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Washington State Department of Ecology
PO Box 47600
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RE: Comments on Publication No. 11-09-050, *Fish Consumption Rates Technical Support Document, A Review of Data and Information about Fish Consumption in Washington*

The National Council for Air and Stream Improvement, Inc. (NCASI) is an independent, nonprofit membership organization that provides technical support to the forest products industry on a wide range of environmental issues. An important part of our mission is to ensure that regulatory decision making is based on sound science. In this capacity, NCASI reviewed the September 2011 document titled: *Fish Consumption Rates Technical Support Document, A Review of Data and Information about Fish Consumption in Washington* (Publication No. 11-09-050), and offers the attached comments.

Overall, NCASI finds that Ecology has not made a compelling case for increasing statewide default fish consumption rates (FCRs). Ecology should clearly explain the level of protection afforded by existing environmental standards for protection of human health, and the incremental benefit to public health that would result from making these standards up to 41 times more stringent. We also have serious concerns that the fish consumption data used to develop the proposal are not representative of the general population, and that these data have been interpreted in an arbitrary manner that leads to an extreme conclusion.

Sincerely,

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NCASI COMMENTS ON WASHINGTON'S PROPOSAL TO REVISE STATEWIDE DEFAULT FISH CONSUMPTION RATES

In September 2011 Washington State Department of Ecology (Ecology) issued Publication No. 11-09-050, *Fish Consumption Rates Technical Support Document, A Review of Data and Information about Fish Consumption in Washington*. This technical support document (TSD) summarizes available fish consumption studies and proposes that the state adopt default fish consumption rates (FCR) of between 157 and 267 grams per day (g/day). One or more default rates would be used to establish regulatory requirements under the following programs:

- Sediment Management Standards (SMS) rule, which establishes standards for cleanup of contaminated sediments in fresh and marine waters; this rule is currently being revised and a default FCR will be part of the revisions
- Model Toxics Control Act (MTCA), which regulates cleanup of contaminated soils and sediments
- Clean Water Act water quality standards (WQS) established by states and tribes to limit the effects of contaminants ingested with fish and water on human health.

Current default FCRs are 6.5 g/day for WQS and 54 g/day for MTCA cleanup standards. Thus, Ecology is proposing to make human health WQS more stringent by a factor of between 24 and 41, and to make MTCA cleanup standards more stringent by a factor of between 2.9 and 4.9. Ecology is currently working to revise the SMS rule and anticipates establishing a default FCR for sediment cleanups. Ecology also intends to update Washington's WQS and has stated that the information contained in the TSD and the SMS rule revision "will likely strongly influence the rates included in future human health-based water quality criteria."

Ecology has requested comments on the TSD and the proposed range of default FCRs. NCASI offers the following general comments and answers to questions posed in the TSD.

General Comments

1. <u>Any decision to change the current default FCRs should be justified in terms of overall benefit to public health</u>. The underlying premise of the report is that use of the current default FCRs result in water quality or sediment management standards that are not sufficiently protective. However, the TSD provides no perspective on the degree to which public health is protected under the existing FCRs. More importantly, the TSD provides no basis for gauging the overall benefit to public health that might result from changing these FCRs. Ecology should present a coherent assessment of health risks to the general population of the state represented by the current default FCRs and contrast them with the health risks that would result if the default FCRs were increased as recommended in the TSD. This assessment is imperative as there is currently no viable comparator for the costs that would be borne by both Ecology and the regulated community in responding to lowered sediment and water quality criteria as a result of increased FCRs. Without knowledge of what the benefit might be, it is impossible to determine if these costs would be justified.

Understanding what benefit to public health might result from increasing the FCRs is critically important in this context because the current risk assessment paradigm already results in highly protective environmental standards as a result of multiple conservative assumptions. For example, the calculation of risks resulting from consuming contaminants in fish generally assumes that fish are consumed at the default rate for 70 years, that all fish consumed are contaminated to the same degree (which is functionally equivalent to assuming all fish are from the same body of water), and that there are no losses of contaminants during preparation. Beyond this, the maximum dose of a chemical considered to be safe is always adjusted downward from the level indicated by the toxicological data. In the case of non-cancer endpoints, the product of the multiple safety factors (termed uncertainty or modifying factors) used to develop a reference dose (RfD) can approach well over 1000, meaning that the dose used in a risk assessment could be 1000 times lower than the dose directly indicated by the toxicological data. For carcinogens, this safety factor is typically 10, and the acceptable risk level is typically set at one hypothetical additional cancer case per million lifetimes. This is an exceedingly small incremental risk in light of a current lifetime cancer incident rate due to all causes of about 40% (400,000 in one million)[1]. Finally, the paradigm completely discounts any health benefits attributable to consuming fish.

