Risk Assessment of the Potential Human Health Effect of Applying Continuous Inspection to Catfish

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Table of Contents

Acknowledgements 3

Table of Figures ..... **Error! Bookmark not defined.**

Table of Tables 7

Executive Summary 9

1. Introduction 13

2. Model overview 15

3. Exposure Assessment 20

3.1 Catfish-associated Hazard Concentration (X, $prev_{domestic}$, and $prev_{imports}$) 20

3.2 Storage and Cooking Effect (G, C_{Baked}, and C_{Fried}) 24

3.3 Catfish Consumption ($S_{Bread}, S_{Nonbread}, f_{Bread}, f_{Baked}, f_{imports}$ and $N_{servings}$) 28

4. Hazard Characterization (Dose-Response) 32

5. Risk characterization 33

5.1 Default estimation of numbers of *Salmonella* illnesses per year 34

5.2 Comparison of illnesses per year using surveillance data 36

5.3 Modeling program effectiveness 38

5.4 Program effectiveness estimates 42

5.5 Sensitivity of default illnesses estimates to changes in model inputs 53

5.6 Uncertainty scenario analyses 57

6. Summary 65

7. References 67

8. Appendix: Hazard Identification 73

8.1 Prioritization of Microbial Hazards 73

8.2 Identification of Chemical Hazards 80

8.3 Selected Chemical Residues Detected in Catfish 104

Table of Figures

Figure 1. Inputs to number of *Salmonella* illnesses among U.S. consumers per year..... 15
Figure 2. Inputs to probability of illness per contaminated serving 17
Figure 3. Log reductions of Salmonella due to baking catfish. 26
Figure 4. Log reductions of *Salmonella* due to frying catfish. 27
Figure 5. The cumulative empirical distribution for serving size. 30
Figure 6. Uncertainty in the effectiveness of regulation on the annual number of *Salmonella* illnesses avoided over 10-yrs following FSIS regulation of catfish. These values assume a 5-yr timeframe and the Siluriformes definition of catfish. 44
Figure 7. Uncertainty in the effectiveness of regulation on the annual number of *Salmonella* illnesses avoided over 10-yrs following FSIS regulation of catfish. These values assume a 5-yr timeframe and the Ictaluridae definition of catfish. 49
Figure 8. Tornado diagram describing the elasticity of the model's annual illness estimates to various model inputs. The x-axis here is in elasticity units. 56
Figure 9. Cumulative reduction in the number of illnesses for combined lower bound scenarios. 61
Figure 10. Cumulative increase in the number of illnesses for combined upper bound scenarios. 62

Table of Tables

Table 1. Summary of *Salmonella* concentrations in enumerated positive broiler carcass rinse samples (USDA-FSIS Nationwide Broiler Chicken Microbiological Baseline Data Collection Program, 1994-1995) 23
Table 2. The estimated distribution of Salmonella per gram of contaminated catfish carcass (X). 24
Table 3. Parameters for cooking and growth inputs 25
Table 4. The distribution of growth effect multiplier per serving (*G*) estimated by the model is shown. 26
Table 5. Kilograms of varieties of catfish available for consumption in the United States, 2008..... 31
Table 6. Mean Estimates of Catfish Servings 31
Table 7. Model outputs for the probability of illness per contaminated serving for the combinations of cooking and breading effects. 35
Table 8. The estimated annual numbers of *Salmonella* illnesses for each definition of catfish. 35
Table 9. *Salmonella* Foodborne Outbreaks from 1990 through 2007. 37
Table 10. Estimated baseline *Salmonella* illnesses per year. 43
Table 11. Estimated Number of *Salmonella* illnesses avoided due to FSIS regulation assuming the Siluriformes definition of catfish and a 2-year to effectiveness timeframe.46
Table 12. Estimated Number of *Salmonella* illnesses avoided due to FSIS regulation assuming the Siluriformes definition of catfish and a 10-year to effectiveness timeframe. 47
Table 13. Estimated Number of *Salmonella* illnesses avoided due to FSIS regulation assuming the Siluriformes definition of catfish and a 15-year to effectiveness timeframe. 48
Table 14. Estimated Number of *Salmonella* illnesses avoided due to FSIS regulation assuming the Ictaluridae definition of catfish and a 2-year to effectiveness timeframe... 50
Table 15. Estimated Number of *Salmonella* illnesses avoided due to FSIS regulation assuming the Ictaluridae definition of catfish and a 10-year to effectiveness timeframe. 51

Table 16. Estimated Number of *Salmonella* illnesses avoided due to FSIS regulation assuming the Ictaluridae definition of catfish and a 15-year to effectiveness timeframe. 52
Table 17. An outline of potential lower and upper bound values for various model inputs is shown. Symbols are used to identify changes in Figure x and y. 59
Table 18. Estimated Number of *Salmonella* illnesses avoided by FSIS regulation of catfish using the Siluriformes definition of catfish; assuming a 5-year timeframe and 50% effectiveness of FSIS inspection. 64
Table 19. FDA Violation Codes for Catfish Refusals 75
Table 20. Summary of Recent Catfish Residue Data 105

Executive Summary

The Food, Conservation, and Energy Act of 2008 (Public Law 110-246, §10016(b)), known as the 2008 Farm Bill, amended the Federal Meat Inspection Act (FMIA) to provide that "catfish, as defined by the Secretary," is an amenable species under the FMIA. The 1994 Federal Crop Insurance Reform and Department of Agriculture Reorganization Act (Title III, § 304, 7 U.S.C. 6901), requires the United States Department of Agriculture (USDA) to ensure that all "major regulations" – a regulation estimated to have an annual impact on the economy of at least $100 million in 1994 dollars – involving human health, safety, or environment are supported by a sound risk assessment and benefit-cost analysis.

In accordance with this mandate, the USDA Food Safety and Inspection Service (FSIS) considers it important to assess the food safety risk associated with consuming farm-raised catfish in the United States. However, limited information on the distribution of microbial contamination and chemical residues on catfish limit our ability to make strong statements about the baseline risk. Furthermore, the lack of experience with implementing continuous inspection programs in the context of aquaculture makes estimating the impact of such a program on risk difficult. As such, the risk assessment FSIS presents here simply provides insight into the risk reductions that might accompany the implementation of the type of continuous inspection program now required for catfish under the FMIA. The illustrative risk assessment presented here focuses on exposure to *Salmonella* because a broad hazard identification study identified *Salmonella* as a potential concern in catfish. We are particularly interested in *Salmonella* because the general burden of illness from this pathogen in the U.S. remains a concern and there is evidence that at least one outbreak of human salmonellosis may have been related to catfish consumption.[25] Although catfish-specific information is unavailable, FSIS has empirical evidence describing the effectiveness of an FSIS continuous inspection program for *Salmonella* control in other regulated species (i.e., poultry). The Appendix of this report identifies other potential chemical and microbial hazards. Once implemented,

[25] For purposes of convenience, this risk assessment simply uses the term "catfish" to refer to all fish classified within the order of Siluriformes. The use of this term is not with prejudice to what fish FSIS will ultimately determine to be "catfish" for purposes of the final rule.

the continuous inspection program will generate data on chemical and microbial hazards that can be used to develop better estimates of risk.

The objectives of this illustrative risk assessment for *Salmonella* are:

1) To estimate the annual numbers of human salmonellosis cases from catfish
2) To estimate the potential number of cases that might be avoided following implementation of an FSIS continuous inspection program
3) To compare these estimates with those based on to public health surveillance evidence
4) To explore the sensitivity of these estimates to different modeling assumptions
5) To characterize some aspects of the uncertainty surrounding these risk assessment model estimates.

The risk assessment model uses Monte Carlo techniques to combine the random variables that estimate exposures for four different exposure classes, which include the most common ways catfish is prepared in the United States. There are four key assumptions underlying the risk assessment model:

1) Estimates of the current level of *Salmonella* contamination on catfish
    - *Salmonella* contamination data from poultry were used as surrogates for catfish contamination
    - The same data (from poultry) were used for both import and domestic catfish
    - Catfish handling during retail and home storage was considered independent of the initial *Salmonella* concentration on the catfish carcass.
2) Estimated amount of catfish consumption in the US
    - Each catfish serving was derived from a single catfish carcass.
3) Modeled estimates of illness incidence
    - Incidence of salmonellosis cases was estimated using WHO/FAO's dose-response relationship
4) Potential levels of effectiveness associated with the FSIS continuous inspection program
    - Empirical data on program effectiveness for FSIS poultry inspection (i.e. broilers) was used.

With regard to the risk assessment for catfish, FSIS continues to evaluate the hazards, particularly *Salmonella*, associated with this fish. FSIS invites all interested stakeholders to submit additional data and scientific evidence specific to catfish food safety. FSIS will

consider this information and other data in the development of a final risk assessment in this proceeding.

The range of risk estimates is dependent on uncertainty about the model form and inputs. The assumptions listed above and the quality of available data both contribute to the level of uncertainty in risk assessment model outputs. Such input uncertainties translate into substantial uncertainty about the estimated baseline number of salmonellosis cases attributable to catfish consumption. Consideration of modeled lower and upper bound scenarios suggest estimates between 100 and 6,200 salmonellosis cases might be associated with catfish consumption annually, depending upon how many fish are actually inspected.

The eventual determination regarding how catfish will be defined in this regulation directly effects the estimated reduction in salmonellosis cases following introduction of an FSIS catfish inspection program. One potential definition of catfish includes all fish in the order Siluriformes, whereas another potential definition includes only fish within the Ictaluridae family. This risk assessment estimates a current annual average of 2,308 salmonellosis cases under the potential Siluriformes definition of catfish and a current annual average of 1,764 salmonellosis cases under the potential Ictaluridae definition. These estimates seem consistent with an independent estimate based on the limited data available from the Department of Health and Human Services' Centers for Disease Control and Prevention (CDC) regarding outbreaks that may have been associated with catfish. Regardless of the definition of catfish, the model estimates an average probability of illness of 1.5×10^{-6} salmonellosis cases per serving, though this number could be substantially lower because our baseline information on the rate of contamination is extremely limited. This probability incorporates the prevalence of contaminated servings and suggests that *Salmonella* illness from catfish is an uncommon event.

There is substantial uncertainty regarding the effectiveness of a future FSIS inspection program aimed at reducing the prevalence of *Salmonella*-contaminated catfish, and different levels of effectiveness yield different levels of benefit. To better serve as a decision tool, this risk assessment models a range of assumptions – from 10% to 90%

inspection program effectiveness – to estimate public health benefit outcomes. For example, if an FSIS inspection program is 50% effective within a 5-year timeframe, our model estimates that between 50 and approximately 3,100 *Salmonella* illnesses (Siluriformes definition) or between 38 and approximately 2,353 *Salmonella* illnesses (Ictaluridae definition) might be prevented annually. In the scenario of a 2-year time frame and a range of 10% to 90% effectiveness, the model estimates that between 176 and 1,587 *Salmonella* illnesses per year might be prevented if catfish is defined as Ictaluridae. This is about 24% fewer salmonellosis cases prevented per year compared to when catfish are defined as Siluriformes.

This risk assessment's outputs are subject to substantial uncertainty regarding both the estimated baseline number of salmonellosis cases attributable to catfish consumption and the extent to which the experience associated with controlling salmonella in poultry is applicable to controlling salmonella in catfish. Once the FSIS inspection program is in place, however, the data generated will allow the Agency to further address the effect of inspection on chemical hazards and other microbial hazards (in addition to *Salmonella)* that can cause adverse human health outcomes associated with the consumption of farm raised catfish.

1. Introduction

This risk assessment provides an estimate of the differential effect of introducing an FSIS continuous catfish inspection program on the potential number of human *Salmonella* illnesses from farm-raised catfish consumption each year. The Appendix provides a comprehensive catalog of other chemical and microbiological hazards that have been associated with seafood or aquaculture and, thus, have the potential to be present in catfish. Additionally, the Appendix provides information on current testing data for chemical hazards. The main body of this risk assessment report, however, describes the quantitative modeling approach used for the analysis of the high priority microbial hazard *Salmonella*. The identification of *Salmonella* as a microbial hazard of potential concern includes reasons outlined in the executive summary as well as the Hazard Identification section in the Appendix.Appendix: Hazard Identification.

This risk assessment model estimates the potential public health effect of implementing an FSIS continuous inspection program for farm-raised catfish. Incorporated into the model was the consideration of two different potential definitions of catfish. The definition of catfish that is consistent with the 2002 Farm Bill[26] is specific to the family Ictaluridae, native to North America. However, there are additional families of fish on the commercial market in the order Siluriformes, where the North American family Ictaluridae resides. Therefore, an evaluation of public health effect of using the Ictaluridae definition of "catfish" represents a different range of exposure to that of the Siluriformes definition for "catfish". This risk assessment includes an evaluation of public health risks resulting from exposure to *Salmonella* for both Siluriformes and Ictaluridae.

This report consists of four sections. An overview section explains the conceptual model and its mathematical structure. The exposure assessment section explains the modeling inputs used to estimate exposures of humans to *Salmonella* in catfish servings. The hazard characterization section introduces the dose-response relationship used to estimate the probability of illness per *Salmonella*-contaminated catfish serving. The risk

[26] Farm Security and Rural Investment Act of 2002, known as the 2002 Farm Bill, amended the Federal Food, Drug, and Cosmetic Act (21 United States Code §§ 321d(a), 343(t); Public Law 107-171, Title X, §10806, 116 Statute 526).

characterization section combines the exposure assessment with the hazard characterization to:

- estimate numbers of human *Salmonella* illnesses occurring per year
- estimate the potential number of human *Salmonella* illnesses that might be avoided following implementation of an FSIS inspection program
- determine the consistency of these estimates relative to public health surveillance evidence
- examine the sensitivity of these estimates to different modeling assumptions
- characterize the uncertainty surrounding these risk assessment model estimates.

2. Model overview

Estimating annual human salmonellosis cases potentially resulting from consuming contaminated catfish comprises two basic steps. First, the number of contaminated catfish servings consumed each year is based on domestic catfish production and import data, and estimates of the prevalence of *Salmonella* contamination of catfish (Figure 1). Second, the estimated average probability of illness across all contaminated catfish servings is determined by modeling contaminated servings of catfish from the point of production through consumption (Figure 2). The product of these two steps estimates the annual number of human salmonellosis cases in the United States.

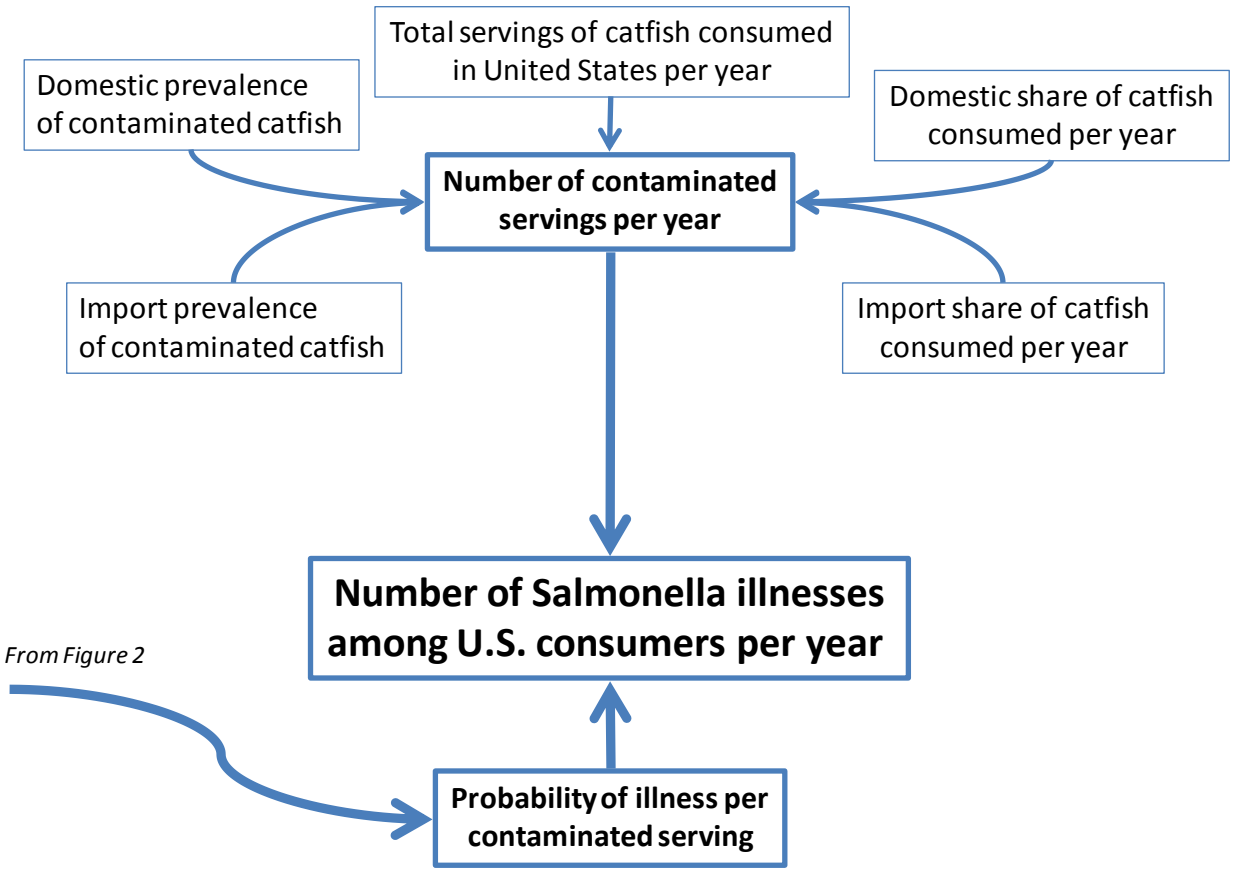

Figure 1. Inputs to number of *Salmonella* illnesses among U.S. consumers per year

Mathematically, the first step is a simple algebraic calculation of the annual number of *Salmonella*-contaminated catfish servings.

Equation 1

$$\#\ contaminated\ servings\ /\ yr\ = N_{servings}\left[\ f_{imports} \times prev_{imports}\ +\ (1-f_{imports}) \times prev_{domestic}\ \right]$$

where $N_{servings}$ is the total number of servings of catfish consumed in the U.S. per year, f_{import} is the fraction (share) of all servings generated by imported catfish, $prev_{domestic}$ and $prev_{import}$ are the proportions of domestic and imported catfish contaminated with some level of *Salmonella*. This modeling approach assumes that each catfish carcass produces roughly the same average number of servings regardless of its contamination status. The values for these inputs are described in the Exposure Assessment section.

The model assumes each catfish serving derives from a single catfish carcass (i.e., servings are not mixtures of multiple carcasses). The model considers the average concentration of *Salmonella* (per gram of a catfish carcass) for contaminated catfish only. This concentration randomly varies among contaminated catfish. It is assumed that the average concentration of *Salmonella* per gram of a contaminated catfish is independent of the size of serving generated from a catfish (i.e., the grams of catfish in a consumed serving does not depend on the amount of *Salmonella* per gram on the contaminated carcass). Furthermore, it is assumed that handling of catfish during retail and home storage (and cooking of catfish serving prior to consumption) is independent of the concentration of *Salmonella* initially on the carcass. (Because consumers will not be aware of the concentration of *Salmonella* on any particular catfish carcass, these assumptions seem reasonable.)

