# 1 Introduction

Toxic chemicals from point sources such as industrial or municipal discharges, and from non-point sources such as agricultural runoff have contaminated some surface waters and their sediments across the United States (U.S. EPA, 1992; Schmitt and Brumbaugh, 1990; Schmitt et al., 1990). In addition, naturally occurring chemicals such as mercury can also contaminate waters and sediments. Many of these pollutants concentrate in fish tissues by accumulating in fat or binding to muscle. These contaminants found in fish may pose health risks to people eating the fish. Those eating higher than average amounts of fish, such as sport and subsistence anglers, are at a potential greater risk from eating contaminated fish than the general population. In an effort to protect public health, state, local, and federal agencies and tribes issue fish consumption advisories, when necessary, that usually recommend limits on the number of fish meals which can safely be consumed within a specified time period (U.S. EPA, 1997a; Reinert et al., 1996; Dourson and Clark, 1990). These advisories are often issued for certain species of fish from specific bodies of water, to address local contamination.

Fish consumption advisories are the current method for consumers to gain information on health risks of contaminated fish. It is States and Tribes that issue fish consumption advisories and they use varying methods and scientific judgments in reaching their conclusions. In addition, policy issues may also be considered in setting these advisories, leading to greater difficulties for individuals trying to determine their personal risks (Kamrin and Fischer, 1999).

While these advisories are generally based solely on considerations of the potential adverse effects posed by the chemicals in fish, these same fish are an excellent source of low-fat protein and may provide additional health benefits. Some recent publications have suggested that the health benefits of eating even contaminated fish may outweigh the potential risks caused by the presence of contaminants (e.g., Anderson and Weiner, 1995).

Fish consumption advisories, however, are not regulations and compliance with the governmental advice varies (e.g., May and Burger, 1996; Knuth, 1995). It is individuals who make the decision whether and how much fish to eat. Anglers, fishery experts, and health care experts have all identified the importance of having information about how risks change with different levels of fish consumption (Velicer and Knuth, 1994). Studies have demonstrated that some anglers do respond to health risk information by changing their fishing-related behavior. Changes include eating less sport-caught fish, changing fish-cleaning methods, changing fishing locations, changing species eaten, changing the size of fish eaten, and changing cooking methods (Connelly et al., 1992). Connelly et al. (1996) provided evidence that fish consumption suppression (anglers eating less fish than they would in the absence of health advisories) was prevalent among Lake Ontario anglers.

Studies of licensed anglers have indicated the perceived importance of health advisory information on potential health benefits and risks associated with fish consumption. These same studies also note that anglers recognize the importance of how risks change as more or less fish is eaten, and compare the health risks of eating fish with the risks from other protein sources (e.g., Connelly et al., 1992; Connelly and Knuth, 1993).

Evaluating the potential risks (and benefits) requires information on contamination levels and consumption rates. Surveys of anglers and their families have shown that rates of fish consumption vary widely among subpopulations by race or ethnicity, age, sex, income, fishing mode, region of the country and other demographic variables (CAL EPA, 1997). For example, regional surveys of sport fishing populations report overall mean rates for consumption of sport fish ranging from 12.3 to 63.2 g/day (CALEPA, 1997), while U.S. EPA estimates a fish consumption rate for the general population for all fish of 20.1 g/day (uncooked weight) (U.S. EPA, 1997b). Studies among tribal and subsistence fishing populations have found much higher levels of consumption (see for example Toy et al., 1996, CALEPA 1997 and U.S. EPA, 1997b). This wide variability in consumption rates and patterns reinforces the necessity of evaluating fish pollutants and consumption on a case-by-case or local basis.

While contaminants in fish pose a public health risk, fish is also an excellent source of protein and provides additional health benefits not available from other foods. It has been recognized for over a decade that a need exists to evaluate the benefits of fish as a food source, as well as the risks from contaminants, when setting fish consumption advisories (CDHS, 1988; Kimbrough 1991; Egeland and Middaugh, 1997). The California Department of Health Services sponsored a workshop in 1988 called "Balancing the Scales: Weighing the Benefits and Risks of Fish Consumption." Speakers addressed the nutritional composition of fish, cardiovascular effects from n-3FA and benefits of fish oil consumption, along with exposures and health risks. Over ten years later there is more scientific data on potential health benefits of eating fish.
Putting risks into perspective is even more important when the fish are a part of a traditional subsistence diet, which is important to a group's cultural identity (Egeland et al., 1998). In addition, for some communities, alternate foods are not readily available or affordable.