All this supports the current water and sediment quality standards as being highly protective of the residents of Washington, and any proposal to revise these standards should be based on an analysis of the public health benefit to be gained.

2. <u>The proposed range of default FCRs overstates the fish consumption rates for the vast majority of residents of the state.</u> The proposed range is based on high-end statistical consumption rates (e.g., 80th to 95th percentile values) developed from five fish consumption rate studies of known high fish consuming subpopulations. Four of the studies are of tribal groups and the fifth is a study of the King County Asian and Pacific Islander (API) subpopulation. Notwithstanding the methodological concerns we have about Ecology's interpretation of some of these studies (see general comment no. 3), the FCRs recommended in the TSD have the effect of establishing protections for the general population of Washington residents using consumption rates derived from a total surveyed population of 996 individuals reflecting the behaviors of an estimated 0.2-0.9% of the total population of the state.

   Studies that apply to general populations suggest that fish consumption rates are considerably lower than Ecology's proposed range. For example, EPA[2] indicates that for US adults, the 90th and 95th percentile consumption rates of freshwater and estuarine finfish and shellfish are 17.4 and 49.6 g/day, respectively. These values suggest that Ecology's proposed FCR range is not representative of fish consumption rates for the general population statewide.

3. <u>Ecology's analysis of the data from the fish consumption studies used to develop the proposed FCRs is significantly flawed.</u> First, the API study is dominated by first-generation residents (89% of respondents), who are known to consume more fish than later generations.

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[1] See, for example, the American Chemical Society at http://www.cancer.org/Cancer/CancerBasics/lifetime-probability-of-developing-or-dying-from-cancer

[2] USEPA. 2002. *Estimated Per Capita Fish Consumption in the United States*.

This known bias in the results casts considerable doubt on the representativeness of the results to describe the fish consumption rates of the broader API population.

Another significant issue with the API study is that the consumption rates used in the TSD to generate a proposed range of FCRs for adoption are not corrected for cooking losses, non-local harvest, or API population demographics. EPA Region 10 reanalyzed these data[3], adjusted for these biases, and determined the reasonable maximum exposure (RME, the 95th percentile value) to be 51.1 g/day not including anadromous fish, or 57 g/d including anadromous fish (see table on pg. 61 of TSD). Contrast this with the unadjusted data in the TSD, where the 95th percentile value is shown as 306 g/day (e.g., Table A-1 in TSD). It is unclear why Ecology believes that consumption data biased high by inclusion of non-locally harvested fish should be the basis of its FCR proposal when more scientifically defensible estimates are available. To be clear, any default FCRs should reflect consumption of locally harvested fish only.

It appears that the data from the Tulalip and Suquamish Island tribes also need to be adjusted to remove non-locally harvested fish, as EPA Region 10 did in developing its guidance for site-specific cleanup levels[4]. In addition, Pacific salmon comprised a significant fraction of the fish diet for all the Native American fish consumption studies. For reasons discussed in Appendix A, inclusion of salmon in a statewide default FCR is clearly not appropriate.

Because the actual data from most of the fish consumption surveys are not publically available, Ecology used descriptive statistics to develop composite log-normal distributions based on seven different weighting schemes. (As noted above, these datasets should be adjusted (per EPA Region 10 guidance) to eliminate fish that are not locally harvested before developing composite distributions). Ecology ultimately chose to use a scheme in which each of the five surveys was given equal weight to develop a composite distribution from which the proposed range (80th to 95th percentiles) of FCRs was developed. Given that these data represent only known high fish consuming subpopulations, the use of statistics that characterize the upper extremes (e.g., 80th to 95th percentile values) of a composite distribution that intentionally excludes the vast majority of fish consumers and, more importantly, the vast majority of the general population, would be inappropriate for establishing default FCRs for statewide application. Beyond this, assigning equal weights to each of the five surveys is arbitrary, giving a proposed FCR that is driven by survey results from as few as 50 people (95th percentile of 996 surveyed adults). It would be more defensible to weigh each of these studies according to the estimated total adult populations represented by the underlying data (e.g., per weighing scheme #2 in Appendix C of the TSD), and this process should include the total population of Washington State (with consumption rates taken from EPA[5,6] or other appropriate studies).

