.02
GEI Unpublished*	H-BHC1	Green Sunfish	Lotic	0.28	1.45	2.16	20.17
GEI Unpublished*	H-BHC2	Green Sunfish	Lotic	0.29	1.45	2.16	19.87
GEI Unpublished*	H-BHC3	Green Sunfish	Lotic	0.24	1.45	2.16	24.26
GEI Unpublished*	H-BLB1	Green Sunfish	Lotic	0.37	1.45	2.16	15.62
GEI Unpublished*	H-BLB2	Creek Chub	Lotic	0.36	1.99	1.4	17.67
GEI Unpublished*	H-CC1	Green Sunfish	Lotic	0.42	1.45	2.16	13.56
GEI Unpublished*	H-HC1	Creek Chub	Lotic	0.89	1.99	1.4	7.18
GEI Unpublished*	H-JSB1	Green Sunfish	Lotic	3.97	1.45	2.16	1.44
GEI Unpublished*	H-LCR2	Bluegill	Lotic	0.62	2.13	2.85	4.78
GEI Unpublished*	H-LF1	Green Sunfish	Lotic	0.49	1.45	2.16	11.74
GEI Unpublished*	H-LKC1	Creek Chub	Lotic	0.33	1.99	1.4	19.59
GEI Unpublished*	H-MR1	Green Sunfish	Lotic	0.13	1.45	2.16	43.33

Reference	Site	Species	Site Type	EF[a]	CF[b]	TTF[composite-c]	Cwater[d]
GEI Unpublished*	H-MR2	Green Sunfish	Lotic	0.15	1.45	2.16	38.99
GEI Unpublished*	H-MR3	Green Sunfish	Lotic	0.23	1.45	2.16	24.88
GEI Unpublished*	H-MR4	Green Sunfish	Lotic	0.77	1.45	2.16	7.43
GEI Unpublished*	H-SB1	Green Sunfish	Lotic	0.60	1.45	2.16	9.6
GEI Unpublished*	H-SF1	Green Sunfish	Lotic	0.32	1.45	2.16	17.69
GEI Unpublished*	H-SF2	Green Sunfish	Lotic	0.40	1.45	2.16	14.4
Saiki and Lowe 1987	San Luis Drain	Western Mosquitofish	Lotic	0.36	~~1.63~~ 1.69	2.46	~~10.94~~ 11.96
Saiki and Lowe 1987	Volta Wasteway	Western Mosquitofish	Lotic	1.03	~~1.63~~ 1.69	2.46	~~3.82~~ 4.18
Saiki et al. 1993	Mud Slough at Gun Club Road	Bluegill	Lotic	1.37	2.13	2.12	~~2.55~~ 2.89
Saiki et al. 1993	Salt Slough at the San Luis National Wildlife Refuge	Bluegill	Lotic	0.43	2.13	2.12	~~8.18~~ 9.22
Saiki et al. 1993	San Joaquin R. above Hills Ferry Road	Bluegill	Lotic	0.36	2.13	2.12	~~9.78~~ 11.01
Saiki et al. 1993	San Joaquin R. at Durham Ferry State Recreation Area	Bluegill	Lotic	0.75	2.13	2.12	~~4.68~~ 5.29
GEI 2014c*	BC-3	Redside Shiner	Lotic	0.53	1.96	1.73	10
GEI 2014c*	CC-2	Creek Chub	Lotic	0.98	1.99	1.4	6.56
GEI 2014c*	DC-1	Creek Chub	Lotic	1.52	1.99	1.4	4.22
GEI 2014c*	DC-2	Brook Stickleback	Lotic	0.74	1.69	2.38	6.05
GEI 2014c*	DC-3	Brook Stickleback	Lotic	0.68	1.69	2.38	6.52
GEI 2014c*	GC-2	Creek Chub	Lotic	0.85	1.99	1.4	7.53
GEI 2014c*	GC-3	Creek Chub	Lotic	0.55	1.99	1.4	11.73
GEI 2014c*	HG-2	Creek Chub	Lotic	0.75	1.99	1.4	8.58

Notes:

* Additional studies added to the database.

[a] Geometric mean of the median enrichments functions (EF) for all available food types (algae, detritus, and sediment). EF (L/g) = Cfood/Cwater.

[b] Taxa-specific conversion whole-body to egg ovary conversion factor (CF; dimensionless ratio).