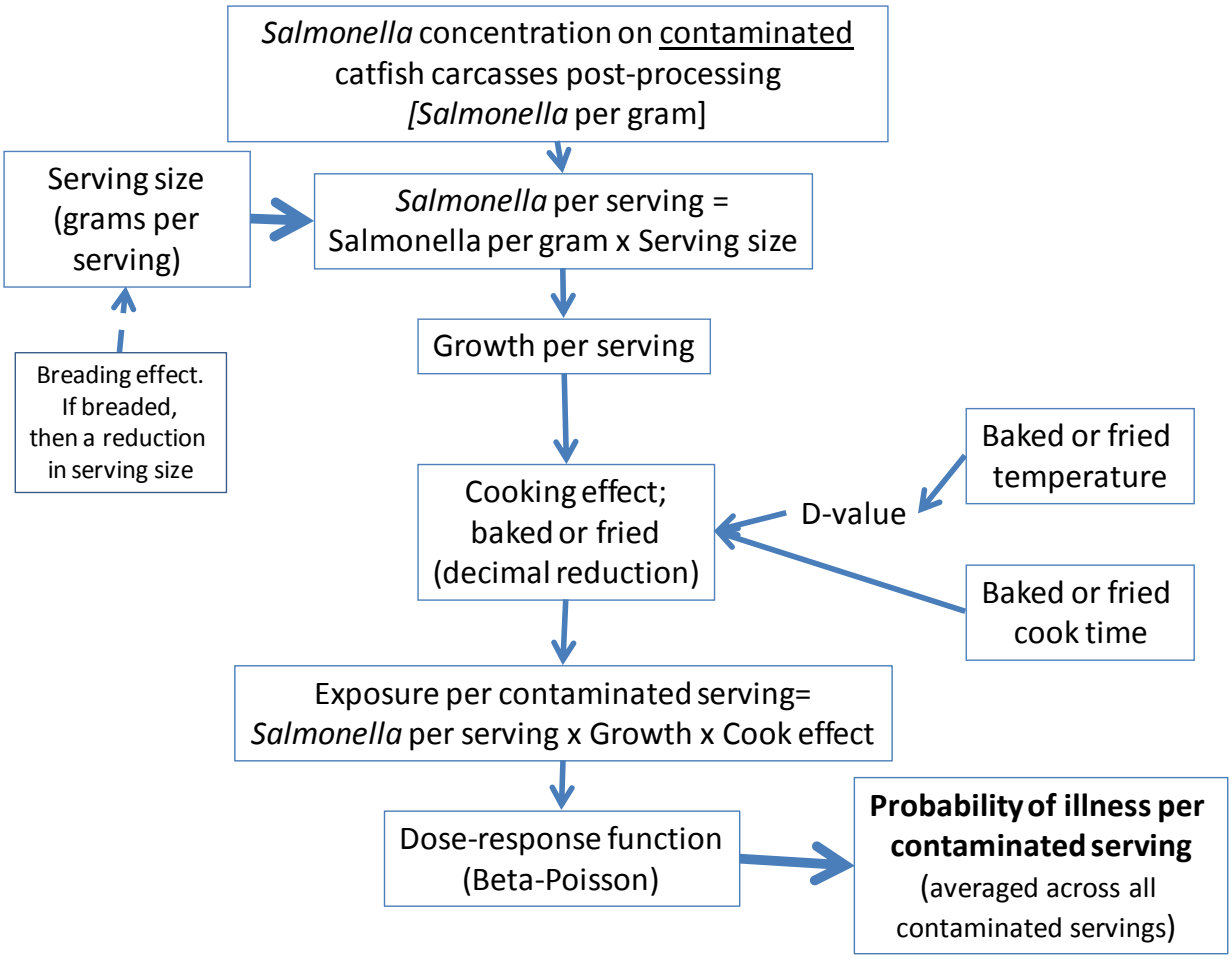

Figure 2. Inputs to probability of illness per contaminated serving

Mathematically, the average exposure dose of *Salmonella*[27] consumed in a random contaminated catfish serving is modeled as;

Equation 2 $D = X \times S \times G \times C$

where D is one instance of an average exposure dose of *Salmonella* consumed, X is one instance of an average *Salmonella* concentration per gram of a contaminated catfish carcass, S is one instance of a catfish serving size (in grams consumed), G is one instance

[27] Average dose of *Salmonella* is modeled because the beta-Poisson dose-response relationship is based on an average number of organisms in a serving. For example, if a value for average *Salmonella* dose of 0.2 CFU is used in the beta-Poisson, the function determines the probability that a serving will contain one or more CFU's (based on Poisson probabilities), as well as the probability that each integer unit *Salmonella* dose will result in illness (based on beta probabilities). Ignoring this aspect may lead to incorrectly including a Poisson function to determine integer *Salmonella* doses consumed in the exposure assessment; this would essentially 'double-count' the Poisson effect once the beta-Poisson relationship was included.

of the growth of *Salmonella* on a catfish carcass (to account for handling and storage between processing and consumption), and C is one instance of the expected reduction of *Salmonella* in a serving of catfish caused by the effects of cooking. The inputs to this calculation (X, S, G, C) are random variables. The inputs for catfish serving size and the effect of cooking, however, are somewhat complicated.

The amount of catfish in a serving depends on whether the serving was breaded or not. Breaded servings contain a smaller amount of catfish, on average, than non-breaded catfish servings. Therefore, there are actually two variables for the servings of catfish – one for breaded servings (S_{Bread}) and one for non-breaded servings ($S_{Nonbread}$).

The effect of cooking depends on the method used. Baking tends to involve longer cook times than frying. Therefore, there are two variables to differentiate the type of cooking used for catfish – one for baked servings (C_{Baked}) and one for fried servings (C_{Fried}).

A dose-response relationship is used to predict the probability of salmonellosis for each serving of catfish contaminated with *Salmonella*. There are four categories of catfish exposures assessed:

1. Breaded and baked ($D_{Bread,Baked}$);
2. Breaded and fried ($D_{Bread,Fried}$);
3. Non-breaded and baked($D_{Nonbread,Baked}$); and
4. Non-breaded and fried ($D_{Nonbread,Fried}$).

For each category of catfish consumed, the average probability of salmonellosis across all contaminated servings within the class is determined as:

Equation 3 $$P_{b,c}(ill) = \frac{1}{n}\sum_{i=1}^{n}\left[1-\left(1-\frac{D_{b,c_i}}{\beta}\right)^{-\alpha}\right]$$

where n is the number of iterations of the Monte Carlo model, and b and c symbolize the breading and cooking indexes, respectively. This calculation is a numeric integration assuming a beta-Poisson dose-response function with parameters α and β .

Given the preceding discussion, the annual number of human salmonellosis cases from catfish exposure is estimated as:

Equation 4

$$Number_ill/yr = \#contaminated\ servings/yr \times \left[\begin{array}{l} f_{Bread} \times f_{Baked} \times P_{Bread,Baked}(ill) + \\ f_{Bread} \times \left(1 - f_{Baked}\right) \times P_{Bread,Fried}(ill) + \\ \left(1 - f_{Bread}\right) \times f_{Baked} \times P_{NonBread,Baked}(ill) + \\ \left(1 - f_{Bread}\right) \times \left(1 - f_{Baked}\right) \times P_{NonBread,Fired}(ill) \end{array} \right]$$

where f_{Bread} is the fraction of catfish servings that are breaded and f_{Baked} is the fraction of catfish servings that are baked.

The risk assessment model uses Monte Carlo techniques to convolve the random variables (X, S, G, C) that predict exposures for each of the four exposure classes and complete the numeric integration step described in Equation 3. The model is currently developed in the R software package (http://www.r-project.org/ Version 2.9.1), but is equivalently solvable in any software that supports Monte Carlo simulation. Each simulation of the model comprises three million iterations. Each model iteration represents a different contaminated serving of catfish across all four exposure pathways.

3. Exposure Assessment

The exposure assessment estimates the annual exposures to *Salmonella* from catfish consumed in the U.S. Model inputs for the exposure assessment are explained in the following sections. The catfish-associated hazard concentration section describes the development of the inputs X, $prev_{domestic}$, and $prev_{imports}$. The storage and cooking effect section considers the effects of G, C_{Baked}, and C_{Fried}. The section on catfish consumption describes the development of the inputs S_{Bread}, $S_{Nonbread}$, $f_{Breaded}$, f_{Baked}, $f_{imports}$, and $N_{servings}$.

3.1 Catfish-associated Hazard Concentration (X, $prev_{domestic}$, and $prev_{imports}$)

No empiric evidence regarding concentrations of *Salmonella* on processed catfish carcasses was available and limited evidence was available regarding the prevalence of *Salmonella* contaminated catfish. One U.S. study collected 220 catfish fillets from August 1994 through May 1995 (McCaskey et al., 1998). That study found 5 (2.3%) positive samples. This evidence was used to represent the default prevalence of *Salmonella* contamination of catfish ($prev_{domestic}$) in the model.

Although the Food and Drug Administration's (FDA) Office of Regulatory Affairs/Division of Field Science collects some samples of imported catfish, those samples are pooled samples of multiple catfish homogenized for regulatory testing. Furthermore, the samples are intentionally targeted towards imported shipments thought to have a higher probability of testing positive. The pooled and biased nature of these catfish data would likely over-estimate the prevalence of *Salmonella* contamination of catfish consumed in the U.S. Furthermore, these inherent sampling and *Salmonella* testing biases make reasonable inferences about *Salmonella* prevalence among imported catfish from FDA data nearly impossible. Lacking any other evidence regarding *Salmonella* prevalence on imported catfish, the catfish risk assessment assumed that the prevalence of *Salmonella* on imported catfish is the same as the prevalence of *Salmonella* found on domestic catfish (i.e., a default assumption that $prev_{imports} = prev_{domestic}$).

While there is limited data on the prevalence of *Salmonella*-contaminated catfish, there is no data on the amount (concentration) of *Salmonella* per gram of catfish. Therefore, the concentration of *Salmonella* on contaminated catfish, model input X , is assumed to be reflected by available *Salmonella* enumeration results from FSIS poultry (i.e. broiler) testing programs. There are a variety of limitations with the use of poultry *Salmonella* testing data as a surrogate that effects what we might see after implementing a continuous inspection program for catfish. On the other hand, we note that it might be the best option available for such an analysis because:

1. Of the species FSIS currently regulates, poultry represent a surface area to mass ratio that most closely approximates this ratio for catfish.
2. *Salmonella* testing methods for poultry would more nearly approximate those used for catfish (i.e., both methods use whole carcass rinsing) than testing results for other species that FSIS regulates. Also, the enumeration of *Salmonella* concentrations on poultry using these methods makes extrapolation to *Salmonella* per carcass more intuitive compared to cattle or hog carcass sampling techniques that do not involve rinse sampling of the entire carcass surface area.
3. Poultry processing typically involves a carcass chilling step that requires submersion of carcasses in water that might reflect the potential cross-contamination that can occur in the aquatic environment of catfish.

Although use of poultry concentration data as a surrogate for catfish concentration data is arguable, the concept that *Salmonella* contamination levels on catfish are variable is crucial to assessing risk. Ignoring this variability in the risk assessment would potentially undervalue the risk posed to consumers because catfish servings with larger concentrations of *Salmonella* might not be considered.

The FSIS nationwide broiler chicken microbiological baseline data from 1994-1995 were used to estimate *Salmonella* concentrations on catfish (USDA-FSIS, 1996). This survey was chosen because it represented a snapshot of the poultry industry prior to the formal implementation of a new FSIS inspection program (HACCP). The current regulatory decision for the catfish industry is similar to the decision made in the mid-1990's for broiler poultry and other FSIS-regulated species in that a new FSIS program

will be implemented. The existing regulatory program under FDA serves as the baseline protection of food safety, upon which the new FSIS inspection program will be built. Because this risk assessment will ultimately predict human illnesses avoided following implementation of a new FSIS-style regulatory system within the catfish industry, it seems appropriate to consider the status of the broiler poultry industry prior to the implementation of HACCP by FSIS.

The broiler poultry data imply that most contaminated carcasses have low *Salmonella* concentrations (Table 1). For this analysis, positive broiler poultry samples with a Most Probable Number per milliliter (MPN/ml) values <0.03 (i.e., below the limit of enumeration) were assumed to be uniformly distributed between 0.0025 MPN/ml (i.e., the assumed absolute lower limit of qualitative detection in a 400 ml chicken rinse sample) and 0.03 MPN/ml. For *Salmonella* concentrations greater than 0.03 MPN/ml, values are randomly distributed according to the data summarized in Table 1[28]. To adjust these data to units of *Salmonella* per gram of catfish, the following calculation was completed:

Equation 5

$$Salmonella/gram = \frac{MPN}{ml} \times 400ml \times \frac{1}{1500g}$$

This calculation indicates that the *Salmonella* concentration per ml of rinse is expanded by the 400 ml rinse volume to estimate total MPN per carcass; this total is then divided by 1,500 grams to account for the average weight of a broiler poultry carcass.

Broiler poultry rinse samples typically come from skin-on carcasses. Evidence suggests that pathogen concentrations are 0.4 to 0.9 logs less for skinless poultry carcasses (Davis and Conner, 2007; Berrang et al., 2002). Because catfish are generally sold skinless, broiler poultry concentrations are translated to catfish concentrations by adjusting for the skinless catfish carcass. As a default, it is assumed that catfish *Salmonella* concentrations are 0.65 logs (midway between 0.4 and 0.9) less than poultry concentrations. This step is modeled by multiplying the value obtained in Equation 5 by 0.22 ($10^{-0.65} = 0.22$).

[28] Initial attempts to fit these data to parametric distributions suggested a poor fit. Therefore, this risk assessment uses an empirical cumulative distribution based on the data in Table 1 to model variability in *Salmonella* concentration.

Equation 6 $$Salmonella/gram_{NoSkin} = \frac{MPN}{ml} \times 400ml \times \frac{1}{1500g} \times 0.22$$

One last adjustment truncates the distribution of *Salmonella* concentration on catfish at a minimum of 1 colony forming unit (CFU) per 330 gram to represent the average weight of a catfish carcass (Morris, 1993)[29]. For a default assumption, any concentration resulting from the adjusted broiler poultry data that is less than 0.003 CFU/g is assumed to equal 0.003 CFU/g. Nevertheless, in scenarios exploring uncertainty, the risk assessment model randomly redistributes concentrations less than 0.003 CFU/g to values above that threshold.

Table 1. Summary of *Salmonella* concentrations in enumerated positive broiler carcass rinse samples (USDA-FSIS Nationwide Broiler Chicken Microbiological Baseline Data Collection Program, 1994-1995)

Range, MPN/ml	Number of samples	Cumulative percent
<0.03	109	41.9
0.03 – 0.30	118	87.3
0.301 - 3.0	24	96.5
3.01 - 30.0	6	98.8
>30.0	3	100.0
Total	260	

The resulting random variable X (average *Salmonella* per gram of contaminated catfish carcass) estimates that 64% of contaminated carcasses have *Salmonella* concentrations of 0.003 per gram (the theoretic minimum level) (Table 2). Because a serving of catfish generally represents something less than the entire carcass weight, the amount of *Salmonella* actually in a serving of catfish could be less than one *Salmonella* bacterium. The maximum concentration of *Salmonella* on a catfish carcass is estimated to

[29]It is assumed that the average catfish marketed in the U.S. is 1.44 pounds (http://usda.mannlib.cornell.edu/usda/nass/CatfProd//2000s/2009/CatfProd-01-30-2009_revision.pdf) and an average dressing percentage of 50% (Morris, 1993).

be 16.7 bacteria per gram. For comparison, the maximum concentration for broiler poultry was ~75 *Salmonella* per gram[30].

Table 2. The estimated distribution of Salmonella per gram of contaminated catfish carcass (X).

Cumulative frequency	*Salmonella* per gram of catfish carcass	Average *Salmonella* per carcass*
0%	0.003	1
64%	0.003	1
68%	0.005	2
75%	0.006	2
76%	0.007	2
80%	0.010	3
81%	0.013	4
82%	0.014	5
87%	0.016	5
90%	0.029	10
91%	0.030	10
92%	0.039	13
95%	0.064	21
96%	0.157	52
97%	0.417	139
98%	1.006	335
99%	2.106	701
100%	16.715	5,566

* Average *Salmonella* per carcass is estimated by assuming each carcass weighs 333 grams

3.2 Storage and Cooking Effect (G, C_{Baked}, and C_{Fried})

Salmonella concentrations on raw processed catfish at the point of consumption are adjusted to account for concentration changes associated with both storage and cooking of catfish. Microbial hazard concentrations may increase during storage and preparation and typically decrease during cooking. Specific modifying factors for *Salmonella* were calculated based on cooking style (e.g. baked versus fried). Because

[30] The maximum *Salmonella* MPN/ml from the USDA-FSIS 1994-1995 baseline study was 280. The maximum implied a *Salmonella* concentration per gram of chicken of: $\frac{280MPN}{ml} \times \frac{400ml}{1500g} = 74.7MPN/g$.

specific evidence regarding *Salmonella* growth and cooking effects is not available for catfish, modeling techniques from a published risk assessment regarding *Salmonella* in chicken were used for these factors (Oscar, 2004).

Variability of growth multiplication and cooking decimal reductions was based on *Pert* (min, most likely, max) distributions for log growth, cooking time, and cooking temperature (Table 3). The *Salmonella* growth model and parameters were adopted directly from predictive microbial models for chicken developed by Oscar (2004); that model includes the assumption that growth could only occur among 0.02% of servings. The cooking model was also based on Oscar (2004), but time and temperature parameters for baking or frying catfish were based on expert opinion and review of several on-line cooking recommendations.

Table 3. Parameters for cooking and growth inputs

Factor	Equation	Cooking type	Parameters		
			Min	Most likely	Max
Cooking	$C=\frac{1}{10^{\left(\frac{Pert\ \underset{time}{min},\ \underset{time}{most\ likely},\ \underset{time}{max}}{10^{\left(8.7344-\left(0.1316*Pert\ \underset{temp}{min},\ \underset{temp}{most\ likely},\ \underset{temp}{max}\right)\right)}}\right)}}$	Baked (minutes)	12.00	13.50	15.00
		Baked (°C)	58.75	64.20	69.70
		Fried (minutes)	6.00	9.00	12.00
		Fried (°C)	58.75	64.17	69.70
Growth	$G=10^{Triangle\ \ min,\ most\ likely,max}$	All methods	0	0.04	0.15

The random variable for growth effect (G) estimates 99.98% of servings are unchanged between processing and consumption (Table 4). The remaining small fraction of contaminated servings in which growth occurs experience a 10% to 40% increase in the number of *Salmonella* within the serving.

Table 4. The distribution of growth effect multiplier per serving (*G*) estimated by the model is shown.

Cumulative frequency	Growth effect multiplier
0.000%	1
99.970%	1
99.980%	1.1
99.992%	1.2
99.999%	1.3
100.000%	1.4

The reduction in *Salmonella* per serving caused by baking (C_{Baked}) extends from nearly 1.2 logs to nearly 40 logs (Figure 3). The logs of the median and mean reductions are about 7 and 3, respectively.

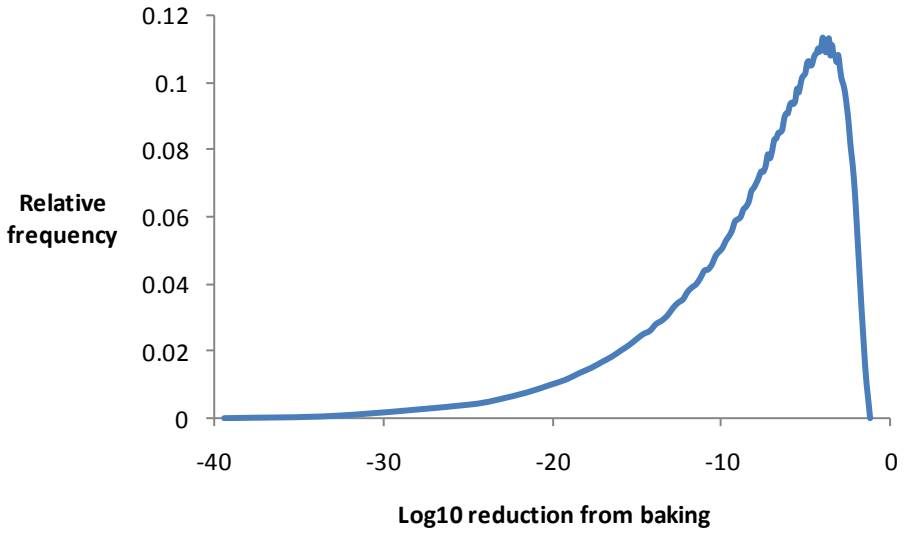

Figure 3. Log reductions of Salmonella due to baking catfish.

The reduction in *Salmonella* per catfish serving caused by frying (C_{Fried}) extends from less than 1 log to nearly 30 logs (Figure 4). The logs of the median and mean reductions are about 4.5 and 2, respectively.