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[3] Kissinger, L. 2005. *Application of data from an Asian and Pacific Islander (API) seafood consumption study to derive fish and shellfish consumption rates for risk assessment*.

[4] USEPA. 2007. *Framework for selecting and using tribal fish and shellfish consumption rates for risk-based decision making at CERCLA and RCRA cleanup sites in Puget Sound and the Strait of Georgia*.

[5] USEPA. 2002. *Estimated Per Capita Fish Consumption in the United States*.

[6] USEPA. 2011. *Exposure Factors Handbook: 2011 Edition*.

In addition to these general comments, responses to specific questions posed by Ecology in the TSD are provided below. Note that some of these responses draw on information presented in Appendix A, which provides a brief review of what is known about the accumulation of persistent, bioaccumulative, and toxic (PBT) chemicals by salmon.

Responses to Questions Posed by Ecology in the TSD

1. How should default rates take into account the consumption of fish species like salmon that spend much of their life outside of Washington waters?

The consumption of salmon should be excluded from any statewide default FCR. This conclusion is based on review of the scientific literature (Appendix A), which indicates that different species of salmon and different runs of the same species of salmon will accumulate PBT chemicals to differing degrees. In addition, the literature supports the contention that the major fraction of any PBT burden carried by returning adult salmon (i.e., salmon that will be harvested and consumed) is acquired in the open ocean. The fact that resident Puget Sound salmon generally exhibit higher burdens than true open ocean salmon is not inconsistent with this, and simply points out that Puget Sound is a unique habitat (i.e., Puget Sound is not the open ocean).

Because of this, it might be appropriate to assess risk to select Puget Sound residents as a separate activity, and inclusion of salmon in an FCR used in such a risk assessment may well be warranted. However, given that Chinook, Coho, sockeye, pink, and chum salmon are predicted to accumulate different body burdens of PBT chemicals even when they share a common migration corridor, salmon consumption should be apportioned between species, and not simply lumped together as "salmon." In addition, only salmon harvested directly from Puget Sound should be included in an FCR used for this purpose: ideally, only truly resident salmon (i.e., "blackmouth" salmon) would be included.

2. How should the complex life cycle and biology of the different salmon species be considered when making regulatory decisions?

As noted above, the complexities of salmon biology and/or ecology require that:

- salmon be excluded from any default FCR,
- a site-specific FCR include only "resident" salmon, and only when there are data showing that these salmon are impacted by local sources of chemical contaminants,
- whenever salmon are included in a site-specific FCR, consumption must be broken out on a species-specific basis, and the associated risk assessment must use species-specific chemical concentrations and, when necessary, bioaccumulation factors (BAFs).

3. What is the status of resources pertaining to the harvest of fish and shellfish in Washington?

This question seems irrelevant to the issue at hand.

4. How many people in Washington consume fish? How many people in Washington can be considered high-end fish consumers?

NCASI suggests that assigning individuals to a "consumer" or "non-consumer" category is a false dichotomy, and that it would be more correct to consider fish consumption on a continuum having, essentially, no non-consumers (there are likely to be very few individuals that consume no fish over the course of a lifetime). Thus, according to the TSD, there are 5,143,186 adult consumers of fish in Washington State currently. Beyond this, any categorization of what constitutes "high-end" consumption is unavoidably arbitrary in the sense that it will always be a matter of subjective opinion. This is, and will remain true regardless of statistical categorizations or the overall accuracy or completeness of associated fish consumption data.

5. What are scientifically defensible methods for characterizing fish consumption rates?

A variety of survey methods have been used to generate fish consumption data, as the TSD discusses; each method has both strengths and weaknesses. Regardless, the more important issue is whether the method used accurately captures the consumption habits of the targeted population which, for purposes of establishing default statewide FCRs, should be the population of the entire State of Washington.

