Application of Data from an Asian and Pacific Islander (API) Seafood Consumption Study to Derive Fish and Shellfish Consumption Rates for Risk Assessment

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1. **Introduction**
2. **Overview of Methodology**
   - 2.1. **Adjusting API Survey Results to Reflect API Ethnic Composition in King County**
   - 2.2. **Correction of Seafood Weights from a Cooked to an Uncooked Basis**
   - 2.3. **Computation of Overall Seafood Consumption for Each Respondent**
3. **Results**
4. **Evaluation of the Impact of Assumptions Underlying the Analysis and Uncertainties**
   - 4.1. **How Well Does the API Study Sample Represent an Unbiased Estimate of the Seafood Consumption Behavior of API King County Residents?**
   - 4.2. **How Does the Correspondence Between the API Study Sample and the King County API Population Affect the Weights Used to Adjust API Study Sample Results to Reflect the King County API Population?**
   - 4.3. **What is the Degree of Uncertainty in Fish Consumption Rate Estimates?**
5. **Body Weight**
6. **Policy Rationale and Recommended Values**

Appendix A: Derivation of Percent Cooking Loss for Crab
Appendix B: U.S. Census Data on Ethnicity and Race for King County Washington

1. Introduction

An EPA-sponsored survey of fish and shellfish consumption by local Asians and Pacific Islanders (API) was conducted in 1999 (Sechena et al. 1999, 2003). The study evaluated consumption for a number of API ethnic groups. While the study analyzed consumption rates in a variety of ways, a number of statistics of interest to EPA risk assessors were not available. Of particular interest were upper percentile consumer-only consumption rates for fish and shellfish. EPA consequently re-analyzed the data to obtain statistics of interest for potential application to EPA-lead RCRA and Superfund sites.

EPA's analysis indicated that API seafood consumption rates are greater than the rate currently used in the Model Toxics Control Act (MTCA) for derivation of surface water cleanup levels, (i.e. MTCA utilizes a consumption rate of 54 grams per day. Assuming one-half of the seafood consumed is potentially affected by site related contaminants results in an effective consumption rate of 27 g/day for purposes of establishing cleanup levels).

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Census and other information indicates that the API population is well-represented in residential areas along the Duwamish River corridor and that APIs use Elliott Bay and the Duwamish River to harvest seafood. The API community represents 11.3% of the general population of King County, approximately 196,200 individuals out of a population of 1,737,034 (U.S. Census 2000). Several surveys have documented that fishing activity occurs along the Duwamish River and within Elliott Bay and that a substantial fraction of these anglers are APIs (NOAA 1985, NOAA 1987, McCallum 1985, King County 1999). King County (1999), evaluating fishing activity in the Duwamish River and Elliott Bay, determined that 24% of the anglers encountered were APIs. NOAA (1985, 1987) documented fishing activity for shore and boat anglers in urban embayments in Puget Sound. NOAA determined that for Elliott Bay, 30.1% of shore side and 8.1% of boating anglers were APIs. McCallum (1985), surveying fishing activity at Port Gardener, Sinclair Inlet and Elliott Bay, determined that 29% of Elliott Bay anglers surveyed were APIs.

In light of the aforementioned considerations, Ecology asked for EPA's assistance in developing API fish and shellfish consumption rates appropriate for use in MTCA surface water equations to develop cleanup levels for sites that may release contamination to the Duwamish River and Elliott Bay. Additionally, the body weight used to compute cleanup levels was evaluated and a recommendation consistent with an API seafood consuming population was provided. The statistical approaches used by EPA were developed with the assistance of Dr. Nayak Polissar. Dr. Polissar has been the lead statistician on virtually every seafood consumption survey done in the Pacific Northwest.

The adoption of alternate, site-specific exposure parameter values under MTCA requires consultation with the MTCA Science Advisory Board, the Washington State Department of Health, and EPA. The purpose of this memo is to support the consultation process by:

1) Developing API consumer-only seafood ingestion rates that consider where seafood was harvested;
2) Discussing issues related to the selection of an appropriate consumption rate for risk assessment activities;
3) Developing an API body weight to be used in conjunction with API consumption rates for risk assessment activities; and
4) Recommending consumption rate and body weight values for use in making risk-based decisions, including the development of cleanup levels, at sites where contaminant releases may impact the Duwamish River and Elliott Bay.

The information provided by this analysis of the API study results may be useful in determining appropriate fish and shellfish consumption rates for making risk-based decisions at cleanup sites in the Puget Sound area outside the Duwamish River and Elliott Bay. It is recommended that census data or other information from these other areas be reviewed to determine whether API contaminant exposure via seafood consumption should be used for risk analysis and cleanup level development. If it is found that API seafood consumption risks need consideration, then the location of the site should be considered in determining which of the consumption rates presented in Table 8 of this analysis would be most appropriate.

2. Overview of Methodology

EPA's API study collected seafood consumption information for a number of different ethnic groups residing in King County (Sechena et al. 1999, Sechena et al. 2003). Unfortunately, due to the small number of respondents per ethnic group, the utility of EPA's API study in deriving fish and shellfish consumption rates for individual ethnic groups is limited. The small sample size per ethnic group precludes development of robust upper percentile consumption rates for individual ethnic groups. Consumption rates developed from data on all study participants are more robust than those developed for individual ethnic groups. This exercise is hence directed toward developing upper percentile consumption rates for Asians and Pacific Islanders as a group.

The API study characterizes the source of seafood on an individual basis. Respondents recorded the percentage of seafood obtained from the following sources: consumed in restaurants, purchased in grocery stores, harvested within King County, and harvested outside of King County. The focus of this exercise is to characterize consumption of harvested seafood, though estimates of total seafood consumption are included for comparison purposes.