[c] Composite trophic transfer factor (TTFcomposite). Product of TTF values for all trophic levels.

[d] Translated water concentration corresponding to a revised egg-ovary criterion element of 17.90 mg Se/kg dw (original criterion = 15.8 mg Se/kg dw).

Revised EPA Table B-7 updated with additional GEI data

Common name	Scientific name	Order	Family	Genus	TTF	TTF source data
Alligator Gar	*Atractosteus spatula*	Lepistosteiformes	Lepisosteidae	Atractosteus	~~1.27~~ 1.26	All fish
Black Bullhead	*Ameiurus melas*	Siluriformes	Ictaluridae	Ameiurus	~~0.91~~ 0.87	Exact match
Black Crappie	*Pomoxis nigromaculatus*	Perciformes	Centrarchidae	Pomoxis	2.67	Exact match
Black Redhorse	*Moxostoma duquesnei*	Cypriniformes	Catostomidae	Moxostoma	~~1.05~~ 1.04	Family Catostomidae
Blacknose Dace	*Rhinichthys atratulus*	Cypriniformes	Cyprinidae	Rhinichthys	~~1.46~~ 0.71	~~Family Cyprinidae~~ Exact Match
Blue Catfish	*Ictalurus furcatus*	Siluriformes	Ictaluridae	Ictalurus	0.73	Genus Ictalurus
Bluegill	*Lepomis macrochirus*	Perciformes	Centrarchidae	Lepomis	1.48	Exact match
Bluehead Sucker	*Catostomus discobolus*	Cypriniformes	Catostomidae	Catostomus	1.04	Exact match
Brassy Minnow	*Hybognathus hankinsoni*	Cypriniformes	Cyprinidae	Hybognathus	~~1.46~~ 1.26	Family Cyprinidae
Brook Stickleback	*Culaea inconstans*	Gasterosteiformes	Gasterosteidae	Culaea	~~1.69~~ 1.79	Exact match
Brook Trout	*Salvelinus fontinalis*	Salmoniformes	Salmonidae	Salvelinus	~~0.88~~ 0.97	Exact match
Brown Bullhead	*Ameiurus nebulosus*	Siluriformes	Ictaluridae	Ameiurus	~~0.91~~ 0.87	Genus Ameiurus
Brown Trout	*Salmo trutta*	Salmoniformes	Salmonidae	Salmo	1.44	Exact match
Bullhead		Siluriformes	Ictaluridae		~~0.82~~ 0.80	Family Ictaluridae
Chain Pickerel	*Esox niger*	Esociformes	Esocidae	Esox	2.04	Genus Esox
Channel Catfish	*Ictalurus punctatus*	Siluriformes	Ictaluridae	Ictalurus	0.73	Exact match
Common Carp	*Cyprinus carpio*	Cypriniformes	Cyprinidae	Cyprinus	~~1.34~~ 1.29	Exact match
Common Snook	*Centropomus undecimalis*	Perciformes	Centropomidae	Centropomus	~~1.48~~ 1.45	Order Perciformes
Crappie	*Pomoxis sp.*	Perciformes	Centrarchidae	Pomoxis	2.67	Genus Pomoxis
Creek Chub	*Semotilus atromaculatus*	Cypriniformes	Cyprinidae	Semotilus	~~1.12~~ 1.02	Exact match
Cutthroat Trout	*Oncorhynchus clarkii*	Salmoniformes	Salmonidae	Oncorhynchus	1.07	Exact match
Dolly Varden	*Salvelinus malma*	Salmoniformes	Salmonidae	Salvelinus	~~0.88~~ 0.97	Genus Salvelinus
Fathead Minnow	*Pimephales promelas*	Cypriniformes	Cyprinidae	Pimephales	~~1.57~~ 1.52	Exact match

