Developing Baseline Risk Fish Ingestion Estimates for Baseline Human Health Risk Assessments

Jason C. Kinnell
Matthew F. Bingham

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1851 Evans Road
Cary, NC 27513
Office: **919.677.8787**
Fax: **919.677.8331**

VERITAS
Economic Consulting
VeritasEconomics.com

Abstract

Evaluating alternative remedial options under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) requires understanding human health risk under regulatory baseline conditions as specified in the National Contingency Plan [55 *FR* 8711] (NCP). As the preamble to the NCP describes, "…one specific objective of the risk assessment is to provide an analysis of baseline risk (i.e., the risks that exist if no remedial action or institutional controls are applied to a site)." Fish consumption advisories are considered a form of institutional control (U.S. Environmental Protection Agency [USEPA] 2010). Therefore, the baseline risk assessment requires estimates of fish consumption if the site-specific fish consumption advisory were not in force, but all other site conditions were the same (not in force means that a posted sign is not present on site and/or published materials warning anglers about risks from consuming site fish and crab are not available).

This manuscript presents a methodology for developing baseline-risk fish-ingestion estimates using site-specific data. The methodology involves linking current trip-taking and consumption to baseline trip-taking and consumption via behavioral modeling supported by survey research. The manuscript provides an empirical example of the methodology by developing baseline-risk fish-ingestion estimates for the Lower Passaic River Study Area (LPRSA)—a 17-mile stretch of urban and industrial river in northeastern New Jersey.

The results of the analysis estimate a mean of 0.85 grams per day for the 90th percentile of all LPRSA anglers (consumers and non-consumers) under baseline risk conditions. By comparison, default rates prepared for the LPRSA have been as high as 34.6 g/day (USEPA 2014). This default rate is also higher than estimates for the population of LPRSA consuming anglers who consume at the 90th (3.14 g/day), 95th (5.19 g/day), and 99th percentile (15.13 g/day).

1. Introduction

Evaluating alternative remedial options under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) requires understanding human health risk under regulatory baseline conditions. One of the key parameters that influences estimates of baseline human health risk is the level of fish consumption at a site.

The regulatory requirement of a baseline risk assessment is to characterize risk in the absence of any site-related controls that might reduce exposure. Under 40 *CFR* 300.430(d)(4), the CERCLA statute directs that the "…lead agency shall conduct a site-specific baseline risk assessment to characterize the current and potential threats to human health and the environment." As the preamble to the National Contingency Plan [55 FR 8711] describes, "…one specific objective of the risk assessment is to provide an analysis of baseline risk (i.e., the risks that exist if no remedial action or institutional controls are applied to a site)."[1]

Fish consumption advisories are considered a form of institutional control (USEPA 2010). Because institutional controls can reduce or preclude exposure while not actively remediating a site, the U.S. Environmental Protection Agency (USEPA) considers that their presence does not represent the baseline risk situation. Therefore, to assess baseline human health risk in a specific Study Area, the baseline risk assessment must characterize what the Study Area's fish consumption level would likely be if the Study Area's site-specific fish consumption advisory were not in force, but all other site conditions were the same (e.g., an urban and/or industrial setting, access, and/or degraded water and/or sediment quality).[2]

Because current consumption can be observed, under CERCLA, *current* consumption (and regulatory risk) can be evaluated using traditional on-site survey techniques. In contrast, *regulatory baseline* risk (and consumption) refers to conditions that would exist in the absence of institutional controls that may reduce risk. The implication for sites with fish consumption advisories is that quantifying baseline regulatory risk requires estimating what fish consumption *would be* if the relevant fish consumption advisories were not in force.

Unlike current fish consumption, regulatory baseline fish consumption is not directly observable; this complicates the identification of regulatory baseline risk. A common solution is to use default rates or transfers of fish consumption from other sites. Default rates are essentially current consumption rates estimated at sites with either no or lower consumption

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[1] The National Contingency Plan provides the blueprint for CERCLA implementation.

[2] By not in force we mean that a posted sign is not present on site and/or published materials warning anglers about risks from consuming site fish and crab are not available, but all other site conditions remain under their Current conditions.

advisories. Although default-rate transfers are straightforward to conduct, fishing sites and behaviors can differ greatly in ways other than those related to consumption advisories. For example, there can be important differentiators from sites used to generate default values including the affected population, access, water quality, and species availability (Kinnell et al. 2007). As a result, it can be inappropriate to apply default values to a specific study area. In addition, a number of U.S. Environmental Protection Agency (USEPA) guidance documents encourage risk assessors to collect site specific data in determining risk estimates (USEPA 1989, 1998a, 1998b, 2001). The agency notes specifically that states should “use results from fish intake rates … that are likely to most closely represent the defined populations being addressed. Generally, the more specific the data are to the individuals who use the waterbody of interest, the better the data are considered to be for estimating accurate fish intake rates” (USEPA 1998b).

This manuscript presents a methodology for developing baseline-risk fish-ingestion estimates using site-specific data. The methodology involves linking current trip-taking and consumption to baseline trip-taking and consumption via behavioral modeling supported by survey research. The manuscript provides an empirical example of the methodology by developing baseline-risk fish-ingestion estimates in the Lower Passaic River Study Area (LPRSA)—a 17-mile stretch of urban and industrial river in northeastern New Jersey (see Figure 4.2). A critical part of implementing the methodology involved developing a Fish Consumption Simulation Model that characterizes the LPRSA angling population, fishing pressure at numerous LPRSA sites, and fish consumption rates under current and baseline conditions. The Fish Consumption Simulation Model combines data and results from a number of studies of Passaic River angling behavior: two site-specific creel angler surveys conducted on the Passaic River, one in 2000–2001 (Kinnell et al. 2007; Ray et al. 2007a; Ray et al. 2007b) and a second in 2011–2012 (Law 2011), and two population-specific studies, one in 2000 (Bingham et al. 2011) and a second in 2013 (Bingham et al. 2014).

The model’s structural foundation follows the public policy modeling approach described by Vining (1984) that “the real thing that is being reacted to and talked about,” in this case anglers’ trip-taking frequency, consumption behaviors, and corresponding consumption rates, “does in fact exist; it lies there in time and space ready to be depicted (page 13).” Specifically, the Fish Consumption Simulation Model combines information from each of these sources with the preference function developed from the fishing data collected during the 2000 and 2013 New Jersey Outdoor Recreation Survey (Bingham et al. 2014; Bingham et al. 2011). The preference function identifies how anglers trade off the varying characteristics of the relevant fishing sites they have to choose from when they decide where to go fishing. For example, when anglers take a trip, they have a choice of which site to visit. The sites that they can choose from have characteristics such as the distance from their home, the number of fish they expect to catch, facility amenities (e.g., presence of a boat launch), and waterbody characteristics and surroundings (e.g., presence of a fish-consumption advisory, level of industrialization, and crime rates). The preference function provides the ability to simulate how anglers' behaviors would change under the baseline risk conditions.

2. Background

In regulatory risk assessments conducted under CERCLA, risk estimates are generated for both Reasonable Maximum Exposure (RME) and Central Tendency Exposure (CTE) to quantify upper-bound and average risks, respectively. The RME is defined as the 90^{th} percentile or greater of the expected exposure and is intended to provide an estimate of the upper range of exposure in a population (USEPA 1992). As stated in the NCP (55 *FR* 8710), "The reasonable maximum exposure scenario is 'reasonable' because it is a product of factors, such as concentration and exposure frequency and duration, that are an appropriate mix of values that reflect averages and 95th percentile distributions."

One of the key variables for calculating exposure (and risk) via fish consumption in regulatory risk assessment is the rate at which the angling population consumes fish from the study area—described as the ingestion rate and measured in units of grams per day (GPD). The ingestion rate can be expressed as a distribution for specific populations such as all anglers (consumers and non-consumers) and consuming anglers only (and other subpopulations that may be identified—e.g., children, pregnant or nursing women, or women of child-bearing age). By developing distributions of the consumption rate, it is possible to identify the RME consumption rate by evaluating the 90^{th} percentile or greater consumption rates.

To fulfill the objective of the baseline risk assessment as described above, it is necessary to assess to what extent the site-specific, fish-consumption advisory may have altered baseline consumption, that is, the consumption that would occur but for the presence of the site-specific, fish-consumption advisory.

Critical quantitative inputs to calculating grams per day for anglers include trip frequencies and per-trip consumption behaviors. When combined, these inputs yield an estimate of the distribution of grams per day from which the 90^{th} percentile (and other percentiles, as well as the average) can be identified. While this process involves a number of steps, Figure 2.1 presents a high-level depiction of the analysis necessary to estimate grams per day based on existing data for a specific Study Area's fish consuming population.

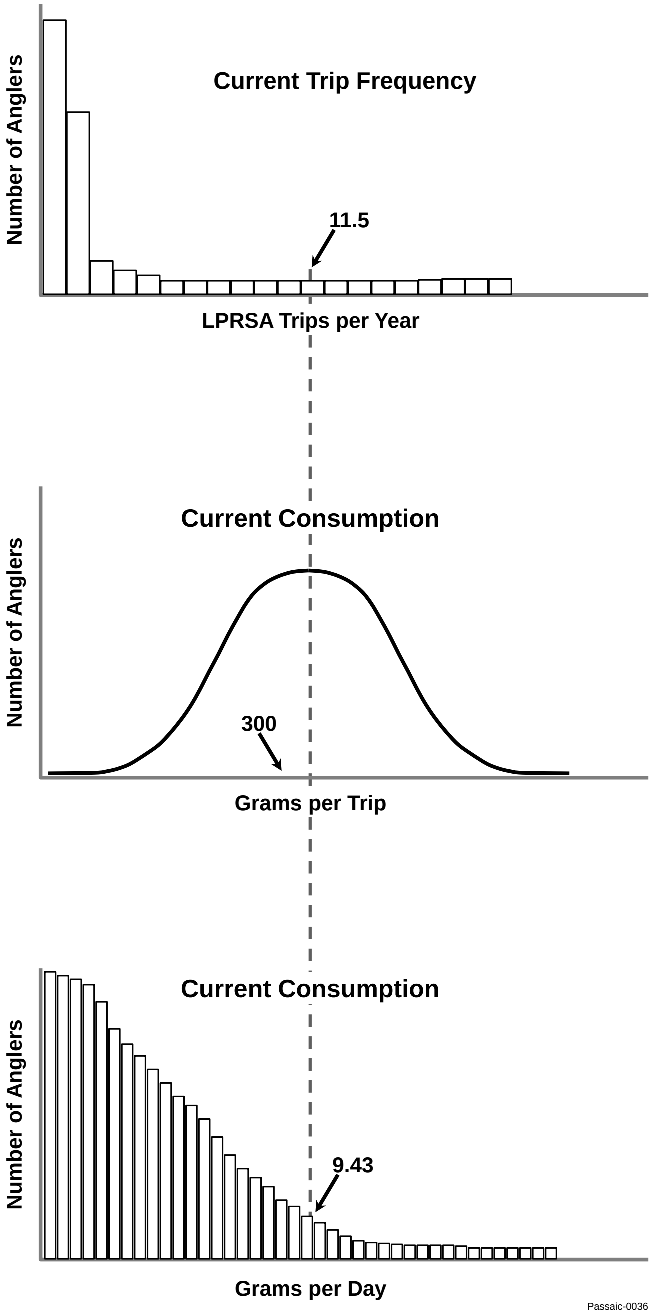

Figure 2.1: The 90th Percentile of Consuming Anglers' GPD under Current Conditions

As Figure 2.1 shows, the process consists of identifying the current consuming trip frequency distribution (top panel of Figure 2.1) and Current per-trip consumption (middle panel of Figure 2.1). These are combined to identify Current grams per day (bottom panel of Figure

2.1).[3] The estimates presented in Figure 2.1 (11.5, 300, and 9.43) are for illustrative purposes only in the examples presented throughout this section.

Using this foundation of the Current risk metric, the remainder of this section presents the implications of assessing the Baseline risk metric. In particular, how might consuming trips under Baseline conditions differ from consuming trips under Current conditions? An immediate consideration is that while Current behaviors can be identified entirely by an on-site survey, Baseline behaviors could also come from people who do not currently fish in the Study Area. Therefore, a means for assessing the total change in trips (and sensitivities to this total change) is needed. Also, changes in the 90th percentile risk metric depend upon behaviors of groups that might respond differently under Baseline conditions. For example, the difference between Current and Baseline behaviors and their effect on the 90th percentile of grams per day is likely to be different for those who currently fish the Study Area and those who do not. Therefore, the analysis needs to consider approaches that recognize the existence of subpopulations. The specific subpopulations identified for this analysis are:

- Type 1—Anglers that fish in the Study Area, eat self-caught fish, and eat Study Area fish
- Type 2—Anglers that fish in the Study Area, eat self-caught fish, but do not eat fish they catch from the Study Area
- Type 3—Anglers that fish in the Study Area but do not eat any self-caught fish
- Type 4—Anglers that do not fish in the Study Area but eat self-caught fish
- Type 5—Anglers that do not fish in the Study Area and do not eat self-caught fish
- Type 6—Individuals that do not currently fish.

2.1 Estimating Changes in Trips from Current to Baseline

To develop baseline consumption estimates, the analysis estimates the number of trips and consumption per trip that would likely occur without the site-specific fish consumption advisory in force, but with all other site conditions held constant. One way to understand potential changes in trips involves simulating a change to the current advisory condition within a mathematical model of angler site choice. If this is conducted within a perfectly specified, statistically estimated model, it is possible to accurately predict trips to the Study Area if there were not a site-specific, fish-consumption advisory in force. Simulating a change in advisory conditions to the Baseline conditions requires changing the advisory in a model of angler site

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[3] For simplicity in the exposition, the remaining examples present the implications for changes in the 90th percentile of baseline grams-per-day estimates for the consuming population. The analysis conducted for this manuscript also evaluated the implications for the entire angling population (consumers and non-consumers).

choice so that it matches the baseline-risk conditions of the Study Area: the Study Area's fish-consumption advisory is not in force, but all other site characteristics (e.g., access, level of urbanization and industrialization, and water quality) remain the same. The difference between trips predicted under Current conditions and those predicted under Baseline conditions would be the expected number of additional trips to the Study Area under Baseline conditions.

The next step that the analysis accounts for is the distribution of these trips across angler types. As the following subsections show, the Baseline 90th percentile for consuming anglers is more sensitive to differences in trip frequencies between Current and Baseline than it is to the total number of trips.

2.2 Distributing Trips over Angler Types

Different consuming behaviors by population subgroups underlie the ultimate risk metric. These subgroups' behaviors affect the risk metric differently and can be identified in different ways. This means it is important to identify these subgroups as well as methods of characterizing their behaviors and related risk-metric sensitivities. These groups are Angler Types 1–6 described above.

The trip frequency distributions, as well as the per-trip consumption estimates, can be characterized under current advisory conditions for the first three groups. That is, because Type 1, 2, and 3 Anglers fish in the Study Area, they can be interviewed on-site and their current risk can be assessed using traditional practices (i.e., as detailed in Law 2011; Kinnell et al. 2007, Ray et al. 2007a; Ray et al. 2007b). To estimate baseline risk under the "but for" advisory scenario, we must undertake the following:

1. Identify the angling frequency and consumption rates that would occur without the site-specific advisory conditions for each subgroup (Type 1–Type 6)
2. Compile the groups into a population
3. Identify the baseline risk level of consumption, the Reasonably Maximally Exposed (RME) individual's consumption rate (i.e., the 90th percentile or greater level of consumption measured in grams per day).

Of these steps, the first is the most challenging. A particular difficulty is that what the anglers of each type *would* do in the absence of the current, site-specific advisory condition cannot be observed. This means that directly estimating the Study Area's baseline risk level of consumption via observed behavior is not possible and a combination of other approaches and sensitivity analysis must be employed. The following diagrams and discussion detail the implications that different behaviors across each angler type have for the estimate of the risk metric. The next subsections present these as sensitivities in the baseline metric for three of the six angler types: Angler Types 1, 2, and 4 (Angler Types 3, 5, and 6 have similar characteristics as 1, 2, and 4 and are excluded for brevity).

2.2.1 Type 1 Anglers

Type 1 anglers are currently eating self-caught fish from the Study Area and, combined with non-eating anglers, comprise the population that creates the current 90th percentile consumption estimate for all anglers. Figure 2.2 depicts potential differences between Current and Baseline conditions for Type 1 anglers.

As the figure indicates, there are three important components to calculating current risk metrics. These three components are illustrated by each of the panels depicted in Figure 2.2's leftmost column. Beginning at the top, the process for calculating current risk metrics consists of calculating the

- Current trip frequency distribution
- Current per-trip consumption
- Current grams per day.

The center and right columns depict the process for calculating the Baseline risk metric of grams per day. Each column presents one of two different baseline cases to illustrate

1. the implications of differences between Baseline and Current behaviors
2. the potential errors (bias) that can occur in each step of the process of estimating the baseline risk metric.

As depicted in the first row of Figure 2.2, the first difference between Current and Baseline behaviors could occur in the trip frequency distribution. The center trip frequency diagram illustrates the case where high-frequency consuming anglers could take relatively more consuming trips. This is illustrated by the fact that the tail of the diagram is longer than that of the current trip frequency depicted in the left-most column. The far-right, trip-frequency diagram illustrates the case where low-frequency consuming anglers could take relatively more trips. This is illustrated by the lowering of the first two bars in the trip frequency diagram and increases in the subsequent bars.