Clearly, Ecology has a large body of data characterizing the fish consumption habits of four Puget Sound tribal communities, certain Columbia Basin tribes and the API population residing in King County. Ecology apparently does not have data sufficient to characterize fish consumption by the general population of Washington State to anywhere near the same level of confidence as it has for these very specific subpopulations. This is a critical information gap that must be filled in order to fully understand the risks to public health resulting from the consumption of fish.

6. What is currently known about the fish consumption habits and rates for different fish-consuming populations in Washington?

What is known are the consumption patterns of a few Native American tribes and the API population residing in King County. As a whole, the sampled population represents approximately 311,300 adults (from Table C-2 in the TSD). This number is equivalent to approximately 11% of the adult consumers of purchased fresh fish (as estimated by Washington's Department of Health, Table 5 in the TSD), approximately 8% of the adult consumers of store-bought fish, and approximately 6% of the general adult population. The TSD provides no details relevant to the consumption habits of the remaining population besides that taken from DOH (e.g., 74% of the general adult population consumes store-bought fish).

7. Would establishing a statewide default fish consumption rate (or rates) be a useful step toward consistency among regulatory programs (for example, MTCA cleanups and water quality-based permitting)?

NCASI notes that statewide default fish consumption rates are already in place for the development of water quality standards (6.5 g/d) and for MTCA cleanups (54 g/d), and Ecology has stated that it intends to adopt a default FCR for sediment management standards (SMS). Thus, any questions regarding the utility of intra-program default FCRs appear to be moot, and

the real question is whether there is a benefit to be had from adopting a single default FCR applicable to all programs. NCASI suggests that the answer to that question is no.

Given the distinctly different scopes and missions of Ecology's different programs (e.g., the MCTA program focuses on cleanup of geographically limited sites posing risk to very specific populations and known to be contaminated with specific chemicals, while the Clean Water Act applies to the whole state regardless of any known source of contamination by any single chemical), it is hard to image that adopting a single default FCR for all programs would actually provide any benefit beyond conceptual simplicity. The validity of this conclusion is best illustrated by the range of FCRs exhibited across different subpopulations and the degree to which these FCRs clearly reflect geographic location. With this last point in mind, the only defensible statewide default FCR for any regulatory program is an FCR reflecting mean consumption by the statewide general population. In situations where subpopulations are believed to be subject to significantly greater risks than the general population (e.g., a subpopulation taking fish from near a MCTA site), an appropriate, risk-based response would be to conduct a population- or site-specific risk assessment[7] to determine if actual risk (in this case due to a greater than average FCR) for that subpopulation exceeds target values considering all aspects of exposure including, in this case, the health benefits of eating fish[8].

8. <u>What is an appropriate statewide default fish consumption rate (or rates) given available data, uncertainties and variability in fish consumption habits, and current statutes, regulations, and policies?</u>

As noted, the only defensible statewide default FCR is one that reflects consumption by the general population as a whole (i.e., without attempting to discriminate "consumers" from "non-consumers").

Consistent with this, if Ecology is driven to adopt a single default FCR for use statewide and has no data characterizing fish consumption by the general population of Washington State, it should draw from EPA's data for the general US population[6]. Based on these data, EPA[9] has concluded that the mean consumption rate of freshwater and estuarine finfish and shellfish by adults (18 and older) is 7.50 g/day. The associated 90th and 95th percentile consumption rates are 17.4 and 49.6 g/d, respectively. Although these FCRs are almost certainly high-biased (i.e., conservative) estimates for the general US population, they provide a much better measure of fish consumption by the general population of Washington State than the range of FCRs proposed by Ecology, which clearly reflects high-end consumers exclusively, and so are preferable for use as default values meant to apply statewide. Using the flexibility afforded under different regulatory programs (MTCA, etc.), adjustments to a "general population" default FCR can then be made using site-specific information, meaning that Ecology can decide to make site-specific standards more protective when circumstances clearly warrant.

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[7] USEPA. 2000. *Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (2000).*
[8] Washington Department of Health. 2006. *Human Health Evaluation of Contaminants in Puget Sound Fish.*
[9] USEPA. 2002. *Estimated Per Capita Fish Consumption in the United States*.