The need to consider the beneficial aspects of fish consumption has also been recognized by the Federal-State-Tribal Fish Forum sponsored by EPA (AFS, 1997). This group of federal, state and tribal scientists and public health officials has identified consideration of benefits from fish as one of their top issues needing research and guidance. The research discussed in this document is a direct result of this group's request.

When advisories are issued and suggestions made to reduce consumption of contaminated fish, individuals may respond in a number of ways. They may follow the fish advisory and reduce their consumption of that particular type of fish, they may reduce exposure to contaminants by selecting a less-contaminated fish or preparation method, they may stop eating fish, or, they may ignore the advice and eat without regard to the advisory. Ideally, by selecting and eating the least contaminated species, one can enjoy fish and its benefits without the health risks of contaminants. However, if individuals do reduce their consumption of contaminated fish and replace it with other non-fish foods; depending on the food choices made, these dietary changes may not reduce overall health risks and may actually result in greater overall health risks. Situations of subsistence populations, who have limited alternatives to a contaminated fish source, may encounter this dilemma of needing to weigh the benefits and risks. To fully evaluate the risks and benefits, one needs to examine the target risk – that is the adverse health effect from eating fish with chemical contaminants – as well as the countervailing risks, such as the consequences of reducing fish consumption and the potentially reduced nutritional or health benefits of the substituted foods.

Graham and Wiener explore the issues of target and countervailing risks for a number of public health issues in their book Risk vs. Risk: Tradeoffs in Protecting Health and the Environment (1995). For example, if a fish consumption advisory recommends reducing consumption of fish contaminated with a particular chemical, and

- the fish in the diet is replaced with a large amount of fruits and vegetables, the consumer may trade a decreased cancer risk from contaminants in fish (the target risk, i.e., the risk the advisory is designed to reduce) for an increased cancer risk from increased ingestion of anthropogenic and natural pesticides (the countervailing risk, i.e., the risk that may increase as a result of the advisory).

- the fish in the diet is replaced with red meat, the consumer may be trading a decreased risk of mortality from cancer (target risk) for an increased risk of mortality from heart disease (countervailing risk), due to an increased consumption of saturated fat.

- the consumption of local fish high in PCBs, such as salmon, is replaced with an increased consumption of canned tuna high in methylmercury, the consumer may be trading increased risk of developmental toxicity and cancer from PCBs (target risk), for an increased risk of neurological disease from methyl mercury (countervailing risk).

In one chapter of this book Anderson and Wiener (1995) concluded that the protective effect of increasing fish consumption on chronic heart disease far outweighed the increased cancer risk posed by contaminants in fish. Using U.S. EPA's cancer slope factors and assuming that fish contained the FDA limits of 6 common fish contaminants[1], Anderson and Wiener (1995) found that the cancer risk associated with eating 1 gram of fish per day for a 70-year lifetime was 5 x 10-4. Based on their analysis, increasing consumption of fish from 0 to 40 grams per day would increase the average American's risk of dying by 2 percent from cancer[2]. However, the same increase in fish consumption would decrease the average American's risk of dying from heart disease by 35 percent. Thus, public health officials and consumers might want to evaluate a broad range of dietary information before making decisions regarding consumption of contaminated fish.

Countervailing risks can go beyond the health implications of food substitutions and include social, economic, religious and cultural impacts (Wheatley and Paradis, 1996). Harris and Harper (1997) have explored how to evaluate impacts other than direct risk to health. They have developed a Native American exposure scenario that identifies parameters for evaluating countervailing impacts on cultural and religious activities. These may affect quality of life, which in turn impacts both individual and community health and well-being.

The direct benefits of fish consumption can be thought of as arising from two sources. The first relates to the change in the incidence of a particular health outcome as related to fish consumption rate (e.g., decrease in heart disease with increasing fish consumption). The results

[1] Chlorpyrifos, Chlordane, DDT, Dioxin, PCBs and Methylmercury

[2] Anderson and Weber (1995) recognized that EPA's cancer risk method predicts upper bound incidence of cancer, but assumed that cancer incidence was the same as cancer mortality in order to err on the side of protecting public health.

of these studies can be used to derive a dose-response relationship between fish consumption rate and the health outcome being investigated (within limits imposed by the data). The second relates to how general nutritional status changes as fish is substituted for some other source of protein or is removed from the diet.