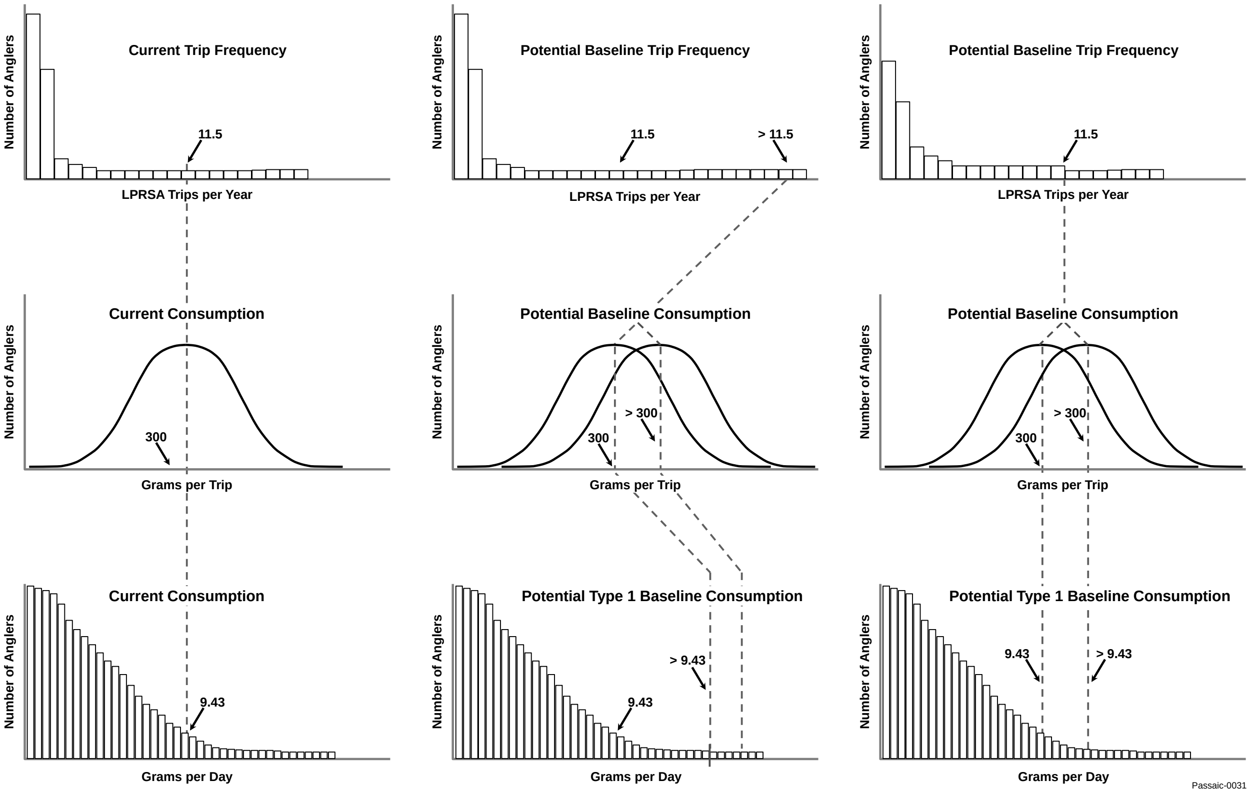

Figure 2.2: Current and Potential Baseline Annual Consumption for Type 1 Anglers

Of these two cases, the center column with high-frequency consuming anglers taking more trips leads to an increase in the 90th percentile of trip frequency for consuming anglers (identified by the >11.5 trips label). Other things being equal (i.e., per-trip-consumption practices), the increase in the trip frequency will lead to higher risk metrics. This is illustrated by tracing the dotted line from the >11.5 trips-per-year estimate through the 300 grams-per-trip estimate, which results in a 90th percentile baseline consumption estimate that is greater than the current, 9.43-grams-per-day example estimate.

The other case, illustrated by the third column in Figure 2.2, is when new trips by Type 1 anglers come from low frequency anglers. In this case, other things being equal (i.e., per-trip-consumption practices), risk metrics would remain the same because the 90th percentile of angling frequency has not changed from the current trip frequency. This is illustrated by tracing the dotted line from the 11.5 trips-per-year estimate through the 300 grams-per-trip estimate, which results in a 90th percentile baseline consumption estimate that is the same as the current, 9.43 grams-per-day estimate.

The middle row of Figure 2.2 provides a second important factor that influences the potential consumption estimate under Baseline conditions: per-trip, fish-consuming behavior. It is possible that Type 1 anglers could eat less, the same, or more fish per trip under Baseline conditions as they would under Current conditions. Here, for ease of exposition and as might be anticipated, we depict that Type 1 anglers would either eat the same amount or more under Baseline conditions. In the diagrams on the second row, the normal distribution in the left column represents current per-trip consumption for Type 1 anglers. In the second and third columns of the panel, the normal distributions to the left indicate the case where per-trip consumption does not change.[4] The distributions to the right indicate that per-trip consumption has increased (the median being greater than the example median's 300 grams per trip under Current conditions).

On the last row of Figure 2.2, Current angling frequency and consumption as well as Baseline possibilities are traced through to implications for annual estimates of grams per day. Beginning in the left column, the distribution of Current consumption in grams per day contains the risk metric (90th percentile or greater in grams per day) for Type 1 anglers under Current conditions (9.43 grams per day is an example 90th percentile estimate for consuming anglers under Current conditions).

In the center column, the 90th percentile of Baseline trip frequency is greater than 9.43 (illustrated by the 9.43 label) because the highest frequency Type 1 anglers increased their number of trips. Under this condition, consumption per trip can either stay the same or increases, but in either case the 90th percentile grams-per-day estimate will increase beyond the current 9.43 estimate. The implication is that the risk metric is always higher under Baseline than Current conditions for Type 1 anglers if anglers who already take many trips increase their number of trips.

The final diagram in the bottom, right-hand corner represents the case where low frequency Type 1 anglers increase their angling frequency. In this case, there is no change in the 90th percentile of trip frequency if their consumption behaviors remain the same. However, if they increase their consumption behaviors, the 90th percentile grams per day estimate increases over the current 9.43 grams-per-day estimate. The implication is that any increase in the grams-per-day risk metric occurs through changes in per-trip consumption.

2.2.2 Type 2 Anglers

Type 2 anglers eat self-caught fish and currently fish in the Study Area, but do not eat Study Area fish. Figure 2.3 depicts potential differences between Current and Baseline condition for Type 2 anglers.

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[4] This also holds for other consumption behaviors, such as what parts anglers eat.

An important difference between Type 1 and Type 2 anglers is that all anglers in the Type 2 group take zero fish-consuming trips to the Study Area under Current conditions. Looking at the leftmost set of figures in Figure 2.3, this is depicted as a high bar on zero in the fish-consuming trip-frequency histogram, which represents all anglers in this category. Continuing down the left side, there is no representation of consumption per trip, and all Type 2 anglers consume zero grams per day, which is the current risk metric for this group. As the upper middle panel indicates, without the consumption advisory, some of these anglers would take fish-consuming trips. An important characteristic of the potential outcome represented in this panel is that some of the Type 2 anglers who were not consuming fish from the Study Area under Current conditions are now taking more fish consuming trips than the 90th percentile of Type 1 anglers.

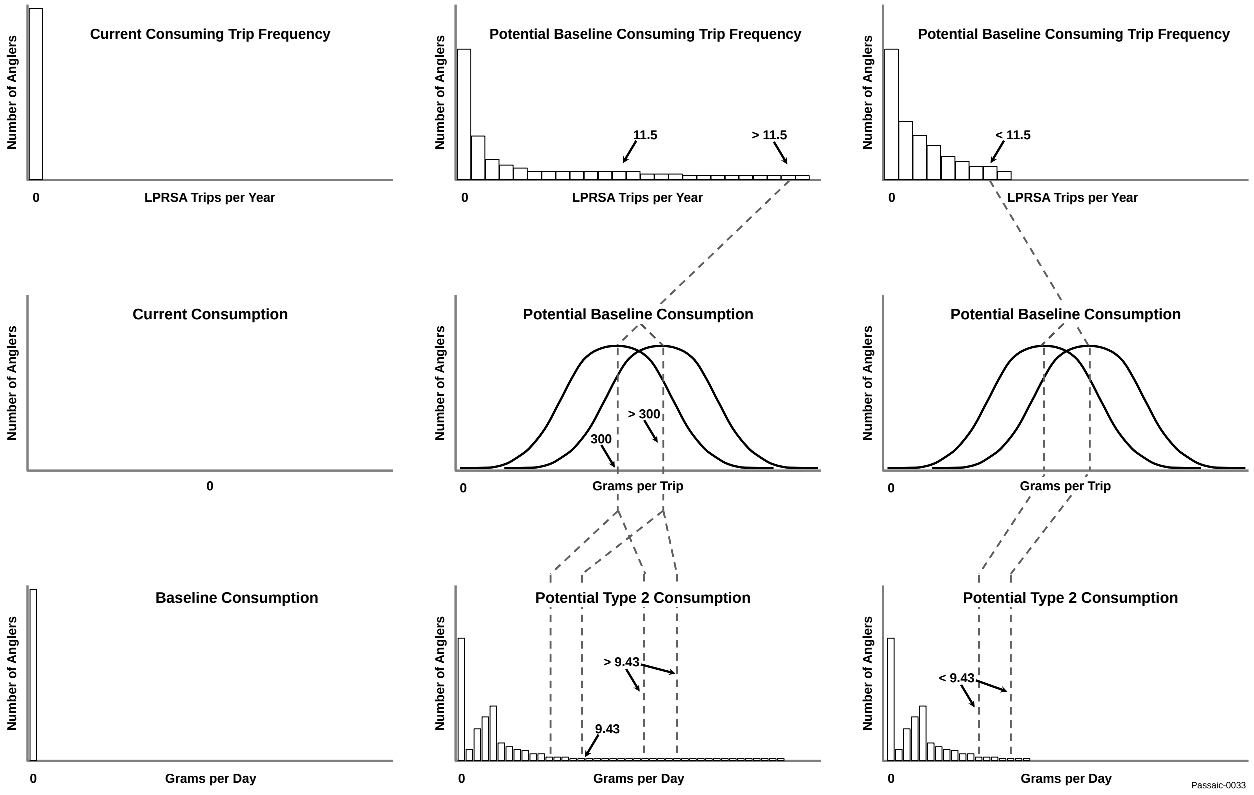

Figure 2.3: Current and Potential Baseline Annual Consumption for Type 2 Anglers

Following through to the second row, per trip consumption is again depicted as being either equal to or higher than per-trip consumption of currently consuming anglers (Type 1 anglers). The final row depicts that the risk metric for this group of anglers, previously 0, is now positive. There are some anglers consuming above the rate of the highest Type 1 consumers (they consume above the 90th percentile of Type 1 anglers). However, because not all of these anglers begin eating fish, the risk metric for this group remains below that for the Type 1 anglers. The final column depicts an outcome where none of the Type 2 anglers have a consuming trip frequency greater than Type 1 anglers. In this case, there is an increase in the risk metric for Type 2 anglers. However, increasing from the Current risk metric of Type 1 anglers requires that the now-consuming Type 2 anglers consume significantly more fish per trip than Type 1 anglers (not depicted).

2.2.3 Type 4 Anglers

Type 4 anglers currently do not fish in the LPRSA, but do eat self-caught fish. Figure 2.4 depicts potential differences between Current and Baseline condition for Type 4 anglers. Unlike the previous angler types, anglers in this group take no trips at all to the Study Area under Current conditions. Beginning with the leftmost column of Figure 2.4, this is represented as having no trips or consumption. Again the middle column represents the case where a change in consuming trips by this group of anglers has the potential to increase the Current 90th percentile risk metric. In this case, the added anglers take no trips with zero consumption. Some of these new anglers take a number of consuming trips that are above the 90th percentile of Type 1 anglers under Current conditions. Per-trip consumption is considered similarly as in the other cases, where it could either be identical to or higher than per-trip consumption of Type 1 anglers.

As in the other examples, this has the potential to increase the 90th percentile risk metric. The set of figures on the right represent an alternative outcome. In this case, some new anglers take non-consuming trips and other new anglers take consuming trips at a level lower than the 90th percentile of Type 1 anglers. Some of the anglers eat Study Area fish and others do not. As in the other cases, the result is that an increase in the risk metric (i.e., adding anglers who consume more than the current 90th percentile of Type 1 anglers) requires per-trip consumption rates higher than Current Type 1 anglers.

Because Type 4 anglers do not currently take trips to the Study Area, the potential behaviors of this group cannot be identified by an on-site survey. An appropriately specified site-choice model has the potential to identify changes in trips to the Study Area that would occur in the absence of an advisory. This would be accomplished by simulating trips to the Study Area where the site characteristic data would represent advisories under the Current Baseline conditions.

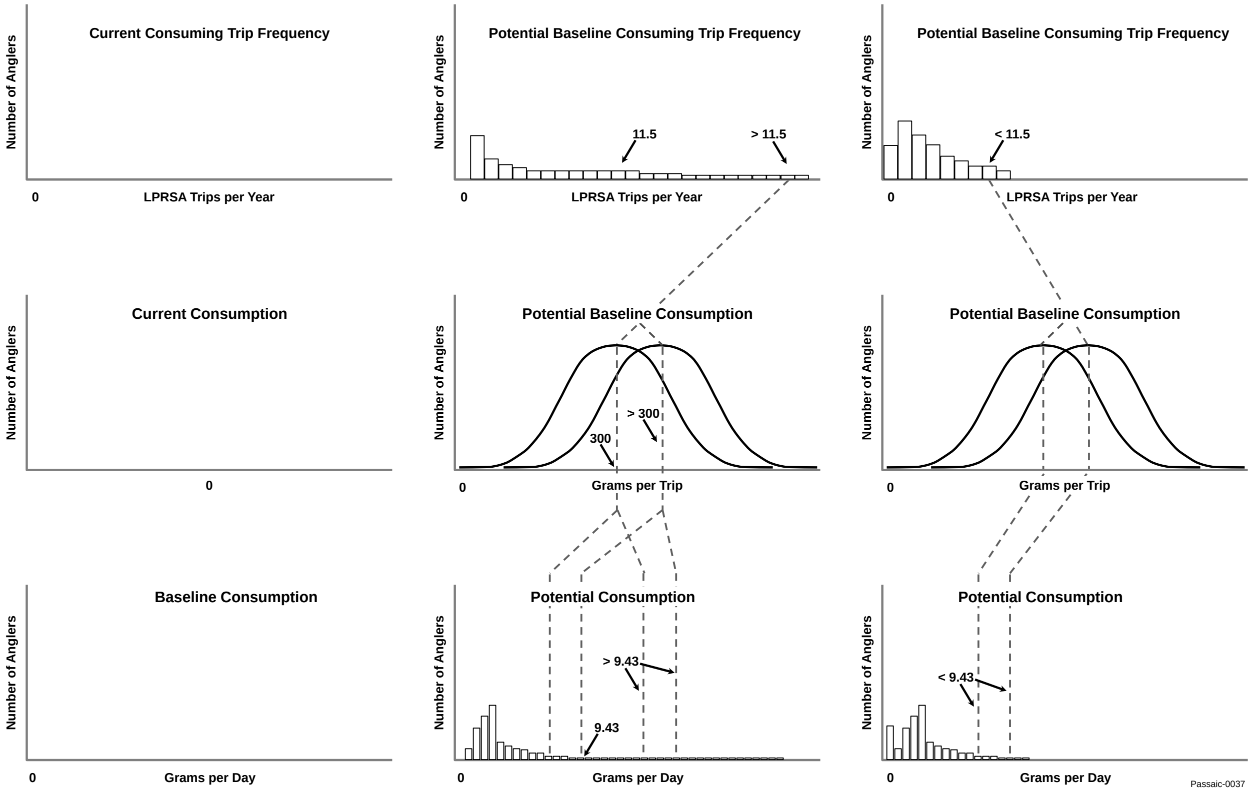

Figure 2.4: Current and Potential Baseline Annual Consumption for Type 4 Anglers

2.3 Implications for Baseline Risk Metric

This evaluation of potential behaviors by angler types under Baseline conditions reveals several interesting implications. An important conclusion is that differences in consuming trip frequencies between Current and Baseline conditions is likely to drive results more than the total number of trips. However, the change in the total number of trips is important in that it weights the difference between the trip frequencies under Current conditions and those under Baseline conditions. An important outcome is that when consuming anglers are the relevant population, it is possible for the *regulatory* risk metric (i.e., grams per day for 90th percentile of consuming anglers) to *decrease* under Baseline conditions. This would occur whenever new Study Area anglers consume at a rate that is less than the current Study Area anglers and would be magnified by large trip changes. For example, with 100 anglers, consumption of the top 10 defines the 90th percentile. The addition of 100 new anglers would take the population to 200 and consumers at and above the 90th percentile would be the top 20 consumers. If the new consumers consume less than the previous top ten, the 90th percentile will be lower. Another possibility is that the risk metric would remain relatively unchanged. This could occur if new anglers consume at the same rate as existing anglers. It could also occur if existing anglers consumed more, but the additional consumption was driven by people who are below the 90th percentile under Current conditions.