The degree to which migratory species may be affected by site-specific contamination is uncertain. To facilitate consideration of this issue, consumption rates for all species and resident (i.e non-anadromous) species were developed.

API consumption rates were generated for the following scenarios:

1) Consumption of all fish/shellfish species harvested from King County;
2) Consumption of non-anadromous fish/shellfish species harvested from King County;
3) Consumption of all harvested fish/shellfish species;
4) Consumption of harvested non-anadromous fish/shellfish species; and
5) Consumption of all fish/shellfish regardless of source.

2.1. Adjusting API Survey Results to Reflect API Ethnic Composition in King County

Participants from each ethnic group in the original API study were not drawn in proportion to the occurrence of each ethnic group in the King County API population as determined in the 1990 King County Census. For example, Vietnamese comprised a higher fraction of the API study population than the King County Vietnamese population. This over-sampling was carried out to yield a specified minimum number of participants per ethnic group, the goal being to have more data for API ethnic groups that might be especially high seafood consumers. By over sampling some groups, other groups were relatively under represented. Thus, in order to use the API study consumption rates across ethnic groups to come up with a single estimate of, for example, the 95th percentile of King County API consumption of locally harvested fish, something must be done to address over- and under-sampling. The ethnic group percentages associated with API study results must be brought into alignment with the percentages of different ethnic groups in the King County API population.

The adjustment process required use of U.S. census data on the populations of different API ethnic groups in King County. In the 1999 API study, 1990 census data were used to adjust the raw study data, as year 2000 census data were not yet available. The analysis given to the SAB in March 2005 also used 1990 census data. However, the current report used year 2000 census data, as it was felt

that 2000 census data more accurately represented the current API ethnic composition of King County.

In order to obtain appropriate estimates of fish consumption for the combined population of fish consumers in these ethnic groups, statistical weighting of the observations is needed. The weighting is a straightforward application of the following general principle used in survey sampling: if n_i people have been drawn at random from the i-th population of size N_i, then each sampled person represents N_i/n_i people in the source population, and N_i/n_i should be the relative weight for each person's ingestion rate.

To compute percentiles it is necessary that the sum of the weights for every observation in the sample sum to 1.0, a process called normalization. Normalization involves multiplying each and every person's relative weight by a common multiplier so that the sum of the weights associated with each respondent's ingestion rate in the sample is 1.0. For this general case, the common multiplier used to normalize the weighting factors is the sum of N_i/n_i for each member of the sample. The normalized weighting factor for a particular ethnic group is therefore: $N_i/n_i / \sum(N_i/n_i)$.

Every person's weight could be multiplied by any positive number prior to normalization, because such a multiplier cancels when the weights are finally normalized. In particular, rather than using N_i/n_i as the relative weight, each N_i can be divided by a constant, the total King County API population (N_{tot}). N_i/N_{tot} is then the fraction of the King County API population that is comprised of a particular API ethnic group, and $(N_i/N_{tot}) \times 100$ is the percentage of a particular ethnic group.[2] The notation P_i will be used to represent $(N_i/N_{tot}) \times 100$. The relative weighting factor for an observation for an individual's ingestion rate is now P_i/n_i. The normalized weighting factor is now $P_i/n_i/\sum(P_i/n_i)$.

This analysis of the API data is for individuals that are consumers of seafood harvested from King County. Therefore, the denominator of the relative weighting factor becomes the number of consumers in each ethnic group, denoted n_{ci}. However, the numerator of the relative weighting factor, P_i, needs further evaluation. The estimates being presented are for consumers only, so the source population would be just those in the specific population who are consumers. Thus, for example, if 80% of a specific ethnic population consists of consumers, then 80% of the census population count should be used as the population count of interest. Census data to estimate the fraction of various ethnic groups that are consumers do not exist. However, the fraction of the population who are consumers can be estimated using the fraction of API study participants who are consumers of seafood harvested from King County.

There is one additional point to consider before a fraction of consumers term can be computed, and that is whether the fraction of consumers varies across ethnic groups. A statistical test was performed to see whether the proportion of consumers varies across ethnic groups:

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[2] One would expect that summing P_i across all ethnic groups would yield 100%. However, the P_i value for the Mien was estimated to be the same as the Laotians (3.07%) and so the sum of P_i is 103.7%

The null hypothesis (H_0) for our test is that the fraction of consumers does not vary by ethnic group.

The alternative hypothesis (H_A) for our test is that the fraction of consumers does vary by ethnic group.

Unfortunately, the sample sizes for the various ethnic groups are rather small, and so the proportion of consumers is not well determined. For example, among the Hmong, the 4 out of 5 individuals who are consumers yield a consumer percentage of 80%, but a 95% confidence interval for the percentage is very wide: 28%-99%. Even among the Chinese (one of the two largest sample groups), the observed consumer proportion of 53% has a wide confidence interval of 34%-72%. A larger sample size for computing the proportion is helpful. Thus, if the proportion of consumers does not vary more than expected by chance, we can pool all of the ethnic groups to get a combined proportion.

The sample counts of consumers and non-consumers are noted in Table 1, along with the percent consumers. The "p-value" noted at the bottom of the table is the statistical significance of the null hypothesis that all of the groups have the same consumer rate. The value of $p = 0.054$ (Fisher's exact test) is just above the cutpoint for a common definition of "statistically significant" ($p < 0.05$), but, even more important, most of the departure from the null hypothesis is contributed by the Mien with their 90% rate. If the Mien are excluded, then $p = 0.3$. These results suggest that the observed differences in fraction of consumers among the ten ethnic groups is consistent with chance.

Consequently, the null hypothesis that the fraction of consumers does not vary across ethnic groups is accepted, and all data were pooled to determine the fraction of consumers.