APPENDIX A

A BRIEF REVIEW OF ISSUES RELEVANT TO THE ACCUMULATION OF PERSISTANT, BIOACCUMULATIVE, AND TOXIC (PBT) CHEMICALS BY SALMON

INTRODUCTION

In September 2011 Washington State Department of Ecology (WDOE) issued Publication No. 11-09-050, *Fish Consumption Rates Technical Support Document, A Review of Data and Information about Fish Consumption in Washington*. This technical support document (TSD) was generated to support decision making regarding how to obtain an appropriate fish consumption rate (FCR) for use in calculating water quality standards for protecting human health (HHWQS). One of the issues WDOE raised in this TSD was whether consumption of salmon should be included in whatever FCR is ultimately used in these calculations, and if it is concluded that salmon should be included in an FCR, how to do so.

The driver behind this is human exposure to toxic chemicals, specifically via consumption of fish (or aquatic tissue in general). The greatest risk to human health from consumption of fish is generally understood to result from the presence of persistent, bioaccumulative, and toxic (PBT) chemicals. Thus the primary factor in determining the appropriateness of including consumption of salmon in an FCR is where salmon actually pick up these contaminants. A brief review of what is known about this subject is presented herein.

WHERE SALMON ACCUMULATE PBT CHEMICALS

As discussed by NOAA (2005), different runs of salmon exhibit different life histories. More specifically, NOAA described stream-type and ocean-type life histories. Behavioral attributes of these two general types of salmon are summarized in Table 1.

Table 1. A Summary of the Juvenile Characteristics of Stream and Ocean Life History Types

Stream-Type Fish	Ocean-Type Fish
Species	
Coho salmon	Coho salmon
Some Chinook populations	Some Chinook populations
Steelhead	Chum
Sockeye	Pink
Attributes	
Long period of freshwater rearing (>1 yr)	Short period of freshwater rearing
Shorter ocean residence	Longer ocean residence
Short period of estuarine residence	Longer period of estuarine residence
Larger size at time of estuarine entry	Smaller size at time of estuarine entry
Mostly use deeper, main channel estuarine habitats	Mostly use shallow water estuarine habitats, especially vegetated ones

[SOURCE: NOAA 2005]

From Table 1, different species of salmon and different runs of the same species can exhibit distinctly different life histories, including how much time is spent in freshwater and where in

freshwater systems this time is spent. These differences are potentially significant in that they may lead to differences in the mass (burden) of chemical contaminants (e.g., PBT chemicals) ultimately accumulated by the salmon, and in the fraction of this ultimate burden accumulated in freshwater vs. saltwater. Although the latter may not be relevant when assessing the risk to human health resulting from eating contaminated fish in general, it is relevant when considering what fraction of this overall risk results from accumulation of contaminants in freshwater systems vs. saltwater systems.

This last point is directly relevant to the question of whether there is any utility in including consumption of salmon in an FCR that will be used to drive remedial action(s) on the geographically limited scale of a single state. If a significant fraction of the contaminant burden found in salmon is accumulated in true freshwater systems it makes sense that the consumption of salmon be included in an FCR. However, if accumulation in the open ocean dominates, inclusion of salmon in an FCR makes no sense because there is no action the state can take that will have a significant effect on the contaminant burden found in returning adult salmon.

Exclusion of salmon from an FCR does not imply that human exposure to contaminants due to consumption of salmon should not be accounted for when assessing overall risks to human health. Instead, these issues should be weighed when deciding whether salmon are accounted for when assessing the risks resulting from consumption of freshwater fish (by including consumption of salmon in an FCR) or when assessing the risks resulting from consumption of saltwater or marine fish (salmon would be backed out of the risk assessment for deriving a freshwater HHWQS via the relative source contribution or RSC). Ultimately, the issue of where the risks from consumption of salmon are counted appears to be an academic question. The more important factor (from the perspective of characterizing risk) is to ensure that consumption of salmon is not double counted by including it in both an FCR **and** as a component of the RSC.

In any case, the issue of salmon (or anadromous fish in general) is unique in that it is quite likely that a generic salmon will accumulate contaminants in both freshwater and saltwater habitats, and that the relative fraction accumulated in one habitat vs. the other will vary with species, run, and even individual. Taken to the extreme, this implies that each run needs to be evaluated independently to determine where contaminants are accumulated. However, much of the scientific literature supports accumulation in the open ocean as the dominant pathway for uptake of PBT chemicals by salmon, with the work of O'Neill, West, and Hoeman (1998), West and O'Neill (2007), and O'Neill and West (2009) providing perhaps the most through examination of the issue.