Common name	Scientific name	Order	Family	Genus	TTF	TTF source data
Flannelmouth Sucker	*Catostomus latipinnis*	Cypriniformes	Catostomidae	Catostomus	1.06	Exact match
Flathead Catfish	*Pylodictis olivaris*	Siluriformes	Ictaluridae	Pylodictus	~~0.82~~ 0.80	Family Ictaluridae
Flathead Chub	*Platygobio gracilis*	Cypriniformes	Cyprinidae	Platygobio	~~1.46~~ 1.26	Family Cyprinidae
Freshwater Drum	*Aplodinotus grunniens*	Perciformes	Sciaenidae	Aplodinotus	~~1.48~~ 1.45	Order Perciformes
Gizzard Shad	*Dorosoma cepedianum*	Clupeiformes	Clupeidae	Dorosoma	~~1.27~~ 1.26	All fish
Goldeye	*Hiodon alosoides*	Hiodontiformes	Hiodontidae	Hiodon	~~1.27~~ 1.26	All fish
Green Sunfish	*Lepomis cyanellus*	Perciformes	Centrarchidae	Lepomis	~~1.27~~ 1.12	Exact match
Iowa Darter	*Etheostoma exile*	Perciformes	Percidae	Etheostoma	1.62	Family Percidae
Kokanee Salmon	*Oncorhynchus nerka*	Salmoniformes	Salmonidae	Oncorhynchus	1.19	Genus Oncorhynchus
Largemouth Bass	*Micropterus salmoides*	Perciformes	Centrarchidae	Micropterus	~~1.27~~ 1.41	Exact match
Largescale Sucker	*Catostomus macrocheilus*	Cypriniformes	Catostomidae	Catostomus	~~1.05~~ 1.04	Genus Catostomus
Longnose Dace	*Rhinichthys cataractae*	Cypriniformes	Cyprinidae	Rhinichthys	~~1.46~~ 1.26	Family Cyprinidae
Longnose Sucker	*Catostomus catostomus*	Cypriniformes	Catostomidae	Catostomus	0.90	Exact match
Mixed					0.87	Exact match
Mosquitofish	*Gambusia sp.*	Cyprinodontiformes	Poeciliidae	Gambusia	~~0.86~~ 0.97	Exact match
Mottled Sculpin	*Cottus bairdi*	Scorpaeniformes	Cottidae	Cottus	1.38	Exact match
Mountain Whitefish	*Prosopium williamsoni*	Salmoniformes	Salmonidae	Prosopium	1.38	Exact match
Northern Pike	*Esox lucius*	Esociformes	Esocidae	Esox	2.04	Exact match
Northern Pikeminnow	*Ptychocheilus oregonensis*	Cypriniformes	Cyprinidae	Ptychocheilus	~~1.46~~ 1.26	Family Cyprinidae
Northern Plains Killifish	*Fundulus kansae*	Cyprinodontiformes	Fundulidae	Fundulus	1.27	Exact match
Northern Redbelly Dace	*Chrosomus eos*	Cypriniformes	Cyprinidae	Chrosomus	~~1.46~~ 1.26	Family Cyprinidae
Northern Squawfish	*Ptychocheilus oregonensis*	Cypriniformes	Cyprinidae	Ptychocheilus	~~1.46~~ 1.26	Family Cyprinidae
Quillback	*Carpiodes cyprinus*	Cypriniformes	Catostomidae	Carpiodes	~~1.05~~ 1.04	Family Catostomidae
Rainbow Trout	*Oncorhynchus mykiss*	Salmoniformes	Salmonidae	Oncorhynchus	1.19	Exact match