Table 1. Consumers and non-consumers among ten ethnic groups

Ethnicity	Sample Size	# Consumers	# Non-consumers	Percent Consumers
Cambodian	20	11	9	55%
Chinese	30	16	14	53%
Filipino	30	14	16	47%
Hmong	5	4	1	80%
Japanese	29	12	17	41%
Korean	22	10	12	45%
Laotian	20	12	8	60%
Mien	10	9	1	90%
Samoan	10	2	8	20%
Vietnamese	26	9	17	35%
All groups	**202**	**99**	**103**	**49%**

Null hypothesis: all ethnic groups have the same population percentage of consumers; $p = 0.054$, Fisher's exact test ($p = 0.3$ without Mien)

The derivation of relative weights proceeds as follows.

Notation:

n_i = sample size, i-th ethnic group, i = 1, ..., 10

n_{ci} = number of consumers in the sample, i-th ethnic group

N_i = Census count of population, i-th ethnic group (consumers and non-consumers).

Based on these quantities, we calculate

N_{tot} = total population, all ten ethnic groups, $\sum N_i$

P_i = population of i-th ethnic group as a percent of the total of 10 populations, $100\%*N_i/N_{tot}$

f_{ci} = fraction of consumers, i-th ethnic group, n_{ci}/n_i

f_c = the estimated fraction of consumers in the pooled 10 ethnic populations, $\sum[N_i*(n_{ci}/n_i)]/N_{tot}$ or equivalently $\sum[P_i*(n_{ci}/n_i)]/(\sum P_i) = \sum[P_i*(f_{ci})]/(\sum P_i)$. Since $\sum P_i = 1$, f_c reduces to $\sum P_i*f_{ci}$

w_{0i} = relative weight associated with an individual ingestion rate observation assuming that the fraction of consumers does not vary across ethnic groups, the null hypothesis weight

With these quantities in hand and under the null hypothesis (H_0) that all ethnic groups have a common percentage of consumers, the relative statistical weight given to a member of the i-th ethnic group is:[3]

$$w_{0i} = f_c*P_i/n_{ci}$$

Again, to be able to develop percentiles, the sum of the weights of all respondents must sum to 100%. This requires normalization of the relative weighting factors. This is done by dividing w_{0i} by $\sum w_{0i}$ for every study participant. The normalized statistical weight given to a member of the i-th ethnic group is:

$$w_{0i} = f_c*(P_i/n_{ci}) / \sum(f_c*P_i/n_{ci})$$

[3] As a side note, the statistical weight (w_{Ai}) calculated under the alternative hypothesis (H_A) that not all ethnic groups have the same percentage of consumers is: $w_{Ai} = f_{ci}*P_i/n_{ci} = P_i/n_i$. The estimated percentiles of fish consumption using either set of weights, w_{0i} or w_{Ai}, are very similar (See section 4.3 for examples run using both weighting approaches).

The data needed to compute weighting factors for API study consumers of King County harvested seafood are presented in Table 2:

Table 2: Weighting factors for API study consumers of King County harvested seafood

Ethnicity	n_i	Normalized P_i	n_{ci}	$f_{ci} = n_{ci} / n_i$	$P_i * f_{ci}$	$f_c * P_i / n_{ci}$	$w_{0i} = f_c * P_i / n_{ci} / \sum(f_c * P_i / n_{ci})$
Cambodia	20	3.91%	11	0.550	0.021	0.0017	0.36%
Chinese	30	26.57%	16	0.533	0.142	0.0078	1.66%
Filipino	30	19.90%	14	0.467	0.093	0.0067	1.42%
Hmong	5	0.52%	4	0.800	0.004	0.0006	0.13%
Japanese	29	12.66%	12	0.414	0.052	0.0050	1.06%
Korean	22	11.81%	10	0.455	0.054	0.0056	1.18%
Laotian	20	2.97%	12	0.600	0.018	0.0012	0.25%
Mien	10	2.97%	9	0.900	0.027	0.0016	0.33%
Samoan	10	2.47%	2	0.200	0.005	0.0058	1.23%
Vietnamese	26	16.22%	9	0.346	0.056	0.0085	1.80%
Totals:	202	100.00%	99				

Percentile consumption rates were then computed by:

1) Rank ordering the consumption rates from lowest to highest;
2) Computing a running sum of the weighting factor (w_{0i}), essentially the summed fraction of the population represented;
3) Locating the summed fraction of the weights (i.e. cumulative percent) bracketing the percentile of interest; and
4) Linearly interpolating between the rates associated with the cumulative percent values identified in (3) to obtain the consumption rate associated with the percentile of interest. This method of calculating percentiles for weighted data is used in the survey package of the statistical package "R," which is widely used by statisticians.

The data used to develop the 95th percentile of King county harvested seafood consumption are given in Table 3.

Table 3: Computation of 95th percentile consumption rates for individuals harvesting seafood from King County (no correction for cooking)				
Individual	**Ethnicity**	**Statistical Weight, (w_{0i})**	**Cumulative Percent**	**Seafood Consumption Rate, g/day**
AV10	Cambodia	0.0036	0.4%	0.16
JR62	Vietnamese	0.0180	2.2%	0.31
AR28	Cambodia	0.0036	2.5%	0.57
		...		
EV35	Korean	0.0118	94.2%	35.2
FV01	Laotian	0.0025	94.4%	48.3
CR30	Filipino	0.0142	95.9%	48.5
ER14	Korean	0.0118	97.0%	49.2
FR13	Laotian	0.0025	97.3%	57.5
DR03	Japanese	0.0106	98.3%	75.3
DV09	Japanese	0.0106	99.4%	77.6
AV13	Cambodia	0.0036	99.8%	81.0
FR15	Laotian	0.0025	100.0%	196.6

Linear interpolation between the ingestion rates for individuals 92 and 93 (SEE shaded cells in Table 3) results in a 95th percentile ingestion rate of 48.4 g/day.