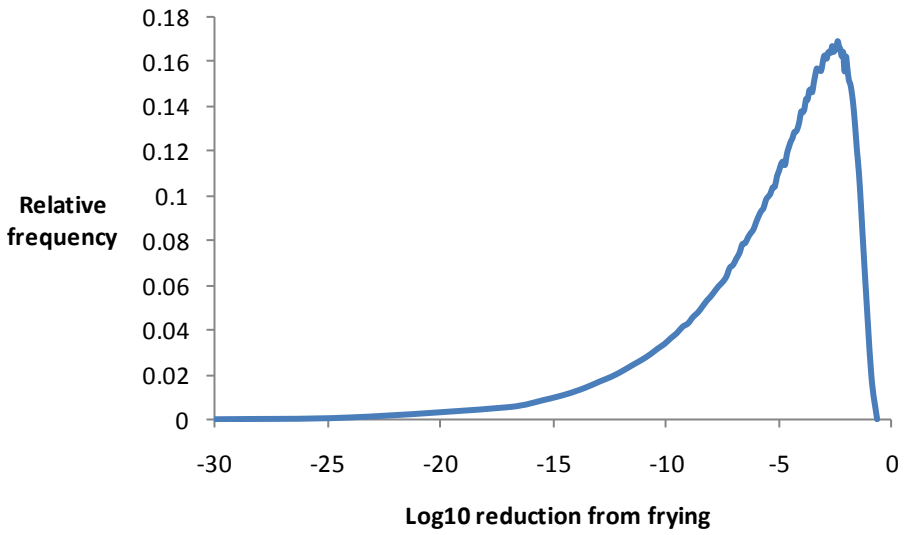

Figure 4. Log reductions of *Salmonella* due to frying catfish.

3.3 Catfish Consumption ($S_{Bread}, S_{Nonbread}, f_{Bread}, f_{Baked}, f_{imports}$ and $N_{servings}$)

Data on the consumption of catfish in the U.S. were obtained from the National Health and Nutrition Examination Survey (NHANES). Four 2-year consumption survey data sets (1999-2006) of total size 41,474 were combined to create an 8-year data file of single 24-hour consumption recall estimates and a combined 4-year file of two 2-year datasets (2003-2006) of total size 20,471, with first and second day 24-hour recall estimates. The 8-year file of consumption data was taken from the 1-day mobile examination center (MEC) face-to-face interviews and used 8-year MEC weights permitting standardization of the sample results to the 2000 U.S. census. Estimates were made for the U.S. population at the midpoint of the 8-year survey period using SAS-Callable SUDAAN software (version 10, Research Triangle Institute International, Research Triangle Park, NC). Similarly, the 4-year dataset used the MEC examination and interview results for the first 24-hour recall and a second telephone interview 24-hour recall within 3 to 10 days of the first interview. The 2-day NHANES weights, corrected for post stratification and non-response, were used in the 4-year dataset analysis. Each dataset was validated for completeness and 2122 subjects were eliminated from the calculations leaving 39,352 validated subjects in the 8-year dataset, 18,382 validated subjects in the first day of the 4-year dataset, and 16,781 validated subjects in the second day of the 4-year dataset.

The 8-year dataset provided 249 consumers of catfish, while the 4-year one and two day combined datasets provided 125 and 110 consumers respectively. In the latter study, only 8 subjects were validated for both first and second day interviews. The 8-year dataset provided the estimate for grams of catfish consumed per day, which did not differ significantly from the combined 4-year dataset estimate. The estimates for the fractions of baked and breaded catfish consumed and annual percent catfish consumers were made from the combined averaged data over all survey years and interview days.

Two datasets were evaluated because of the low frequency of catfish consumers in the survey population and the motivation to find the best dataset. The NHANES priority was to over-sample women, children, and minorities requiring a multi-stage sampling design for estimation of U.S. population mean and standard error of the total daily grams of catfish consumption and the fractions of baked and breaded catfish

consumed. Because the second day data did not sufficiently provide within subject variability estimates due to only eight persons actually validated for both first and second day interviews, a correction for the averaged first and second day responses was assessed by simulation using the SUDAAN "HOTDECK" procedure to produce estimates of between and within subject error providing the necessary factors for reducing increased variance bias using the National Research Council (1986) recommendation for bias correction. Additionally, the recommended procedure for estimating nutrient intake from complex survey data was employed (Nusser et al., 1996).

Due to the smaller sample size, the mean, variance, and percentile estimates for daily grams catfish consumed for the combined 4-year dataset were not significantly different from the 8-year dataset using standard T-tests for the mean, F-tests for variance, and the Kolmogorov-Smirnov two-sample test for distribution shape at 95% confidence. The standard Taylor series linearized estimates from the SUDAAN DESCRIPT procedure provided the smallest error estimates compared with the internal validation methods employed. The validation methods were Jackknife (N-1) (SUDAAN proc DESCRIPT), balanced repeated replication (Fay's modified BRR in WesVar, Westat, Inc. Rockville, MD 2008), and the Rao-Wu-Yue bootstrap (Rao et al., 1992). Each of the validation methods provided mean and percentile estimates that were within the 95% confidence intervals of the Taylor series estimates. However, the variance estimates showed significantly more variability and were each contained only within the 99% confidence interval. This type of variability was expected and did not affect the risk model since the mean estimate for grams catfish consumed per day was used which was shown to be stable.

The mean serving size determined from the 8-year dataset analysis was 122.28 grams per eating occasion. Given the low frequency of catfish consumption, this analysis assumed the quantity consumed in one day represented a single catfish serving. The serving size random variable ranges from 5 grams to over 500 grams (1^{st} and 99^{th} percentiles) (Figure 5). This random variable is modeled as an empiric distribution because attempts to fit the data to parametric distributions did not demonstrate adequate goodness of fit.

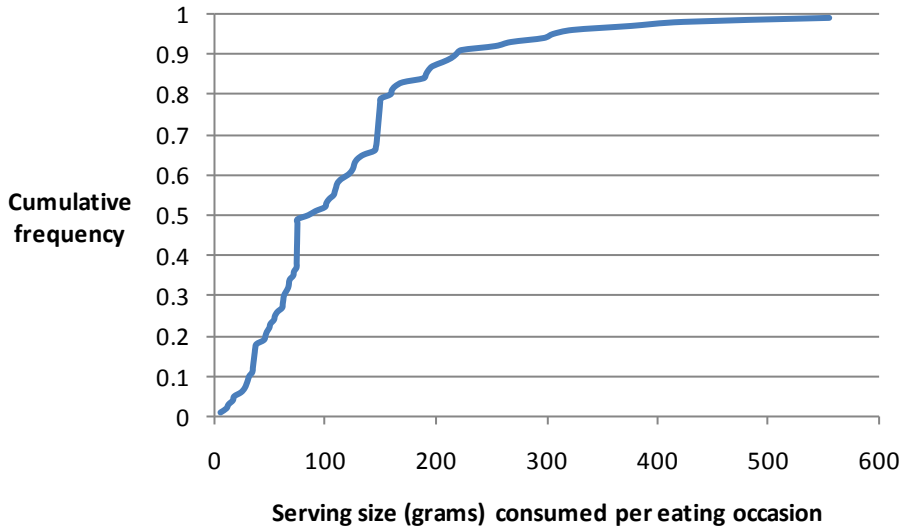

Figure 5. The cumulative empirical distribution for serving size.

The estimates for fraction baked and fraction breaded were taken from both the one and two day datasets as independent estimates using the SUDAAN CROSSTAB procedure and averaged. Six catfish food codes were used to ascertain the fraction baked (versus fried) and the fraction breaded as proportions of the weighted U.S. population catfish consumer estimates. The population-adjusted estimates were $f_{Bread} = 0.79$ and $f_{Baked} = 0.24$. Breading is assumed to represent between 20% and 30% of total serving weight (TAES, 1989). Therefore, serving size for breaded servings is multiplied by a randomly selected value between 0.7 and 0.8 (i.e. $Bread_effect = Uniform(0.7, 0.8)$) to adjust for the amount of catfish in such servings.

Data from 2008 regarding total sales of catfish products were summarized (USDA-NASS, 2009). These data were adjusted slightly to estimate the proportion of amount sold that was catfish meat. For example, whole dressed and steak cuts were assumed to be 67.5% and 80% edible meat, respectively. In contrast, fillets and nuggets were assumed to represent 100% edible meat.

The combination of total domestic sales and total imported catfish in 2008 was assumed to represent the total quantity of catfish consumed annually (Table 5). Imported catfish were reported by type; *Ictalurus*, *Pangasius* and other Siluriformes. Imports constitute a smaller fraction of total *Ictalurus* $\left(f_{imports} = \frac{10,470,953}{116,150,192} \approx 9\% \right)$ than total

Siluriformes $\left(f_{imports} = \frac{46,276,651}{151,955,889} \approx 30\% \right)$. Also, total Ictaluridae catfish available for consumption represent about 76% $\left(\frac{116,150,192}{151,955,889} \right)$ of all fish in the order Siluriformes.

Table 5. Kilograms of varieties of catfish available for consumption in the United States, 2008.

Origin	*Ictalurus*	*Pangasius*	Other Siluriformes	Totals
Imported	10,470,953	35,748,529	57,169	46,276,651
Domestic	105,679,239	0	0	105,679,239
Total	116,150,192	35,748,529	57,169	151,955,889

Given the estimates for average serving size and total catfish consumed, the total number of catfish servings $N_{servings}$ is estimated (Table 6). Nevertheless, average serving size is adjusted to account for the fraction of servings that are breaded (i.e., serving size reported by consumers includes the breading material, while catfish sales does not include breading). The average serving size of catfish (adjusted for breading material) is calculated as follows:

$$Avg.serving\ size = Serving_size_{NHANES}\left[1 - f_{Bread} + f_{Bread} \times Bread_effect \right] = 98.13 grams$$

Table 6. Mean Estimates of Catfish Servings

Catfish definitions	Mean Serving Size (g)[1]	Annual U.S. Catfish Consumption (kg)[2]	Annual U.S. Catfish Servings[3]
Siluriformes	98.13	151,955,889	1,548,519,606
Ictaluridae	98.13	116,150,192	1,183,638,553

[1] Calculated from NHANES data
[2] Domestic and import catfish production data
[3] Annual U.S. Catfish Consumption divided by Mean Serving Size

4. Hazard Characterization (Dose-Response)

The dose-response equation described by the World Health Organization and Food and Agriculture Organization (WHO/FAO, 2002) was used to estimate the probability of illness resulting from exposure to *Salmonella* in a single serving of catfish. The dose-response function is:

Equation 7 $$P\ \ ill \mid exp\ \ = 1 - \left(1 + \frac{D}{\beta}\right)^{-\alpha}$$

with parameters ($\alpha = 0.1324$, $\beta = 51.45$).

This dose-response relationship is assumed to be the same for all humans exposed (i.e., regardless of age, sex or susceptibility) and all *Salmonella* strains. Although such assumptions are arguable, this relationship represents an international guideline that is assumed adequate for estimating effects across whole populations of consumers. Nevertheless, assessing the risk for specific consumers or classes of consumers might benefit from adjustments to this dose-response relationship.

5. Risk characterization

The risk of *Salmonella* illness potentially associated with the estimated catfish consumption distribution is characterized by combining the exposure assessment with the hazard characterization. Equations 1 – 4 outline the mathematics of this process.

This section will present the default model estimation for the annual number of human cases of salmonellosis potentially associated with catfish consumption. This estimation stems from the number of exposures generated from contaminated catfish and the average probability of illness among those exposures.

The analysis also compared the modelled estimation of annual *Salmonella* illnesses associated with catfish with the available public health surveillance (i.e., epidemiological) evidence. Estimates of total annual cases of human salmonellosis from all sources are adjusted by the fraction of cases attributable to catfish.

Because the ultimate purpose of this risk assessment is to inform regulatory decision-making, this report focuses on the approach taken to model the effectiveness of an FSIS inspection program in reducing the annual burden of human illness. This section of risk characterization provides a qualitative description of how FSIS seeks to improve food safety for catfish, as well as describing the mathematics, available evidence and uncertainty associated with modeling the effectiveness of an FSIS catfish inspection program.

Estimates of the potential effectiveness of an FSIS catfish inspection program are presented relative to the default annual number of *Salmonella* illnesses estimated to be currently associated with catfish. Even allowing for uncertainty about the default number of annual illnesses, substantial uncertainty remains about the level of effectiveness that can be achieved by FSIS inspection and the rate at which the effectiveness can be achieved.

The final sections of risk characterization examine the sensitivity of the estimated number of *Salmonella* illnesses associated with catfish to some changes in the risk assessment model inputs and the effects of uncertainty about inputs on model estimates. Several scenarios are examined to explore the potential error in predictions caused by influential and highly uncertain risk assessment model inputs.

5.1 Default estimation of numbers of *Salmonella* illnesses per year

The computer model comprises 3 million iterations. By running the model multiple times, it was determined that the estimated number of illnesses per year stabilized such that there was a 95% confidence that any simulation was within ~2.5% of the average estimate calculated across the multiple simulations of 3 million iterations each.

A seed value was used for sensitivity and scenario analyses that generated an annual number of illnesses equivalent to the mean across multiple simulations. This approach allowed a direct comparison between the estimated numbers of illnesses using the model's default settings and alternative settings.

For the default model settings, the number of contaminated servings per year was 30,970,392 using the Siluriformes definition of catfish. This number determines the servings generated from *Salmonella*-contaminated catfish; it represents the annual potential exposures to *Salmonella*. If catfish are defined as Ictaluridae, then 23,673,768 contaminated servings per year are estimated. The difference in contaminated servings is determined solely by the share of Ictaluridae among Siluriformes.

Exposures from contaminated servings are determined using the average *Salmonella* dose per exposure. A dose-response function determines the probability of illness for each exposure dose. The probability of illness per contaminated serving for each combination of cooking and breading is generally very small (Table 7) with, for example, the 75^{th} percentiles suggesting the probability of illness is less than 1.6 in one million for contaminated servings. The maximum probability of illness across all exposures is 0.35; for the default beta-Poisson dose-response function, this probability of illness corresponds to a maximum dose of 1,280 *Salmonella* in a serving. The mean probability of illness is slightly larger for non-breaded servings than breaded servings because serving size is larger for non-breaded servings. The mean probability of illness is somewhat larger for fried than baked servings because cooking time for frying is generally less than baking; therefore, baked servings usually involve more reduction of *Salmonella* prior to consumption than fried servings.

Table 7. Model outputs for the probability of illness per contaminated serving for the combinations of cooking and breading effects.

Probability of *Salmonella* illness per contaminated serving	Minimum	25th percentile	Median	Mean	75th percentile	Maximum	Standard. deviation
Baked and non-Breaded	$0.0E^{+00}$	$8.2E^{-15}$	$1.2E^{-10}$	$2.1E^{-05}$	5.3E-^{08}	$2.2E^{-01}$	$7.9E^{-04}$
Fried and non-Breaded	$0.0E^{+00}$	$4.3E^{-11}$	$2.8E^{-08}$	$1.1E^{-04}$	$1.6E^{-06}$	3.5E-01	$2.5E^{-03}$
Baked and Breaded	$0.0E^{+00}$	$6.2E^{-15}$	$9.3E^{-11}$	$1.6E^{-05}$	$4.0E^{-08}$	$2.0E^{-01}$	$6.4E^{-04}$
Fried and Breaded	$0.0E^{+00}$	$3.2E^{-11}$	$2.1E^{-08}$	$8.8E^{-05}$	$1.2E^{-06}$	$3.2E^{-01}$	$2.1E^{-03}$

The estimated numbers of *Salmonella* illnesses per year using the Siluriformes and Ictaluridae definitions are 2,308 and 1,764, respectively. Because *Salmonella* prevalence among domestic and imported catfish is assumed to be equal in the default model settings, the number of Ictaluridae-associated annual illnesses is simply 76% of the number of Siluriformes-associated illnesses. Therefore, there is no significant difference between Siluriformes and Ictaluridae in the risk of salmonellosis *per serving*; rather the amount of total illnesses depends on the total volume of catfish consumed in the U.S. (Table 8).

Table 8. The estimated annual numbers of *Salmonella* illnesses for each definition of catfish.

Definition of catfish	Number of contaminated servings (exposures)	Average probability of illness per contaminated serving	Estimated number of *Salmonella* illnesses per year
Siluriformes	30,970,392	$7.452E^{-05}$	2,308
Ictaluridae	23,673,768	$7.452E^{-05}$	1,764

On the basis of total servings of catfish consumed, the average probability of illness per serving is $\frac{2308 \text{ illnesses/yr}}{1,548,519,606 \text{ servings/yr}} = 1.5 \times 10^{-6}$. This probability incorporates the

prevalence of contaminated servings and suggests that *Salmonella* illness resulting from consuming a serving of catfish is an uncommon event.

5.2 Comparison of illnesses per year using surveillance data

Salmonella illnesses attributable to catfish are rare. In the past 20 years there has been only one suspected outbreak reported (10 illnesses in May 1991 associated with a restaurant in New Jersey). Furthermore, catfish consumption has not been identified as a factor in epidemiological (specifically, case–control) studies of salmonellosis. Nevertheless, it is possible that there is a low level of sporadic cases of salmonellosis associated with catfish occurring in the U.S. which are not detected with current levels of surveillance.

The Centers for Disease Control and Prevention (CDC) lists annual reports of foodborne outbreaks from 1990 through 2007 (U.S. CDC, 2009). These reports show there are a little more than 100 outbreaks of salmonellosis in the U.S. each year. Approximately 60% of these outbreaks have a vehicle identified (Table 9). These data are used to determine an alternative estimate for the number of catfish-related *Salmonella* illnesses each year. This estimation multiplies the fraction of foodborne outbreaks with identified vehicles that were attributed to catfish by the estimated total *Salmonella* illnesses per year.

Table 9. *Salmonella* Foodborne Outbreaks from 1990 through 2007.

Year	*Salmonella* Outbreaks	Vehicles Identified	%
1990	138	82	59.4%
1991	123	64	52.0%
1992	80	48	60.0%
1993	95	62	65.3%
1994	88	52	59.1%
1995	94	51	54.3%
1996	80	47	58.8%
1997	80	54	67.5%
1998	124	62	50.0%
1999	113	77	68.1%
2000	112	76	67.9%
2001	112	78	69.6%
2002	109	74	67.9%
2003	108	70	64.8%
2004	123	64	52.0%
2005	94	67	71.3%
2006	116	62	53.4%
2007	135	69	51.1%
Total	**1,924**	**1,159**	**60.2%**

If it is assumed that the proportion of all *Salmonella* illnesses caused by a vehicle is equivalent to the proportion of outbreaks caused by that vehicle, then the expected proportion for any given year (p_t) using the evidence from the previous year would be

Equation 8 $$p_t = \frac{s_{t-1} + 1}{n_{t-1} - s_{t-1} + 2}.$$

where p_t is the mean of a beta distribution (Vose, 2000), s_{t-1} is the number of outbreaks caused by a particular vehicle in the previous year and n_{t-1} is the number outbreaks in the previous year.

For 2007, given 69 outbreaks in which the vehicle was identified to not be catfish, the value of p_t would be 0.014. It would be reasonable, however, to include evidence from earlier years. The expected proportion for any given year using the evidence from *m* previous years would be

Equation 9 $$p_t = \frac{\left(\sum_{i=1}^{m} s_{t-i}\right)+1}{\left(\sum_{i=1}^{m} n_{t-i} - s_{t-i}\right)+2}.$$

If the entire set of reports from CDC is used, then there is one outbreak in which catfish is identified as the vehicle and 1158 outbreaks in which other vehicles were identified. The expected value for p_t is 2/1160 = 0.0017. The 95% confidence limits are from 0.0002 to 0.0048.

Mead et al. (1999) estimates there are about 1.4 million illnesses due to *Salmonella* annually. If the proportions calculated above are multiplied by 1.4 million, the estimated number of annual human illnesses is 2,400, with a lower limit of 280 and an upper limit of 6,700.

5.3 Modeling program effectiveness

Traditionally, FSIS has monitored the food safety performance of an industry based on a reduction in the prevalence of a pathogen on specific food products. Although monitoring the number (concentration) of pathogens on carcasses is an alternative and advantageous approach, laboratory enumeration of pathogen levels on carcasses is cumbersome and generally non-routine.