With respect to bias, the implication is that not including new Study Area anglers (Types 4, 5, and 6) who would be low level (under 90th percentile) consumers in the analysis will lead to an overestimate of the 90th percentile under Baseline conditions. Not including these anglers if they would be predominantly high-level consumers (i.e., more than 10 percent of them would eat more than the top 10 percent under Current conditions) would lead to an underestimate of the 90th percentile risk metric. The implications for current low-level consumers (including non-consumers) who visit the Study Area (i.e., non-consuming Types 2 and 3 and low-level consumers of Type 1) is that ignoring their behaviors under Baseline conditions will not bias results, unless they would increase their consumption beyond that of the highest levels of Type 1 consuming anglers *under Baseline conditions*. The most potential for underestimating increases in the 90th percentile of consuming anglers under Baseline conditions comes about from underestimating changes in consumption from those who form the 90th percentile under Current conditions.

3. Methods and Data

The goal of the methodology is to combine all of the existing angling information in a manner that most accurately predicts the angling and consumption patterns of the population of anglers taking trips to a specific Study Area and allows for simulations of how the behaviors of Study Area anglers would change under baseline risk conditions. To illustrate the model's application, the manuscript uses data collected from a number of studies conducted on the Lower Passaic River Study Area (LPRSA), a 17-mile stretch of river that flows through northeastern New Jersey (see Figure 4.2).

The methodology integrates information on recreational angling behavior derived from household samples of the population (Bingham et al, 2014; Bingham et al. 2011) with information on recreational angling and consumption from on-site surveys (Law 2011 and Kinnell et al. 2007). The integration of these data in the behavioral simulation framework is based on the public policy modeling approach described by Vining (1984). It also incorporates statistical methodologies of hybrid samples as detailed by McFadden (1997), Manski and McFadden (1981), and Manski and Lerman (1977). Specifically, these papers provide insight into the mathematical properties and statistical applications of combining these different data sources to create a representative sample of a population's choice decisions. In addition, the methodology builds on the work of Bingham et al. (2011), Jakus and Shaw (2003), and Mathews, Gribben, and Desvousges (2002), who have laid the foundation for applying preference functions from random utility maximization (RUM) models, to estimate frequency, and ultimately consumption (see Mathews, Gribben, and Desvousges [2002] for a full treatment of the relationship between RUMs and risk assessment).

The methodology combines the preference function presented in Bingham et al., 2014 with information from the 2000–2001 and 2011–2012 creel/angler surveys conducted on the LPRSA (Kinnell et al. 2007 and Law 2011) and the 2013 and 2000 New Jersey Outdoor Recreation Surveys (see Kinnell et al. 2007; Ray et al. 2007a; and Ray et al. 2007b for a complete description of the 2000–2001 Passaic River Creel/Angler Survey; Bingham et al. 2014 for a complete description of the 2013 New Jersey Outdoor Recreation Survey (NJORS); Bingham et al. 2011 and Kinnell et al. 2006 for a complete description of the 2000 New Jersey Outdoor Recreation Survey). Specifically, the methodology combines the preference function with the site characteristics (e.g., distance from the angler's home to the site, catch rate, advisory index, crime rate) compiled for all the LPRSA and relevant substitute sites and the size, characteristics, and demographics of the angling population to predict how many trips anglers take to the LPRSA and relevant substitute sites under current and baseline risk conditions. Populating the methodology with this data produces a Fish Consumption Simulation Model for the LPRSA. The Fish Consumption Simulation Model also combines this predicted LPRSA trip information with the current catch and consumption information from the creel/angler surveys (e.g., likelihood of keeping caught fish; number, type, and size of species kept; and parts consumed) and baseline catch and consumption information from the 2013 NJORS to predict how many of what types of fish anglers keep and consume from the LPRSA under current and baseline-risk conditions. The simulation model combines all of these parameters to develop predicted estimates of how many grams of self-caught fish anglers consume within a year under current and baseline risk conditions. The following list summarizes the specific parameters in the Fish Consumption Simulation Model estimates:

- The size of the angler population taking trips to the LPRSA under current and baseline risk conditions
- The number and frequency of trips taken to the LPRSA under current and baseline risk conditions
- The likelihood of keeping fish from the LPRSA and the corresponding sizes of the catch-and-release and catch-and-keep populations
- The number of fish kept per trip by species and size under current and baseline risk conditions
- The parts consumed
- The number of grams consumed per day under current and baseline risk conditions.

Consumption quantities of interest (i.e., average grams per day) under current and baseline conditions for Miles 0–17, Miles 0–8, and Miles 8–17 of the LPRSA arise from the Fish Consumption Simulation Model's data generating process that can be generalized as the following:

$$C_{ijk} = f\,(Trips_{ijt}, X_{ijt}, Catch_{ijk}) \qquad \textbf{(3.1)}$$

where:

C_{ijk} represents the consumption of fish k by angler i from site j. It is a function of each of the following:

- $Trips$, t, by angler i to site j
- Site characteristics X (this includes characteristics that influence the eating decision independent of the site-choice decision, such as presence of an advisory)
- $Catch$ (this is estimated or taken from the RUM as the expected catch variable).

Figure 3.1 summarizes the steps used to develop the Fish Consumption Simulation Model and to estimate C_{ijk} under current and baseline conditions.

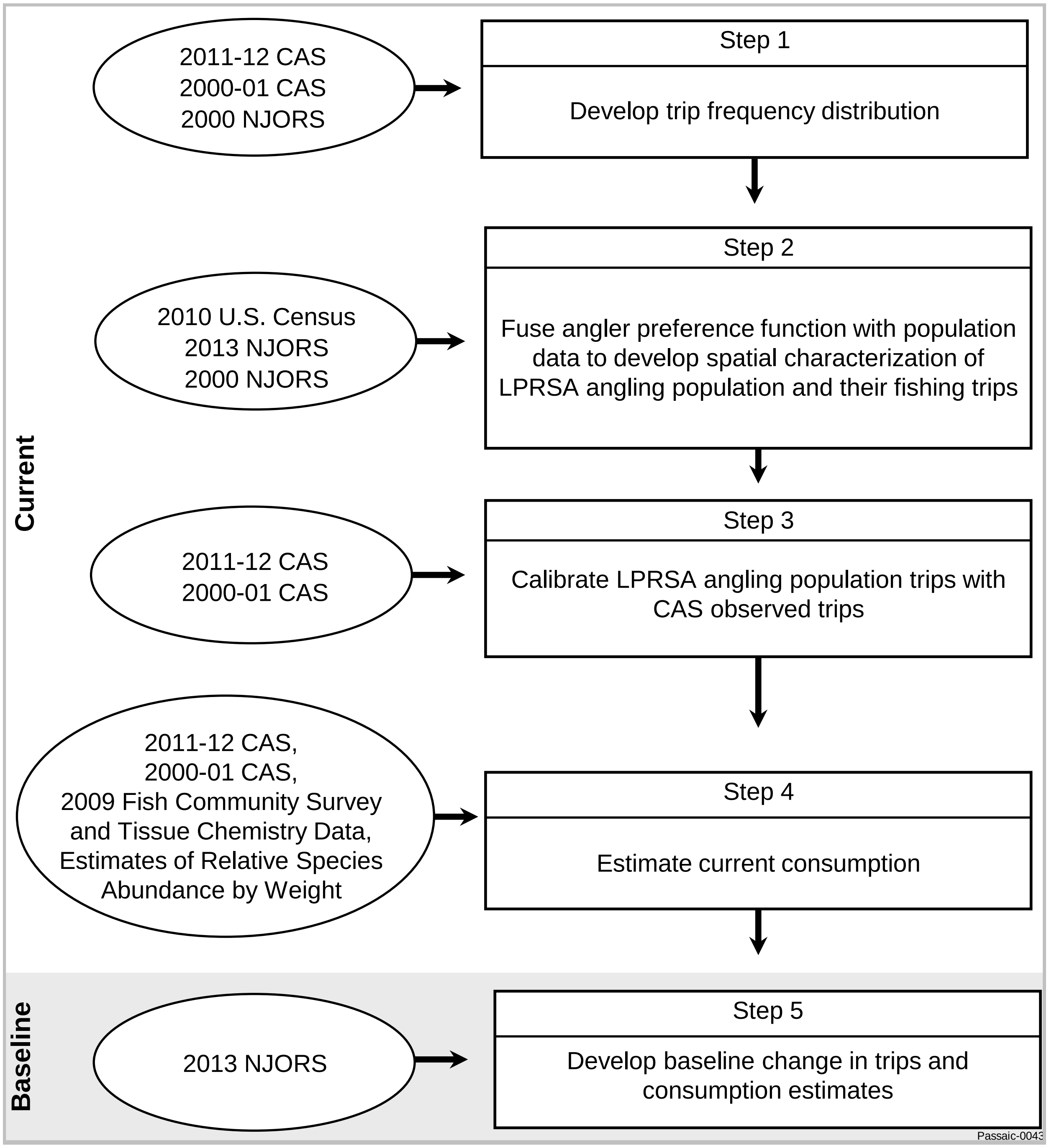

Figure 3.1: Steps Used in Developing Current and Baseline Fish-Consumption Estimates

3.1 Step 1: Develop the Current Trip Frequency Distribution

The first step in the modeling is to develop the trip frequency distribution for the entire Study Area. The circles on the left side of Figure 3.1 show the data that the model uses for each step. In this first step, the model uses the observed trip-taking frequencies from the 2000–01 and 2011–12 LPRSA creel/angler surveys and the relative trip-frequency distribution from the 2013 and 2000 New Jersey Outdoor Recreation Surveys to develop annual trip-frequency estimates for the 17-mile LPRSA. The analysis also separates these trip frequencies across two distinct geographies within the 17-mile Study Area: Miles 0–8 and Miles 8–17. The separation is based on the observed trip-taking rates to sites in Miles 1–7 during the 2000–2001 CAS and Miles 0–8 and Miles 8–17 in the 2011–2012 CAS. The separation allows the model to conduct scenario analysis on differences in trip-taking behavior, and ultimately consumption, across the two sections of the river.

In addition, the trip frequencies are further separated by consuming and non-consuming anglers. This separation allows for further scenario analysis of ingestion rates calculated across different populations: the entire LPRSA angling population and the LPRSA fish-consuming population.

Figures 3.2 and 3.3 provide the combined Miles 0–8 and Miles 8–17 (Miles 0–17) trip frequency distribution for consumers and non-consumers (the individual trip frequencies for each subpopulation [consuming and non-consuming] and geography [Miles 0–8 and Miles 8–17] are excluded for brevity). The mean trips per year for consuming anglers in Figure 3.2 is 1.7, with a maximum trips per year of 16. The mean trips per year for non-consumers in Figure 3.3 is 2.1, with a maximum trips per year of 37.

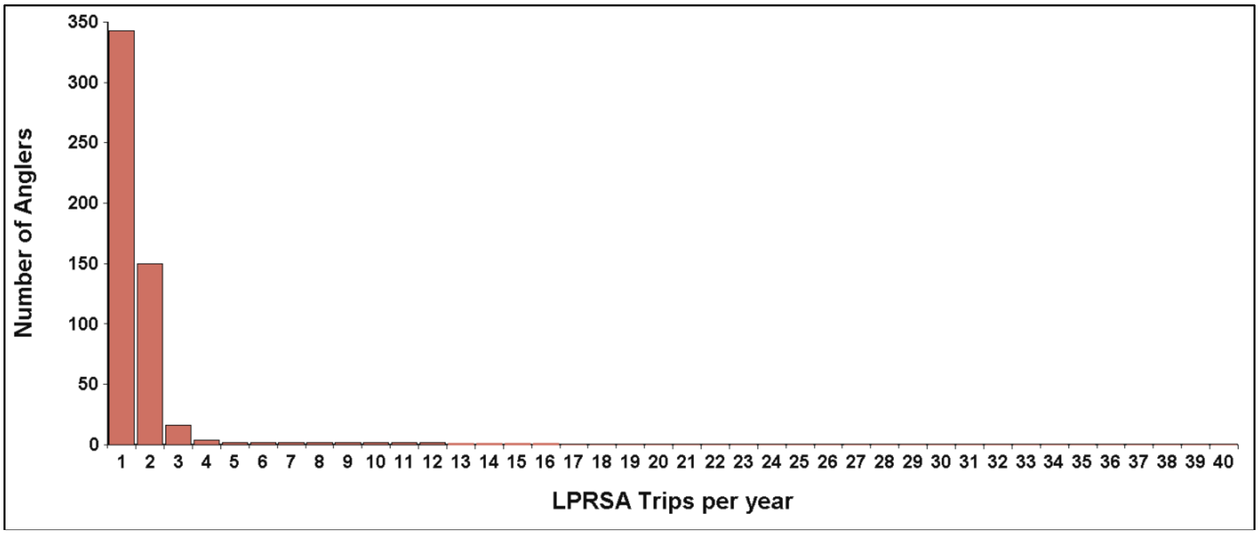

Figure 3.2: Current Trip Frequency Distribution for Consuming Anglers, Miles 0–17

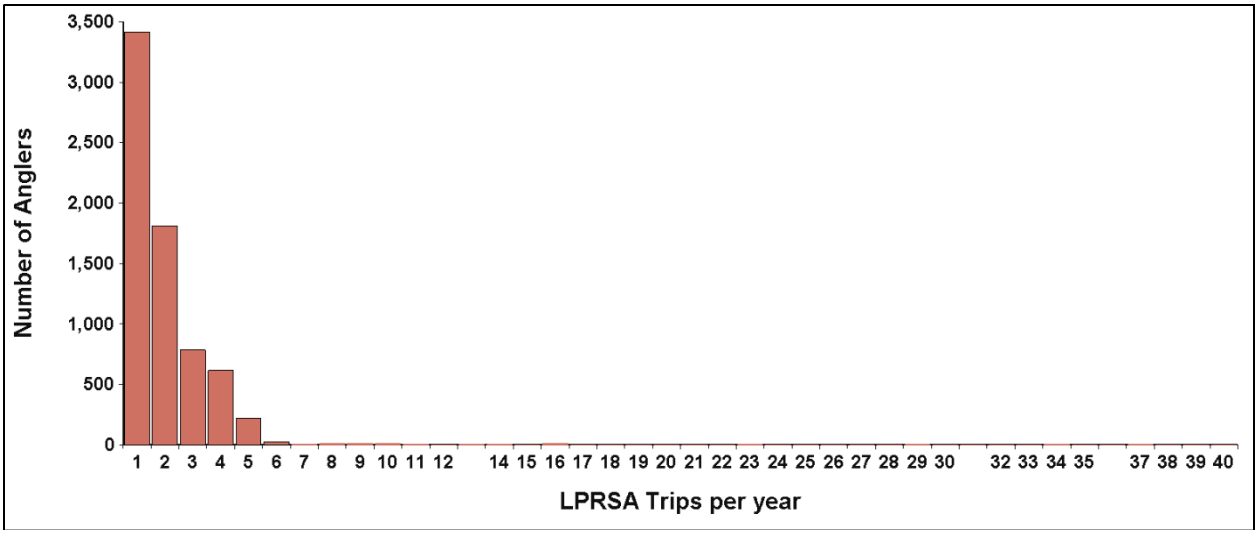

Figure 3.3: Current Trip Frequency Distribution for Non-Consuming Anglers, Miles 0–17

3.2 Step 2: Fuse Angler Preference Function with Population Data to Develop Spatial Characterization of LPRSA Angling Population and Their Fishing Trips

In this step, ZIP-Code-level population data from the five counties surrounding the Lower Passaic River Study Area is fused with a preference function estimated for anglers in the five counties (Bergen, Hudson, Essex, Passaic,.\ and Union Counties, herein referred to as the Five County Area). The preference function is estimated from the 2013 and 2000 New Jersey Outdoor Recreation Surveys and identifies how anglers trade off the characteristics of the fishing sites from which they have to choose when they decide where to go fishing.[5] For example, when anglers take a trip, they have a choice of which site to visit. The sites from which they can choose have numerous characteristics, such as the distance from their home, the number of fish they expect to catch, facility amenities (e.g., presence of a boat launch), and waterbody characteristics and surroundings (e.g., presence of a fish-consumption advisory, level of industrialization, and crime rates). Bingham et al. (2014) estimates the preference function for Five County Area anglers using random utility maximization (RUM) modeling.

RUM models measure anglers' preferences for different fishing sites in terms of the utility or satisfaction that an angler derives from fishing. RUM models are based on economic welfare theory and measure angler satisfaction or utility (V_{ij}) as:

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[5] See Bingham et al. (2014) for a detailed discussion on the 2013 New Jersey Outdoor Recreation Survey and the estimation of the angler preference function used in this analysis; see Bingham et al. (2011) and Kinnell et al. (2006) for a detailed discussion of the 2000 New Jersey Outdoor Recreation Survey

$$V_{ij} = X_{ij}\beta + \varepsilon_{ij} \tag{3.2}$$

where:

i = individual angler
j = fishing site
X = matrix of site characteristics
β = vector of the estimated coefficients for X
ε = random error term

Thus, RUM models measure the preference for a specific site as a function of the site characteristics of the fishing site. The characteristics of each fishing site, such as fish catch rate, the presence of a fish-consumption advisory, and distance to the site from the angler's home, distinguish one site from another. The RUM model uses anglers' actual fishing site choices to model the factors that influence fishing-site selection. By compiling information from anglers on all the fishing sites they visit for each trip and the characteristics of those sites, a RUM model explains the relative importance of different site characteristics on the anglers' site-choice decisions (e.g., the effect that the presence of a fish-consumption advisory has on the likelihood that an individual will visit the site). In addition, because the RUM model evaluates anglers' fishing decisions as a function of site characteristics, it provides the ability to simulate what anglers' behaviors would most likely be under different states of the world, such as the baseline risk conditions where all site conditions remain the same except that the site-specific, Do Not Eat fish consumption advisory on the LPRSA is not in force (see Bingham et al. 2014 for the results of these simulations on trip-taking predictions).