2.2. Correction of Seafood Weights from a Cooked to an Uncooked Basis

Expression of seafood consumption in terms of uncooked or raw wet weight is desirable, as analysis of chemical contaminants in seafood is frequently done on uncooked samples. EPA's API study recorded all finfish and some shellfish consumption in terms of uncooked weight. However consumption of the following shellfish species was recorded in terms of cooked weight: butter clams, cockles, crab, geoducks, horse clams, macoma, manila/little neck, moon snail, mussels, oysters, razor clams, and scallops. These organisms were steamed or boiled in order to facilitate removal of edible tissue from the shell. An issue with using cooked weights is that the weight of cooked tissue is frequently less than the weight of uncooked tissue. Thus, treating all consumption as if it were uncooked could result in uncooked seafood consumption rates that were biased low. Consequently, it was decided to attempt to adjust cooked shellfish consumption rates so that they reflected consumption of uncooked seafood.

The API study data included each respondent's consumption rate for individual shellfish species. Converting a cooked seafood consumption rate to an uncooked rate can be calculated by:

Cooked consumption rate x (weight seafood prior to cooking / weight seafood after cooking)

Some information is available on relationships between cooked and uncooked seafood weights. In 1975, the USDA published a handbook on the yields of food following various types of preparation. There were a number of relevant entries in the handbook:

Table 4: Percent weight loss during cooking for seafood (USDA, 1975)			
Entry #	**Description**	**Preparation**	**% Loss in Weight**
1624	Shucked raw oysters	panned, cooked over hot water, cover on	25
2288	Shucked, thawed scallops	Boiled	50

In conjunction with work done to evaluate seafood consumption for the Quinault Tribe, EPA determined the percent weight lost after steaming for shucked shellfish. The values obtained for oysters (23.5% +/- 2.5%) and mussels (37.4% +/- 1.1%) were consistent with the values tabulated by USDA (Kissinger 2005).

The API study did provide data on weight lost during cooking for crab. These data were used in preference to information in the USDA guidance. In the API study (SEE Appendix B, Sechena et al. 1999), five crabs used for model preparation were weighed before and after cooking. The weight of the edible meat and crab butter (or hepatopancreas) was also recorded. Using these data, a weight loss of 18% for edible tissue was derived (SEE Appendix A).

Correcting shellfish consumption for each individual from a cooked to an uncooked basis was done by means of the following formula:

$$\text{Shellfish Rate} = \sum (\text{consumption rate uncooked species})_i +$$

$$\sum (\text{consumption rate cooked species})_i / (\text{shellfish cooked to uncooked correction factor}) +$$

$$(\text{crab consumption rate}) / (\text{crab cooked to uncooked correction factor})$$

A crab cooked to uncooked correction factor of 0.82 (e.g. 100% – 18% weight loss) was used for all analyses. There was more uncertainty in the correction factor used for other shellfish. Two analyses were run utilizing weight loss correction factors of 0.5 (e.g. 100% - 50% weight loss) and 0.75 (100% - 25% weight loss) respectively. The impact of applying these correction factors on overall seafood consumption percentiles was then evaluated.

2.3. Computation of Overall Seafood Consumption for Each Respondent

Ingestion rates of harvested fish/shellfish were computed using the following data from each respondent:

RateA:	Anadromous fish consumption rate, g/kg/day
FKCoA:	Fraction of anadromous fish harvested from King County
FOA:	Fraction of anadromous fish harvested outside of King County
RateF:	Freshwater fish consumption rate, g/kg/day
FKCoF	Fraction of freshwater fish harvested from King County
FOF	Fraction of freshwater fish harvested from outside of King County

RateP:	Pelagic fish consumption rate, g/kg/day
FKCoP:	Fraction of pelagic fish harvested from King County
FOP	Fraction of pelagic fish harvested from outside of King County
RateB:	Benthic fish consumption rate, g/kg/day
FKCoB:	Fraction of benthic fish harvested from King County
FOB	Fraction of benthic fish harvested from outside of King County
$RateS_u$:	Shellfish consumption rate, g/kg/day, no correction for cooking
$RateS_{50}$:	Shellfish consumption rate, g/kg/day, 50% cooking loss correction
$RateS_{25}$:	Shellfish consumption rate, g/kg/day, 25% cooking loss correction
FKCoS:	Fraction of shellfish harvested from King County
FOS	Fraction of shellfish harvested from outside of King County
BW:	Body weight, kg

These data are provided in the attached API spreadsheet.

The formulas for computation of individual ingestion rates are provided below. Rates were computed in units of grams per day.

1. Consumption of harvested fish/shellfish from King County

Rate (g/day) = (RateA * FKCoA + RateF * FKCoF + RateP * FKCoP + RateB * FKCoB + $RateS_X$ * FKCoS) * BW

2. Consumption of harvested non-anadromous fish/shellfish from King County

Rate (g/day) = (RateF * FKCoF + RateP * FKCoP + RateB * FKCoB + $RateS_X$ * FKCoS) * BW

3. Consumption of harvested fish/shellfish

Rate (g/day) = [RateA * (FKCoA + FOA) + RateF * (FKCoF + FOF) + RateP * (FKCoP + FOP) + RateB * (FKCoB + FOB) + $RateS_X$ * (FKCoS + FOS)] * BW

4. Consumption of harvested non-anadromous fish/shellfish

Rate (g/day) = [RateF * (FKCoF + FOF) + RateP * (FKCoP + FOP) + RateB * (FKCoB + FOB) + $RateS_X$ * (FKCoS + FOS)] * BW

5. Total API fish/shellfish consumption rate:

Rate (g/day) = [RateF + RateP + RateB + $RateS_X$] * BW

NOTE: $RateS_X$ denotes a range of shellfish consumption rates (i.e. rates uncorrected for cooking, $RateS_U$; rates assuming a 50% cooking loss, $RateS_{50}$; and rates assuming a 25% cooking loss, $RateS_{25}$.) Consequently, three different rates reflecting different shellfish cooked to uncooked weight corrections were computed for each option.