In the risk assessment model, it is assumed that the effect of FSIS inspection will be some reduction in the prevalence of *Salmonella*-contaminated catfish carcasses. Although FSIS inspection may also influence the number (concentration) of *Salmonella* on contaminated carcasses, that effect is not modeled.

It is further assumed that the effect of FSIS inspection will be equivalent for domestic and imported catfish. This assumption is reasonable because import regulations intend to establish equivalency in food safety risk between imports and products of domestic origin.

Given these assumptions, predicting the number of human salmonellosis illnesses associated with catfish avoided each year is straightforward, given Equation 1 and Equation 4. The effectiveness of FSIS inspection may be some fraction, g_{FSIS}, of the

default prevalence of contaminated carcasses. For example, if $g_{FSIS} = 0.1$, then a 10% reduction in prevalence of contaminated carcasses following implementation of FSIS inspection is expected. Similarly, the new *Salmonella* prevalence of contaminated catfish carcasses can be modeled by multiplying the default prevalence (i.e., 2%) by $1 - g_{FSIS} = 0.9$. Because the number of contaminated servings per year is linear with respect to g_{FSIS}, predicting the annual illnesses avoided is a simple calculation;

$$Number_ill\ \textbf{avoided}\ /\ yr =$$

$$\#contaminated\ servings\ \textbf{avoided}\ /\ yr \times \left[\begin{array}{l} f_{Bread} \times f_{Baked} \times P_{Bread,Bakedd}(ill) + \\ f_{Bread} \times \left(1 - f_{Baked}\right) \times P_{Bread,Fried}(ill) + \\ \left(1 - f_{Bread}\right) \times f_{Baked} \times P_{Nonbread,Baked}(ill) + \\ \left(1 - f_{Bread}\right) \times \left(1 - f_{Baked}\right) \times P_{Nonbread,Fried}(ill) \end{array} \right]$$

with

$$\begin{array}{l} \#\ contaminated\ servings\ \textbf{avoided}\ /\ yr\ = \\ N_{servings}\left[\ f_{imports} \times \left[g_{FSIS} \times prev_{imports} \right] \ + \ (1 - f_{imports}) \times \ g_{FSIS} \times prev_{domestic} \ \right] \end{array}$$

Or, given a default number of human salmonellosis cases associated with catfish estimated to occur prior to an FSIS inspection program (*Number_ill / yr*), the illnesses avoided by an FSIS cafish inspection is simply;

Equation 10 $Number_ill\ \textbf{avoided}\ /\ yr = g_{FSIS} \times Number_ill\ /\ yr$

Given the nature of Equation 10, it is reasonable to imagine the annual number of human salmonellosis cases from catfish as a binomial process. In other words, there are a number of *Salmonella*-contaminated catfish servings (i.e., number of trials, *n*) and each serving has an independent probability of resulting in human illness (i.e., a probability of "success", *p*). Furthermore, given a large number of catfish servings (trials) and a small probability of human illness (defined as a "success" in terms of mathematical probabilities), this binomial process can be approximated as a Poisson process with rate parameter $\lambda = n \times p$ (Vose, 2000). This development allows an appreciation of the nature

of the model's estimated annual cases. These estimated cases can be assumed to be the rate parameter to a Poisson distribution; so year-to-year variability in the number of cases could be modeled using this distribution. For the most part, this variability is ignored in this risk characterization because it represents a change of only about 5% around the estimated annual rate. Compared to the substantial uncertainty surrounding the effectiveness of FSIS inspection, this amount of variability is minor.

The true effectiveness of FSIS inspection for reducing catfish-associated human illnesses is unknown. Also, the rate at which FSIS inspection will achieve its ultimate reductions is unknown. Consequently, the model incorporates substantial uncertainty about program effectiveness. A plausible range might be from more than 90% to less than 10% effectiveness, and so the risk assessment model includes an evaluation of possible effectiveness levels – 10%, 50% and 90% – to provide a range of predictions. Similarly, the model evaluates the public health effect if the FSIS catfish inspection program achieves peak effectiveness in 2, 5, 10 or 15 years following its implementation (note: linear interpolation is used to predict illnesses avoided in years prior to achieving peak effectivness).

Given its mission, FSIS expects to provide assurance of industry control and reduction of foodborne hazards to protect U.S. consumers. FSIS has maintained continuous inspection of poultry and meat carcasses for several decades. In the mid-1990s FSIS further implemented a HACCP-based regulatory system for all products it regulates. FSIS inspectors comprise veterinarians and other food safety scientists whose responsibilities extend from overseeing humane handling to sanitation, slaughter dressing and final approval of carcasses. All of their activities contribute to assuring proper food safety controls to prevent or mitigate foodborne hazards in all FSIS-regulated products.

Although FSIS does not have experience with catfish slaughter establishments, it does have substantial experience with regulatory oversight of other animal slaughter and corresponding processing industries. The process of converting live catfish to retail-ready meat products is not unlike the process of slaughtering poultry, turkeys, cattle or hogs. Catfish are eviscerated and usually skinned and deheaded to produce fillets and other edible products (Wyatt et al., 1979). At each step of the process, the potential for cross-contamination of the carcass exists. This contamination can occur from the skin of catfish

directly to the meat surface, via processing workers' hands, or via the processing environment.

The role of hide or skin contamination is substantial in sanitary carcass dressing. These sources of pathogens are recognized as possibly more important than the role of intenstinal colonization in the contamination of poultry, turkey, beef or hog carcasses. Although intestinal colonization of catfish with *Salmonella* may be uncommon (McCaskey 1998; Wyatt et al. 1979; Pao et al. 2008), environmental contamination of catfish skin may have some similities to poultry and other animal contaminations. The catfish pond environment is potentially exposed to amphibians, reptiles and mammals that may carry and shed *Salmonella*.

The role of daily FSIS inspection of catfish processing establishments in reducing potential contamination events is expected to be important. The presence of FSIS inspectors should serve to enforce compliance with regulations; FSIS personnel observe the daily operations in processing facilities and require that immediate corrective actions are taken if deficiencies are noted. Inherent in the expected importance of FSIS inspection is the assumption that enhanced sanitation is correlated with reduced pathogen contamination. FSIS also conducts periodic testing of products it inspects for the presence of pathogens and chemicals.

5.3.1 Need for data after program implementation

Predicting the effectiveness of FSIS inspection for the reduction of illness from catfish consumption is uncertain because data are currently unavailable. Once the FSIS catfish inspection program is implemented, substantial amounts of pathogen and chemical hazard testing data for catfish will become available. Over time, it is expected that testing data will show a progressively lower occurrence of pathogens and chemicals among processed catfish carcasses, particularly if significant levels are found. As FSIS inspectors work to improve the compliance of processors with its regulations, such violations, if found, would be expected to decline. The nature (i.e., severity) of potential violations would also be expected to trend downward. It is expected that subsequent quantitative risk assessments for catfish then could be developed and used to evaluate future policy options intended to control any chronic violations that might be key risk

indicators for carcass contamination. Public health monitoring may provide indications of program effectiveness. Outbreaks and recall investigations associated with catfish may similarly serve as indicators of the program's effectiveness.

5.3.2 Poultry evidence

Although the risk assessment model includes uncertainty about the effectiveness of FSIS inspection as a range between 10% and 90%, evidence from before and after implementation of the FSIS HACCP regulation provides some indication of a midpoint between these extremes. For example, the 1994-95 nationwide broiler chicken microbiological baseline study found 20% of 1,297 poultry carcasses *Salmonella*-positive. That study was repeated in 1999-2000 and found 8.7% of 1,225 poultry carcasses *Salmonella*-positive. In 2007-2008, FSIS again completed a nationwide baseline study of poultry carcasses and found approximately 7.5% (volume-weighted) of 3,275 samples *Salmonella*-positive[31].

The trend in *Salmonella* prevalence among poultry carcasses does not directly demonstrate the effectiveness of the HACCP regulation; too many factors might influence *Salmonella* occurrence among carcasses to attribute the trend solely to FSIS inspection activities. Nevertheless, this trend provides an empirical estimate of how FSIS inspection might influence *Salmonella* occurrence among FSIS-regulated products. This trend – if fully attributed to FSIS' inspection program – implies that *Salmonella* prevalence might decrease (i.e., by $\left(1-\frac{8.7\%}{20\%}\right)=56.5\%$ or $\left(1-\frac{7.5\%}{20\%}\right)=62.5\%$) following implementation of FSIS' catfish inspection program.

5.4 Program effectiveness estimates

Estimates of the potential effectiveness of FSIS catfish program are presented relative to the default (baseline) estimated number of salmonellosis cases associated with catfish consumption. As discussed previously, predicted program effectiveness depends upon the number of baseline *Salmonella* illnessses, the peak effectiveness rate of an FSIS catfish inspection program, and the timeframe required to achieve peak effectiveness.

[31] See http://www.fsis.usda.gov/Science/Baseline_Data/index.asp for all baseline studies

Depending on whether catfish is defined as Siluriformes or Ictaluridae for rulemaking purposes, estimates of the number of baseline *Salmonella* illnesses attributable to catfish differ. If a subset of product is not included in the definition; and therefore, does not fall under FSIS's authority to regulate, then consumption of that subset of product is unaffected by any FSIS regulation. Thus the number of baseline *Salmonella* illnesses estimated is higher (2,308 illnesses per year) for Siluriformes, and lower (1,764 illnesses per year) for Ictaluridae. Because these baseline *Salmonella* illnesses are assumed to be Poisson distributed, the risk assessment estimates (Table 10) also include 5^{th} and 95^{th} percentiles.

Table 10. Estimated baseline *Salmonella* illnesses per year.

Catfish definition	mean	confidence interval	
		5^{th}	95^{th}
Siluriformes	2308	2229	2387
Ictaluridae	1764	1695	1833

Substantial uncertainty remains about the level of peak effectiveness that could be achieved by an FSIS inspection program for catfish. In theory, FSIS inspection of catfish could be completely effective (100% peak effectiveness) at reducing salmonellosis cases assocated with the consumption of catfish, or FSIS inspection could be totally ineffective (0% peak effectiveness). Model results are summarized for three plausible effectiveness levels (i.e., 10%, 50%, and 90%).

Additional uncertainty exists about the number of years required to achieve peak effectiveness. Based on Agency projections, any FSIS regulation of the catfish industry, whether catfish is defined as Siluriformes or Ictaluridae, would likely take approximately 1½ years to become fully implemented. So it is assumed in the risk assessment that the soonest that FSIS' catfish inspection program could achieve peak effectiveness could be 2 years (therefore the 3^{rd} year would be the first year of inspection under peak effectiveness). At the other extreme, it is assumed that an FSIS catfish inspection program could take 15 or more years to achieve peak effectiveness. Other plausible scenarios modeled include a 5-year timeframe and a 10-year timeframe.

5.4.1 Using Siluriformes definition

Figure 6 shows several aspects of the the uncertainty about the estimated peak effectiveness of an FSIS regulation in predicting the annual number of *Salmonella* illnesses avoided, using the Siluriformes definition of catfish. This graph assumes a 5-year timeframe for reaching an uncertain peak effectiveness. Note that the relative estimanted number of illnesses avoided across 10 years of an FSIS catfish inspection program is directly related to the assumption about the timing of peak effectiveness.

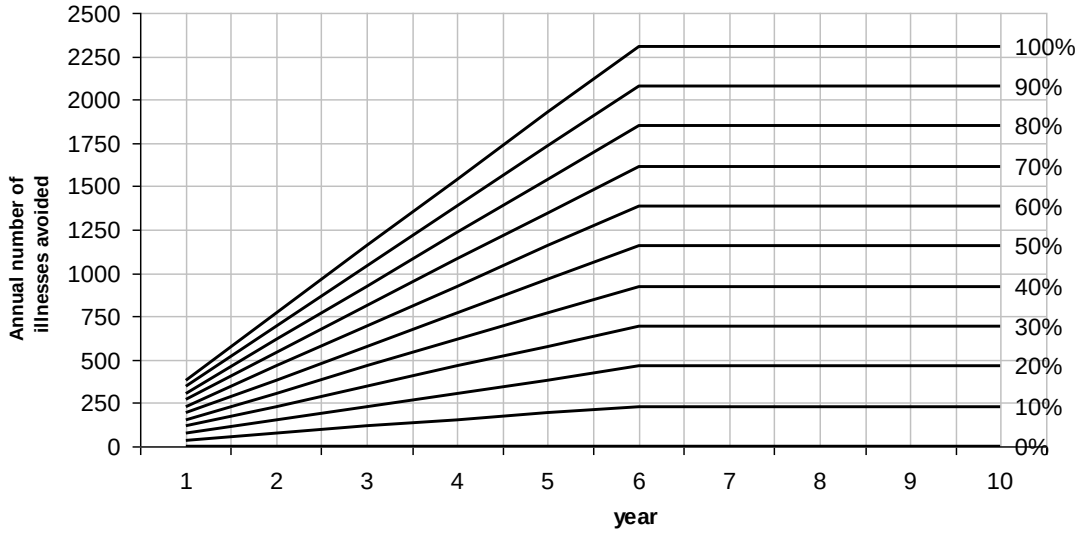

Figure 6. Uncertainty in the potential effectiveness of regulation on the annual number of *Salmonella* illnesses avoided over 10-yrs following FSIS regulation of catfish. These values assume a 5-yr timeframe and the Siluriformes definition of catfish.

Table 11 through Table 13 show the number of *Salmonella* illnesses avoided each year over a 10-year planning horizon for 10%, 50%, and 90% peak effectiveness, assuming a 2, 10 or 15-year timeframe for achieving peak effectiveness.

Estimated illnesses avoided are then projected for each of 10-years following policy implementation. If the peak effectiveness of an FSIS catfish inspection progam is assumed to be a 50% decline in salmonellosis cases related to catfish, then a comparison of Table 11 through Table 13 shows that predicted *Salmonella* illnesses from catfish avoided in the first year ranges from a low of 72 (assuming a 15-year timeframe to

achieve peak effectiveness) to a high of 384 (assuming a 2-year timeframe to achieve peak effectiveness).

If the peak effectiveness of an FSIS catfish inspection progam is assumed to be at 90%, then comparing Table 11 through Table 13 shows predicted *Salmonella* illnesses from catfish avoided in the first year ranges from a low of 129 (assuming a 15-year timeframe to achieve peak effectiveness) to a high of 692 (assuming a 2-year timeframe to achieve peak effectiveness).

In this analysis, the risk asssessment model is used to project the estimated number of *Salmonella* illnesses associated with catfish that might be avoided over a 10-year period to allow for the calculation of the discounted value of human illnessess avoided for a 10-year benefit-cost analysis. It is worth noting that the longer timeframes require more time to achieve higher predicted illnesses avoided. For example, using the 15-year timeframe and assuming peak effectiveness at 90%, the risk assessment model estimates 1,298 *Salmonella* illnesses avoided in the tenth year. In a valuation calculation of these human illnesses in the present, they must be discounted for 10 years. The shorter the timeframe required to achieve peak effectiveness, the smaller the gap between the estimated number of *Salmonella* illnesses associated with catfish avoided in the near-years of the planning horizon and the estimated number of illnesses avoided in the out-years of the planning horizon. This has potentially important implications for benefit-cost analysis.

Table 11. Estimated Number of *Salmonella* illnesses avoided due to FSIS regulation assuming the Siluriformes definition of catfish and a 2-year to effectiveness timeframe.

	90% effectiveness			50% effectiveness			10% effectiveness		
		confidence interval			confidence interval			confidence interval	
year	Mean	5th percentile	95th percentile	mean	5th percentile	95th percentile	mean	5th percentile	95th percentile
1	692	649	735	384	352	416	76	62	90
2	1,384	1,323	1,445	769	723	815	153	133	173
3	2,077	2,002	2,152	1,154	1,098	1,210	230	205	255
4	2,077	2,002	2152	1,154	1,098	1,210	230	205	255
5	2,077	2,002	2,152	1,154	1,098	1,210	230	205	255
6	2,077	2,002	2,152	1,154	1,098	1,210	230	205	255
7	2,077	2,002	2,152	1,154	1,098	1,210	230	205	255
8	2,077	2,002	2,152	1,154	1,098	1,210	230	205	255
9	2,077	2,002	2,152	1,154	1,098	1,210	230	205	255
10	2,077	2,002	2,152	1,154	1,098	1,210	230	205	255

Table 12. Estimated Number of *Salmonella* illnesses avoided due to FSIS regulation assuming the Siluriformes definition of catfish and a 10-year to effectiveness timeframe.

	90% effectiveness			50% effectiveness			10% effectiveness		
		confidence interval			confidence interval			confidence interval	
year	Mean	5th percentile	95th percentile	mean	5th percentile	95th percentile	mean	5th percentile	95th percentile
1	188	165	211	104	87	121	20	13	28
2	377	345	409	209	185	233	41	31	52
3	566	527	605	314	285	343	62	49	75
4	755	710	800	419	385	453	83	68	98
5	944	893	995	524	486	562	104	87	121
6	1,133	1,078	1,188	629	588	670	125	107	143
7	1,321	1,261	1,381	734	689	779	146	126	166
8	1,510	1,446	1,574	839	791	887	167	146	188
9	1,699	1,631	1,767	944	893	995	188	165	211
10	1,888	1,817	1,959	1,049	996	1,102	209	185	233

Table 13. Estimated Number of *Salmonella* illnesses avoided due to FSIS regulation assuming the Siluriformes definition of catfish and a 15-year to effectiveness timeframe.

	90% effectiveness			50% effectiveness			10% effectiveness		
		confidence interval			confidence interval			confidence interval	
Year	mean	5th percentile	95th percentile	mean	5th percentile	95th percentile	mean	5th percentile	95th percentile
1	129	110	148	72	58	86	14	8	20
2	259	233	285	144	124	164	28	20	37
3	389	357	421	216	192	240	43	33	54
4	519	482	556	288	260	316	57	45	70
5	649	607	691	360	329	391	72	58	86
6	778	732	824	432	398	466	86	71	101
7	908	858	958	504	467	541	100	84	116
8	1,038	985	1,091	577	537	617	115	97	133
9	1,168	1,112	1,224	649	607	691	129	110	148
10	1,298	1,239	1,357	721	677	765	144	124	164

5.4.2 Using Ictaluridae definition

Figure 7 shows the uncertainty about the peak effectiveness of FSIS regulation in predicting the estimated annual number of *Salmonella* illnesses avoided using the Ictaluridae definition of catfish. This graph assumes a 5-year timeframe for reaching an uncertain peak effectiveness.

Table 14 through Table 16 show the estmated number of *Salmonella* illnesses avoided each year over a 10-year planning horizon for 10%, 50%, and 90% peak effectiveness assuming a 2, 10, and 15-year timeframe for achieving the peak effectiveness. If the peak effectiveness of an FSIS catfish inspection progam is assumed to be a 50% decline in *Salmonella* illnesses related to catfish, then a comparison of Table 14 through Table 16 shows that predicted *Salmonella* illnesses from catfish avoided in the first year ranges from a low of 55 (assuming a 15-year timeframe to achieve peak

effectiveness) to a high of 294 (assuming a 2-year timeframe to achieve peak effectiveness).

If the peak effectiveness of an FSIS catfish inspection progam is assumed to be 90%, then a comparison of Table 14 through Table 16 shows that estimated illnesses avoided in the first year range from a low of 99 (assuming a 15 timeframe to achieve peak effectiveness) to a high of 529 (assuming a 2-year timeframe to achieve peak effectiveness).