The data on anglers' fishing trips used to estimate RUM models are typically collected from surveys of the relevant angling population. Survey models employ demographic information to weight sample results such that they represent the population the frame is drawn from. Generally speaking, weights are developed for strata. In urban environments such as the Five County Area, demographics can vary significantly over small areas. Although demographic information is available at small scales (ZIP Code), survey costs preclude stratifying at this level. Thus, ZIP Code-specific weights are unavailable because not all ZIP Codes are sampled and few of them are sampled at a high enough rate to support weighting. However, as the results of the 2000–01 CAS and 1995 and 1999 NBC Surveys show, consumption is related to demographics (Kinnell et al. 2007; Ray et al. 2007a, 2007b; Burger 2002; Pflugh et al. 1999; Burger et al. 1999). Therefore, to allow incorporation of location-specific demographic influences, Step 2 fuses the preference function estimated from the 2013 and 2000 New Jersey Outdoor Recreation Surveys with U.S. Census information at the ZIP-Code level.

In order to fuse the angler preference function with U.S. Census data, demographic data on the population for every ZIP Code in the Five County Area are collected and compiled from the 2010 U.S. Census. There are 168 ZIP Codes with population data partially or fully contained in the Five County Area. Demographic data used in the analysis include the interaction between gender and race. Table 3.1 presents the aggregate demographic breakdown of the 168 ZIP Codes in the Five County Area.

Table 3.1
Demographic Breakdown of Five County Area

Demographic Category	Number of Residents	Percent of Total Population
Hispanic male	456,103	13%
Hispanic female	461,287	14%
White male	742,252	22%
White female	779,329	23%
Black male	274,315	8%
Black female	324,092	9%
Asian male	146,087	4%
Asian female	155,591	5%
Other race male	35,228	1%
Other race female	37,412	1%
Total	**3,411,696**	

Not all of the Five County Area's 3.4 million population fishes. Therefore, to develop the estimate of fishing trips that the Five County Area's angling population takes to the LPRSA, the model includes angling participation rates by each demographic profile listed in Table 3.1. The angling participation rate is created using the demographic profile of the On-Site observations from the creel/angler surveys.

3.3 Step 3: Calibrate LPRSA angling population trips with CAS observed trips

In Step 3, the demographic profiles and predicted trips to each LPRSA site estimated in Step 2 are calibrated with the angler population's demographics and annual trips estimated to each site from the 2011–2012 and 2000–2001 creel/angler surveys. Trip calibration variables are developed to calibrate trips to the LPRSA in total, to sites in Miles 0–8, and to sites in Miles 8–17. The trip calibration variables are designed to adjust the visitation rates by demographic profile of the predicted anglers using the 2010 Census demographics of the population, so that the demographic profile of the anglers predicted at each site matches the demographic profile observed from creel/angler surveys.

3.4 Step 4: Estimate Current Consumption

In the fourth step, data on specific parameters are combined to estimate how much fish LPRSA anglers consume under current conditions. Figure 3.4 presents an overview of this process and identifies each of the parameters that are developed under both current (white boxes) and baseline conditions (gray boxes). As the top, left side of Figure 3.4 shows, data from the 2000–2001 and 2011–2012 creel/angler surveys are used to develop a statistical model that predicts the relationship between demographics and the number of fish an individual angler is predicted to keep on each LPRSA fishing trip. In addition, data from the 2013 New Jersey Outdoor Recreation Survey are used to predict the relationship between demographics and whether the angler consumes LPRSA fish or not. The analysis then combines these two parameters to develop predicted estimates of the number of fish kept per trip by fish consuming anglers. The total number of fish kept per trip is then combined with information from the two creel/angler surveys on the composition of kept catch by species to predict the number of each species that consuming anglers keep on each LPRSA trip.

To develop the predicted amount of fish consumed per day, the analysis first estimates the weight of each kept species. To develop the weight estimates, the analysis combines length-to-weight estimates from the 2000–2001 creel/angler survey data with the weight of observed species from the LPRSA Fish Community Survey (Windward 2010) and from fish and crab tissue chemistry data (Windward 2011). The information is combined to develop estimates of the LPRSA's species abundance by size. The analysis combines this information with data on the edible portion estimates of each species from Ray et al. (2007b) to develop estimates of the edible weight of each species. The analysis then uses data on the parts anglers report that they consume of each species from the creel/angler surveys with data on the size of each part consumed from Ray et al. (2007b). This estimates the amount consumed by species type. The analysis combines the amount consumed across all species to develop the predicted estimate of grams consumed per trip by demographic group under current conditions. The grams per trip are then combined with the number of predicted trips by demographic group to develop the total grams consumed per year. To calculate grams per day, the annual estimates are summed across demographic groups and divided by 365. The following subsections provide additional detail on the steps for linking demographics to the number of fish kept per trip and developing the size of fish kept.

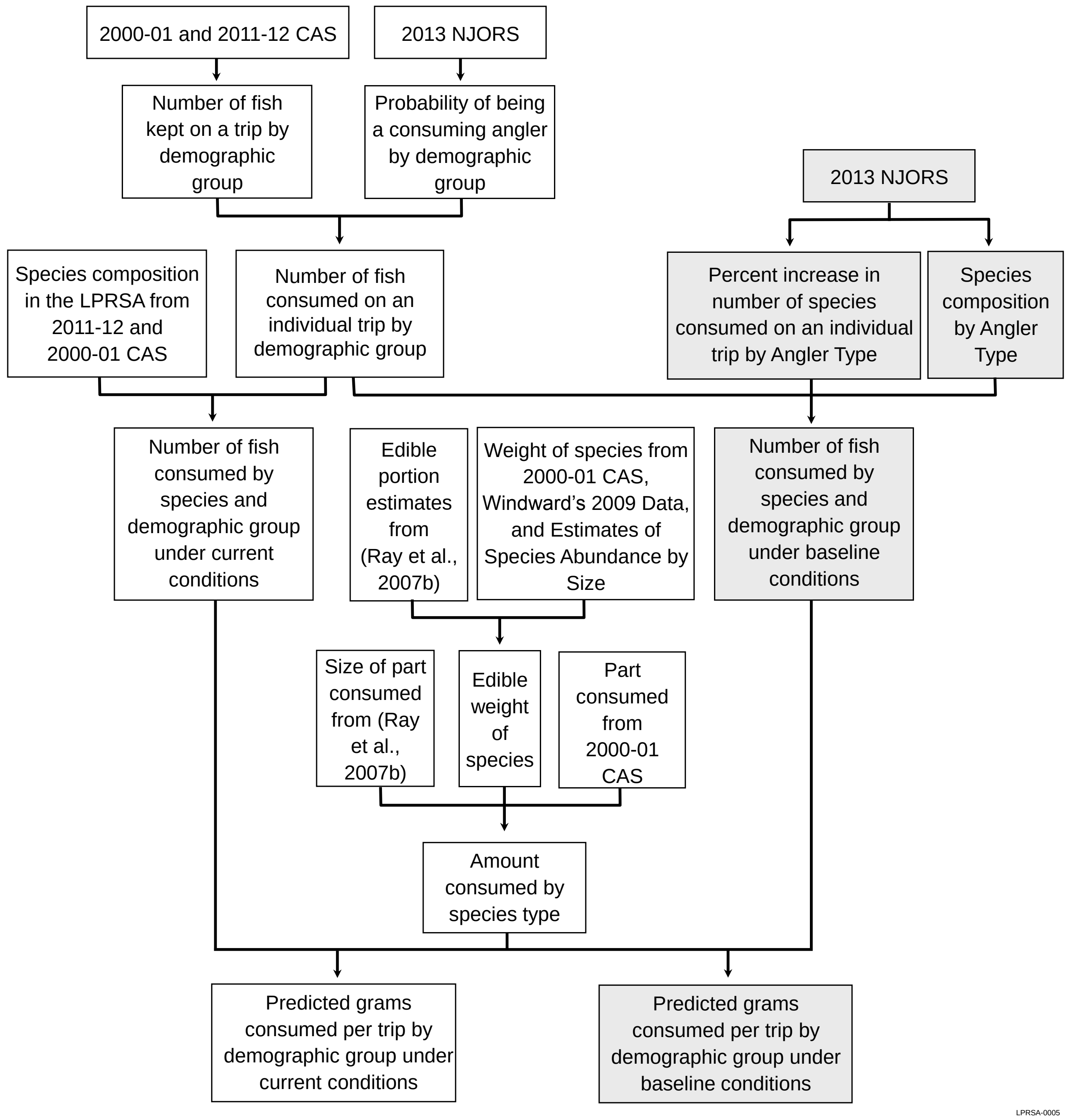


Figure 3.4: Developing Estimates of Grams/Trip

3.4.1 Step 4.1: Link Consumption to Demographics

In this step a statistical model is estimated using the 2000–2001 and 2011–2012 CAS data to examine the relationship between demographics and kept catch. Equation 3.3 presents the statistical model and Table 3.2 presents the results.

$$FK_i = \beta_0 + \beta_1 M_i + \beta_2 B_i + \beta_3 H_i + \beta_4 A_i + \varepsilon_i \qquad \textbf{(3.3)}$$

where:

FK_i = number of fish kept on trip i
B_0 = constant
M_i = angler on trip i is male
B_i = angler on trip i is black
H_i = angler on trip i is Hispanic
A_i = age of angler on trip i
ε_{ip} = error term on trip i

Table 3.2
Model Results for Number of Fish Kept

Variable Name	Coefficient ($ß_n$)	t-Statistic
Constant	-1.29***	-2.79
Male	-0.78***	-3.63
Black	2.73***	7.96
Hispanic	1.68***	4.35
Age	0.01**	2.33

** Significant at 5% N = 78
*** Significant at 1%

As the results show, black anglers kept more fish per trip than Hispanic anglers, and both black and Hispanic anglers kept more fish on average than white anglers (the omitted category in the model). Female anglers kept more fish on average than male anglers, and older anglers kept more fish than younger anglers.

3.4.2 Step 4.2: Develop Relative Abundance by Weight for Each Kept Species

The species and abundance data from the 2009 Fish Community Survey of the LPRSA conducted by Windward were incorporated into the model because of potential differences in the type, size, and abundance between the lower and upper study area segments. By incorporating Windward's 2009 FCS and 2009 Tissue Chemistry Data, wherein data on the type, number, and size of the species present in the LPRSA were collected, uncertainty surrounding the weight of the species kept and consumed was introduced into the model. Relative to the size of the fish kept by anglers interviewed during the 2000–2001 CAS, the weight of the fish caught in the upper ten miles during the 2009 FCS and presented in the 2009 Tissue Chemistry Tissue Data includes much larger specimens. The maximum species' weights from the 2009 FCS and 2009 Tissue Chemistry Data were included in the weight distribution used in the model, accounting for much larger fish caught and, accordingly, more grams to be consumed. The following subsections provide details about incorporating the 2009 FCS and 2009 Tissue Chemistry Data weights of species present in the LPRSA, kept fish from the 2000–2001 CAS, and relative abundance and weights of kept species from the Electric Power Research Institute (EPRI) (2012).

The fish consumption data from the 2000–2001 Passaic River Creel/Angler Survey contain the size of the species that the anglers kept from the river. The analysis converts this length data into weights following the methods presented in Ray et al. (2007a and 2007b). The analysis also incorporates size data from Windward's 2010 report *Fish and Decapod Field Report for the Late Summer/Early Fall 2009—Draft* (Windward 2010) and Windward's 2011 report *2009 Fish and Blue Crab Chemistry Data for the Lower Passaic River Study Area* (Windward 2011). Windward (2010) and Windward (2011) present the weights of species caught from the River using electrofishing and netting techniques. These three datasets are used to develop the weights of the species kept from the LPRSA.

For carp, catfish, and striped bass, the mean and maximum weights from the 2000–2001 CAS are smaller than those in the Windward (2010, 2011) data. Therefore, to incorporate the weights from both data sets in a manner that most accurately matches both the relative species abundance in the LPRSA stocks available to anglers and anglers targeting and success rates by species, the analysis includes the relative fish-species abundance by weight to represent the size of each species that anglers are most likely to catch from the LPRSA.

These estimates are developed by creating age-structured transition (i.e., Leslie) matrices (Leslie 1945, 1948; Caswell 2001) that characterize the stocks of each of the species that had different mean and maximum values between the 2000–2001 CAS and Windward (2010, 2011) data: white perch, catfish, carp, and striped bass (the other kept species from the LPRSA—American eel and blue crab—had similar means and maximums in both the 2000–2001 CAS and Windward [2010, 2011] data). The Leslie matrix model is frequently used in fisheries management. Equation 3.4 presents its mathematical representation:

$$\underbrace{\begin{pmatrix} N_{1,t+1} \\ N_{2,t+1} \\ N_{3,t+1} \\ \vdots \\ N_{A,t+1} \end{pmatrix}}_{\substack{\textbf{Estimated} \\ \textbf{Population at} \\ \textbf{Time t + 1}}} = \underbrace{\left(\begin{array}{cccc} \multicolumn{4}{c}{\overbrace{\hphantom{S_0 f_1 \quad S_0 f_2 \quad \cdots \quad S_0 f_A}}^{\textbf{Fecundity}}} \\ S_0 f_1 & S_0 f_2 & \cdots & S_0 f_A \\ S_1 & 0 & \cdots & 0 \\ 0 & S_2 & 0\ldots & 0 \\ \vdots & 0 & \vdots & \vdots \\ 0 & \cdots & S_{A-1} & 0 \end{array}\right)}_{\textbf{Transition Matrix}} \underbrace{\begin{pmatrix} N_{1,t} \\ N_{2,t} \\ N_{3,t} \\ \vdots \\ N_{A,t} \end{pmatrix}}_{\substack{\textbf{Initial} \\ \textbf{Population at} \\ \textbf{Time t}}} \tag{3.4}$$

This representation consists of a stock vector and a transition matrix. $N_1 \ldots N_A$ is the stock vector (on the far right of Equation 3.4). The stock vector represents the age-structured population of a single stock at time t with $N_{1,t}$ being the number of Age 1's in the stock at time t, $N_{2,t}$ the number of Age 2's, and so forth through all the ages. Survival rates (S) in the transition matrix represent the probabilities that a fish in a population will survive to the next life stage. Fecundity f_ns is the number of eggs laid annually by each female of a particular age-class.

The approach relies on steady state characterizations of the affected stocks. Initial survival and fecundity estimates used for populating the Leslie Matrix were obtained from a recent EPRI fish life-history reference document (EPRI 2012). Population growth and regulation were modeled using an uncertainty-based procedure similar to Perry et al. (2003). Under this approach, fixed carrying capacities are defined for each catchable age class. In Perry et al. (2003) these constraints are identified from measured age-specific population maximums observed over a period of time in biological samples and applied across all life stages. In this study they are specified as double the steady-state mean. When fishable age-specific population levels exceed the carrying capacities, they are reset to twice the mean. This uncertainty represents environmental variability. It is introduced by varying the age-specific fecundity and survival estimates. The uncertainty in survival parameters is depicted in Table 3.3.

Table 3.3
Stock Dynamic Uncertainty Representation

Category	Distribution	Mean	Uncertainty
Fecundity	Poisson	EPRI (2012)	Function of mean
Survival (all but juvenile)	Beta	EPRI (2012)	COV = 10 percent or 25 percent of mean
Juvenile	Bernoulli	EPRI (2012)	p = 0.2 of usual survival x 10

In this table, EPRI (2012) under "Mean" indicates that all average survival rates were taken from this document. EPRI (2012) did not evaluate variances. Following Perry et al. (2003) for fecundity, a Poisson distribution is employed around eggs laid per female. For the Poisson distribution, variance is calculated as a function of the mean, and thus none is specified. Beta distributions are functions of scale parameters (alpha and beta). These alpha and beta are specified such that the coefficient of variation is 10 percent of the mean when mean survival is outside the interval of 0.10 to 0.90. It is 25 percent of the mean when the mean is inside this interval. Juvenile survival is specified as a Bernoulli distribution. As indicated under the uncertainty column, one-fifth of the time juvenile survival is ten times higher than it is the other four-fifths of the time.

The model is then tuned to stability by adjusting the juvenile survival rate upwards until no change in the average abundance of the population occurs over a 50-year simulation period. This approach was used to develop steady state age-structured stock representations of all modeled species that are consistent with survival rates and weight at age information from EPRI (2012). The results of these stock-assessment models provide the relative abundance by weight for each individual species. The LPRSA Fish Consumption Simulation Model uses these relative abundance-by-weight estimates for the size of fish that an angler is likely to catch and keep on an individual trip to the LPRSA. The following example presents the relative abundance estimates for white perch (the other species included in the model are excluded in this example for brevity).

White Perch Relative Abundance

Figure 3.5 presents the relative abundance of age groups in the white perch stock population. As Figure 3.5 illustrates, the age-structured stock population of white perch is 46 percent Age 1+, 25 percent Age 2+, 14 percent Age 3+, 7 percent Age 4+, and the remaining 8 percent is Ages 5+ through Age 10+.