Common name	Scientific name	Order	Family	Genus	TTF	TTF source data
Razorback Sucker	*Xyrauchen texanus*	Cypriniformes	Catostomidae	Xyrauchen	~~1.05~~ 1.04	Family Catostomidae
Red Shiner	*Cyprinella lutrensis*	Cypriniformes	Cyprinidae	Cyprinella	~~1.46~~ 1.34	~~Family Cyprinidae~~ Exact Match
Redbreast Sunfish	*Lepomis auritus*	Perciformes	Centrarchidae	Lepomis	~~1.37~~ 1.30	Genus Lepomis
Redear Sunfish	*Lepomis microlophus*	Perciformes	Centrarchidae	Lepomis	~~1.37~~ 1.30	Genus Lepomis
Redside Shiner	*Richardsonius balteatus*	Cypriniformes	Cyprinidae	Richardsonius	~~1.46~~ 0.77	~~Family Cyprinidae~~ Exact Match
River Carpsucker	*Carpiodes carpio*	Cypriniformes	Catostomidae	Carpiodes	~~1.05~~ 1.04	Family Catostomidae
River Redhorse	*Moxostoma carinatum*	Cypriniformes	Catostomidae	Moxostoma	~~1.05~~ 1.04	Family Catostomidae
Rock Bass	*Ambloplites rupestris*	Perciformes	Centrarchidae	Ambloplites	~~1.48~~ 1.41	Family Centrarchidae
Roundtail Chub	*Gila robusta*	Cypriniformes	Cyprinidae	Gila	~~1.46~~ 1.26	Family Cyprinidae
Sacramento Perch	*Archoplites interruptus*	Perciformes	Centrarchidae	Archoplites	~~1.48~~ 1.41	Family Centrarchidae
Sacramento Pikeminnow	*Ptychocheilus grandis*	Cypriniformes	Cyprinidae	Ptychocheilus	~~1.46~~ 1.26	Family Cyprinidae
Sailfin Molly	*Poecilia latipinna*	Cyprinodontiformes	Poeciliidae	Poecilia	~~1.06~~ 1.11	Family Poeciliidae
Sand Shiner	*Notropis stramineus*	Cypriniformes	Cyprinidae	Notropis	~~1.83~~ 1.60	Exact match
Sauger	*Sander canadensis*	Perciformes	Percidae	Sander	1.82	Genus Sander
Sculpin	*Cottus sp.*	Scorpaeniformes	Cottidae	Cottus	1.29	Exact match
Shadow Bass	*Ambloplites ariommus*	Perciformes	Centrarchidae	Ambloplites	~~1.48~~ 1.41	Family Centrarchidae
Shorthead Redhorse	*Moxostoma macrolepidotum*	Cypriniformes	Catostomidae	Moxostoma	~~1.05~~ 1.04	Family Catostomidae
Silver Carp	*Hypophthalmichthys molitrix*	Cypriniformes	Cyprinidae	Hypophthalmichthys	~~1.46~~ 1.26	Family Cyprinidae
Smallmouth Bass	*Micropterus dolomieu*	Perciformes	Centrarchidae	Micropterus	~~1.27~~ 0.83	~~Genus Micropterus~~ Exact Match
Smallmouth Buffalo	*Ictiobus bubalus*	Cypriniformes	Catostomidae	Ictiobus	~~1.05~~ 1.04	Family Catostomidae
Speckled Dace	*Rhinichthys osculus*	Cypriniformes	Cyprinidae	Rhinichthys	~~1.46~~ 1.26	Family Cyprinidae

Common name	Scientific name	Order	Family	Genus	TTF	TTF source data
Spotted Bass	*Micropterus punctulatus*	Perciformes	Centrarchidae	Micropterus	~~1.27~~ 1.12	Genus Micropterus
Spotted Gar	*Lepisosteus oculatus*	Lepistosteiformes	Lepisosteidae	Lepisosteus	~~1.27~~ 1.26	All fish
Stonecat	*Noturus flavus*	Siluriformes	Ictaluridae	Noturus	~~0.82~~ 0.80	Family Ictaluridae
Striped Bass	*Morone saxatilis*	Perciformes	Moronidae	Morone	~~1.48~~ 1.45	Order Perciformes
Striped Mullet	*Mugil cephalus*	Mugiliformes	Mugilidae	Mugil	~~1.27~~ 1.26	All fish
Sucker		Cypriniformes	Catostomidae		~~1.05~~ 1.04	Family Catostomidae
Sunfish Species		Perciformes	Centrarchidae		2.00	Exact match
Tilapia		Perciformes	Cichlidae		~~1.48~~ 1.45	Order Perciformes
Trout Species	*Oncorhynchus sp.*	Salmoniformes	Salmonidae	Oncorhynchus	1.19	Genus Oncorhynchus
Tui Chub	*Gila bicolor*	Cypriniformes	Cyprinidae	Gila	~~1.46~~ 1.26	Family Cyprinidae
Utah Sucker	*Catostomus ardens*	Cypriniformes	Catostomidae	Catostomus	~~1.05~~ 1.04	Genus Catostomus
Walleye	*Sander vitreus*	Perciformes	Percidae	Sander	1.82	Exact match
Western Mosquitofish	*Gambusia affinis*	Cyprinodontiformes	Poeciliidae	Gambusia	1.25	Exact match
Westslope Cutthroat Trout	*Oncorhynchus clarkii lewisi*	Salmoniformes	Salmonidae	Oncorhynchus	1.20	Exact match
White Bass	*Morone chrysops*	Perciformes	Moronidae	Morone	~~1.48~~ 1.45	Order Perciformes
White Crappie	*Pomoxis annularis*	Perciformes	Centrarchidae	Pomoxis	2.67	Genus Pomoxis
White Sturgeon	*Acipenser transmontanus*	Acipenseriformes	Acipenseridae	Acipenser	~~1.27~~ 1.26	All fish
White Sucker	*Catostomus commersonii*	Cypriniformes	Catostomidae	Catostomus	~~1.18~~ 1.04	Exact match
Wiper	*Morone chrysops x Moron saxatilis*	Perciformes	Moronidae	Morone	~~1.48~~ 1.45	Order Perciformes
Yellow Perch	*Perca flavescens*	Perciformes	Percidae	Perca	1.42	Exact match