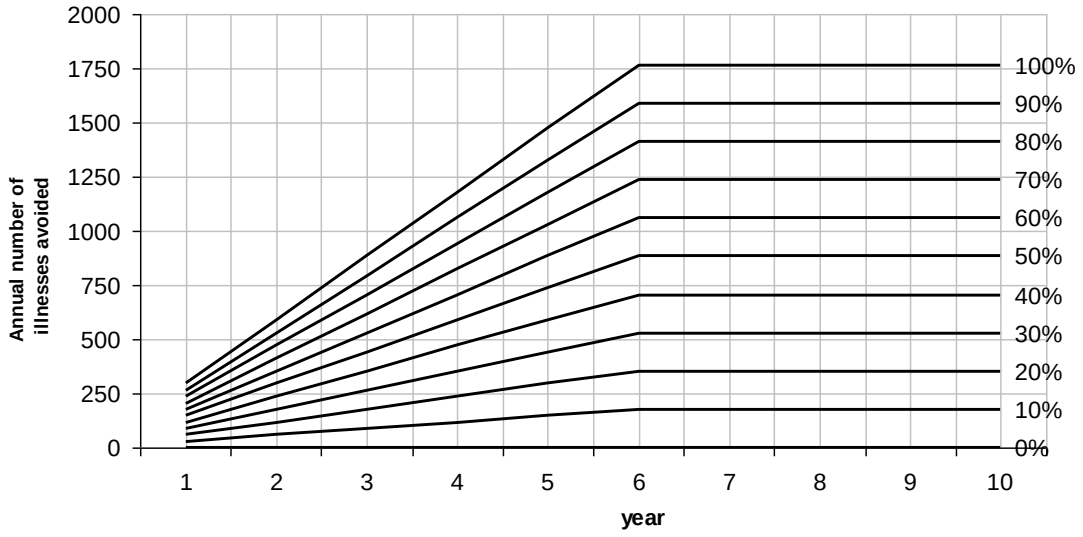

Figure 7. Uncertainty in the potential effectiveness of regulation on the annual number of *Salmonella* illnesses avoided over 10-yrs following FSIS regulation of catfish. These values assume a 5-yr timeframe and the Ictaluridae definition of catfish.

Table 14. Estimated Number of *Salmonella* illnesses avoided due to FSIS regulation assuming the Ictaluridae definition of catfish and a 2-year to effectiveness timeframe.

	90% effectiveness			50% effectiveness			10% effectiveness		
		confidence interval			confidence interval			confidence interval	
year	mean	5th percentile	95th percentile	mean	5th percentile	95th percentile	mean	5th percentile	95th percentile
1	529	491	567	294	266	322	58	46	71
2	1,058	1,004	1112	588	548	628	117	99	135
3	1,587	1,521	1653	882	833	931	176	154	198
4	1,587	1,521	1653	882	833	931	176	154	198
5	1,587	1,521	1653	882	833	931	176	154	198
6	1,587	1,521	1653	882	833	931	176	154	198
7	1,587	1,521	1653	882	833	931	176	154	198
8	1,587	1,521	1653	882	833	931	176	154	198
9	1,587	1,521	1653	882	833	931	176	154	198
10	1,587	1,521	1653	882	833	931	176	154	198

Table 15. Estimated Number of *Salmonella* illnesses avoided due to FSIS regulation assuming the Ictaluridae definition of catfish and a 10-year to effectiveness timeframe.

	90% effectiveness			50% effectiveness			10% effectiveness		
		confidence interval			confidence interval			confidence interval	
Year	mean	5th percentile	95th percentile	mean	5th percentile	95th percentile	mean	5th percentile	95th percentile
1	144	124	164	80	65	95	16	10	23
2	288	260	316	160	139	181	32	23	42
3	432	398	466	240	215	265	48	37	60
4	577	537	617	320	291	349	64	51	77
5	721	677	765	400	367	433	80	65	95
6	865	817	913	481	445	517	96	80	112
7	1,010	958	1,062	561	522	600	112	95	129
8	1,154	1,098	1,210	641	599	683	128	109	147
9	1,298	1,239	1,357	721	677	765	144	124	164
10	1,443	1,381	1,505	801	754	848	160	139	181

Table 16. Estimated Number of *Salmonella* illnesses avoided due to FSIS regulation assuming the Ictaluridae definition of catfish and a 15-year to effectiveness timeframe.

	90% effectiveness			50% effectiveness			10% effectiveness		
		confidence interval			confidence interval			confidence interval	
Year	mean	5th percentile	95th percentile	mean	5th percentile	95th percentile	mean	5th percentile	95th percentile
1	99	83	115	55	43	67	11	6	17
2	198	175	221	110	93	127	22	15	30
3	297	269	325	165	144	186	33	24	43
4	396	363	429	220	196	244	44	33	55
5	496	459	533	275	248	302	55	43	67
6	595	555	635	330	300	360	66	53	79
7	694	651	737	385	353	417	77	63	91
8	793	747	839	441	406	476	88	73	103
9	893	844	942	496	459	533	99	83	115
10	992	940	1044	551	512	590	110	93	127

5.5 Sensitivity of default illnesses estimates to changes in model inputs

A limited sensitivity analysis was completed on inputs to the catfish risk assessment model to inform the uncertainty analysis and to test the sensitivity of certain modeling assumptions. This sensitivity analysis was conducted on the baseline number of *Salmonella* illnesses.

Below is a description of the procedures used to evaluate the influence of various risk assessment model parameters on public health estimates (i.e., the sensitivity of model variables).

Elasticities, Є, are calculated for every sensitivity test based on the following formula:

Є = %Δ in output / (%Δ in input)

where %Δ is read "percent change". The greater the absolute value of the elasticity, the more effect a change in a model input can be expected to have on the outputs of this risk assessment model.

For the sensitivity procedure, the model was run for 3 million *Salmonella*-contaminated catfish servings and the output was collected (YBASE). A change to an input parameter was initiated in the model, then the model was re-run for 3 million *Salmonella*-contaminated servings and the output was again collected (YSHOCK). To assure consistency of comparisons, the same starting seed value was used in all baseline and sensitivity scenario runs of the model.

The %Δ in output is calculated as:

$$\%\Delta \textit{ in output} = (\textit{YSHOCK} - \textit{YBASE}) / \textit{YBASE}$$

Similarly, the %Δ *in input* values could be determined. In practice these were entered as exogenous pre-run changes to one input variable at a time in the model code.

This model uses several input parameters. The advantage of elasticity-based sensitivity analysis is that the analyst can compare and contrast sensitivities across all inputs using a common metric.

5.5.1 Prevalence

Both import and domestic prevalence assumptions were tested by increasing the default inputs by 10%.

5.5.2 Growth

One sensitivity scenario tested *Salmonella* growth assumptions in post- process catfish carcasses by increasing the most likely parameter of the log growth *Pert* distribution by 100%. This large change was needed for this sensitivity scenario because very few servings experience growth.

5.5.3 Cooking practices

Pert distributions were used to model cooking times and temperatures for baked or fried servings. Sensitivities to cooking time and cooking temperature were tested separately for baking and frying. The most likely cooking times were adjusted by 10%. The most likely cooking temperatures were adjusted by 8.5% because a 10% increase would exceed the maximum parameter in the *Pert* distribution.

Additional sensitivity scenarios tested model assumptions about fraction of catfish meals baked and the fraction of servings breaded. Both of these scenarios assumed 10% increases in the respective input parameter.

5.5.4 Serving Size

The sensitivity of the model's output to serving size was modeled by multiplying random draws for the non-parametric serving size distribution (documented elsewhere in this report) by a factor of 1.1 – thus achieving a 10% increase in serving size.

Additionally, sensitivity analyses were developed on assumptions about the reduction in serving size due to breading. These scenarios involved increasing the minimum and maximum reductions in serving size from breading by 10%.

5.5.5 Dose-Response

The beta-Poisson dose response function for *Salmonella* was tested for sensitivity by analyzing small changes to the individual parameters of the beta-Poisson. Both the α and β parameters were adjusted by 10%.

5.5.6 Assumptions about extrapolating from poultry to catfish

Two assumptions regarding extrapolation of poultry to catfish carcasses were tested. A 10% change to the assumption about the average weight of a poultry carcass in a rinse bag (used to estimate *Salmonella* concentration) was tested. Also, this risk assessment includes an evaluation of model assumptions about the effect of skin removal on overall carcass contamination by adjusting that value by 10%.

5.5.7 Sensitivity analysis findings

Sensitivity scenario results can be loosely grouped into 3 categories (|Є|>1, |Є|~1, |Є|<<1). By far, the most sensitive model inputs are the assumptions about cooking ((|Є|>1). Frying parameters seem much more sensitive than baking parameters. Cooking temperature also seems more sensitive than cooking time. Elasticities for a second category of input parameters are close to one; therefore a proportional change in *Salmonella* illnesses results for a given change in input values. Those include the α and β parameters of the dose response function, serving size, underlying assumptions about poultry contamination (effect of skin removal, and weight of chicken carcass in the rinse solution used to extrapolate contamination levels) and domestic prevalence. All other parameters fall into a third category of inputs having elasticities less than one. Results of the sensitivity analysis on all relevant *Salmonella* input variables are shown in Figure 8.

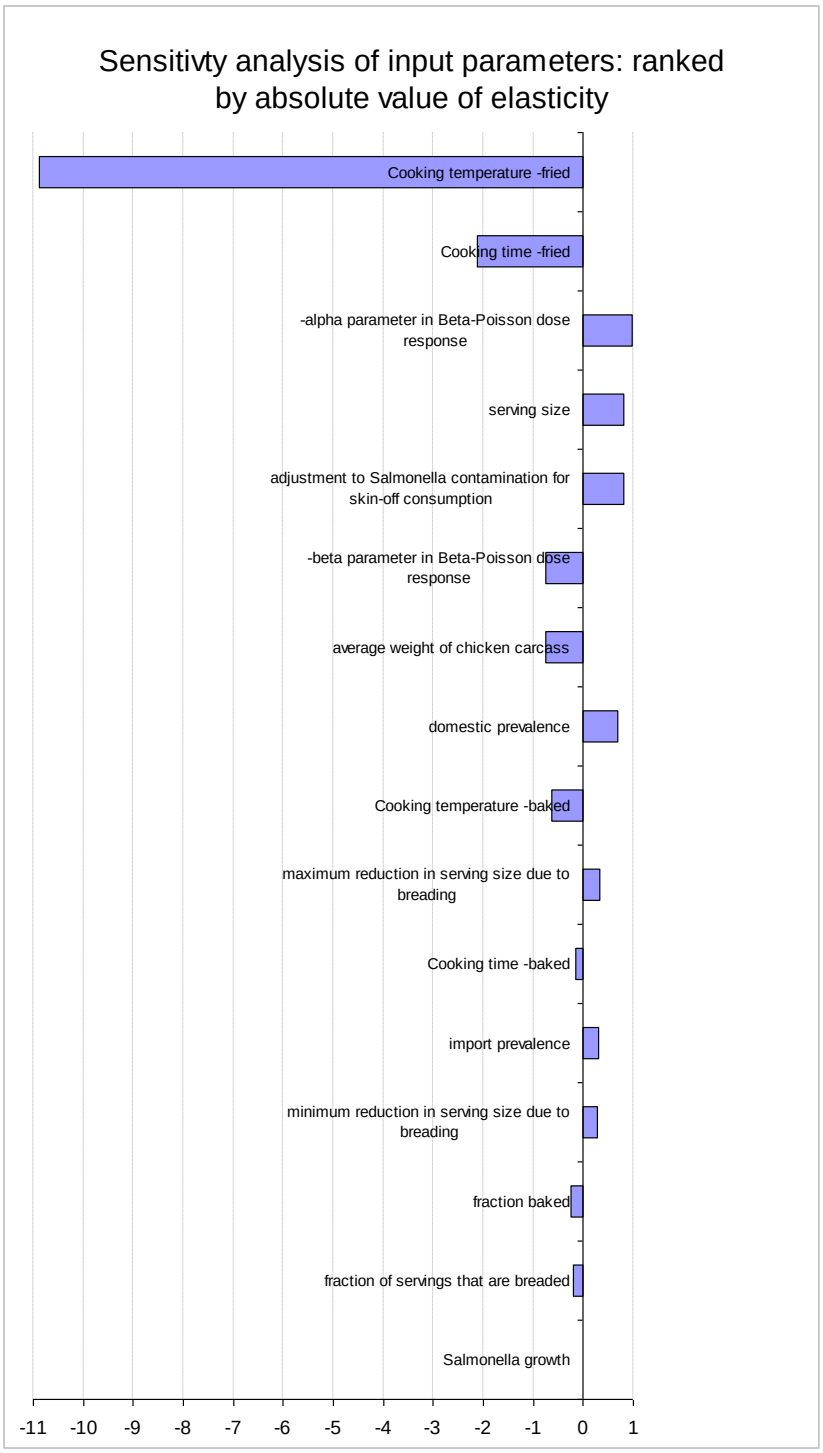

Figure 8. Tornado diagram describing the elasticity of the model's annual illness estimates to various model inputs. The x-axis here is in elasticity units.

5.6 Uncertainty scenario analyses

The purpose of uncertainty analysis is to examine the effect of some of the default estimates on the annual number of human *salmonellosis* cases estimated from catfish consumption. Although this risk assessment uses a simple model, the default input values were usually based on assumptions or very limited data. Uncertainty analysis can also highlight the need for specific data to improve a risk assessment's estimates. Both these objectives are treated in a mostly qualitative manner in this section.

To evaluate the uncertainty in some model estimates, the risk assessment estimates annual numbers of illnesses for various model inputs using the Siluriformes definition of catfish. For various model inputs, potential lower and upper bound values are used (Table 17). In some cases, the potential lower and upper bounds are determined from statistical confidence limits; while in other cases the settings are determined based on judgments of the data underlying the default assumptions. For example, there is some evidence suggesting an upward trend in imported catfish products (USDA-NASS, 2009). In addition, there is some evidence to suggest *Salmonella* prevalence might be larger than 2% for some share of imported catfish (Broughton and Walker 2009)[32]. Given this limited evidence, an upper bound scenario for prevalence adjusts the prevalence among imports and increases the share of imports. Nevertheless, a similar effect could have been modeled by simply increasing prevalence among domestic catfish. Alternatively, a lower bound scenario for prevalence assumes that *Salmonella* prevalence among all catfish is closer to 1% based on limited sampling at retail (Pao et al. 2008).

The default growth, breading effect, and post-processing concentration modeling assumptions were considered already to be near lower bound settings, so only upper bound scenarios were developed for these inputs. Potential upper and lower bound settings for cooking effectiveness were established by adjusting cooking times such that frying became equivalent to baking (lower bound) or baking became equivalent to frying (upper bound).

Each change (lower and upper) was simulated to estimate the annual number of illnesses and the change from the default model estimate was noted. For each potential

[32] Nevertheless, there is also historic evidence that *Salmonella* prevalence among domestic catfish may also be higher than 2% (Wyatt et al. 1979).

upper and lower bound value, the inputs were sorted from smallest change to largest change. Scenarios that progressively combined more changes were simulated next, so that the incremental effect on estimated illnesses could be examined.

This approach progressively assumes that uncertainty about model inputs is perfectly correlated. In other words, if the true value for one input is its lower bound, then the true values for one, two, three, etc. other inputs is/are also their lower bounds. Such an approach predicts extreme boundaries because any assumption about uncertainties not being perfectly correlated will demonstrate less change in the model estimates than shown. Nevertheless, the progressive inclusion of multiple inputs into scenarios illustrates the range of uncertainty about the lower and upper bounds. As opposed to only providing the most extreme result (setting all inputs to their potential lower/upper bounds), we assume the range for these boundaries is qualitatively useful for decision-makers.

Table 17. An outline of potential lower and upper bound values for various model inputs is shown. Symbols are used to identify changes in Figure x and y.

Input name	Symbol	Lower bound scenario	Upper bound scenario
Serving size	*S*	Use lower 95% confidence limit for quantiles of empiric distribution	Use upper 95% confidence limits for quantiles of empiric distribution
Dose-response parameters	*DR*	Use lower 95% confidence limit alpha and beta parameters from WHO/FAO, 2002; α =0.094, β =43.75	Use upper 95% confidence limit alpha and beta parameters from WHO/FAO, 2002; α =0.1817, β =56.39
Skinless effect adjustment	*K*	Reduce poultry contamination data by 0.9 logs	Reduce poultry contamination data by 0.5 logs
Prevalence of contaminated catfish	*P*	Reduce prevalence to 1% for both domestic and imported catfish	Increase prevalence for imported catfish to 4% and increase import share to 40%
Cooking effectiveness	*C*	Frying time distribution set equal to baking time distribution	Baking time distribution set equal to frying time distribution
Growth effect	*G*	No change	Set probability of growth to 0.2%; most likely log growth=0.40; maximum log growth=1.5
Breading effect	*B*	No change	Minimum adjustment=0.85; maximum=0.95 (i.e., breading constitutes 5% to 15% of serving size)
Post-processing concentration	*X*	No change	Truncate *Salmonella* concentration distribution at 0.03 *Salmonella* per gram, but re-distribute lower values randomly to values above threshold

The analysis completed for the potential lower bound scenario illustrates that the estimated annual *Salmonella* illnesses associated with catfish may range from 1,942 to 100 (relative to a default of 2,308) depending on how many inputs assume the potential lower bound values (Figure 9). Although other combinations are possible (e.g., $S+K$ or $S+P+C$), this approach is one system for examining how the model's estimate is reduced as more of its inputs are set at their lower bounds.

As the graph progressively includes another uncertain input set to its potential lower bound, the estimated annual illnesses decreases. The pattern suggests a weak exponential-like decline as each input limits the amount of exposure (or response to exposure) among catfish servings. Nevertheless, the incremental effect of improved cooking (C) at the end of the progression is limited in Figure 9 relative to its effect when all other inputs are set at their default values. If the cooking inputs for the lower bound scenario are the only change to the default model, then estimated annual illnesses are 524 (i.e., the incremental effect of lower bound cooking adjustment eliminates 1784 illnesses relative to the default estimate). This effect alone is nearly equivalent to the effect estimated by the $S+DR+K+P$ combined scenario. But, when the cooking change is modeled in combination with all other changes, its influence on illnesses is modulated because fewer contaminated servings with fewer organisms (and a lower probability of illness) are available in the model to be affected by the improved cooking effectiveness.

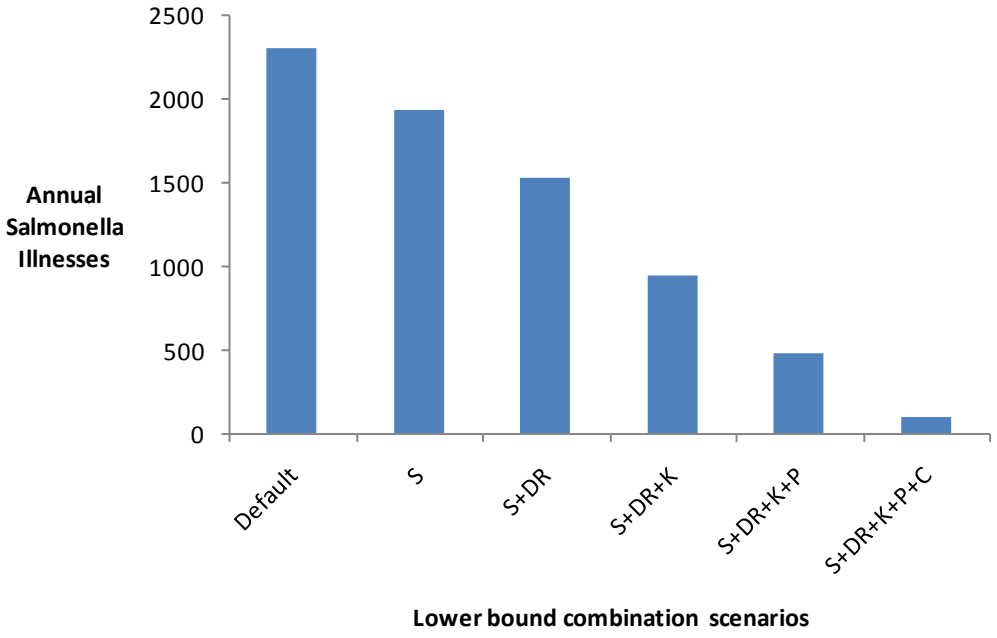

Figure 9. Cumulative reduction in the estimated number of illnesses for combined potential lower bound scenarios.

The analysis completed for the potential upper bound scenario illustrates that the estimated annual illnesses may range from 2,397 to 16,000 (relative to a default of 2,308) depending on how many inputs assume their potential upper bound values (Figure 10). The trend in this graph suggests an exponential-like increase in estimated annual illnesses as more inputs are set to their upper bounds.