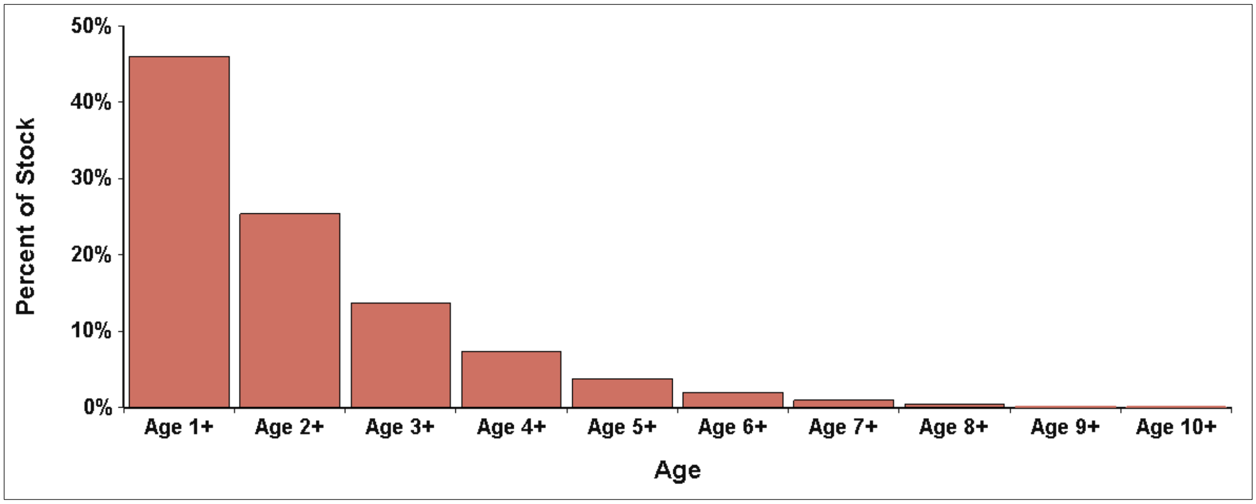


Figure 3.5: White Perch Relative Abundance

Figure 3.6 provides the weight of each age group from EPRI (2012). The weight ranges from less than 100 grams to slightly less than 700 grams. Specifying that anglers catch and keep in the same manner as the stock population, the mean and maximum of white perch is

31.43 grams and 281 grams. Both the mean and the maximum are lower than the white perch anglers from the 2000–2001 CAS were observed keeping.

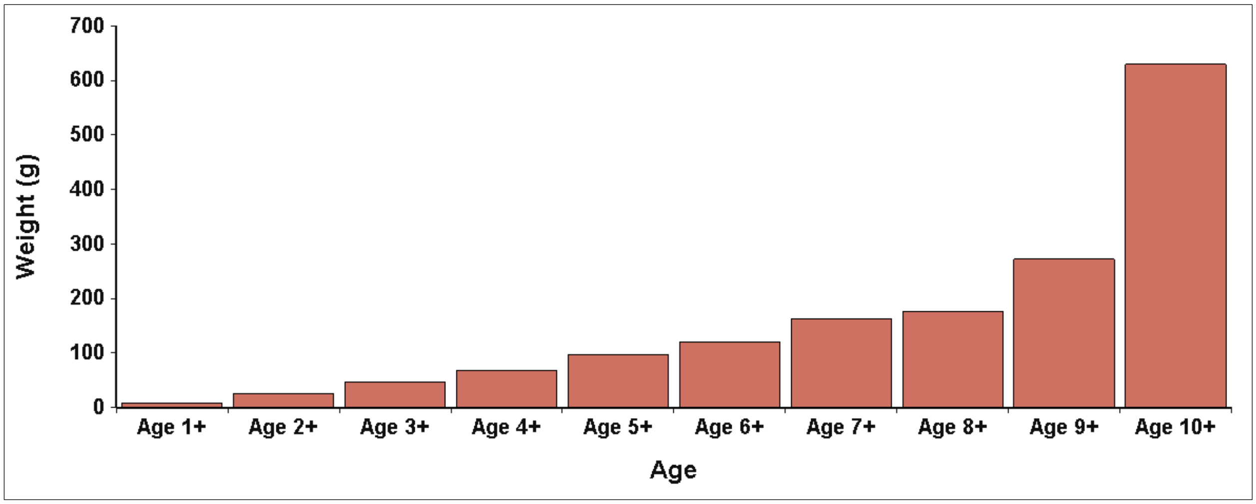


Figure 3.6: White Perch Age by Weight

Therefore, the age-structured stock population is adjusted to represent what anglers could catch and what they would keep. Figure 3.7 provides the relative abundance for white perch. Using this percent stock breakdown and the weights of each age, the mean of the white perch is 95.76 grams with a maximum of 281 grams (consistent with Windward 2010 and 2011 data).

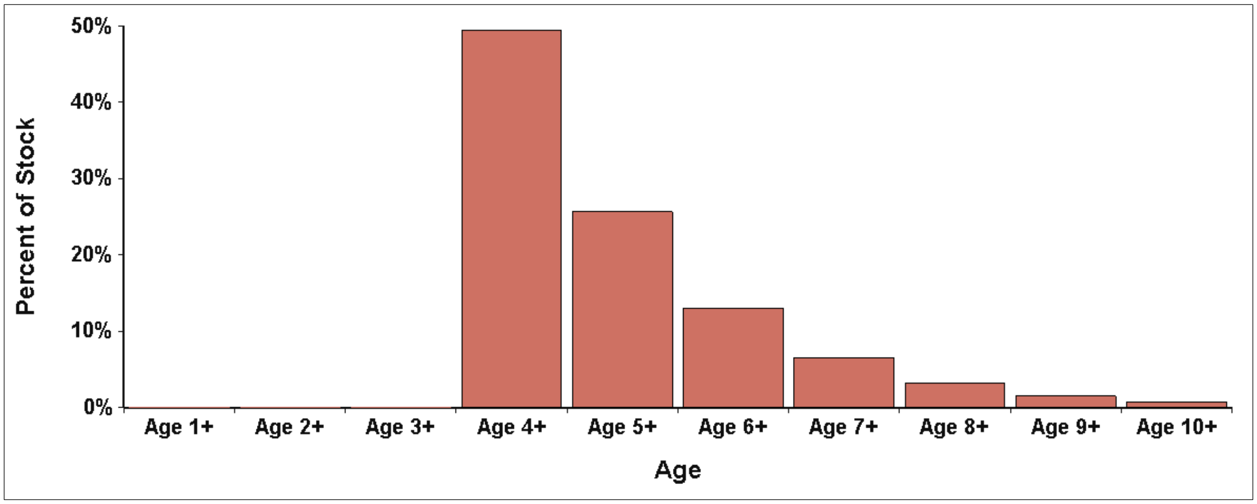


Figure 3.7: White Perch Relative Abundance of Kept Catch

3.5 Step 5: Develop Baseline Trips and Consumption Estimates

In addition to developing trip and consumption estimates under current risk conditions, the Fish Consumption Simulation Model also estimates changes in trips and consumption under baseline risk conditions. As the shaded portion of Figure 3.4 shows, the baseline risk consumption estimates use changes in behavior data from the 2013 NJORS. The 2013 NJORS provides the data needed to develop baseline trips and increases in consumption by species and Angler Type. Specifically, respondents state whether they are aware of the Do Not Eat Advisory on the LPRSA. If they are aware of the advisory, respondents then state whether they would increase trips to the LPRSA and/or increase consumption under baseline risk conditions.

Increased baseline trip and consumption predictions were developed by Angler Type. The Angler Types under baseline conditions fall into three categories:

1. Current Angler Type 1s (LPRSA consumers) who are unaware of the advisory
2. Current Angler Type 1s (LPRSA consumers) who are aware of the advisory
3. Current Angler Types 2–5 who are aware of the advisory and become consumers or non-consumers under baseline conditions.

According to the 2013 NJORS, 35 percent of current Angler Type 1s are unaware of the advisory. These anglers do not have a change in trip-taking and consumption behavior under baseline risk conditions. Current Angler Type 1s who are aware of the advisory, current Angler Types 2 and 3, and current Angler Types 4 and 5 have a combination of increased trips and/or increased consumption. The following subsections describe the processes for developing increased trip and consumption predictions under baseline-risk conditions for the three Angler Types listed above.

3.5.1 Develop Increase in Anglers by Angler Type

Using the data from the 2013 NJORS, the analysis develops the number of baseline consumers and non-consumers under baseline risk conditions. Table 3.4 presents the results of the 2013 NJORS by angler type. As Table 3.4 summarizes, Current Angler Type 1s remain consumers under baseline conditions. Under current conditions, current risk is evaluated for Angler Types 1–3; the consuming angler grams/day are estimated for Angler Type 1, and all anglers grams/day are estimated for Angler Types 1–3.

In the 2013 NJORS, 16 percent of current Angler Types 2 and 3 (those who currently fish in the LPRSA but do not consume LPRSA fish) state they would consume fish from the LPRSA under baseline risk conditions. Eleven percent of current Angler Types 4 and 5 (those who do not currently fish in the LPRSA and do not consume LPRSA fish) stated that they would fish in the LPRSA and consume LPRSA fish under baseline conditions; eight percent said they would fish in the LPRSA, but not consume LPRSA fish. The analysis uses the percentages presented in Table 3.4 to develop the total number of baseline risk consumers from Angler Types 2–3 and the number of new non-consuming anglers from Angler Types 4–5.

Table 3.4
Changes in Trip-Taking and Consumption Behavior by Angler Type

Current Angler Type	Percent that Consume Under Baseline	Percent that Do Not Consume Under Baseline
1	100%	0%
2 and 3	16%	84%
4 and 5	11%	8%

3.5.2 Develop Increase in Trip Frequency Distribution by Angler Type

The 2013 NJORS also collects data on current annual trips to the LPRSA and how anglers would increase trips under baseline conditions. Current Angler Type 1s, those who are unaware of the advisory, do not change trip-taking behavior under baseline risk conditions; therefore, their trip frequency looks the same under baseline and current conditions (i.e., their baseline trip frequency looks like Figure 3.2 with a mean of 1.7 trips per year and a maximum of 16).

Angler Type 1s who are aware of the advisory and Angler Types 2–5 who become consumers or non-consumers have a shift in the trip frequency distribution under baseline risk conditions. The 2013 NJORS informs this shift using data from the percent increase of trips by the respondents. The change in trip behavior is applied to the calibrated 2013 NJORS current trips.

Using the calibrated current trip distribution from the 2013 NJORS, the baseline trip frequency distribution is developed using the percent change responses from the 2013 NJORS. For example, of 1-trip Current Angler Type 1s who are aware of the advisory, 25 percent would not increase their annual trips. The remaining percentage would increase their trip-taking by a range of 2 to 6 trips per year under baseline risk conditions. Of 2-trip Current Angler Type 1s who are aware of the advisory, 23 percent would not increase their annual trips. The remaining 2-trip anglers would increase their trip-taking by a range of 3 to 8 trips per year under baseline risk conditions. The analysis repeats this process using the percent increase responses to develop baseline trip-frequency distributions. Figure 3.8 presents the current and baseline trip-frequency distribution for current Angler Type 1s who are aware of the advisory. As Figure 3.8

illustrates, the mean increases from 1.67 trips per year to 3.24 trips per year. The maximum trips per year increase from 15 to 29 trips per year.

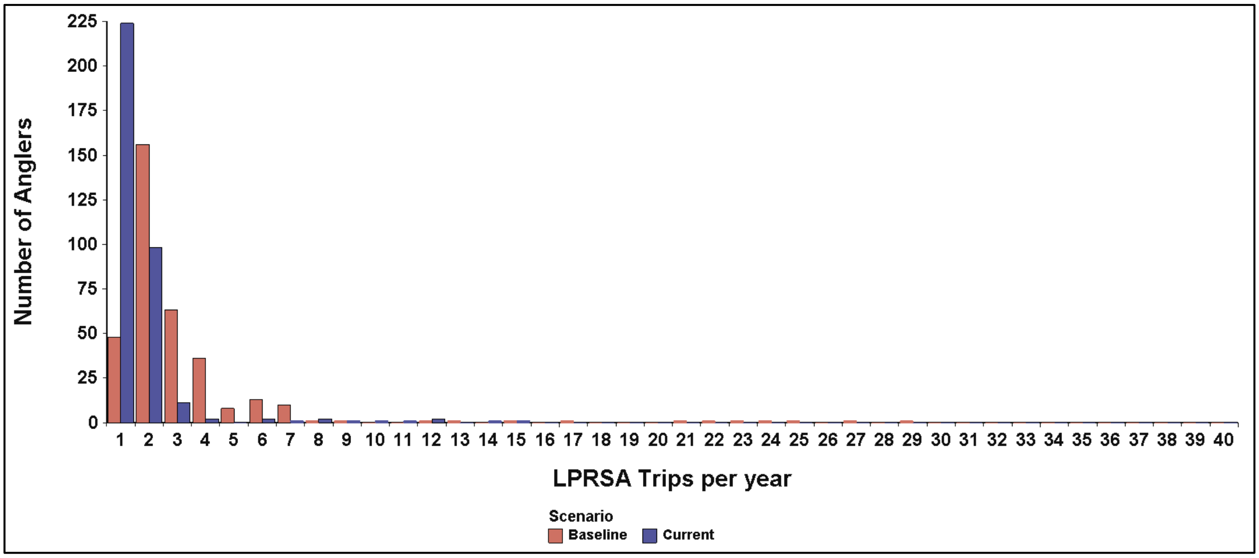


Figure 3.8: Current and Baseline Trip Frequency Distribution for Current Angler Type 1 Who Are Aware of the Advisory, Miles 0–17

The analysis uses two sets of trip-frequency distributions for Current Angler Types 2–5: anglers who become LPRSA consuming anglers and anglers who fish in the LPRSA but do not consume. The 2013 NJORS data provide the current LPRSA annual trips for Current Angler Types 2–3 who would and would not consume under baseline risk conditions. Current Angler Types 4–5 do not have current trips to the LPRSA.

Applying the percentage increase responses from the 2013 NJORS to the calibrated current trip distribution from the 2013 NJORS results in the baseline trip-frequency distribution. For example, of 1-trip Current Angler Type 2s and 3s who would become new consumers, 50 percent would not increase their annual trips. Seventeen percent would increase their trip-taking to 2 trips per year under baseline risk conditions; 17 percent would increase their trip-taking to 3 trips per year under baseline conditions. The remaining 17 percent of 1-trip Current Angler Type 2s and 3s would increase their trip-taking to 6 trips per year under baseline conditions.

In contrast, of 1-trip Current Angler Type 2s and 3s who would remain non-consumers under baseline risk conditions, 91 percent would not increase their annual trips. Four percent would increase their trip-taking to 2 trips per year under baseline conditions. The remaining percent of 1-trip Current Angler Type 2s and 3s would increase their trip-taking to 4 trips per year under baseline risk conditions.

Angler Type 4s and 5s do not take trips to the LPRSA under current risk conditions. The 2013 NJORS provides the new trip-taking frequency distribution for Angler Type 4s and 5s who would start taking trips to the LPRSA and consume (new Angler Type 1s) and Angler Type 4s and 5s who would start taking trips to the LPRSA but not consume.

The analysis shift in baseline trips uses the process as described above and applies it to the increase in the number of consumers and non-consumers for Current Angler Types 2–5. Figures 3.9 and 3.10 provide the current and baseline trip frequency distribution for Angler Types 2–5 who become consumers and who are non-consuming LPRSA anglers under baseline risk conditions. Figure 3.9 presents the trip-frequency distribution for new consumers under baseline conditions. There is no current trip-frequency distribution because these anglers are not consumers under current conditions. The mean of annual trips is 3.47 trips per year, with a maximum of 30 trips per year.

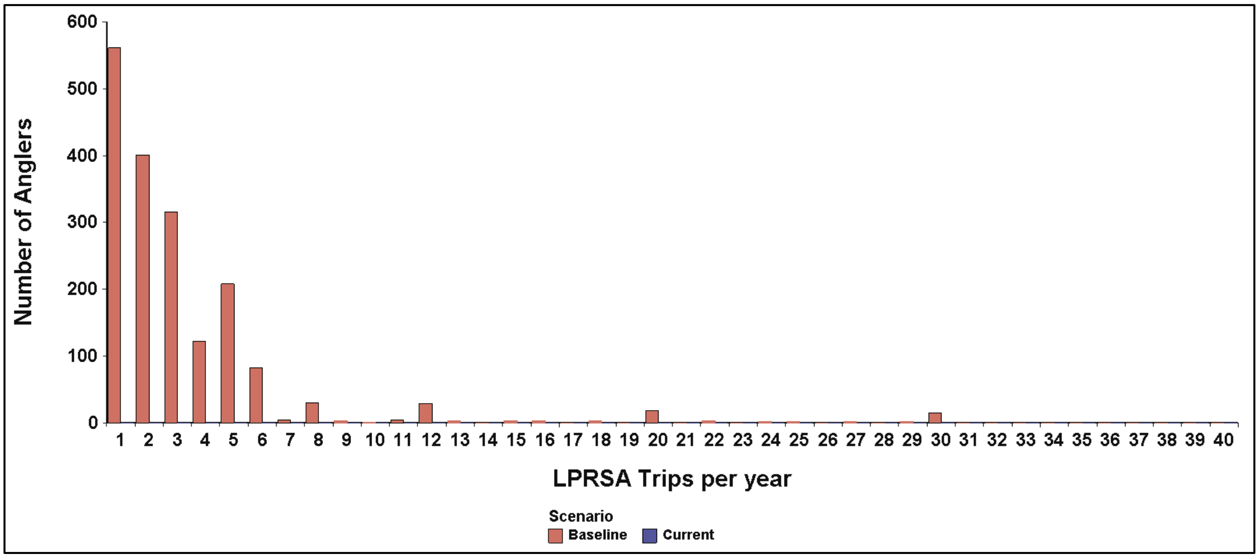


Figure 3.9: Current and Baseline Trip Frequency Distribution for Angler Type 2–5 Who Would Become Consumers, Miles 0–17

Figure 3.10 presents the current and baseline trip-frequency distribution for Angler Types 2–5 who will fish in the LPRSA under baseline risk conditions but not consume fish. The mean of annual trips per year for these non-consumers increases from 2.1 trips per year to 3.0 trips per year. The maximum increases from 37 trips per year to 40 trips per year.