Figure 1 is taken from O'Neill and West (2009) and shows that levels of polychlorinated biphenyls (PCBs) in adult Chinook salmon (fillets) collected from a wide range of geographic locations are relatively uniform except for fish taken from Puget Sound, which show three to five times higher levels of PCBs than fish taken from other locations. As discussed by the authors, these data can be interpreted as indicating accumulation of PCBs in Puget Sound and/or along the migratory routes of these fish, which, depending on the specific runs, can pass through some highly contaminated Superfund sites (e.g., Duwamish Waterway). However, O'Neill and West (2009) concluded that, on average, >96% of the total body burden (mass) of PCBs in these Puget Sound Chinook was accumulated in the Sound and not in natal river(s).

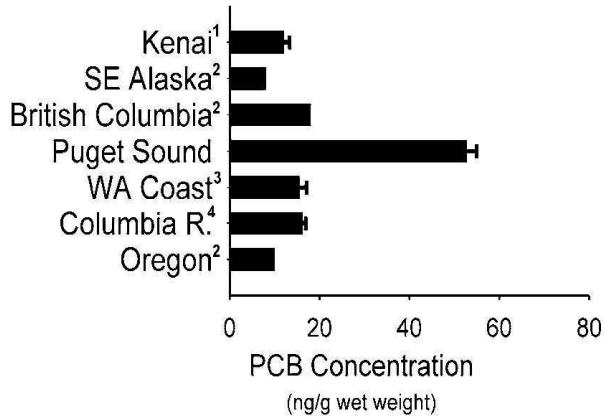

Figure 1. Average (±SE) PCB Concentration in Chinook Salmon Fillets
Data for Puget Sound were based on 204 samples collected by the Washington Department of Fish and Wildlife from 1992 to 1996; data for other locations were taken from the following (indicated by superscript numbers): [1]Rice and Moles (2006), [2]Hites et al. (2004; estimated from publication), [3]Missildine et al. (2005), and [4]United States Environmental Protection Agency (USEPA 2002)
[SOURCE: O'Neill and West 2009]

The basis for this conclusion is presented in Table 2, which compares PCB concentrations and body burdens in out migrating Chinook smolts collected from the Duwamish River and adults returning to the Duwamish.

TABLE 2.—Concentration of PCBs (ng/g) and body burden of PCBs (total ng/fish) in out-migrating Chinook salmon smolts and returning adults from the contaminated Duwamish River, Washington.

Variable	Smolts	Adults
Number of samples	80	34
Mean fish weight (g)	10	6,000
Whole body PCB concentration (ng/g)[a]		
Mean	170	57
95th percentile	860	88
PCB body burden (ng/fish)[a]		
Mean	2,100	350,000
95th percentile	9,200	800,000
Mean % of PCB body burden from the most contaminated smolts[b]	—	3.8

[a] Values for smolts are from J. P. Meador (National Oceanic and Atmospheric Administration Fisheries, Northwest Fisheries Science Center, personal communication); values for adults were estimated from measured muscle tissue concentration using the fillet–whole-body regression (see Methods) for PCBs.

[b] Contaminant data were only available for out-migrating subyearling smolts, so only samples with adults that went to sea as subyearlings were included in the analysis.

[SOURCE: O'Neill and West 2009]

These data show that even the most contaminated out migrating smolts contained no more than 4% of the body burden (mass) of PCBs found in returning adults. Thus, >96% of the PCB mass (burden) found in the returning adults was accumulated in Puget Sound. Even allowing for an order of magnitude underestimate in the body burden of out migrating smolts, O'Neill and West (2009) concluded that accumulation in freshwater would account for <10% of the average PCB burden ultimately found in adults returning to the Duwamish. By extension, this analysis supports the conclusion that Chinook salmon passing through uncontaminated estuaries during out migration accumulate a dominant fraction of their ultimate PCB body burdens in the open ocean. Other researchers have also reached this conclusion using their own data (e.g., Johnson et al. 2007; Cullon et al. 2009).