The largest increase in estimated annual illnesses occurs when the *Salmonella* concentration data (derived from poultry) is truncated differently. The default assumption is that concentrations less than 0.003 *Salmonella* per gram are equal to 0.003. This assumption creates a high frequency of contaminated catfish carcasses with exactly 0.003 *Salmonella* per gram. In the potential upper bound scenario, any value less than 0.003/g is randomly redistributed to values above the threshold. This approach is conceptually similar to zero-truncated discrete distributions in which values of zero are removed from the distribution and the probabilities for remaining feasible values are adjusted to sum to one (Klugman 2004).

For example, the default model estimates a mean (mode) of 0.13 (0.003) *Salmonella*/g on contaminated catfish carcasses. The potential upper bound scenario estimates a mean (mode) of 0.35 (0.016) *Salmonella*/g (i.e., nearly a 3-fold increase in

average concentration). This increase in concentration translates into a nearly proportional increase in annual illnesses (i.e., from 2308 to 6318 cases per year).

Although the truncation method is a modeling assumption, the default model creates a contamination distribution that is consistent with conventional wisdom. It is generally reasonable to assume that the frequency of contamination levels decreases with increasing contamination levels (i.e., that contamination frequency is a monotonically decreasing function of contamination). Nevertheless, there are no catfish contamination data currently available for testing this assumption; once FSIS inspection begins, this uncertainty can be addressed by collecting catfish samples and enumerating *Salmonella* levels on positive samples.

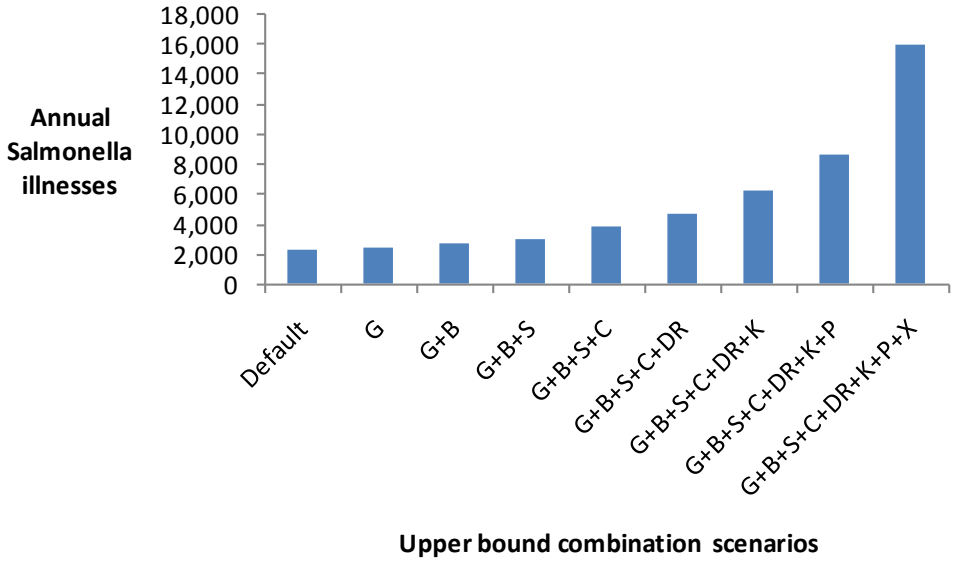

Figure 10. Cumulative increase in the estimated number of illnesses for combined potential upper bound scenarios.

A comparison of these potential upper and lower bound analyses with the inferences drawn from public health surveillance data suggests that the potential lower bound estimates are similar for both (i.e., 100 versus 280 estimated from public health data), but the potential upper bound estimates from this boundary analysis trend toward substantially larger annual illnesses (e.g., 16,000) than those estimated from public health data (6,700). Because it is assumed that a large number of annual illnesses is inconsistent

with current public health surveillance data (i.e., if catfish were truly responsible for tens of thousands of *Salmonella* illnesses each year, it is expected that there would be more evidence of this food source based on epidemiological data), the risk assessment model is designed to examine the scenario from the upper bound analysis that most closely approximates the 6,700 annual illnesses estimated from the analysis of public health data. This scenario, $G+B+S+C+DR+K$, estimates 6,193 annual illnesses. The risk assessment model is used to examine the effect of FSIS inspection on this scenario and the $S+DR+K+P+C$ lower bound scenario.

Recalling that the effect of FSIS regulation on catfish is dependent on the assumption about the peak effectiveness of the regulation and on the timeframe required to achieve peak effectiveness, incorporating additional uncertainty with respect to baseline illness projections further complicates presentation of these results. For illustrative purposes, assume a 50% peak effectiveness of FSIS inspection and a 5-year timeframe for achieving that level of peak effectiveness (Table 18). Given these assumptions, Table 18 shows the number of *Salmonella* illnesses avoided for both the lower bound scenario ($S+DR+K+P+C$ lower) and the plausible upper bound scenario ($G+B+S+C+DR+K$ upper). Annual illnesses avoided ranges from a low of 8 (potential lower bound scenario) to a high of 516 (potential upper bound scenario) in the first year of the program. Since these average estimates are again Poisson distributed, confidence intervals are placed around these estimates of *Salmonella* illnesses avoided per year. Similar to the estimates using the default parameter values, these estimates will vary by year depending on the assumption about timeframe and peak effectiveness of FSIS regulation.

Table 18. Estimated Number of *Salmonella* illnesses avoided by FSIS regulation of catfish using the Siluriformes definition of catfish; assuming a 5-year timeframe and 50% effectiveness of FSIS inspection.

	lower bound scenario[1]			upper bound scenario[2]		
		confidence interval			confidence interval	
year	mean	95th percentile	5th percentile	Mean	95th percentile	5th percentile
1	8	13	4	516	553	479
2	16	23	10	1032	1085	979
3	25	33	17	1548	1613	1483
4	33	43	24	2064	2139	1989
5	42	53	32	2580	2664	2496
6	50	62	39	3096	3188	3004
7	50	62	39	3096	3188	3004
8	50	62	39	3096	3188	3004
9	50	62	39	3096	3188	3004
10	50	62	39	3096	3188	3004

[1] combines lower bound assumptions for serving size, dose response parameter values, skinless effect on fillet contamination levels, *Salmonella* prevalence in catfish, and cooking affect.

[2] combines upper bound assumptions for growth, breading affect, serving size, cooking affect, dose response parameter values, skinless affect on fillet contamination levels.

6. Summary

This risk assessment was completed to inform regulatory rule-making for establishing an FSIS catfish inspection program. This risk assessment considered two definitions for catfish – the definition of the order Siluriformes and the subset of the family Ictaluridae. As a baseline, i.e. prior to the establishment of an FSIS catfish inspection program, this risk assessment estimates an average of 2,309 *Salmonella* illnesses per year in the U.S. associated with the consumption of catfish, based on the definition of catfish as Siluriformes. The assessment estimates an average of 1,764 illnesses based on the definition of catfish as Ictaluridae. These estimates are not inconsistent with those that might be projected by extrapolating current CDC epidmiological data (i.e., outbreak data). Based on the total number of servings of catfish consumed in the U.S., regardless of the definition of catfish, the default probability of *Salmonella* illness per catfish serving is estimated to be 1.5×10^{-6}. This probability incorporates the prevalence of *Salmonella*-contaminated catfish servings and suggests salmonellosis from consuming a serving of catfish is an uncommon event.

There is substantial uncertainty regarding the actual effectiveness of a future FSIS catfish inpsection program. The actual effectiveness of FSIS' catfish inspection program in reducing the prevalence of *Salmonella*-contaminated catfish will directly influence the size of the likely benefits of such a program. To illustrate, this risk assessment predicts that if FSIS has a catfish inspection program fully operational within a two year timeframe, then between 230 and 2,077 salmonellosis cases from catfish consumption (if defined as Siluriformes) might be prevented per year, depending on whether the program is 10% or 90% effective.

Another factor that directly effects the benefits of an FSIS catfish inspection program is the definition of catfish, either as the order Siluriformes or as the family Ictaluridae. Given the same scenario (i.e., 2-year timeframe and a progam that ranges from 10% to 90% effective), between 176 and 1,587 salmonellosis cases per year might be prevented if catfish is defined as Ictaluridae. This is about 24% less salmonellosis cases prevented per year compared to if catfish are defined as Siluriformes.

Finally, the range of risk estimates depends on uncertainty about the model inputs (e.g., data quality and assumptions). Uncertainty about these inputs translates into substantial uncertainty about the baseline estimates of the annual number of human salmonellosis cases attributable to the consumption of catfish. Consideration of potential lower and upper bound model scenarios suggest plausible model estimates between 100 and 6,200 salmonellosis cases associated with catfish per year. Given these public health estimates, this risk assessment estimates that between 50 and about 3,100 salmonellosis cases might be prevented if an FSIS inspection program is 50% effective within a 5-year timeframe. These estimates are based on a definition of catfish as Siluriformes. If catfish were defined as Ictaluridae, then between 38 and about 2,353 cases might be prevented each year.

This food safety risk assessment for catfish provides estimates of potential public health benefits of an FSIS catfish inspection program given current uncertainties about the effectiveness of this future program and limited contamination data for catfish.

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8. Appendix: Hazard Identification

8.1 Prioritization of Microbial Hazards

Several bacterial pathogens have been associated with farmed fish (Ramos and Lyon, 2000). Because catfish is typically cooked prior to consumption, catfish-associated microbes do not routinely present problems of public health concern (Engle et al., 2009). Therefore, defining specific microbiological hazards based on historical trends is a challenge with catfish because the pathogen-product pair relationships are not well established through epidemiological data. For these reasons, the microbial hazard identification was general to foodborne and waterborne pathogens potentially associated with fresh-water fish products.

Pathogens of concern were categorized based on a combination of findings from literature reviews and catfish-associated outbreak information obtained from the Centers for Disease Control and Prevention (CDC) into two priority groups (higher and lower). Categorization was based on microbial association with the water in which catfish are raised, the catfish themselves and the final product, and also with the potential of the microorganisms to cause adverse public health effects through catfish consumption. Hazards are further delineated in terms of their potential relevance to raw or ready-to-eat (RTE) catfish (*i.e.*, the relevant pathogen-product pairs).

For illustrative purposes, the subsequent steps (exposure assessment, hazard characterization (dose-response) and risk characterization) in this catfish risk assessment were applied to just the higher priority hazards identified via the risk characterization process.

Higher Priority Microbial Hazards (Section 8.1.1)

- Non-Typhi *Salmonella* spp. in raw and RTE catfish
- *Listeria monocytogenes* on RTE catfish
- *Clostridium botulinum* and toxins on raw and RTE catfish
- Enterohemophagic, shigatoxigenic, enterotoxigenic and enteropathogenic *E. coli* on raw catfish

Lower Priority Microbial Hazards (Raw and Ready-to-Eat Catfish) (Section 8.1.2)

- *Vibrio spp.*
- Toxins associated with cyanobacteria
- *Edwardsiella tarda*
- *Shigella dysenteriae*
- *Pleisiomonas shigelloides*
- *Salmonella* Serotype *typhi*
- Waterborne parasites
- Viruses

Potential Indicator Bacteria (Section 8.1.3)

- Generic *Escherichia coli* on raw catfish
- Gas-forming anaerobic bacteria on RTE catfish
- Other indicator bacteria for assessing sanitation on raw and RTE catfish

8.1.1 Higher priority microbial hazards

These are recognized foodborne pathogens historically linked to consumption of various freshwater fish products.

Salmonella is a potential microbial hazard for aquatic environments and, thus, may be a concern with respect to catfish products. **Non-*typhi Salmonella*** are regarded as one of the higher priority hazards because the general burden of illness from this pathogen in the U.S. remains a concern and there is evidence that at least one outbreak of human salmonellosis may have been related to catfish consumption. Specifically CDC surmised that an outbreak of 10 cases of salmonellosis (*Salmonella hadar*) at a restaurant in 1991 may have been caused by catfish consumption. (U.S. CDC, 1991).

Salmonella was reported in 21% of 153 aquaculture catfish collected from aquaculture ponds and retail markets (Wyatt, 1979) and can be harbored within catfish for 30 days after exposure to high levels (Ward, 1989). McCaskey et al. (1998) found *Salmonella* on 2.3% of 220 fillets sampled from three processing plants. Most recently, an examination of U.S. Food and Drug Administration (FDA) seafood import refusal data from 1998-2004 identified *Salmonella* contamination to be the most frequent violation in catfish (41.91% of violation categories) (Buzby, 2009) (Table 19). The combination of

data presented in the literature, along with outbreak data and FDA import refusal data show that the highest microbial hazard associated with catfish consumption is *Salmonella*.

Table 19. FDA Violation Codes for Catfish Refusals

FDA Violation Code[1]	Frequency	Percent	Cumulative Frequency	Cumulative Percent
FALSE	1	0.74	1	0.74
FALSECAT	4	2.94	5	3.68
FILTHY	18	13.24	23	16.91
IMPTRHACCP	1	0.74	24	17.65
INCONSPICU	2	1.47	26	19.12
INSANITARY	5	3.68	31	22.79
LABELING	2	1.47	33	24.26
LACKS FIRM	7	5.15	40	29.41
LACKS N/C	3	2.21	43	31.62
LIST INGRE	1	0.74	44	32.35
LISTERIA	3	2.21	47	34.56
MFR INSAN	2	1.47	49	36.03
NO ENGLISH	1	0.74	50	36.76
NO PROCESS	2	1.47	52	38.24
NUTRIT LBL	3	2.21	55	40.44
SALMONELLA	57	41.91	112	82.35
USUAL NAME	19	13.97	131	96.32
WRONG IDEN	5	3.68	136	100.00

[1] All capitalized terms are FDA shorthand code for import violations. List can be found at www.fda.gov/ora/oasis/ora_oasis.

Listeria monocytogenes is a potential hazard for certain RTE catfish products. Because it is a common environmental and aquatic contaminant, its presence in raw catfish may pose an indirect risk for cross-contaminating RTE product (Fernandes et al., 1997). Because *L. monocytogenes* (Lm) often contaminates and grows in cold-smoked fish products, there are likely to be similar risks for cold-smoked, RTE catfish products. Chou et al. (2006) identified Lm in 25 to 47% of raw catfish fillets at three U.S. processing plants. Some isolates were persistently found in processed fillets, suggesting either that the sanitation was inadequate or that these isolates originated from the natural habitats of

the catfish. McCaskey et al. (1998) found a prevalence of 5.9% Lm on catfish fillets. Chou et al. (2006) found that Lm was most commonly isolated from catfish in the winter with a prevalence rate of 51%, compared to 41% in the spring, 36.7% in the fall and 19% in the summer.

Clostridium botulinum is a toxin-forming bacterium capable of causing a rare but life-threatening illness. *C. botulinum* has been isolated from catfish at retail (Baker et al., 1990). While toxins A and B are the primary botulinum toxin types associated with meat and poultry products, catfish and other products from aquatic environments have the potential for contamination by Toxin E-type *C. botulinum*. Unlike the A- and B-type strains, type-E *C. botulinum* can grow and develop neurotoxin during refrigerated storage and, given the serious nature of the illness, warrants special consideration for effective control measures.

Enterohemorrhagic, shigatoxigenic, enterotoxigenic and enteropathogenic *E. coli* are fecal contaminants that cause waterborne and foodborne gastroenteritis. A 2003 outbreak linked catfish and coleslaw consumption to 41 cases of Enterotoxigenic *E. coli* (ETEC) O169:H41-related illness (Beatty, 2004). In this case the outbreak may have been due to cross-contamination, however it remains clear that enterotoxigenic (ETEC) and enteropathogenic *E. coli* (EPEC) are recognized waterborne hazards that could be associated with raw catfish. Shigatoxigenic (STEC) and Enterohemorrhagic (EHEC) *E. coli*, including *E. coli* Serotype O157:H7, have been associated with both waterborne and foodborne gastroenteritis outbreaks. Runoff from ruminant animal farms is a common source for waterborne *E. coli* O157:H7 contamination; proximity to animal farms or access of wild animals to aquaculture ponds could be significant contributing factors.

8.1.2 Lower Priority Microbial Hazards

These include a broad scope of recognized waterborne pathogens, both within and beyond the U.S., that could be harbored on raw fish products, however, the potential for catfish as a vector for foodborne illness remains unclear. This list includes:

***Vibrio* spp.** These known aquatic pathogens include *V. parahaemolyticus* and *V. vulnificus*, associated with seafood products from saltwater and brackish water sources. Their potential for association with catfish from freshwater environments is unclear. Although most environmental *V. cholerae* isolates do not produce cholera toxin, Fernandes et al. (1997) found *V. cholerae* in 10-45% of catfish fillets tested. Catfish consumption has been associated, though not definitively implicated, in *Vibrio* illness in immunocompromised people.

Toxins associated with cyanobacteria (i.e., blue-green algae). These can be hepatotoxic and neurotoxic for humans. Contamination is typically associated with off flavor, so acute exposure has been rare. It is not clear whether there could be more subtle public health risks for exposure to lower levels of these toxins.

Edwardsiella tarda. This is a catfish pathogen that can also cause gastrointestinal illness in immunocompromised people, though human illness has not been definitively linked to catfish consumption.

Shigella dysenteriae. This is a common cause of waterborne gastroenteritis in the developing world, and has the potential to contaminate fish and other food products.

Plesiomonas shigelloides. This has been isolated from freshwater fish in tropical climates. *P. shigelloides* strains associated with human gastrointestinal disease have been isolated from patients living in tropical and subtropical areas. Such infections are rarely reported in the U.S. or Europe.

Salmonella* serotype *typhi. This has not been a focus of FSIS testing because it is typically associated with human rather than food animal carriage; in fact, it has not been grouped with other *Salmonella* species in this assessment because it is not readily detected by the current FSIS *Salmonella* testing method. However, it is a known agent for waterborne gastroenteritis, so catfish are hypothetical vectors for typhoid fever.

Waterborne parasites. Organisms with potential to contaminate domestic and/or imported catfish include *Taenia solium*, *Giardia lamblia*, *Enterobius*, *Cryptosporidium*, *Gnathostoma spinigerum*, *Opisthorchis viverrini* and others.

Viruses (e.g., rotavirus). These can be associated with aquatic environments, but the potential for catfish as a vector for foodborne illness remains unclear.

Other potential pathogens have been tied to catfish and aquatic farm environments, but illness associations with catfish handling or consumption remain unclear. These pathogens include *Pseudomonas aeruginosa* and *Klebsiella pneumoniae*, two opportunistic human pathogens that are typically not associated with either foodborne or waterborne illness, and *Aeromonas hydrophila*, a bacterium that has been considered a suspect but unsubstantiated pathogen.

8.1.3 Potential Indicator Bacteria

Potential indicator bacteria include organisms that indicate the presence of fecal contamination or insanitary conditions, and include:

Generic *Escherichia coli*. These may be useful for understanding the relative risk of aquatic farm environments and raw catfish products. Generic *E. coli* is exclusively associated with fecal contamination and is a commonly used indicator organism for sanitation in the food-processing environment. The International Commission on Microbiological Specifications for Foods recommends that good-quality fresh or frozen fish contain less than 11 CFU *E. coli* per gram (ICMSF, 1986). McCaskey et al. (1998) isolated 2.2 log10 CFU *E. coli* per gram from catfish fillets. Ramos and Lyon (2000) reported levels of -0.8/0 log CFU/g *E. coli* for whole catfish and catfish fillets, respectively. The Sea Grant Extension Program and the International Commission on Microbiological Specifications for Foods recommends *E. coli* limits of 1 and 2.7 log CFU/g for good quality and marginally acceptable fresh and frozen fish products, respectively (ICMSF, 1986).

Gas-forming anaerobic bacteria. Testing could be applied as indicators of potential *C. botulinum* and related proteolytic *Clostridium* spp.

Other indicator bacteria for assessing sanitation on raw and RTE catfish. These could include aerobic plate count (APC), psychrotrophs, coliforms, Enterobacteriaceae, and enterococci. Farid et al. (2000) found levels of 4.3, 2.9 and 2.9 log CFU/g for APC, psychrotrophs and coliforms, respectively. Ramos and Lyon (2000) reported levels of 6.9/7.4 log CFU/g for APC, 6.11/7.11 log CFU/g for anaerobic plate count, and 2.41/2.73 log CFU/g for coliforms for whole catfish and catfish fillets respectively. Andrews et al. (1977) observed APC ranging from 3.8 to 8.3 log CFU/g, total coliforms from <0.48 to 3.97 log CFU/g in fresh catfish. The Sea Grant Extension Program and the International Commission on Microbiological Specifications for Foods recommends that fresh or frozen fish contain less than 5.7 log CFU/g APC for good quality products and less than 7.0 log CFU/g APC for marginally acceptable products.