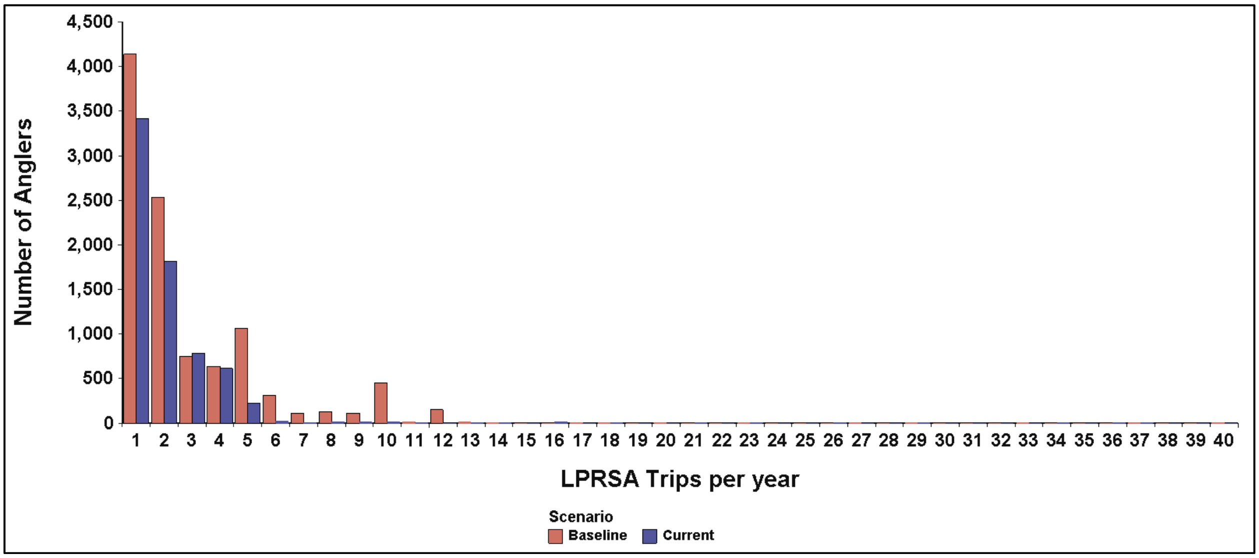


Figure 3.10: Current and Baseline Trip Frequency Distribution for Angler Type 2–5 Who Would Remain Non-Consumers, Miles 0–17

3.5.3 Develop Change in Kept Catch Rates by Angler Type

In addition to estimating increases in trips by Angler Type, the analysis also accounts for potential increases in the number of fish kept under baseline-risk conditions. Current Angler Type 1s who are unaware of the advisory keep and consume in the same manner as under current conditions. The analysis specifies that current Angler Type 1s who are aware of the advisory and current Angler Types 2–5 who become consumers have different kept catch under baseline conditions.

The 2013 NJORS collected current and baseline keep data (i.e., number of each species that consumers catch and keep on a typical trip to the LPRSA) for current consumers. Current Angler Type 1s who are aware of the advisory were asked if they would increase their consumption under baseline risk conditions. If the respondents stated they would increase consumption, they provided the additional number of fish or crab (by species) that they would expect to keep for consumption on a typical trip.

In order to calculate the number of fish caught and kept for Angler Types 2–5 who become consumers under baseline conditions, the analysis used data from the 2013 NJORS on how many of each species anglers would expect to keep per trip under baseline risk conditions. New consumers stated that they would consume 55 percent of what the Current Angler Type 1s catch and keep for consumption. The analysis applies this 55 percent to the number of fish kept by Current Angler Type 1s under current risk conditions.

3.5.4 Develop Consumption Estimate by Angler Type

The analysis uses the inputs described above to calculate baseline risk consumption estimates by each Angler Type. Current Angler Type 1s who are unaware of the advisory do not change trips or consumption behavior under baseline risk conditions. Current Angler Type 1s who are aware of the advisory have a shift in baseline trips (from current trips) and have a percentage increase by species for consumption (i.e., current number of fish kept is multiplied by the percentage increase in fish kept by species). Angler Types 2–5 who become new consumers have a shift in baseline trips and consume at a lower rate than both groups of current Angler Type 1s (unaware and aware).

4. Results

Table 4.1 summarizes the results across the following three scenarios:

- Geography—River Miles 0–17, 0–8, and 8–17
- Angling Population—all anglers versus consuming anglers
- Risk Condition—current versus baseline.

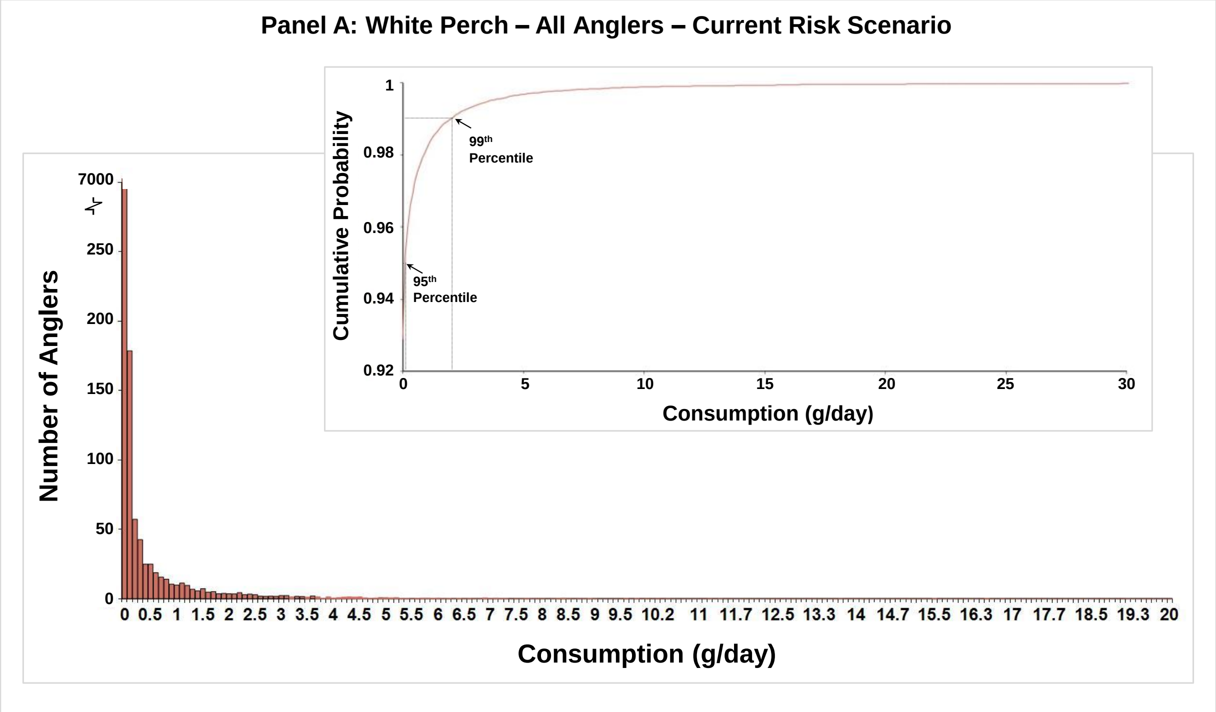
The table presents the mean, median, 90th percentile, 95th percentile, and 99th percentile of the current and baseline risk consumption estimates across each scenario along with the 90 percent confidence interval for each statistic of interest (Tables A.1, A.2, and A.3 in Appendix A expand the scenarios to include estimates by individual species). As Table 4.1 indicates, the mean of current consumption for the entire LPRSA (Miles 0–17) is 0.18 grams/day for all anglers with a 95th percentile of 0.41 grams/day. Under baseline conditions, the mean is 3.31 grams/day for consuming anglers with a 95th percentile of 13.15 grams/day. For Miles 0–8, a subset of the 17-Mile LPRSA, the mean of current consumption for all anglers is 0.13 grams/day, with a 95th percentile of 0.55 grams/day. Under baseline risk conditions for consuming anglers, the mean of consumption is 1.33 grams/day with a 95th percentile of 5.19 grams/day. For Miles 8-17, a subset of the 17-Mile LPRSA, the mean of current consumption for all anglers is 0.13 grams/day, with a 95th percentile of 0.18 grams/day. Under baseline risk conditions for consuming anglers, the mean of consumption is 2.52 grams/day with a 95th percentile of 9.99 grams/day.

Table 4.1
Consumption Estimates by Scenario—All Species

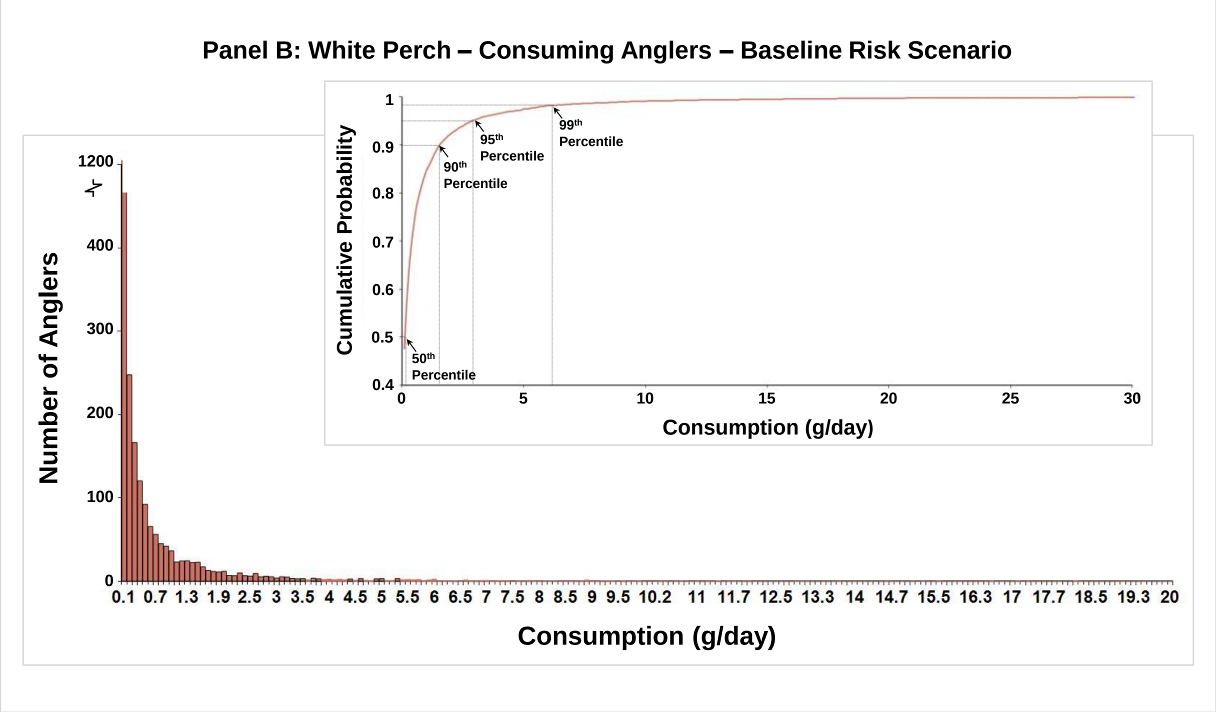
Species Scenario	Geographic Scenario	Angling Population Scenario	Risk Estimate Scenario	Consumption (g/day)				
				Mean	Median	90th	95th	99th
All Species[a]	River Miles 0–17	All Anglers	Baseline	0.61 (0.16-1.51)	0.00 (0.00-0.00)	0.85 (0.20-2.20)	3.07 (0.70-8.36)	12.60 (2.95-33.81)
			Current	0.18 (0.05-0.42)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	0.41 (0.10-0.90)	4.34 (1.20-10.46)
		Consuming Anglers	Baseline	3.31 (0.85-8.25)	1.27 (0.30-3.10)	8.31 (1.90-22.51)	13.15 (3.15-34.42)	29.44 (7.45-69.47)
			Current	2.54 (0.74-5.86)	0.99 (0.20-2.56)	6.91 (1.70-16.86)	8.45 (2.25-20.46)	20.32 (5.90-46.61)
	River Miles 0–8	All Anglers	Baseline	0.29 (0.08-0.74)	0.00 (0.00-0.00)	0.49 (0.10-1.30)	1.38 (0.30-3.60)	5.64 (1.40-15.00)
			Current	0.13 (0.04-0.32)	0.00 (0.00-0.00)	0.13 (0.10-0.30)	0.55 (0.10-1.40)	2.74 (0.70-6.90)
		Consuming Anglers	Baseline	1.33 (0.36-3.39)	0.39 (0.10-1.00)	3.14 (0.70-8.40)	5.19 (1.30-13.60)	15.13 (3.80-38.71)
			Current	0.92 (0.28-2.28)	0.31 (0.10-0.80)	2.06 (0.50-5.20)	3.76 (1.00-9.50)	9.71 (2.50-25.41)
	River Miles 8–17	All Anglers	Baseline	0.46 (0.10-1.18)	0.00 (0.00-0.00)	0.63 (0.10-1.60)	2.29 (0.50-6.00)	9.48 (2.00-26.31)
			Current	0.13 (0.03-0.32)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	0.18 (0.10-0.40)	3.09 (0.70-8.10)
		Consuming Anglers	Baseline	2.52 (0.57-6.52)	0.98 (0.20-2.60)	6.28 (1.30-17.71)	9.99 (2.10-26.90)	22.12 (4.70-58.52)
			Current	1.88 (0.49-4.71)	0.74 (0.20-1.90)	5.29 (1.30-13.80)	6.41 (1.60-16.80)	13.69 (3.40-33.31)

[a] LPRSA species include American eel, blue crab, carp, catfish, striped bass, and white perch. Tables A.1, A.2, and A.3 in Appendix A present the estimates for each species under each scenario presented in Table 4.1.

Figure 4.1 provides a graphical illustration of the results from the Fish Consumption Simulation Model and how the results are produced for each scenario presented in Table 4.1. Panel A presents the results under current risk conditions for the entire angling population, and Panel B presents baseline risk conditions for the fish-consuming angling population. Both present the estimate for an individual species: white perch.



Panel A: White Perch – All Anglers – Current Risk Scenario



Panel B: White Perch – Consuming Anglers – Baseline Risk Scenario

Figure 4.1: Comparison of Consumption for All Anglers and Consuming Anglers under Current and Baseline Risk Scenarios

The consumption estimates in Figure 4.1 are summarized with two graphs for each of the respective populations: a consumption frequency histogram illustrating the relationship between the estimated number of grams consumed per day and the corresponding number of anglers estimated to consume at each daily rate and the cumulative density function associated with the consumption frequency histogram.

The consumption frequency histograms illustrate how many anglers are predicted to consume fish at the various levels of consumption. For example, 177 anglers consume approximately 0.1 grams per day under current risk conditions (Panel A). The top panel reflects the consumption estimates for all anglers; therefore, the histogram illustrates the number of anglers who consume zero grams per day as well as the number of anglers who consume fish at various rates of consumption. The bottom panel removes non-consuming anglers and only reflects the baseline risk consumption estimates for anglers predicted to consume fish. The cumulative density functions show the 50th, 90th, 95th, and 99th percentiles of the consumption estimates.

Figure 4.2 illustrates the number and geographic dispersion of fishing trips that the model predicts to sites throughout the entire LPRSA. Each of the red dots represents a known LPRSA fishing site, based on each of the fishing studies that have been conducted throughout the LPRSA (Law 2011; Kinnell et al. 2007; Burger et al. 1999; Pflugh et al. 1999). The size of each dot corresponds to the annual number of trips the model predicts that anglers take to each site.

The model estimates trips to the LPRSA for anglers who are expected to be most likely to visit the LPRSA: anglers residing in five counties surrounding the LPRSA (illustrated by the shaded ZIP Codes in the lower right-hand panel of Figure 4.2). The shading in Figure 4.2 illustrates differences in the number of trips originating from each ZIP Code in the Five County Area: the darker the shading, the more trips originate from that ZIP Code. The shading illustrates both the distance decay aspect captured by the preference function (all else being equal, the farther an angler is from the LPRSA, the less likely she is to take trips to it) and the varying population in each ZIP Code (i.e., while the ZIP Code may be further away from the LPRSA, it may have a higher population, and therefore a higher overall number of anglers).