However, this analysis does not explain why Chinook salmon collected in Puget Sound exhibit higher concentrations of PCBs than Chinook salmon collected from other locations (Figure 1). Ultimately, O'Neill and West (2009) attributed this to a combination of factors, specifically PCB contamination of the Puget Sound food web (e.g., West, O'Neill, and Ylitalo 2008) combined with a high percentage of Chinook displaying resident behavior. That is, a large fraction of out migrating Chinook smolts take up permanent residence in the Sound, where they feed from a more contaminated food web than found in the open ocean. These factors would not affect Chinook runs or runs of any other species associated with natal rivers that discharge to saltwater outside Puget Sound.

Overall, these data support the position that, as a general rule, the predominant fraction of the ultimate PCB burden found in harvested adult fish is accumulated while in the ocean-phase of their life cycle (e.g., Cullon et al. 2009; Johnson et al. 2007; O'Neill and West 2009). Although this conclusion is specific to PCBs, there is no reason to suppose that it would not also hold for other legacy PBTs (e.g., DDT, dioxins) or globally ubiquitous PBTs (e.g., PBDEs, methylmercury) in general (e.g., Cullon et al. 2009). Because concerns about human consumption of fish are driven by risks from exposure to PBTs, driving the FCR higher by including salmon would thus appear to be of limited utility from the perspective of protecting human health simply because these contaminants are accumulated in the ocean.

With that said, there are sufficient data to conclude that the food web in Puget Sound is contaminated with PCBs to a greater degree than the food web in the open ocean. To the extent that this is a result of true local sources (e.g., sediment hotspots), there may in fact be some "local" action that can be taken to reduce PCBs, or potentially other PBTs, in Puget Sound salmon. However, this is totally dependent on identification of localized sources amenable to remediation, and not simply a conclusion that the food web is contaminated (e.g., West and O'Neill 2007).

Again, simply increasing the FCR by including salmon will have essentially no positive effect on human health given that the dominant fraction of PBT body burdens in salmon appears to be accumulated in the open ocean, and not in waters immediately subject to in-state loadings.

PBT ACCUMULATION BY DIFFERENT SALMON SPECIES

As discussed, there is ample evidence that the body burdens of PBTs found in returning adult Chinook salmon depend to a significant extent on the life history of the specific run. Beyond this, there are interspecies differences in migratory and feeding behavior that suggest Coho, sockeye, pink, and chum salmon will not accumulate PBTs to the same extent as Chinook

salmon under similar exposure scenarios (Groot and Margolis 1991; Higgs et al. 1995). Perhaps the most significant factor differentiating Chinook from the other salmon species is that Chinook tend to eat more fish (Higgs et al. 1995). Thus they effectively feed at a higher trophic level than the other species of salmon, and would be expected to accumulate greater burdens of PBT chemicals even when sharing the same habitat. This is in fact observable. For example, when looking at adult Chinook and Coho returning to the same rivers, O'Neill, West, and Hoeman (1998) found that Chinook muscle contained, on average, almost twice the total PCB concentrations found in Coho muscle. This was also true for adults collected in Puget Sound proper (O'Neill, West, and Hoeman 1998).

Differences between species can also manifest in sub-adults. For example, Johnson et al. (2007) reported ΣPCB concentrations in juvenile wild Coho collected from five different estuaries ranging from 5.9 to 27 ng/g (wet weight; whole body minus stomach contents). The corresponding range for wild Chinook juveniles collected from the same estuaries was 11 to 46 ng/g (wet weight; whole body minus stomach contents). Overall, PCB concentrations in juvenile Coho were, on average, equivalent to nominally 50% of those found in the paired Chinook juveniles. This is essentially the same ratio observed by O'Neill, West, and Hoeman (1998) in adult fish.

All this indicates that PBT residues in salmon will vary within species depending on the specific run, and between species regardless (i.e., even when different species share the same general habitat). Thus, grouping all salmon together does not provide an accurate assessment of PBT doses delivered to human consumers due to consumption of salmon. This suggests that human health risk assessments should, as a general rule, incorporate salmon on a species-specific basis, if not a run-specific basis.

Certainly, none of this is supportive of adopting a single default value for the dose of any contaminant received by humans via consumption of salmon. Thus adoption of a single default FCR for salmon is also not supported.

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