8.1.4 Literature Summary

In general, catfish consumption is considered to pose a relatively low risk to consumers from a microbiological perspective (McCaskey et al., 1998). This can be attributed largely to the competitive advantage of the indigenous spoilage bacterial population over the pathogen flora during the storage resulting in spoilage prior to the multiplication of pathogens to dangerous levels and due to the destruction of pathogens during cooking.

The CDC reports that fish and shellfish account for 5% of the individual cases and 10% of all foodborne illness outbreaks, with most of these resulting from consumption of raw molluscan shellfish. Food poisoning microorganisms associated with fish include bacteria indigenous to water, those associated with pollution of aquatic environments, and those introduced to animals and their products during post harvest handling and processing (Flick, 2008).

8.2 Identification of Chemical Hazards

The Food Safety and Inspection Service has been tasked with the development of a food safety program for catfish and catfish products. The development of an FSIS regulation to ensure the safety of catfish for human consumption considers the conditions under which catfish are raised, transported, and processed. As such, the potential impacts of environmental factors, aquaculture and processing practices on the exposure of hazards to catfish consumers were considered. This hazard identification represents the initial FSIS characterization of hazards based on current catfish aquaculture.

The information obtained for the hazard identification was gathered through discussions with experts from multiple federal agencies, academic institutions, industry representatives and non-government organizations. Information was also obtained through numerous literature searches in PubMed, Food Science and Technology Abstracts, Chemical Abstracts, USDA DigiTop and Web of Science databases.[33] The key words used during chemical oriented database searches included, but were not limited to "catfish" in combination with one or more of the following: "hazard", "food safety", "food borne", "retail", "process*", "human", "chemical", "pesticide", "organo*", "polychlorinated", "dioxin", "herbicide", "veterinar*" and "drug". The United States Department of Agriculture, United States Environmental Protection Agency (EPA), the Food and Drug Administration (FDA), and the Centers for Disease Control and Prevention (CDC) websites were also used to identify the statistics and regulations to analyze in the hazard identification process.

This approach led to the identification of an extensive list of catfish-associated hazards of potential public health concern. Potential chemical hazards included veterinary drugs used in aquaculture as well as pesticides and heavy metals likely to be present in the environment in and/or around catfish farms and catfish processing facilities. Some chemicals are used in multiple ways and may therefore appear in more than one of the

[33]PubMed: http://www.ncbi.nlm.nih.gov/pubmed/;
Food Science and Technology Abstracts: http://www.foodsciencecentral.com/;
Chemical abstracts: http://pubs.acs.org/;
USDA DigiTop: http://riley.nal.usda.gov/digitop_interim/proxy_stop403.html;
Web of Science: http://www.isiwebofknowledge.com. These websites were accessed between July 2008 and November 2009.

following lists, including drugs (section 8.2.1), pesticides (section 8.2.2), and other chemicals associated with aquaculture (section 8.2.3).

8.2.1 Drugs

The following is an alphabetical list of drugs that were identified to be linked with aquaculture. The focus is on domestic drugs due to available information from the Food and Drug Administration website (www.FDA.gov). At the end of this section is a list of drugs used in foreign aquaculture that was generated with help from Dr. Fran Pell at the Center for Veterinary Medicine, Food and Drug Administration.

According to an email correspondence between Dr. Barbara Montwill at the Office of Food Safety, Center for Food Safety and Applied Nutrition within the Food and Drug Administration and Dr. Jay Vodela (Office of Public Health Science, Food Safety and Inspection Service, U.S. Department of Agriculture) on April 30, 2008, FDA has a drug residue monitoring program that includes Chloramphenicol, Nitrofurans, and Fluoroquinolones, Malachite green (and its metabolite Leucomalachite green), Crystal (Gentian) violet (and its metabolite Leucogentian violet), Quinolones (Oxolinic acid and Flumequine), Ivermectin and Methyltestosterone (U.S. FDA, 2008).

Acetic acid

This is an FDA low regulatory priority aquaculture drug. The allowed use is as a parasiticide for fish at a dose of 1,000 to 2,000 ppm dip for 1 to 10 minutes. There is no withdrawal time or regulatory residue level.

Calcium chloride

This is an FDA low regulatory priority aquaculture drug. The allowed use is to increase water calcium concentration to ensure proper egg hardening. Dosages used would be those necessary to raise calcium concentrations to 10-20 ppm. This drug can also be used up to 150 ppm indefinitely to increase the hardness of water during the holding and transport of fish to enable the maintenance of osmotic balance. There is no withdrawal time or regulatory residue level.

Calcium oxide

This is an FDA low regulatory priority aquaculture drug. The allowed use is as an external protozoacide for fingerlings to adult fish at a concentration of 2000 mg/L for 5 seconds. There is no withdrawal time or regulatory residue level.

Carbon dioxide gas

This is an FDA low regulatory priority aquaculture drug. The allowed use is as an anesthetic in cold, cool and warm water fish. There is no withdrawal time or regulatory residue level.

Chorionic Gonadotropin

This hormone drug (Chorulon) is FDA approved as an intramuscular injection for the use in brood fish to aid in spawning. The approved dosage is 50-510 IU/lb for male fish and 67-1816 IU/lb for female fish. It has been approved for up to 3 doses, not to exceed 25,000IU in fish intended for human consumption and is restricted to use by a licensed veterinarian. There is no withdrawal time or regulatory residue level.

Clove Oil

This substance is not an approved drug by the FDA for the use in aquaculture. Clove Oil is an anesthetic when used as an immersion for fish. There is some concern about anesthetic use in the transport of fish from the farm to the processing plant. According to the FDA Guidance for Industry #150 'Concerns Related to the use of Clove Oil as an Anesthetic for Fish' (April 2007), even though clove oil and its components are GRAS for use in dental cement and as a food additive, it is not GRAS for use as an anesthetic for fish (U.S. FDA, 2007). Clove oil is made up of 85-95% eugenol and the rest consists of isoeugenol and methyleugenol. These ingredients are under investigation by the National Toxicology Program. Isoeugenol has been found to be an equivocal carcinogen, methyleugenol is carcinogenic to rodents and eugenol data is still under review.

Copper sulfate

This drug is currently under review by the FDA for use in aquaculture. It can be used under the Investigational New Animal Drugs (INAD). These products can be used in accordance with the EPA registered label. There is no withdrawal time or regulatory residue level.

Florfenicol

This drug is FDA approved as an antibiotic feed additive for the control of catfish enteric septicemia caused by *Edwardsiella ictaluri and* columnaris associated with Flavobacterium columnare. The approved dosage is 10mg/kg/day for 10 consecutive days. It has a withdrawal time of 12 days, a tolerance level of 1 ppm.

Formalin

This drug is FDA approved as in immersion for the control of external protozoa and monogenetic trematodes on fish and fungi on eggs. The approved dosage for parasite control on adults in tanks and raceways is 250 IU/L indefinitely. For fungi control on eggs the approved dosage is 1000-2000ppm for 15 minutes. There is no withdrawal time or regulatory residue level.

Fuller's earth

This is an FDA low regulatory priority aquaculture drug. The allowed use is to reduce the adhesiveness of fish eggs to improve hatchability. There is no withdrawal time or regulatory residue level.

Garlic (whole form)

This is an FDA low regulatory priority aquaculture drug. The allowed use is for the control of helminthes and sea lice infestations of marine salmonids at all life stages. There is no withdrawal time or regulatory residue level.

Hydrogen Peroxide

This drug is FDA approved as an immersion for the control of columnaris disease caused by *Flavobacterium columnare (Flexibacter columnaris)* and for the control of

saprolegniasis fungi on eggs. The approved dosage for fungi control on eggs in warm water it is 750-1000mg/L for 15 minutes. For the treatment of columnaris disease the approved dosage is 100mg/L for 30 minutes or 50-100 mg/L for 60 minutes once per day, every other day for 3 treatments. There is no withdrawal time or regulatory residue level.

Ice

This is an FDA low regulatory priority aquaculture drug. The allowed use is to reduce metabolic rate of fish during transport. There is no withdrawal time or regulatory residue level.

Magnesium sulfate

This is an FDA low regulatory priority aquaculture drug. The allowed use is to treat external monogenic trematode infestations and external crustacean infestations in fish at all life stages. It is used in all freshwater species. The allowed dose is an immersion at 30,000 mg $MgSO_4$/L and 7000 mg NaCl/L solution for 5 to 10 minutes. There is no withdrawal time or regulatory residue level.

Onion (whole form)

This is an FDA low regulatory priority aquaculture drug. The allowed use is to treat external crustacean parasites and to deter sea lice from infesting the external surfaces of salmonids at all life stages. There is no withdrawal time or regulatory residue level.

Oxytetracycline dihydrate (Terramycin)

This drug (Terramycin 200) is FDA approved as a medicated feed for the control of Pseudomonas disease caused by *Pseudomonas* and bacterial hemorrhagic septicemia caused by *Aeromonas liquefaciens*. The approved dosage is 2.5-3.75g/100lb/day for 10 days. It has a withdrawal time of 21 days and a tolerance level of 2ppm.

Oxytetracycline HCl (Terramycin)

This drug is FDA approved as an immersion for the use with mark skeletal tissues. The approved dosage is 200-700mg/L for 2-6 hours. It has no withdrawal times and a tolerance level of 2ppm.

Papain

This is an FDA low regulatory priority aquaculture drug. The allowed use is as a 0.2% solution in removing the gelatinous matrix of fish egg masses in order to improve hatchability and decrease the incidence of disease. There is no withdrawal time or regulatory residue level.

Potassium chloride

This is an FDA low regulatory priority aquaculture drug. The allowed use is as an aid in osmoregulation which helps to relieve stress and prevent shock. Allowed dosages are those that would be necessary to increase chloride ion concentration to 10-2000 mg/L. There is no withdrawal time or regulatory residue level.

Potassium permanganate

This drug is currently under review by the FDA for use in aquaculture. It can be used in accordance with the legal parameters of investigational use consistent with Investigational New Animal Drugs (INAD). There is no withdrawal time or regulatory residue level.

Povidone iodine

This is an FDA low regulatory priority aquaculture drug. The allowed use is as an egg surface disinfectant during and after water hardening at a dose of 100 ppm solution for 10 minutes. There is no withdrawal time or regulatory residue level.

Sodium bicarbonate

This is an FDA low regulatory priority aquaculture drug. The allowed use is as a means of introducing carbon dioxide into the water to anesthetize fish at a dose of 142-642 ppm for 5 minutes. There is no withdrawal time or regulatory residue level.

Sodium chloride

This is an FDA low regulatory priority aquaculture drug. The allowed use is as an osmoregulatory aid for the relief of stress and prevention of shock at a dose of 0.5% to 1.0% solution for an indefinite period. Another allowed use is as a parasiticide at a dose of 3% solution for 10 to 30 minutes. There is no withdrawal time or regulatory residue level.

Sodium sulfite

This is an FDA low regulatory priority aquaculture drug. The allowed use is as a 15% solution for 5 to 8 minutes to treat eggs in order to improve their hatchability. There is no withdrawal time or regulatory residue level.

Sulfadimethoxine, ormetoprim

This drug is FDA approved as an antibiotic feed additive for the control of enteric septicemia caused by *Edwardsiella ictaluri*. The approved dosage is 50mg/kg/day for 5 days. It has a withdrawal time of 3 days and a tolerance level of 0.1ppm.

Thiamine hydrochloride

This is an FDA low regulatory priority aquaculture drug. The allowed use is to prevent or treat thiamine deficiency in salmonids. The allowed dose is to immerse the eggs in a solution of up to 100 ppm for up to 4 hours during water hardening. Sac fry are allowed to be immersed in a solution of up to 1,000 ppm for up to 1 hour. There is no withdrawal time or regulatory residue level.

Tricaine methanesulfonate (MS-222)

This drug is FDA approved as an immersion for the temporary immobilization of fish. The approved dosage is 15-330mg/L and its use in fish intended for food is restricted to Ictaluidae, Salmonidae, Esocidae and Percidae. It has a withdrawal time of 21 days with no regulatory residue level.

Urea and Tannic acid

This is an FDA low regulatory priority aquaculture drug. The allowed use is to denature the adhesive component of fish eggs at concentrations of 15 g urea and 20 g NaCl per 5 liters of water for about 6 minutes, followed by a separate solution of 0.75 g tannic acid per 5 liters of water for an additional 6 minutes. This dose should treat about 400,000 eggs. There is no withdrawal time or regulatory residue level.

The following is a non-inclusive list of drugs used in foreign aquaculture. These drugs are currently not approved for use in aquaculture by the FDA.

Azamethiphos	Glucans	Nifurpirinol
Chloramphenicol	Isoeugenol	Nitrofuran
Dichlorovos	Ivermectin	Nitrofurantoin
Diflubenzuron	Josamycin	Nitrofurazone
Enrofloxacin	Kanamycin	Norfloxacin
Eugenol	Levamisole	Oxolinic Acid
Fenthion	Malachite green	Praziquantel
Flumequine	Methyltestosterone	Rifampicin
Furazolidone	Nalidixic Acid	Saponin

Sarafloxacin	Teflubenzuron	Tributyltin
Spiramycin	Testosterone	Trichlorfon
Streptomycin	Thiamphenicol	Trifluralin

AMDUCA prohibited drugs

The Animal Medicinal Drug Use Clarification Act (AMDUCA) of 1994 (21 CFR 530) allows veterinarians to use approved FDA drugs outside of there labeled species, indication, dose, frequency or route of administration so long as a valid veterinarian-client-patient relationship exists. This is called extra-label use. The following drugs are prohibited from extra-label use in food animals (21 CFR Part 530.41).

Chloramphenicol- broad spectrum antibiotic known to cause aplastic anemia in humans (U.S. FDA, 1992; Young, 2002)

Clenbuterol- β2 adrenergic agonist used as a growth enhancer and linked with acute poisoning of humans who consumed meat from animals given clenbuterol (U.S. FDA, 1991; Chan, 1999)

Diethylstilbestrol – synthetic nonsteroidal estrogen and a teratogen when given to pregnant women (U.S. FDA, 1999)

Dimetridazole – a nitroimidazole

Ipronidazole - a nitroimidazole

Other nitroimidazoles – antibiotic with mutagenic concerns (U.S. FDA, 2009)

Furazolidone – antibiotic and anti-protozoal whose residues in edible tissues are known carcinogens (U.S. FDA, 2002a)

Nitrofurazone – a nitrofuran antibiotic whose residues in edible tissues are known carcinogens (U.S. FDA, 2002a)

Fluoroquinolones – broad spectrum antibiotic with toxicological concerns (U.S. FDA, 2002b)

Glycopeptides – antibiotics banned from extra-label use due to toxicological concern (U.S. FDA, 1997)

Sulfonamides – antibiotic banned from off label use in lactating dairy cattle; sulfonamide use in humans can cause severe allergic reactions to those allergic

Phenylbutazone – non-steroidal anti-inflammatory (NSAID) banned from off label use in female dairy cattle over 20 months of age; can cause blood dyscrasias, hypersensitivity reactions and is carcinogen in humans (U.S. FDA, 2003)

8.2.2 Pesticides

The following is an alphabetical list of pesticides that were identified to be linked with aquaculture. This list was generated from the U.S. FDA/CFSAN Fish and Fisheries Products and Controls Guidance, third edition June 2001 (U.S. FDA/CFSAN, 2001); the *Guide to Drug, Vaccine, and Pesticide Use in Aquaculture*, April 2007 revision put out by the Federal Joint Subcommittee on Aquaculture working group on quality assurance in aquaculture production (US Federal Joint Committee on Aquaculture, 2007). Information on toxicity was found using the U.S. EPA Integrated Risk Information System (IRIS) (U.S. EPA, 2009)..

<u>2, 4-D (2, 4-Dichlorophenoxyacetic acid)</u>

The FDA/CFSAN Fish and Fisheries Products and Control Guidance has set a tolerance level for 2, 4-D at 0.1 ppm. Under CASRN 94-75-7, the EPA has established an oral reference dose (RfD) of 1E-2 mg/kg/day. The adverse effect of exceeding this dose is hematologic, hepatic and renal toxicity. Under CASRN 94-75-7 there is not an established inhalation reference dose or carcinogenicity assessment.

Acetic Acid

This is an EPA registered aquatic herbicide. The EPA does not have a CASRN number or information for acetic acid available on IRIS.

Aldrin/Dieldrin

Production of this pesticide was discontinued in 1989. It has a characteristic of bioaccumulation in fish. The FDA/CFSAN Fish and Fisheries Products and Control Guidance has set an action level for Aldrin/Dieldrin at 0.3 ppm. Under Aldrin, CASRN 309-00-2, the EPA has established an oral reference dose (RfD) of 3E-5 mg/kg/day. Under Dieldrin, CASRN 60-57-1, the EPA has established an oral reference dose (RfD) of 5E-5 mg/kg/day. The adverse effect of exceeding these doses for both Aldrin and Dieldrin is increased risk of liver toxicity. Aldrin and Dieldrin are classified as class B2 probable human carcinogens. Neither CASRN 309-00-2 or CASRN 60-57-1, list an established inhalation reference dose.

Ammonia

Under CASRN 7664-41-7, the EPA has established an inhalation reference concentration (RfC) of 1E-1 mg/cu.m. The adverse effect of exceeding this concentration includes increased severity of rhinitis and pneumonia with respiratory lesions. Under CASRN 7664-41-7 there is not an established oral reference dose or carcinogenicity assessment.

Antimycin A

This is an EPA registered fish toxicant. It is considered a Restricted Use Pesticide (RUP). This means that each application must be approved by appropriate state and federal fish and wildlife agencies. The EPA does not have a CASRN number or information for antimycin A available on IRIS.

Benzenepropanoic acid

This is an EPA registered aquatic herbicide. The EPA does not have a CASRN number or information for benzenepropanoic acid available on IRIS.

Butoxyethyl 2,4-dichlorophenyoxyacetate

This is an EPA registered aquatic herbicide. The EPA does not have a CASRN number or information for butoxyethyl 2,4-dichlorophenyoxyacetate available on IRIS.

Calcium Hypochlorite

This is an EPA registered algicide and fish toxicant. The EPA does not have a CASRN number or information for calcium hypochlorite available on IRIS.

Chlordane

The EPA cancelled its use as a pesticide in 1988. It has the ability to bioaccumulate in both marine and freshwater species as well as bacteria. The FDA/CFSAN Fish and Fisheries Products and Control Guidance has set an action level for Chlordane at 0.3 ppm. Under CASRN 12789-03-6, the EPA has established an oral reference dose (RfD) of 5E-4 mg/kg/day. The adverse effect of exceeding this dose is hepatic necrosis. Chlordane is classified as a class B2 probable human carcinogen. Under CASRN 12789-03-6, the EPA has established an inhalation reference concentration (RfC) of 5E-4 mg/kg/day. The adverse effect of exceeding this concentration is hepatic effects.

Chlordecone

All products containing chlordecone were cancelled in the U.S. between 1977-1978. It has the ability to bioaccumulate in fish. The FDA/CFSAN Fish and Fisheries Products and Control Guidance has set an action level for Chlordecone at 0.3 ppm. Under CASRN 143-50-0, the EPA has established an oral reference dose (RfD) of 3E-4 mg/kg/day. The adverse effect of exceeding this dose is renal lesions. Chlordecone is listed as likely to be carcinogenic to humans and has an oral slope factor of 10 mg/kg/day. Under CASRN 143-50-0, there is not an established inhalation reference concentration.

Chlorine

This is an EPA registered algicide. Under CASRN 7782-50-5, the EPA has established an oral reference dose (RfD) of 1E-1 mg/kg/day. The adverse effect of exceeding this dose

is no observed adverse effects. Under CASRN 7782-50-5, there is not an established inhalation reference concentration or carcinogenicity assessment.