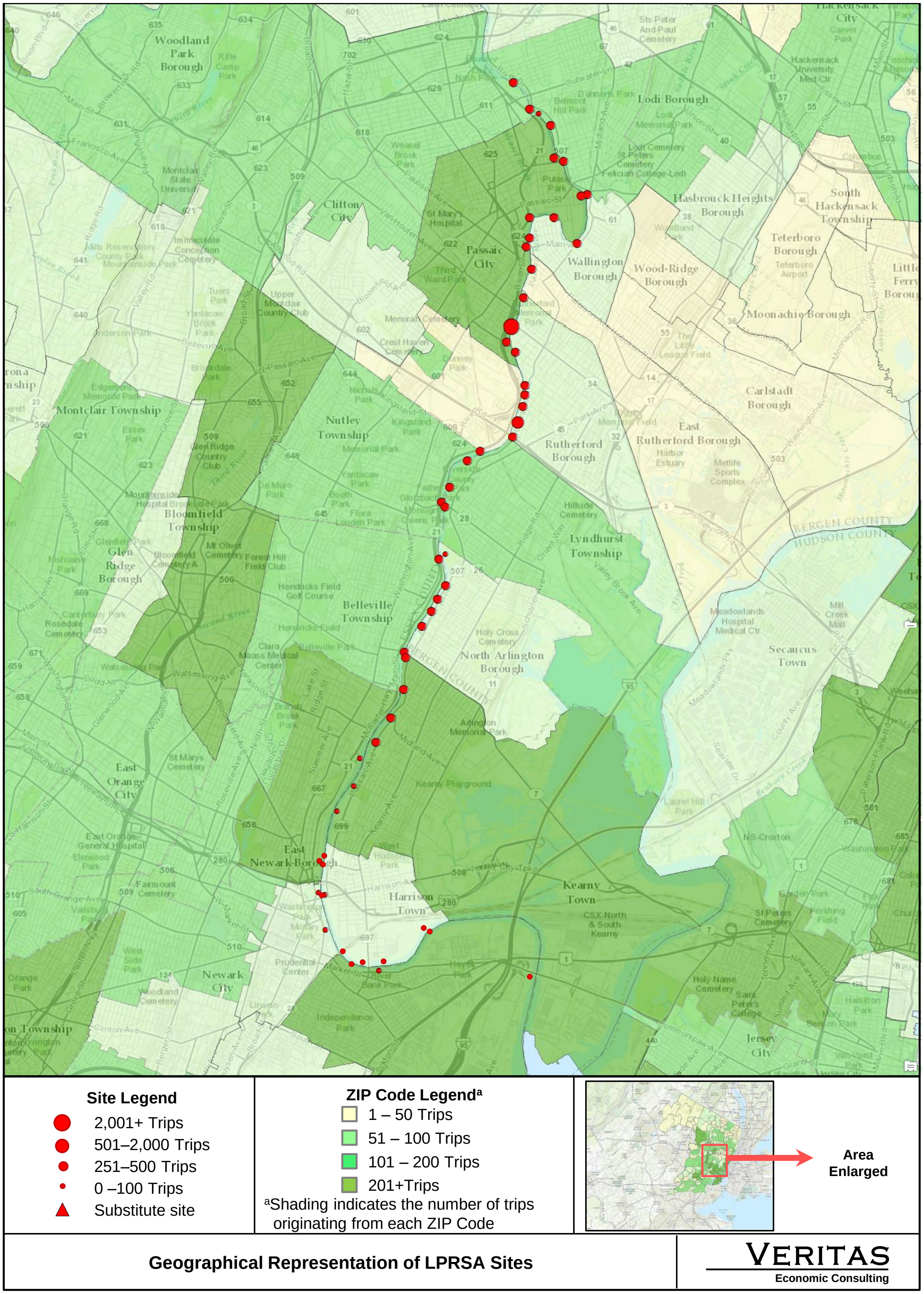


Figure 4.2: Geographic Dispersion of Predicted Fishing Trips to the LPRSA

Uncertainty Evaluation

As summarized in Table 4.1, the analysis estimates uncertainty for each percentile. In statistical analysis, the term *uncertainty* refers to the statistical reliability of estimates. Consumption estimates are most useful when the causes of uncertainty are clearly identified and quantified. Numerous sources of uncertainty may lead to imprecision or bias in consumption estimates. Following Finkel (1990), USEPA classifies uncertainty into two general types (USEPA 2011):

- The first is structural uncertainty, which reflects limited understanding of the appropriate model and relationships among model parameters.
- The second is parameter uncertainty, which reflects imprecision in the specific numeric values of model parameters.

Structural uncertainties will generally lead to inaccuracies, rather than imprecision, in consumption estimates. The analysis accounts for structural uncertainty by building a behavioral model that matches the structural aspects of how people make decisions influencing fish consumption (e.g., how many trips anglers decide to take, where angler decide to take those trips—LPRSA versus substitute sites, the amount of fish they keep, the types of fish they keep, and the parts they consume).

Specifically, the Fish Consumption Simulation Model combines the preference function developed from the 2000 and 2013 NJORS' fishing data with the site characteristics (e.g., distance from the angler's home to the site, catch rate, presence of an advisory, etc.) compiled for all the LPRSA and relevant substitute sites and the size, characteristics, and demographics of the angling population to predict how many trips anglers take to the LPRSA and relevant substitute sites. The preference function provides the simulation model with its behavioral foundation: identifying how anglers trade off the varying characteristics of the relevant fishing sites they can choose when they decide where to go fishing. Additional information, like the catch and consumption information from the 2000–01 and 2011–12 CAS (e.g., likelihood of keeping caught fish; number, type, and size of species kept; and parts consumed) predict how many of what types of fish anglers keep and consume from the LPRSA. The simulation model combines all of these components within its behavior-based structure to develop predicted estimates of the number of anglers taking trips to the LPRSA, the number of fish they catch and keep, and the number of grams of self-caught fish they consume in a year.

To address parameter uncertainty, the model includes a Monte Carlo component that quantifies and incorporates the effects of uncertainty in each input parameter on the overall uncertainty in consumption estimates under each evaluated scenario. The Monte Carlo analysis combines uncertainty in input parameters within the structural behavioral model to quantify uncertainty in consumption. The approach takes specified distributions for each variable input, randomly selects a value from each distribution, and combines the estimates within the framework of the consumption estimation. The resulting combination of the various inputs creates an estimate of consumption under each scenario.

The Monte Carlo analysis for the results in Table 4.1 repeats this process of drawing from the various input distributions 800 times, each time drawing randomly from the designated ranges of values for calculating consumption. Each repetition produces a different estimate of consumption. The resulting distribution of outcomes from the 800 draws produces the range of potential consumption estimates that explicitly addresses uncertainty. The 800-draw Monte Carlo analysis for each geography presented in Table 4.1 took five hours to complete.

Figure 4.3 provides an illustrative example. While numerous inputs are used in the model, Figure 4.3 presents distributions of the underlying uncertainty associated with three specific inputs used to estimate consumption: the probability of catching a fish, the probability of keeping a fish, and the number of fish kept. The illustration shows that there is a distribution associated with each component and the distributions may have different properties. For example, the distribution on the probability of catching a fish is skewed to the right, whereas the distribution associated with the probability of keeping a fish is skewed to the left. Also, each of these distributions vary across demographic profiles. The distributions presented in Figure 4.3 represent the distributions associated with one specific demographic group for each input.

As Figure 4.3 shows, the Monte Carlo analysis draws from each element influencing consumption to determine the distribution of the consumption estimate. For example, in one draw, the analysis may draw a low estimate from the distribution of the probability of keeping a fish, but then draw a high estimate from the number of fish kept, and a mid-level estimate of the size of the fish kept. Putting all three of these estimates together produces one estimate of consumption. The analysis then draws a value for each component again. This time it may draw a mid-level estimate from each element. The process presented in Figure 4.3 is repeated 800 times to produce the distribution of consumption. The analysis evaluates the effect of this uncertainty on relevant statistics of interest.

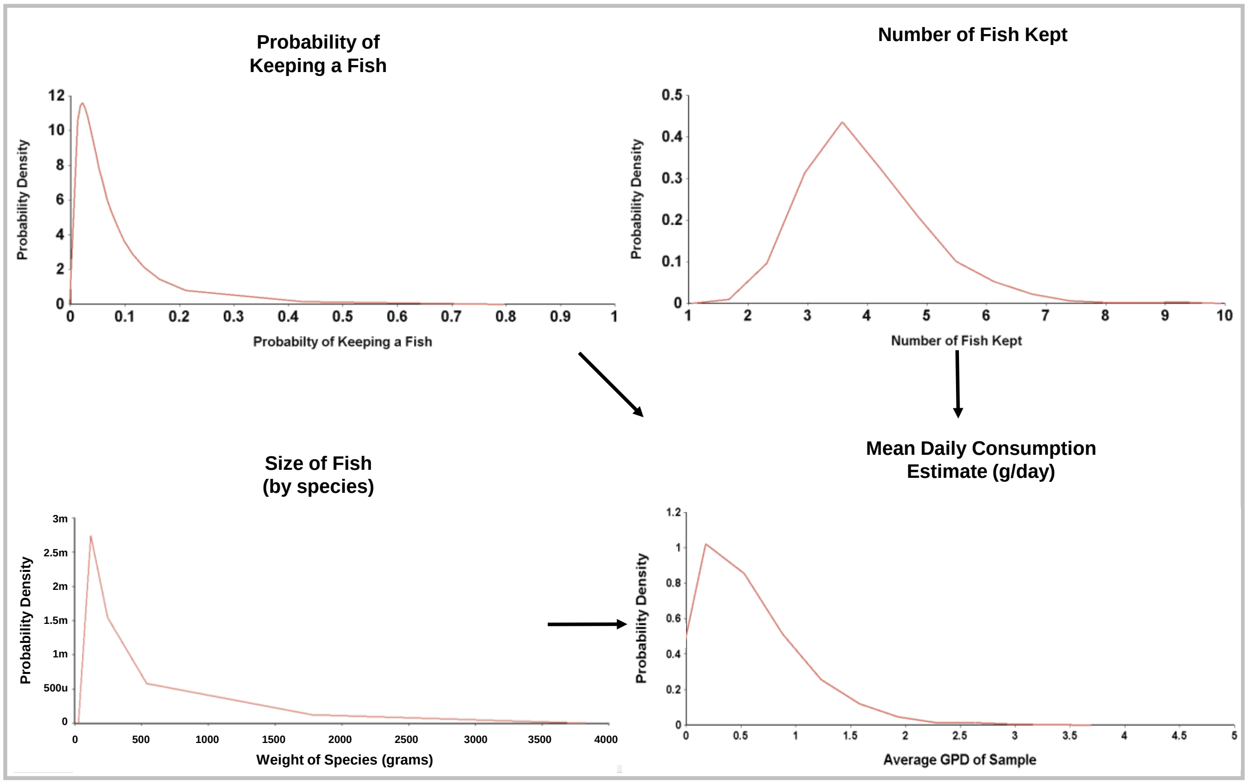


Figure 4.3: **Illustration of Example Inputs in Fish Consumption Simulation Model's Monte Carlo Component**

5. Discussion

The methodology and results described throughout this manuscript illustrate how baseline-risk, fish-ingestion estimates can be developed to inform baseline-risk, human-health risk assessments as required by the National Contingency Plan (40 *CFR* 300.430(d)(4)). The methodology allows for the use of site-specific data and characterizations of the relevant angling population being evaluated in the baseline risk assessment. The methodology also allows for scenario analysis across varying geographies, populations, risk conditions, and species consumed.

The results of the analysis shows that current consumption rates estimated in previous studies fall within the confidence intervals (estimated with Monte Carlo analysis) of the current consumption rates estimated for this study. For example, using data from the 2000–2001 Passaic River Creel/Angler Survey, Ray et al. (2007b) estimated the mean of current consumption for the angling population fishing in nearly all of miles 0–8 as 0.42 grams per day and the 95th percentile as 1.8 grams per day. The ranges for the corresponding estimates from this study are a mean of 0.13 grams per day and a 95th percentile of 0.55 grams per day for the entire angling population.

Default values for baseline consumption rates are outside the confidence intervals (estimated with Monte Carlo analysis) of the 90th percentile consumption-rate estimates from this study. This study estimates a mean of 0.85 grams per day for the 90th percentile of all LPRSA anglers (consumers and non-consumers) under baseline risk conditions, with a 90-percent confidence interval ranging from 0.20 to 2.20 grams per day. By comparison, default rates prepared for the LPRSA have been as high as 34.6 grams per day (USEPA 2014). Estimates for the population of consuming anglers from this study are also lower than the default rate. This study estimates a mean of 8.31 grams per day for the 90th percentile of consuming anglers under baseline risk conditions, with a 90-percent confidence interval ranging from 1.90 to 22.51 grams per day. The proposed default rate is also higher than the 95th and 99th percentile estimated in this study.

The theoretical construct underlying the analysis shows that it is possible for baseline regulatory risk to be *lower* than current regulatory risk. As graphically depicted and described in detail in Section 4, regulatory risk metrics such as the 95th percentile of grams per day consumed are *independent of the size of the population*. This means that adding new consumers under the baseline risk scenario who consume at a lower rate than existing consumers can lead to a lower 95th percentile of grams per day than under current conditions.

Changes in regulatory risk from current to baseline are driven by the behaviors of those who are the highest consumers (e.g., at the 95th percentile level and above) under current conditions. If these anglers increase their consumption under baseline conditions, the 95th percentile of grams per day increases. However, if they do not increase their consumption, it does not change unless other anglers begin consuming at a rate that is higher than this group.

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Appendix A
Baseline and Current Fish Ingestion Estimates by Species

Tables A.1, A.2, and A.3 expand the scenario analysis presented in Section 4 to include the estimates by species in addition to geography (River Miles 0-17, 0-8, and 8-17), population (all anglers and consuming anglers), and risk conditions (current and baseline). Table A.1 presents the results by species for River Miles 0-17, Table A.2 presents the results for River Miles 0-8, and Table A.3 presents the results for River Miles 8-17. Each table presents the mean, median, 90th percentile, 95th percentile, and 99th percentile of the current and baseline risk consumption estimate, along with the 90 percent confidence interval with statistic of interest.

The Monte Carlo analysis for the results in Table A.1-A.3 repeats the process of drawing from the various input distributions 200 times, each time drawing randomly from the designated ranges of values for calculating consumption. Each repetition produces a different estimate of consumption. The resulting distribution of outcomes from 200 draws produces the range of potential consumption estimates that explicitly addresses uncertainty. The 200-draw Monte Carlo analysis for each geography presented in Tables A.1, A.2, and A.3 took seven hours to complete. The sum of the individual percentile estimates across individual species will not equal the all species percentile estimates presented in Table 4.1 because the all species scenario is estimated simultaneously, while the individual species estimates are estimated individually.

Figure A.1 illustrates the gender makeup of the two angling populations as well as the interaction between gender and race. As Panels A and B show, the majority of both the entire angling population (88 percent) as well as the consuming population (87 percent) is male. As Panel A shows, almost 60 percent of male angling population is estimated to be white and approximately almost one-quarter is estimated to be Hispanic. For the female anglers, one-third is estimated to be Asian, followed by black and Hispanics, each accounting for between one-fifth and 30 percent of the female angling population.

Comparing Panels A and B, the demographic composition of the female consuming population for Asians, white, and other race females decreases. The majority of the consuming angler population is estimated to be black (38 percent) and Hispanic (26 percent) females. The demographic profile of the male consumers differs from the entire male angling population. Hispanic males account for almost one-third of the male consuming population and almost 20 percent are black. The number of white males decreases from approximately 59 percent of the total angling population to 47 percent of the consuming population.