3. Results

Application of the rate calculation and "weighting" approaches noted previously resulted in the following percentiles. It should be noted that the number of individuals with non-zero consumption rates changes between consumption rate categories, as the criteria applied result in the selection of different sub-sets of study participants.

Table 5: API Seafood Consumption Percentiles for Seafood

Consumption Rate Category	Number of Individuals w/non-zero Consumption Rates	Shellfish Cooking Correction	Percentile Ingestion Rate, g/day		
			50th	90th	95th
All species harvested from King County	99	None	5.7	22.2	48.4
		25%	5.7	24.3	53.1
		50%	5.8	26.7	61.1
Non-anadromous species harvested from King County	89	None	6.0	20.1	45.5
		25%	6.2	33.2	54.1
		50%	6.9	33.6	60.6
All species harvested anywhere	125	None	6.5	25.9	58.8
		25%	6.8	43.7	72.6
		50%	7.1	54.4	80
Non-anadromous species harvested anywhere	112	None	6.2	37.9	54.1
		25%	6.8	49.2	70.4
		50%	7.5	59.2	74.2
Total seafood consumption regardless of source	202	None	74.0	226.9	286.1
		25%	75.9	232.5	299.3
		50%	75.6	240.4	312.1

For a particular set of criteria (SEE row labels in Table 5), increasing the correction for cooking weight loss generally increases the consumption rates associated with a percentile.

4. Evaluation of the Impact of Assumptions Underlying the Analysis and Uncertainties

The purpose of this section is to discuss the impact of various assumptions used in preparing this analysis as well as uncertainties. The areas to be covered include:

1. How well does the API study sample represent an unbiased estimate of the seafood consumption behavior of API King County residents?
2. How does the correspondence between the API study sample and the King County API population affect the weights used to adjust API study sample results to reflect the King County API population?
3. What is the degree of uncertainty in fish consumption estimates?

4.1. How Well the API Study Sample Represent an Unbiased Estimate of the Seafood Consumption Behavior of API King County Residents?

Specifically, we are concerned as to whether the seafood consumption behavior of API study participants provides an unbiased representation of the behavior of adult King County API seafood consumers. This is a separate issue from weighting the API study results so that they reflect API adult King County seafood consumption.

API study participants were not selected in a truly random fashion. Study participants were recruited using two different methods, rosters from cooperating ethnic organizations and volunteers. Approximately 50% of study participants were recruited by each method. To avoid potential bias in recruiting volunteers, the study was advertised as a dietary study of Asians and Pacific Islanders rather than a seafood consumption survey.

Roster recruitment was done by creating lists of potential study participants from membership rolls of Asian and Pacific Islander community organizations. Study participants were then randomly selected from these lists.

Volunteers were recruited by means of community newspaper press releases as well as posters. All volunteer data were then entered into a database, and participants were randomly selected from that database.

Factors that might cause the study sample to differ from the King County population are provided in Table 6 and are elaborated upon in the accompanying text. Because we do not have any information on those who were considered for the survey but did not participate, (i.e. potential respondents who declined, those in the pool of potential study participants who could not be contacted or who never attempted to contact us) no comparisons can be made to demonstrate that the selection method used produced results similar to a truly random sampling protocol.

Table 6: Differences between the seafood-consuming King County population and API study sample

Item	Sample	U.S. Census of King County
Generation	First and second generation	Not restricted
gender mix (%M, %F)	50:50	Potentially somewhat different from 50:50
Effect of disqualification and respondent selection methodology	volunteers, rosters from selected organizations	Target: all individuals
Ethnic group	ten specified API groups	More groups are specified in the census

Generation: Table R-6 (Sechena et al. 1999) shows somewhat more consumption of "all seafood" by the first generation than the second generation (not statistically significant). Considering the impact of only the generation factor, it is possible that the study sample may have more or fewer 1st generation individuals than the King County adult API population. Consequently generational composition differences between these groups might be associated with the study sample consuming more or less seafood than the King County population.

Gender mix: This is likely to have little impact, because the consumption rates are similar by gender (Table R-2, Sechena et al. 1999).

Effect of failure to contact, disqualification and the respondent selection process: The impact of non-participation in the survey with regards to how well the study sample represents the King County population cannot be determined. Without data on the individuals who were considered for participation in the survey, we can not tell what the impact is of not being able to contact potential participants and the refusal of individuals to participate on the correspondence or lack of correspondence between the API study consumers and the API King County adult seafood consumers.

The respondents in the sample are all essentially volunteers. Even though a roster was used to identify some people, those people still had to agree to participate. Of those roster people contacted and not disqualified, 67% (96/143) agreed ("volunteered") to participate. In addition, it is important to realize how the roster candidate respondents were identified. They were drawn at random from individual rosters obtained from various religious and community organizations, and the organizations themselves were "volunteers."

In summary of this point, the participants were either direct volunteers, or agreeable (volunteering) members of API organizations that voluntarily participated in the survey. The API sample is very tied to volunteerism. The impact of volunteerism on selection of participants with different levels of seafood consumption is unknown. No method of estimating the impact of volunteerism on the consumption estimation process has been discovered or discerned. Ecology staff have searched the literature to find articles on the relationship between volunteerism and dietary intake survey results. No papers discussing this issue were found. In order to avoid potential volunteerism bias on reported fish consumption *per se*, the study was advertised as study of dietary habits rather than as a seafood consumption study.