Chlorophenoxy compounds

This is an EPA registered aquatic herbicide. The EPA does not have a CASRN number or information for ‘chlorophenoxy compounds’ available on IRIS.

Copper Carbonate

This is an EPA registered algicide and aquatic herbicide. The EPA does not have a CASRN number or information for copper carbonate available on IRIS.

Copper Ethanolamine Complex

This is an EPA registered algicide and aquatic herbicide. The EPA does not have a CASRN number or information for ‘copper ethanolamine complex’ available on IRIS.

Copper Hydroxide

This is an EPA registered algicide. The EPA does not have a CASRN number or information for copper hydroxide available on IRIS.

Copper Sulfate

This is an EPA registered algicide, aquatic herbicide, and invertebrate toxicant. The EPA does not have a CASRN number or information for copper sulfate available on IRIS.

Copper Triethanolamine Complex

This is an EPA registered algicide. The EPA does not have a CASRN number or information for ‘copper triethanolamine complex’ available on IRIS.

Crystal Violet (also known as Gentian Violet)

This hazard is an FDA unapproved fungicide. Crystal violet is absorbed into fish tissue and is reduced metabolically to leucocrystal violet. Crystal violet is mutagenic. The EPA does not have a CASRN number or information for crystal violet available on IRIS.

DDT (p,p'-Dichlorodiphenyltrichloroethane), TDE, DDE (p,p'-Dichlorodiphenyldichloroethylene)

After 1972 DDT pesticide was no longer permitted in the U.S. except in cases of public emergency. It is still used throughout the world for the control of malaria. This pesticide has the ability to bioaccumulate in fish. The FDA/CFSAN Fish and Fisheries Products and Control Guidance has set an action level for DDT, TDE, DDE at 5 ppm. Under DDT CASRN 50-29-3, the EPA has established an oral reference dose (RfD) of 5E-4 mg/kg/day. The adverse effect of this dose is liver lesions. DDT and DDE are classified as a class B2 probable human carcinogen under DDE CASRN 72-55-9 and DDT CASRN 50-29-3. Under CASRN 72-55-9 and 50-29-3, DDE and DDT do not have an established inhalation reference concentration. The EPA does not have a CASRN number or information for TDE available on IRIS.

Diflubenzuron

This is an EPA registered invertebrate toxicant. Under CASRN 35367-38-5, the EPA has established an oral reference dose (RfD) of 2E-2 mg/kg/day. The adverse effect of this dose is methemoglobin and sulfhemoglobin formation. Under CASRN, 35367-38-5, there is not an established inhalation reference concentration or carcinogenicity assessment.

Dimethylamine salt of 2,4-D

This is an EPA registered aquatic herbicide. Under CASRN 124-40-3 for dimethylamine, the EPA does not have information for dimethylamine available on IRIS.

Diquat (Diquat Dibromide)

This is an EPA registered algicide and aquatic herbicide. The FDA/CFSAN Fish and Fisheries Products and Control Guidance has set a tolerance level for Diquat at 0.1 ppm. Under CASRN 85-00-7, the EPA has an oral reference dose (RfD) of 2.2E-3 mg/kg/day.

The adverse effect of this dose is minimal lens opacity and cataracts. Under CASRN 85-00-7, there is not an established inhalation reference concentration or carcinogenicity assessment.

Endothall

This is an EPA registered algicide and aquatic herbicide. The EPA has set a tolerance in fish at 0.1ppm for Endothall residues. Under CASRN 145-73-3, the EPA has an oral reference dose (RfD) of 2E-2 mg/kg/day. The adverse effect of this dose is increased absolute and relative weights of stomach small intestine. Under CASRN 145-73-3, there is not an established inhalation reference concentration or carcinogenicity assessment.

Endrin

EPA banned pesticide. Under CASRN 72-20-8, the EPA has an oral reference dose (RfD) of 3E-4 mg/kg/day. The adverse effect of this dose is mild histological lesions in liver and occasional convulsions. Endrin is classified as class D, not classifiable as to carcinogenicity for humans. Under CASRN 72-20-8, there is not an established inhalation reference concentration.

Fluridone (Ansi)

This is an EPA registered aquatic herbicide. The FDA/CFSAN Fish and Fisheries Products and Controls Guidance has set a tolerance level for Fluridone at 0.5 ppm. Under CASRN 59756-60-4, the EPA has an oral reference dose (RfD) of 8E-2 mg/kg/day. The adverse effect of exceeding this dose is glomerulonephritis, atrophic testes, eye keratitis along with a decrease in body and organ weights. Under CASRN 59756-60-4, there is not an established inhalation reference concentration or carcinogenicity assessment.

Glyphosate Isopropylamine Salt

This is an EPA registered aquatic herbicide. The FDA/CFSAN Fish and Fisheries Products and Controls Guidance has set a tolerance level for Glyphosate at 0.25 ppm. Under CASRN 1071-83-6, the EPA has an oral reference dose (RfD) of 0.1 mg/kg/day

for glyphosate. The adverse effect of exceeding this dose is kidney defects in subsequent generations. Glyphosate is classified as class D, not classifiable as a human carcinogen.

Heptachlor

This pesticide hasn't been used since 1988 but it is still registered by the EPA for killing fire ants in buried power transformers. It has the ability to bioaccumulate in fish. The FDA/CFSAN Fish and Fisheries Products and Controls Guidance has set an action level for Heptachlor at 0.3 ppm. Under CASRN 76-44-8, the EPA has an oral reference dose (RfD) of 5E-4 mg/kg/day. The adverse effect of exceeding this dose is an increase of liver weight in males. Heptachlor is classified as a class B2, probable human carcinogen. Under CASRN 76-44-8, there is not an inhalation reference concentration.

Heptachlor Epoxide

This pesticide hasn't been used since 1988 but it is still registered by the EPA for killing fire ants in buried power transformers. It has the ability to bioaccumulate in fish. The FDA/CFSAN Fish and Fisheries Products and Controls Guidance has set an action level for Heptachlor Epoxide at 0.3 ppm. Under CASRN 1024-57-3, the EPA has an oral reference dose (RfD) of 1.3E-5 mg/kg/day. The adverse effect of exceeding this dose is an increased liver-to-body ration in both males and females. Heptachlor epoxide is classified as a class B2, probable human carcinogen. Under CASRN 1024-57-3, there is not an inhalation reference concentration.

Hexachlorobenzene

This pesticide is banned by the EPA. Under CASRN 118-74-1, the EPA has an oral reference dose (RfD) of 8E-4 mg/kg/day. The adverse effect of exceeding this dose is liver effects. Hexachlorobenzene is classified as a class B2, probable human carcinogen. Under CASRN 118-74-1, there is not an inhalation reference concentration.

Imazapyr (isopropylamine salt)

This is an EPA registered aquatic herbicide. The EPA does not have a CASRN number or information for Imazapyr available on IRIS.

Lime (calcium/magnesium hydroxide)

The EPA does not have a CASRN number or information for lime available on IRIS.

Lindane (gamma-hexachlorocyclohexane)

This is a pesticide. Under CASRN 58-89-9, the EPA has an oral reference dose (RfD) of 3E-4 mg/kg/day. The adverse effect of exceeding this dose is liver and kidney toxicity. Under CASRN 58-89-9, there is not an inhalation reference concentration or carcinogenicity assessment.

Malachite Green and Leucomalachite Green

This is an FDA prohibited fungicide. Malachite green is excreted rapidly but >80% is metabolized into Leucomalachite green which can remain in the muscle for months. This hazard is considered a mutagen and teratogen. Brilliant Green is another compound similar in structure to Malachite Green and should also be considered a hazard. The EPA does not have a CASRN number or information for lime available on IRIS.

Methyl Mercury

The FDA/CFSAN Fish and Fisheries Products and Controls Guidance has set a guidance level for Methyl Mercury at 1.0 ppm for finfish. Under CASRN 22967-92-6, the EPA has an oral reference dose of 1E-4. The adverse effect of exceeding this dose is developmental neuropsychological impairment. Methyl mercury is classified as a class C, possible human carcinogen. Under CASRN 22967-92-6, there is not an inhalation reference concentration.

Mirex

This pesticide's use was cancelled in the U.S. between 1977-1978. It has the ability to bioaccumulate in fish. The FDA/CFSAN Fish and Fisheries Products and Controls Guidance has set an action level for Mirex at 0.1 ppm. Under CASRN 2385-85-5, the

EPA has an oral reference dose (RfD) of 2E-4 mg/kg/day. The adverse effect of exceeding this dose is increased risk of liver cytomegaly, fatty metamorphosis, angiectasis and thyroid cystic follicles. Under CASRN 2385-85-5, there is not an inhalation reference concentration or carcinogenicity assessment.

Polychlorinated Biphenyls (PCB's)

Manufacture of PCB's stopped in the U.S. in August of 1977. It has the ability to bioaccumulate in fish. The FDA/CFSAN Fish and Fisheries Products and Controls Guidance has set a tolerance level for PCB's at 2.0 ppm. Under CASRN 1336-36-3, the EPA does not have information for PCB available on IRIS, but does reference readers to see Aroclor 1016, 1248 and 1254.

Potassium Permanganate

The EPA does not have a CASRN number or information for potassium permanganate available on IRIS.

Rotenone (Cube Resins Other than Rotenone) (Piperonyl Butoxide Technical)

This is an EPA registered fish toxicant. It is considered a Restricted Use Pesticide (RUP). This means that each application must be approved by appropriate state and federal fish and wildlife agencies. Under CASRN 83-79-4, the EPA has an oral reference dose (RfD) of 4E-3 mg/kg/day. The adverse effect of exceeding this dose is reduced pup weight. Under CASRN 83-79-4, there is not an inhalation reference concentration or carcinogenicity assessment.

Simazine

The FDA/CFSAN Fish and Fisheries Products and Controls Guidance has set a tolerance level for Simazine at 12 ppm. Under CASRN 122-34-9, the EPA has an oral reference dose (RfD) of 5E-3 mg/kg/day. The adverse effects of exceeding this dose are a reduction in weight gain and hematological changes in females. Under CASRN 122-34-9, there is not an inhalation reference concentration or carcinogenicity assessment.

Sodium 2,4-dichlorophenoxyacetate

This is an EPA registered aquatic herbicide. The EPA does not have a CASRN number or information available on IRIS.

Sodium Bromide

This is an EPA registered algicide. The EPA does not have a CASRN number or information available on IRIS.

Sodium Hypochlorite

This is an EPA registered algicide and fish toxicant. The EPA does not have a CASRN number or information available on IRIS.

Sodium Percarbonate

This is an EPA registered algicide. The EPA does not have a CASRN number or information available on IRIS.

Tartrazine/Erioglaucine

This is an EPA registered algicide and aquatic herbicide. The EPA does not have a CASRN number or information available on IRIS.

Teaseed and mahua oil cake (sapogenin glycosides)

The EPA does not have a CASRN number or information available on IRIS.

Triazine Herbicides

Under atrazine CASRN 1912-24-9, the EPA has an oral reference dose (RfD) of 3.5E-2 mg/kg/day. The adverse effects of exceeding this dose are a reduction in weight gain. Under propazine CASRN 139-40-2, the EPA has an oral reference dose (RfD) of 2E-2 mg/kg/day. The adverse effects of exceeding this dose are a reduction in weight gain. There are no inhalation reference concentrations or carcinogenicity assessments for CASRN 1912-24-9 and 139-40-2.

8.2.3 Other Chemicals Associated with Aquaculture

The following is an alphabetical list of other chemicals that were identified to be linked with aquaculture. This list was generated from WHO technical report series 883, Food Safety Issues Associated with Products from Aquaculture from FAO/NACA/WHO, 1999 (WHO/FAO/NACA, 1999).

Agricultural limestone

Water treatment used to raise pH and to sterilize pond soils between production cycles. The EPA does not have a CASRN number or information available on IRIS.

Ammonium phosphate (mono- and dibasic)

Fertilizer for phytoplankton. The EPA does not have a CASRN number or information available on IRIS.

Aluminum Sulfate

Flocculant used to cause suspended clay particles to precipitate to clear water turbidity. The EPA does not have a CASRN number or information available on IRIS.

Ammonium Sulfate

Fertilizer for phytoplankton. The EPA does not have a CASRN number or information available on IRIS.

Ammonium Nitrate

Fertilizer for phytoplankton. The EPA does not have a CASRN number or information available on IRIS.

Benzalkonium chloride (alkyldimethylbenzylammonium chloride)

Disinfectant used on equipment and holding pens. The EPA does not have a CASRN number or information available on IRIS.

Calcium Hypochlorite

Oxidizing agent for controling phytoplankton, killing disease organisms or oxidizing bottom soils. The EPA does not have a CASRN number or information available on IRIS.

Calcium Peroxide

Oxidizing agent for controling phytoplankton, killing disease organisms or oxidizing bottom soils. The EPA does not have a CASRN number or information available on IRIS.

Calcium Phosphate

Fertilizer for phytoplankton. The EPA does not have a CASRN number or information available on IRIS.

Calcium Sulfate (gypsum)

Flocculant used to cause suspended clay particles to precipitate to clear water turbidity, also an osmoregulator applied to the water to improve conditions for normal osmoregulation. The EPA does not have a CASRN number or information available on IRIS.

Ferric Chloride

Flocculant used to cause suspended clay particles to precipitate to clear water turbidity. The EPA does not have a CASRN number or information available on IRIS.

Hydrogen Peroxide

Oxidizing agent for controling phytoplankton, killing disease organisms or oxidizing bottom soils. The EPA does not have a CASRN number or information available on IRIS.

Hypochlorite

Disinfectant used on equipment and holding pens. The EPA does not have a CASRN number or information available on IRIS.

Lime (calcium/magnesium hydroxide)

Water treatment used to raise pH and to sterilize pond soils between production cycles. The EPA does not have a CASRN number or information available on IRIS.

Phosphoric Acid

Fertilizer for phytoplankton. Under CASRN 7664-38-2, the EPA has an inhalation reference concentration (RfC) of 1E-2 mg/cu.m. The adverse effects of exceeding this dose are bronchiolar fibrosis. Under CASRN 122-34-9, there is not an oral reference dose or carcinogenicity assessment available on IRIS.

Polyvidone iodine (polyvinylpyrrolidone-iodine complex)

Disinfectant used on equipment and holding pens. The EPA does not have a CASRN number or information available on IRIS.

Potassium Chloride

Fertilizer for phytoplankton. The EPA does not have a CASRN number or information available on IRIS.

Potassium nitrate

Fertilizer for phytoplankton. The EPA does not have a CASRN number or information available on IRIS.

Potassium Permanganate

oxidizing agent for controling phytoplankton, killing disease organisms or oxidizing bottom soils. The EPA does not have a CASRN number or information available on IRIS.

Sodium Chloride (salt)

Osmoregulator applied to the water to improve conditions for normal osmoregulation. The EPA does not have a CASRN number or information available on IRIS.

Sodium Nitrate

Fertilizer for phytoplankton, oxidizing agent for controling phytoplankton, killing disease organisms or oxidizing bottom soils. The EPA does not have a CASRN number or information available on IRIS.

Sodium Silicate

Fertilizer for phytoplankton. The EPA does not have a CASRN number or information available on IRIS.

Trace element mixes including iron, zinc, copper, boron and molybdenum

Fertilizer for phytoplankton. The EPA does not have a CASRN number or information available for iron on IRIS. Copper has a CASRN of 7440-50-8, but he EPA does not have information on oral reference dose (RfD), inhalation concentration (RfC) or carcinogenicity available on IRIS. Zinc has a CASRN of 7440-66-6 and oral reference dose (RfD) of 0.3 mg/kg/day with an adverse effect of decreasing erythrocyte Cu, Zn-superoxide dismutase activity in healthy adult male and female volunteers. Under CASRN 7440-66-6, zinc does not have an inhalation reference concentration or carcinogenicity assessment. Boron has a CASRN of 7440-42-8 and oral reference dose (RfD) of 2E-1 mg/kg/day with an adverse effect of decreasing fetal weight. Under CASRN 7440-42-8, boron does not have an inhalation reference concentration or carcinogenicity assessment. Molybdenum has a CASRN of 7439-98-7 and oral reference dose (RfD) of 5E-3 mg/kg/day with an adverse effect of increasing uric acid levels. Under CASRN 7439-98-7, molybdenum does not have an inhalation reference concentration or carcinogenicity assessment.

Urea

Fertilizer for phytoplankton. The EPA does not have a CASRN number or information available on IRIS.

Zeolite

Flocculant used to cause suspended clay particles to precipitate to clear water turbidity. The EPA does not have a CASRN number or information available on IRIS.

8.3 Selected Chemical Residues Detected in Catfish

A variety of potential chemical hazards have been detected in a limited sample of catfish samples. Prevalence and concentrations of residues for some of these hazards are presented in Table 20. For each analyte, the residue data for domestic and imported catfish were obtained using the same analytical procedures, the same laboratories, and fish that were harvested at approximately the same time; this facilitates the comparison of residues in imported and domestic catfish. Combining these data in a single table is illustrative of the concentrations found, but caution should be used in drawing conclusions from this table without taking into account variations in the sample design, thus the ability to generalize the findings.

Additional catfish-specific data are being generated in order to determine both prevalence and concentration of the chemical hazards in catfish. USDA Agricultural Marketing Service (USDA-AMS) catfish pesticide study continues to provide useful data and the USDA Agricultural Research Service (ARS) is working with FSIS to conduct surveillance sampling to determine prevalence and concentration of pathogens and chemical residues in domestic and imported catfish at retail markets and processing plants.

When the FSIS catfish inspection program is in place, the data generated will allow the Agency to further characterize catfish chemical and microbial hazards and to perform risk evaluations to address catfish consumption associated hazards that can cause adverse human health outcomes.

Table 20. Summary of Recent Catfish Residue Data

	Domestic						Concentration			Regulatory Levels	
	% Positive	% Violative	N	Data	Sampling	LOD	Mean (all)	Mean (positives)	Max	FDA	Codex
				Source	Year	ppb	ppb	ppb	ppb	ppb	ppb
DDT	93%	0%	281	1	2008	1	34.4	37	651	5000	
PCB*	98%	0%	120	2	2001-2003	1E-7 to 1E-3	6.0E-04	6.2E-04	4.6E-03	2000	
Chlorpyrifos	1%	0%	303	1	2008	1	0.0	1.8	2.6	0	
Arsenic	0%	0%	20	3	2008	200	0.0	0	0		
Cadmium	0%	0%	20	3	2008	10	0.0	0	0		
Lead	0%	0%	20	3	2008	25	0.0	0	0		300
Mercury	0%	0%	20	3	2008	100	0.0	0	0	1000	500
Malachite Green	0%	0%	16	2	2007	1	0	0	0	0	
Gentian Violet	0%	0%	2	2	2008	0.1	0	0	0	0	
Nitrofurans	ND	0%	ND	-		1	ND	ND	ND	0	
	Import						Concentration			Regulatory Levels	
	% Positive	% Violative	N	Data	Sampling	LOD	Mean (all)	Mean (positives)	Max	FDA	Codex
				Source	Year	ppb	ppb	ppb	ppb	ppb	ppb
DDT	46%	0%	70	1	2008	1	3.1	6.7	53	5000	
PCB*	63%	0%	8	2	2001-2003	1E-7 to 1E-3	3.8E-06	6.0E-06	1.4E-05	2000	
Chlorpyrifos	32%	0%	75	1	2008	1	0.9	2.9	16.4	0	
Arsenic	2%	0%	110	3	2008	200	23.6	1300	1600		
Cadmium	0%	0%	112	3	2008	10	0.0	0	0		
Lead	10%	0%	112	3	2008	25	4.1	42	77		300
Mercury	0%	0%	112	3	2008	100	0.0	0	0	1000	500
Malachite Green	9%	0%	150	2	2007	1	1.2	12.5	122	0	
Gentian Violet	2%	0%	53	2	2008	0.1	0.0	2.5	3	0	
Nitrofurans	ND	0%	ND	-		1	ND	ND	ND	0	

*PCB data reported as toxicity equivalents; LOD varies for each conjener analyzed; ND = no data

Data sources: 1)USDA-AMS 2008; 2) US FDA 2008b; 3)USDA-FSIS, 2009

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