Table A.1
Consumption Estimates by Scenario—Miles 0–17

Species Scenario	Angling Population Scenario	Risk Estimate Scenario	Consumption (g/day)				
			Mean	Median	90th	95th	99th
American eel	All Anglers	Baseline	0.03 (0.02-0.08)	0.00 (0.00-0.00)	0.10 (0.10-0.10)	0.15 (0.10-0.30)	0.43 (0.10-1.50)
		Current	0.02 (0.01-0.05)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	0.10 (0.10-0.10)	0.34 (0.10-1.20)
	Consuming Anglers	Baseline	0.18 (0.10-0.43)	0.10 (0.10-0.10)	0.29 (0.10-0.90)	0.45 (0.10-1.60)	0.99 (0.10-3.40)
		Current	0.25 (0.10-0.77)	0.15 (0.10-0.40)	0.53 (0.10-2.11)	0.65 (0.10-2.30)	1.69 (0.19-6.03)
Blue Crab	All Anglers	Baseline	0.06 (0.02-0.13)	0.00 (0.00-0.00)	0.11 (0.10-0.20)	0.26 (0.10-0.60)	1.21 (0.29-2.80)
		Current	0.01 (0.01-0.01)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	0.10 (0.10-0.10)	0.10 (0.10-0.10)
	Consuming Anglers	Baseline	0.35 (0.13-0.72)	0.12 (0.10-0.20)	0.75 (0.20-1.70)	1.26 (0.30-2.90)	3.14 (0.70-7.01)
		Current	0.11 (0.10-0.14)	0.10 (0.10-0.10)	0.12 (0.10-0.20)	0.14 (0.10-0.30)	0.32 (0.10-0.70)
Catfish	All Anglers	Baseline	0.05 (0.02-0.14)	0.00 (0.00-0.00)	0.11 (0.10-0.20)	0.22 (0.10-0.60)	0.84 (0.10-2.50)
		Current	0.02 (0.01-0.05)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	0.10 (0.10-0.10)	0.35 (0.10-1.10)
	Consuming Anglers	Baseline	0.28 (0.11-0.75)	0.12 (0.10-0.020)	0.55 (0.10-1.60)	0.87 (0.19-2.71)	2.17 (0.39-6.91)
		Current	0.25 (0.11-0.67)	0.14 (0.10-0.30)	0.53 (0.10-1.51)	0.68 (0.10-2.21)	1.74 (0.30-5.51)
Carp	All Anglers	Baseline	0.22 (0.03-0.71)	0.00 (0.00-0.00)	0.32 (0.10-1.00)	1.07 (0.10-3.80)	4.47 (0.39-12.90)
		Current	0.05 (0.01-0.16)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	0.15 (0.10-0.40)	1.23 (0.10-4.10)
	Consuming Anglers	Baseline	1.21 (0.15-3.84)	0.35 (0.10-1.11)	3.03 (0.20-9.10)	4.66 (0.40-12.90)	11.18 (0.90-35.08)
		Current	0.74 (0.12-2.29)	0.37 (0.10-1.20)	1.90 (0.19-5.90)	2.38 (0.20-6.61)	5.96 (0.50-18.74)
Striped bass	All Anglers	Baseline	0.17 (0.03-0.65)	0.00 (0.00-0.00)	0.26 (0.10-0.90)	0.82 (0.10-3.00)	3.47 (0.30-14.14)
		Current	0.02 (0.01-0.07)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	0.11 (0.10-0.20)	0.49 (0.10-1.70)
	Consuming Anglers	Baseline	0.93 (0.14-3.55)	0.30 (0.10-1.00)	2.25 (0.20-8.34)	3.53 (0.30-14.62)	8.41 (0.80-32.93)
		Current	0.33 (0.10-1.04)	0.19 (0.10-0.60)	0.76 (0.10-3.00)	0.92 (0.10-3.71)	2.42 (0.20-9.11)
White perch	All Anglers	Baseline	0.14 (0.04-0.41)	0.00 (0.00-0.00)	0.19 (0.10-0.40)	0.73 (0.20-1.81)	2.78 (0.60-8.91)
		Current	0.09 (0.02-0.22)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	0.19 (0.10-0.40)	2.08 (0.50-4.72)
	Consuming Anglers	Baseline	0.79 (0.22-2.26)	0.22 (0.10-0.60)	1.91 (0.40-5.90)	2.87 (0.60-9.11)	6.27 (1.50-19.53)
		Current	1.22 (0.34-3.06)	0.63 (0.10-1.50)	3.20 (0.79-7.70)	3.92 (1.00-9.04)	9.80 (2.60-25.97)

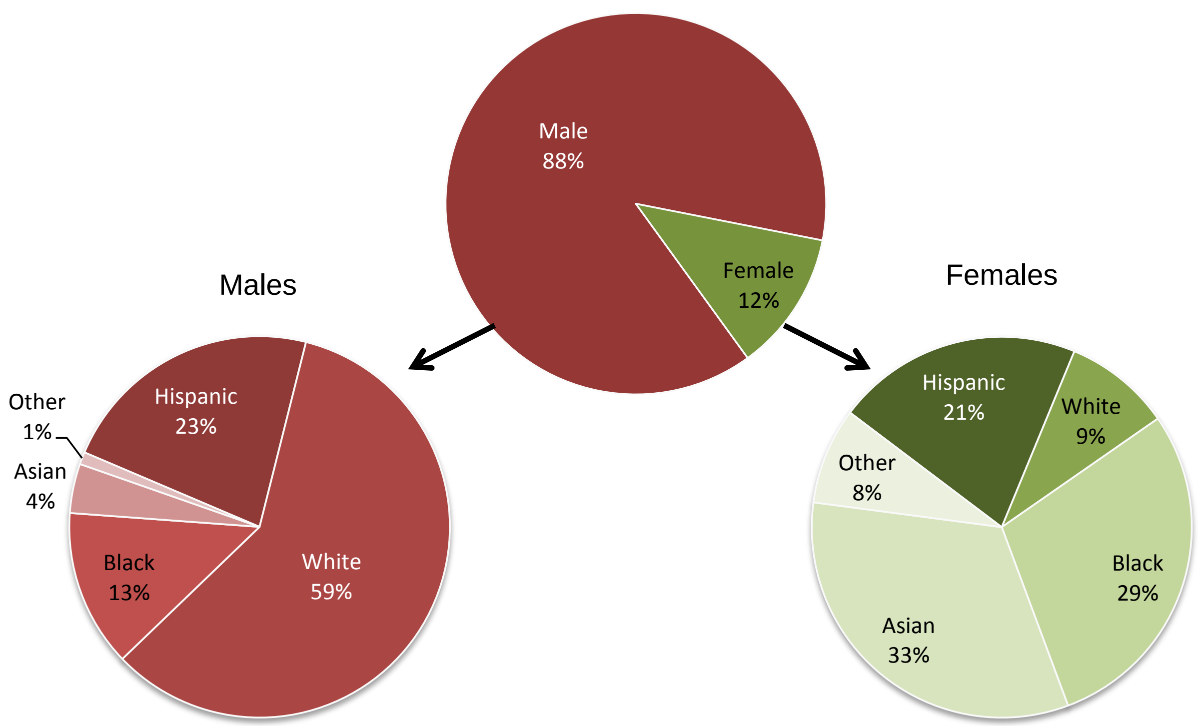
Table A.2
Consumption Estimates by Scenario—Miles 0–8

Species Scenario	Angling Population Scenario	Risk Estimate Scenario	Consumption (g/day)				
			Mean	Median	90th	95th	99th
American eel	All Anglers	Baseline	0.03 (0.02-0.06)	0.00 (0.00-0.00)	0.10 (0.10-0.10)	0.12 (0.10-0.20)	0.25 (0.10-0.85)
		Current	0.02 (0.01-0.04)	0.00 (0.00-0.00)	0.10 (0.10-0.10)	0.11 (0.10-0.15)	0.23 (0.10-0.75)
	Consuming Anglers	Baseline	0.14 (0.10-0.28)	0.10 (0.10-0.10)	0.17 (0.10-0.50)	0.24 (0.10-0.80)	0.84 (0.10-3.00)
		Current	0.14 (0.10-0.27)	0.10 (0.10-0.10)	0.19 (0.10-0.60)	0.31 (0.10-1.00)	0.76 (0.10-2.50)
Blue Crab	All Anglers	Baseline	0.03 (0.02-0.06)	0.00 (0.00-0.00)	0.10 (0.10-0.10)	0.12 (0.10-0.20)	0.38 (0.10-0.90)
		Current	0.01 (0.01-0.02)	0.00 (0.00-0.00)	0.10 (0.10-0.10)	0.10 (0.10-0.10)	0.10 (0.10-0.10)
	Consuming Anglers	Baseline	0.15 (0.10-0.26)	0.10 (0.10-0.10)	0.21 (0.10-0.50)	0.36 (0.10-0.90)	1.04 (0.20-2.56)
		Current	0.10 (0.10-0.11)	0.10 (0.10-0.10)	0.10 (0.10-0.10)	0.10 (0.10-0.10)	0.16 (0.10-0.40)
Catfish	All Anglers	Baseline	0.03 (0.02-0.07)	0.00 (0.00-0.00)	0.10 (0.10-0.10)	0.13 (0.10-0.30)	0.28 (0.10-1.20)
		Current	0.02 (0.01-0.04)	0.00 (0.00-0.00)	0.10 (0.10-0.10)	0.10 (0.10-0.10)	0.22 (0.10-0.60)
	Consuming Anglers	Baseline	0.15 (0.10-0.33)	0.10 (0.10-0.10)	0.22 (0.10-0.70)	0.34 (0.10-1.10)	1.01 (0.20-3.25)
		Current	0.14 (0.10-0.25)	0.10 (0.10-0.10)	0.18 (0.10-0.45)	0.29 (0.10-0.85)	0.74 (0.10-2.15)
Carp	All Anglers	Baseline	0.10 (0.02-0.34)	0.00 (0.00-0.00)	0.18 (0.10-0.50)	0.44 (0.10-1.50)	1.84 (0.10-6.76)
		Current	0.04 (0.01-0.12)	0.00 (0.00-0.00)	0.10 (0.10-0.10)	0.18 (0.10-0.50)	0.76 (0.10-2.75)
	Consuming Anglers	Baseline	0.46 (0.11-1.53)	0.16 (0.10-0.40)	0.99 (0.10-3.70)	1.69 (0.10-6.15)	4.94 (0.40-18.13)
		Current	0.30 (0.10-0.89)	0.13 (0.10-0.30)	0.57 (0.10-1.90)	1.05 (0.10-3.70)	2.68 (0.20-9.45)
Striped bass	All Anglers	Baseline	0.07 (0.02-0.25)	0.00 (0.00-0.00)	0.14 (0.10-0.40)	0.27 (0.10-1.11)	1.06 (0.10-4.76)
		Current	0.02 (0.01-0.06)	0.00 (0.00-0.00)	0.10 (0.10-0.10)	0.12 (0.10-0.20)	0.28 (0.10-1.15)
	Consuming Anglers	Baseline	0.30 (0.11-1.14)	0.13 (0.10-0.30)	0.60 (0.10-2.86)	0.99 (0.10-4.60)	2.88 (0.30-14.29)
		Current	0.15 (0.10-0.45)	0.10 (0.10-0.10)	0.22 (0.10-0.90)	0.37 (0.10-1.60)	0.93 (0.10-4.36)
White perch	All Anglers	Baseline	0.09 (0.03-0.21)	0.00 (0.00-0.00)	0.15 (0.10-0.30)	0.34 (0.10-0.80)	1.29 (0.30-3.15)
		Current	0.06 (0.02-0.14)	0.00 (0.00-0.00)	0.10 (0.10-0.10)	0.24 (0.10-0.55)	1.18 (0.30-2.90)
	Consuming Anglers	Baseline	0.41 (0.15-0.95)	0.12 (0.10-0.20)	0.75 (0.20-1.80)	1.21 (0.30-2.80)	5.10 (1.20-12.50)
		Current	0.42 (0.16-0.99)	0.15 (0.10-0.30)	0.88 (0.20-2.20)	1.64 (0.50-4.30)	4.19 (1.20-10.90)

Table A.3
Consumption Estimates by Scenario—Miles 8–17

Species Scenario	Angling Population Scenario	Risk Estimate Scenario	Consumption (g/day)				
			Mean	Median	90th	95th	99th
American eel	All Anglers	Baseline	0.03 (0.02-0.06)	0.00 (0.00-0.00)	0.10 (0.10-0.10)	0.13 (0.10-0.30)	0.32 (0.10-1.10)
		Current	0.01 (0.01-0.04)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	0.10 (0.10-0.10)	0.25 (0.10-0.90)
	Consuming Anglers	Baseline	0.15 (0.10-0.32)	0.10 (0.10-0.10)	0.23 (0.10-0.70)	0.33 (0.10-1.11)	0.67 (0.10-2.40)
		Current	0.20 (0.10-0.55)	0.13 (0.10-0.30)	0.40 (0.10-1.50)	0.49 (0.10-1.80)	1.06 (0.10-3.80)
Blue Crab	All Anglers	Baseline	0.05 (0.02-0.10)	0.00 (0.00-0.00)	0.10 (0.10-0.10)	0.21 (0.10-0.50)	0.90 (0.20-2.00)
		Current	0.01 (0.01-0.01)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	0.10 (0.10-0.10)	0.10 (0.10-0.10)
	Consuming Anglers	Baseline	0.28 (0.12-0.55)	0.11 (0.10-0.20)	0.57 (0.10-1.30)	0.96 (0.20-2.20)	2.35 (0.50-5.31)
		Current	0.11 (0.10-0.12)	0.10 (0.10-0.10)	0.11 (0.10-0.20)	0.12 (0.10-0.20)	0.21 (0.10-0.40)
Catfish	All Anglers	Baseline	0.04 (0.02-0.10)	0.00 (0.00-0.00)	0.10 (0.10-0.10)	0.17 (0.10-0.50)	0.61 (0.10-1.90)
		Current	0.01 (0.01-0.03)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	0.10 (0.10-0.10)	0.26 (0.10-0.80)
	Consuming Anglers	Baseline	0.22 (0.11-0.55)	0.11 (0.10-0.20)	0.41 (0.10-1.20)	0.65 (0.10-1.90)	1.55 (0.30-4.71)
		Current	0.20 (0.10-0.49)	0.13 (0.10-0.30)	0.41 (0.10-1.20)	0.51 (0.10-1.70)	1.10 (0.20-3.80)
Carp	All Anglers	Baseline	0.17 (0.02-0.52)	0.00 (0.00-0.00)	0.24 (0.10-0.80)	0.79 (0.10-2.71)	3.34 (0.30-9.42)
		Current	0.04 (0.01-0.11)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	0.11 (0.10-0.20)	0.88 (0.10-2.61)
	Consuming Anglers	Baseline	0.92 (0.13-2.86)	0.27 (0.10-0.81)	2.26 (0.20-6.90)	3.49 (0.30-9.81)	8.28 (0.69-25.85)
		Current	0.55 (0.11-1.66)	0.29 (0.10-0.90)	1.45 (0.10-4.50)	1.77 (0.10-4.90)	3.81 (0.30-11.54)
Striped bass	All Anglers	Baseline	0.13 (0.02-0.49)	0.00 (0.00-0.00)	0.21 (0.10-0.60)	0.62 (0.10-2.30)	2.68 (0.20-10.61)
		Current	0.02 (0.01-0.05)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	0.10 (0.10-0.10)	0.55 (0.10-1.30)
	Consuming Anglers	Baseline	0.72 (0.13-2.69)	0.24 (0.10-0.80)	1.71 (0.19-6.43)	2.75 (0.29-11.12)	6.54 (0.60-25.20)
		Current	0.26 (0.10-0.75)	0.16 (0.10-0.40)	0.58 (0.10-2.30)	0.68 (0.10-2.90)	1.49 (0.10-5.53)
White perch	All Anglers	Baseline	0.10 (0.03-0.29)	0.00 (0.00-0.00)	0.15 (0.10-0.30)	0.53 (0.10-1.30)	1.95 (0.40-5.83)
		Current	0.06 (0.02-0.15)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	0.11 (0.10-0.20)	1.48 (0.40-3.42)
	Consuming Anglers	Baseline	0.57 (0.17-1.59)	0.18 (0.10-0.40)	1.43 (0.30-4.41)	2.08 (0.40-6.70)	4.20 (0.99-12.92)
		Current	0.89 (0.26-2.25)	0.48 (0.10-1.11)	2.43 (0.50-5.90)	2.94 (0.79-6.91)	6.26 (1.60-17.14)

Panel A: White Perch – All Anglers – Current Risk Scenario



Panel B: White Perch – Consuming Anglers – Baseline Risk Scenario

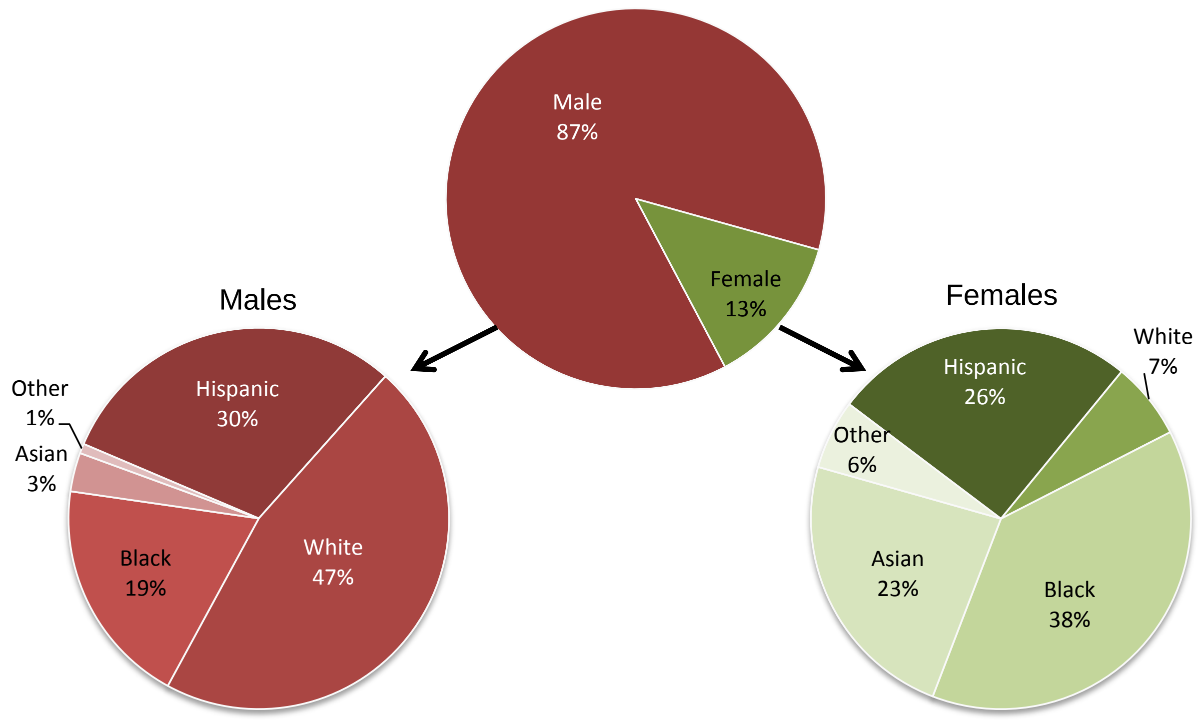


Figure A.1: Comparison of Demographics for All Anglers and Consuming Anglers