Specific Columns from EPA Table B-8 with revised TTF values using additional GEI data

Reference	Site Description	Site ID	Target Fish Species Common Name	Effective TTF	Target Fish TFF	TFF Composite
Default			Black Bullhead	2.03	~~0.91~~ 0.87	~~1.85~~ 1.77
Default			Black Crappie	1.93	2.67	5.14
Default			Blacknose Dace	1.78	~~1.46~~ 0.71	~~2.59~~ 1.26
Default			Blue Catfish	2.11	0.73	1.53
Default			Bluegill	1.93	1.48	2.85
Default			Bluehead Sucker	1.16	1.04	1.21
Default			Brassy Minnow	1.28	~~1.46~~ 1.26	~~1.86~~ 1.61
Default			Brook Stickleb Ack	1.33	~~1.69~~ 1.79	~~2.25~~ 2.38
Default			Brook Trout	2.09	~~0.88~~ 0.97	~~1.85~~ 2.03
Default			Brown Bullhead	2.05	~~0.91~~ 0.87	~~1.87~~ 1.78
Default			Brown Trout	1.73	1.44	2.49
Default			Bullhead	2.05	~~0.82~~ 0.8	~~1.68~~ 1.64
Default			Channel Catfish	1.86	0.73	1.35
Default			Common Carp	1.27	~~1.34~~ 1.29	~~1.70~~ 1.64
Default			Crappie	1.93	2.67	5.14
Default			Creek Chub	1.37	~~1.12~~ 1.02	~~1.53~~ 1.40
Default			Cutthroat Trout	1.89	1.07	~~2.02~~ 2.02
Default			Fathead Minnow	1.77	~~1.57~~ 1.52	~~2.77~~ 2.69
Default			Flannel Mouth Sucker	1.55	1.06	1.64
Default			Flathead Chub	1.91	~~1.46~~ 1.26	~~2.79~~ 2.41
Default			Freshwater Drum	1.86	~~1.48~~ 1.45	~~2.76~~ 2.70
Default			Gizzard Shad	1.00	~~1.27~~ 1.26	~~1.27~~ 1.26
Default			Goldeye	1.74	~~1.27~~ 1.26	~~2.20~~ 2.19
Default			Green Sunfish	1.93	~~1.27~~ 1.12	~~2.44~~ 2.16
Default			Iowa Darter	1.90	1.62	3.08
Default			Kokanee Salmon	1.56	1.19	1.85
Default			Largemouth Bass	1.79	~~1.27~~ 1.41	~~2.27~~ 2.52
Default			Longnose Dace	1.91	~~1.46~~ 1.26	~~2.79~~ 2.41
Default			Longnose Sucker	1.41	0.90	1.27
Default			Mixed	1.41	0.87	1.23
Default			Mosquitofish	1.96	~~0.86~~ 0.97	~~1.69~~ 1.90
Default			Mottled Sculpin	1.92	1.38	2.65
Default			Mountain Whitefis H	2.11	1.38	2.9
Default			Northern Pike	1.79	2.04	3.66
Default			Northern Plains Killifish	1.91	1.27	2.44
Default			Northern Redbelly Dace	1.28	~~1.46~~ 1.26	~~1.87~~ 1.61
Default			Northern Squawfish	1.87	~~1.46~~ 1.26	~~2.73~~ 2.36
Default			Rainbow Trout	2.05	1.19	2.44
Default			Red Shiner	1.74	~~1.46~~ 1.34	~~2.53~~ 2.33
Default			Redside Shiner	2.25	~~1.46~~ 0.77	~~3.28~~ 1.73
Default			River Carpsucker	1.10	~~1.05~~ 1.04	~~1.16~~ 1.14