Ethnic Group: The study sample consisted of 10 different API ethnic groups while the King County API population consists of several additional groups. The surveyed ethnic groups represent a substantial portion (84%) of the King County API population *as tabulated in the 2000 U.S. census*. The census data for these ethnic groups include all ages, while the API study sample includes adults only. Nonetheless, it seems reasonable to use the study sample as a surrogate for King County adult API seafood consumers. It is difficult to say how seafood consumption rates would differ between the ten ethnic groups studied and the full complement of ethnic groups in the census definition of "API". If unsurveyed ethnic groups had seafood consumption patterns that differed greatly from the surveyed ethnic groups, consumption rates could be either greater or lower for adult King County API seafood consumers relative to API study participants. The fact that the 10 surveyed API groups comprise 84% of the census population suggests that consumption rates form the survey are likely to be similar to consumption rates that would have been calculated from a survey of all API groups, as defined by the census. For purposes of this analysis, the API study sample based on ten ethnic groups will be used to represent all ethnic groups comprising the King County API population.

Conclusion: The factors considered above are deemed to have either an unknown or insignificant impact on how well the API study sample represents the seafood consumption behavior of adult API

residents of King County. Consequently, it is concluded that the API study sample results provide a reasonable representation of the seafood consumption behavior of adult API residents of King County.

4.2. How Does the Correspondence Between the API Study Sample and the King County API Population Affect the Weights Used to Adjust API Study Sample Results to Reflect the King County API Population?

The relative percentages of different API ethnic groups from King County as tabulated in the U.S. census were used to weight API study ingestion rates. Ideally census ethnic group percentages would have been derived from a population having the same properties as the API study sample. API study participants were:

1) Age 18 or greater
2) 1st or 2nd generation Asian Pacific Islanders
3) Seafood consumers

Unfortunately, the U.S. census does not provide statistics at this level of detail. The only statistics available are the percentages of each ethnic group in the King County API population. The following text discusses how these factors might affect the relationship between the percentages of the different ethnic groups.

Age: The sample includes 18+ ages only, and the census includes all ages. If the census had broken down ethnic group populations by age, then this could have been easily fixed by using the appropriate age groups from the census. Unfortunately such data are not available. An alternative would have been to adjust the King County ethnic group population percentages using the fractions of API ethnic group populations greater than age 18 for Washington State or national data. Such an adjustment might introduce additional uncertainty, as the age structure of API ethnic groups for Washington or national results may differ from King County. Unfortunately, alternate age structure data do not exist in tabulated form. If the percentages of 18+ year old individuals are similar across ethnic groups, then this adjustment will have little impact. It is possible to calculate the percentages of various King County racial groups that are 18+ years of age from 2000 census data. These values are as follows: whites 80%, blacks 77%, American Indians and Alaska natives 74, Asians 77%, Hawaiians and Pacific Islanders 67%, and Hispanics 67%. Though it is possible that the 18+ years of age fractions for individual API ethnic group populations show greater variation than those observed for larger racial group aggregations, the available data suggest that correcting census ethnic group percentages for age will not greatly alter the relative percentages of the different ethnic groups as tabulated in the census.

Generational issues: What percentage of each ethnic group are 1st or 2nd generation individuals? Census data do not exist to answer this question. If it is assumed that the ethnic groups have similar age structures, then a more specific question might be posed: "How would the census percentages of adults in each ethnic group be altered if only 1st and 2nd generation individuals were considered?" Though the data do not exist to answer this question, the fraction of potential API study participants that were disqualified for not meeting age, residency, generational, and ethnic group membership criteria was only 14%. This provides some suggestion that consideration of generational status would not greatly impact the relative percentages of different ethnic groups in the census data.

Seafood consumers: Census data on seafood consumption by ethnic group do not exist. However, data on disqualified individuals suggest that approximately 1% of potential API study participants were disqualified because they were not seafood consumers. We do not know of a mechanism that would have screened out seafood non-consumers prior to their contact with the survey staff, so it is likely that the API study sample has a fraction of seafood consumers similar to that of the King County API population. This provides some suggestion that consideration of seafood consumption status would not greatly impact the relative percentages of different ethnic groups in the census data.

Conclusion: It is not possible to quantitatively evaluate how the aforementioned issues would alter the relative percentages of different API ethnic groups as tabulated in the census and the factors used to weight API study results. As noted above, there is some indication that adjusting for these issues would not greatly alter the relative percentages of the different King County API ethnic groups. It is concluded that it is reasonable to use available census ethnic group percentages to weight API study results.

4.3. What is the Degree of Uncertainty in Fish Consumption Rate Estimates?

As discussed in the previous sections, there are a number of factors that may contribute to uncertainty with regards to how well the API study sample represents the API King County population and the appropriateness of using U.S. census ethnic group percentages to weight API study results. It is also apparent that the impact of these considerations cannot be assessed in a deterministic, analytical fashion.

However, the standard errors and 95% confidence intervals can be evaluated for the 50th (median), 90th and 95th percentiles of fish consumption using probabilistic techniques. The aforementioned statistics were calculated using the stratified non-parametric bootstrap with 999 re-samples (Efron et al. 1993).

Following is a brief summary of this method. Each of the 999 re-samplings consisted of drawing a new sample of the same size per ethnic group (e.g., 10 Samoans) from the original observations (consumers and non-consumers) with replacement. The estimated proportion of consumers in each of the ethnic groups and the resulting weights were recalculated for each re-sample using the weighting methodology described elsewhere in this report. Using these weights the fish consumption percentile was calculated for each re-sample.