Reference	Site Description	Site ID	Target Fish Species Common Name	Effective TTF	Target Fish TFF	TFF Composite
Default			Roundtail Chub	2.30	1.46 1.26	3.35 2.90
Default			Sacramento Perch	1.29	1.48 1.41	1.90 1.82
Default			Sailfin Molly	1.29	1.06 1.11	1.36 1.43
Default			Sand Shiner	1.55	1.83 1.60	2.84 2.48
Default			Sauger	1.73	1.82	3.16
Default			Sculpin	1.99	1.29	2.57
Default			Shorthead Redhorse	1.41	1.05 1.04	1.48 1.47
Default			Smallmouth Bass	1.86	1.27	2.35
Default			Speckled Dace	1.91	1.46 1.26	2.78 2.41
Default			Stonecat	1.60	0.82	1.31
Default			Sucker	1.20	1.05 1.04	1.27 1.25
Default			Sunfish Species	1.92	2.00	3.84
Default			Tilapia	1.20	1.48 1.45	1.78 1.74
Default			Trout Species	1.97	1.19	2.34
Default			Tui Chub	1.45	1.46 1.26	2.12 1.83
Default			Utah Sucker	1.20	1.05 1.04	1.27 1.25
Default			Walleye	1.76	1.82	3.21
Default			Western Mosquitofish	1.96	1.25	2.46
Default			Westslope Cutthroat Trout	1.91	1.20	2.29
Default			White Bass	1.86	1.48 1.45	2.76 2.70
Default			White Crappie	1.93	2.67	5.14
Default			White Sturgeon	2.00	1.27 1.26	2.53 2.52
Default			White Sucker	1.43	1.18 1.04	1.68 1.49
Default			Wiper	1.72	1.48 1.45	2.55 2.49
Default			Yellow Perch	1.65	1.42	2.35
Saiki et al. 1993			Bluegill	1.43	1.48	2.12
Saiki et al. 1993			Largemouth Bass	1.21	1.27	1.54
Saiki et al. 1993			Western Mosquitofish	1.74	1.25	2.18
Formation 2012	Crow Creek - CC150	CC- 150	Brown Trout	2.08	1.44	3.00
Formation 2012	Crow Creek - CC150	CC- 150	Sculpin	2.08	1.29	2.69
Formation 2012	Crow Creek - 1A	CC- 1A	Brown Trout	2.16	1.44	3.12
Formation 2012	Crow Creek - 1A	CC- 1A	Sculpin	2.16	1.29	2.80
Formation 2012	Crow Creek - CC350	CC- 350	Brown Trout	2.13	1.44	3.07
Formation 2012	Crow Creek - CC350	CC- 350	Sculpin	2.13	1.29	2.75
Formation 2012	Crow Creek - 3A	CC- 3A	Brown Trout	2.19	1.44	3.15
Formation 2012	Crow Creek - 3A	CC- 3A	Sculpin	2.19	1.29	2.82
Formation 2012	Crow Creek - CC75	CC- 75	Brown Trout	2.04	1.44	2.94
Formation 2012	Crow Creek - CC75	CC- 75	Sculpin	2.04	1.29	2.63
Formation 2012	Deer Creek	DC- 600	Brown Trout	2.08	1.44	2.99
Formation 2012	Deer Creek	DC- 600	Sculpin	2.08	1.29	2.68
Formation 2012	Hoopes Spring - HS	HS	Brown Trout	2.72	1.44	3.92
Formation 2012	Hoopes Spring - HS	HS	Sculpin	2.72	1.29	3.51

Reference	Site Description	Site ID	Target Fish Species Common Name	Effective TTF	Target Fish TFF	TFF Composite
Formation 2012	Hoopes Spring - HS3	HS-3	Brown Trout	1.85	1.44	2.67
Formation 2012	Hoopes Spring - HS3	HS-3	Sculpin	1.85	1.29	2.39
Formation 2012	Sage Creek - LSV2C	LSV- 2C	Brown Trout	2.19	1.44	3.16
Formation 2012	Sage Creek - LSV2C	LSV- 2C	Sculpin	2.19	1.29	2.83
Formation 2012	Sage Creek - LSV4	LSV- 4	Brown Trout	2.07	1.44	2.98
Formation 2012	Sage Creek - LSV4	LSV- 4	Sculpin	2.07	1.29	2.67
Formation 2012	South Fork Tincup Cr.	SFTC-1	Brown Trout	2.21	1.44	3.18
Formation 2012	South Fork Tincup Cr.	SFTC-1	Sculpin	2.21	1.29	2.85