The bootstrap standard error for a percentile estimate was then calculated as the standard deviation of the 999 re-sampled percentile estimates. A 95% confidence interval for the population percentile (such as the population 95^{th} percentile of seafood consumption) was calculated as the interval spanning the 0.025 to the 0.975 quantile of the distribution of estimates from re-sampling. This procedure, re-sampling from both consumers and non-consumers with recalculation of the weights, incorporates both the uncertainty in the estimated proportion of consumers and the distribution of fish consumption rates among those who are consumers.

Table 7: Results of uncertainty analysis for King County APIs consuming seafood harvested within King County													
% Cooking weight loss adjustment	Weights	Median				90th percentile				95th percentile			
		Est.	*SE*	*LCB*	*UCB*	*est.*	*SE*	*LCB*	*UCB*	*Est.*	*SE*	*LCB*	*UCB*
0	0	5.7	0.9	3.8	7.4	22.2	6.9	17.4	48.3	48.4	11.7	21.8	72.0
25	0	5.7	1.1	3.9	8.1	24.3	11.2	20.1	53.1	53.1	13.8	24.2	78.9
50	0	5.8	1.5	4.3	9.2	26.7	13.5	22.6	61.2	61.1	15.0	26.7	84.1
0	A	5.7	0.9	3.8	7.3	22.3	6.4	17.3	43.4	48.3	11.0	22.2	66.2
25	A	5.7	1.1	3.9	8.0	26.7	11.4	20.1	53.1	53.2	13.2	24.4	75.4
50	A	5.8	1.4	4.2	9.1	27.4	14.0	22.4	61.4	61.1	14.9	26.8	84.1

Abbreviations: est.-Maximum Likelihood Estimate; SE-Standard Error; LCB-Lower Confidence Bound; UCB-Upper Confidence Bound; Weight 0-indicates that the fraction of consumers was treated as a pooled value; Weight A-indicates that the fraction of consumers was allowed to vary by ethnic group

The treatment of the fraction of consumers as varying across ethnic groups or as pooled value (SEE section 2.1) seems to have little impact on any of the statistics. This report used the "0" weight results. The LCB and UCB values about the estimated value are somewhat asymmetrical. This is often the case in bootstrap simulations. For regulatory purposes, the statistics of concern are the 95th percentile consumption rates assuming cooking correction factors of 25% and 50% respectively. The estimated 95th percentile consumption rate for the 25% cooking correction factor was 53.1 with upper and lower confidence bounds that were approximately 50% greater and lower than the estimated value. The estimated 95th percentile rate for the 50% cooking correction factor was 61.1 with upper and lower confidence bounds that were approximately 40% greater and lower than the estimated value. The relevant values are shaded in Table 7. The lower confidence bounds fall approximately at the current MTCA regulatory value of 27 g/day and indicate that it is likely that the API consumption rate differs from the current MTCA value.

5. Body Weight

The average body weight for all API study participants without applying any weighting methodology to adjust API study data to reflect the King County API population was 63 kg. The average body weight of *all API study participants* calculated using ingestion rate weighting factors specific to this group was 62 kg. The average body weight of *API study participants that consumed any type of seafood harvested from King County* calculated using ingestion rate weighting factors specific to this group was 63 kg. Application of weighting factors and whether or not the data set consisted of consumers or consumers AND non-consumers had little impact on the average body weight.

6. Rationale and Recommendations

What seafood consumption rates should be used for assessment of site risks and development of cleanup levels for sites from which contaminant releases may be impacting the Duwamish River?

EPA, in assessing site related contaminant risks, utilizes "reasonable maximum exposure" or RME. The intent of the RME is to estimate a conservative exposure case (i.e., well above the average case but that is still within the range of possible exposures). RME values are computed using a mixture

of upper bound and average values for relevant exposure parameters. To characterize contact with contaminated media, EPA generally uses 95th percentile media contact rates (e.g. seafood consumption rate) when data are available to support derivation of these values (EPA 1989, EPA 1997). The data set used to derive the 95th percentile is based on the exposed population (EPA 1989). For example, the Exposure Factors Handbook (EPA 1997) provides 95th percentile fish consumption rates for the general population, recreational anglers, and tribal populations. Whichever population is potentially consuming seafood with contaminant levels influenced by a toxic waste would govern the appropriate data set to be used. EPA proposes to develop and use API 95th percentile consumption rates.

The API study characterized the percent consumption of seafood purchased in grocery stores, consumed in restaurants, harvested within King County, and harvested outside of King County. EPA believes that utilizing the total API seafood consumption rate would overestimate the amount of consumed fish and shellfish that may be affected by site-related contamination. The 95th percentile total seafood consumption rate incorporating cooking weight loss considerations falls between 299 and 312 grams per day.

Another alternative would be to use the consumption rate for seafood harvested anywhere, excluding seafood obtained in restaurants and stores. However, the broad area over which seafood harvest might occur is large relative to the area associated with application of these rates (i.e. sites along the Duwamish River). Consequently, EPA believes that using the consumption rate for seafood harvested anywhere also would likely overestimate consumption of seafood affected by site-related contamination.

EPA proposes to use the 95th percentile API seafood consumption rate for all fish and shellfish harvested from King County. This approach may underestimate or overestimate the actual seafood affected by contamination. There are several areas of uncertainty associated with this approach.

The King County area is larger than the boundaries of the cleanup sites for which this rate is to be applied, which could lead to an overestimate of site-related contaminant exposure. However, EPA believes that given the mobility of contaminants and in order to promote safe fish consumption on a regional basis, that the site-related area affecting fish contaminant levels should not strictly be limited to a site's physical boundaries.

API survey respondents obtained fish and shellfish in areas that had been posted with fish advisories. The rates developed from the API study may hence be suppressed and may not reflect higher consumption rates that could occur in the presence of an uncontaminated fisheries resource, or a healthier post-cleanup resource. Proposed cleanup levels would be more stringent if higher consumption rates were used. Data from a study assessing API consumption from an uncontaminated resource area would have been desirable for this exercise, but were not available. The proposed rates may be an underestimate of the appropriate rates to use for cleanup level development.

Another factor to consider is that individuals may consume locally caught fish in restaurants or purchase them in grocery stores. If correct, use of the King County only consumption rate would underestimate site-related contaminant exposure.

The weight lost during cooking for certain species of shellfish is a source of uncertainty in analyzing the API data. EPA believes that sufficient information exists to characterize the range of uncertainty contributed by this factor. EPA proposes that in determining percentiles for seafood consumption rates for risk assessment and cleanup level development, that the average of percentiles developed using 25% and 50% cooking losses should be used. Recommended percentile averages are given in Table 8.

Table 8: Recommended API consumption rates for risk analysis in g/day

	Percentile		
Consumption Rate Category	**50**	**90**	**95**
All species harvested from King County	5.8	25.5	57.1
Non-anadromous species harvested from King County	6.6	33.4	57.3
All species harvested anywhere	6.9	49.1	76.3
Non-anadromous species harvested anywhere	7.1	54.2	72.3
Total API consumption rate	77.8	236.4	305.7

In some circumstances, such as at EPA RCRA and Superfund sites, a decision of whether to use the consumption rate of all species or resident-only species may entail many variables. Considerations include the potential for both anadromous and resident species to bioconcentrate site-related contaminants in the local aquatic environment; and the potential for bioaccumulative chemicals associated with the cleanup site to have been biologically or mechanically transferred to more remote environments where adult anadromous fish later harvested in the local environment could have accumulated them via the food chain. Such decisions may also necessarily depend upon regulatory constraints or on best professional judgment, in the presence of scientific uncertainty.

The API body weight recommended for use in conjunction with these seafood consumption rates is 63 kg.

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Appendix A: Derivation of Percent Cooking Loss for Crab

Appendix B of the API study provided data that permit computation of cooking loss for crab.

C_u = weight of a whole uncooked crab.
C_c = weight of a whole cooked crab
I = weight of inedible material
T_u = weight of uncooked tissue
T_c = weight of cooked tissue (butter + meat)
L = weight difference between a whole uncooked and a whole cooked crab

Then:

$$C_c = I + T_c$$

$$C_u = I + T_u$$

The assumption is made that "I" is constant for cooked and uncooked crabs.

$$L = C_u - C_c$$

$$I + T_c + L = I + T_u$$

"I" cancels out and substituting in $C_u - C_c$ for L gives:

$$T_c + C_u - C_c = T_u$$

The cooking loss correction factor may then be computed as $1 - (T_c / T_u)$.

Table 4: Cooking Loss Correction Factor for Crab (all weights in grams)

Crab #	Uncooked crab weight, C_u	Cooked crab weight C_c	Weight cooked crab butter	Weight cooked meat	Uncooked, tissue weight, $T_c + C_u - C_c$	% Loss, $1-T_c/T_u$
1	758.3	649	118.42	254.54	482.26	23%
2	643.5	586.82	111.56	208.27	376.51	15%
3	626.2	594.84	97.56	193.91	322.83	10%
4	823.9	738.8	122.52	227.28	434.9	20%
5	699.6	605.7	124.64	211.54	430.08	22%
					Average	18%

Appendix B: U.S. Census Data on Ethnicity and Race for King County Washington

The detailed breakdown of King County 200 U.S. census counts for the API ethnic groups included in the API study is provided here, followed by general U.S. census data for King County.

API ethnic group	Population
Cambodian	6623
Chinese	45,018
Filipino	33,714
Hmong	889
Japanese	21,455
Korean	20,005
Laotian	5040
Mien	NA
Samoan	4,182
Vietnamese	27,484
Total:	164,410

Racial classification	Number	Percent
Total population	1,737,034	100.0
One race	1,666,535	95.9
White	1,315,507	75.7
Black or African American	93,875	5.4
American Indian and Alaska Native	15,922	0.9
American Indian	9,921	0.6
Alaska Native	2,292	0.1
Both American Indian and Alaska Native	42	0.0
American Indian or Alaska Native, not specified	3,667	0.2
Asian	**187,745**	**10.8**
Asian Indian	15,827	0.9
Chinese	45,018	2.6
Filipino	33,714	1.9
Japanese	21,455	1.2

Racial classification	Number	Percent
Korean	20,005	1.2
Vietnamese	27,484	1.6
Other Asian category	18,932	1.1
Two or more Asian categories	5,310	0.3
Native Hawaiian and Other Pacific Islander	**9,013**	**0.5**
Native Hawaiian	1,506	0.1
Samoan	4,182	0.2
Guamanian or Chamorro	1,028	0.1
Other Pacific Islander category	2,098	0.1
Two or more Native Hawaiian or Other Pacific Islander categories	199	0.0
Some other race	44,473	2.6
Two or more races	70,499	4.1
Two races including Some other race	18,207	1.0
Two races excluding Some other race, and three or more races	52,292	3.0
Two races excluding Some other race	46,107	2.7
Three or more races	6,185	0.4
HISPANIC OR LATINO		
Total population	1,737,034	100.0
Hispanic or Latino (of any race)	95,242	5.5
Mexican	62,369	3.6
Puerto Rican	4,214	0.2
Cuban	1,792	0.1
Other Hispanic or Latino	26,867	1.5
Not Hispanic or Latino	1,641,792	94.5

Racial classification	Number	Percent
RACE AND HISPANIC OR LATINO		
Total population	1,737,034	100.0
One race	1,666,535	95.9
Hispanic or Latino	85,403	4.9
Not Hispanic or Latino	1,581,132	91.0
Two or more races	70,499	4.1
Hispanic or Latino	9,839	0.6
Not Hispanic or Latino	60,660	3.5