There is some evidence for an association between decreased risk of coronary heart disease (CHD) or myocardial infarction (MI) and consumption of small amounts of fish, including mainly lean (non-fatty) fish. In addition, other health endpoints have been examined and some research suggests that eating fish may be associated with reduced incidences or severity of a number of other endpoints. The possible benefits in the form of reduced risk of particular diseases are discussed in Chapter 2.

There are many nutritional benefits associated with eating fish, regardless of the species type. Perhaps, unlike red meats, eggs and dairy products, fish provides very high quality protein and a "heart healthy"' combination of fatty acids. Further, fish (both lean and fatty) is one of the few foods that contain omega-3 (n-3) fatty acids, a class of fatty acids that are essential for the development of the nervous system and that may have other beneficial health effects. Fish supplies a number of vitamins and minerals that tend to be low in the U.S. diet, including calcium, iron, zinc, vitamin A, niacin, vitamin B6 and vitamin D, in addition to others. The nutritional advantages of fish compared to other protein sources are discussed in Chapter 3.

Fish consumption advisory programs have traditionally focussed on assessing the potential human health risks from eating contaminated fish and estimating safe consumption limits. Chapter 4 discusses potential health risks for a number of common contaminants and discusses the methods for estimating risk used later in this document.

Food, and fish in particular, may also be an important part of a culture, serving economic, social, aesthetic, and religious functions. Specific foods are often seen as having special nutritional or medicinal qualities, and methods of food preparation are frequently part of one’s cultural identity. These cultural factors may need to be considered in evaluating risks and benefits from consumption of contaminated fish for some subpopulations. Chapter 5 outlines the social and cultural importance of fish to particular groups of people.

Chapter 6 develops the comparative dietary risk framework which compares the possible health risks of consuming contaminated fish, while considering the potential health benefits lost by not eating fish. Example outputs using hypothetical data and two case studies with actual exposure scenarios are also included. The result of using the framework is the fish consumption index (FCI), which is a crude quantitative representation of the net risk (or benefit) associated with eating contaminated fish. It provides a mechanism by which users can weigh the possible health risks versus the possible health benefits of eating contaminated fish. Cultural benefits of catching and eating fish (or detriments of not being able to fish or consume fish) may also be considered, however the current version of the framework does not attempt to quantify these benefits.

Because of the data intense process and results of the FCI, a solid risk communication program is necessary to insure successful usage of the information generated. Chapter 7 summarizes key elements of the risk communication process as applied to the comparative dietary risk framework, emphasizing that risk communication is a process of information exchange between the target audience and the risk communicator. Although the framework provides a mechanism for comparing risks and benefits associated with fish consumption, it is not a justification for accepting fish consumption risks as long as there is a net benefit. Decisions about acceptable risks and distribution of risks and benefits throughout society is a social decision, to be made collectively by the communities affected. Rather, the framework helps make the tradeoffs between risks and benefits more transparent.

When alternatives to consumption of contaminated fish are not available or desired, it may be appropriate to weigh the risks of eating less contaminated fish with the benefits gained from eating more of these same fish. The framework developed here can crudely compare these risks and benefits. However, this framework has a number of significant data gaps, which are discussed in Chapter 8. These gaps are sufficiently large so as to prevent any definitive conclusions from this study or any overall recommendations regarding existing fish consumption advisory programs of the U.S. or other countries. Further work is needed to confirm and extend these preliminary findings.

The purpose of the current research is to develop an understanding and framework by which to evaluate the comparative risks posed by dietary changes as a result of fish consumption advisories. This research builds upon previous work from a series of documents developed by the U.S. EPA on "Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories." The four-volume set includes Volume 1-Fish Sampling and Analysis (1995a), Volume 2-Risk Assessment and Fish Consumption Limits (1997a), Volume 3-Overview of Risk Management (1996), and Volume 4-Risk Communication (1995b). The results of this research can lead to a better understanding of the effects that fish consumption advisories have on diet and public health. We anticipate that public health officials and consumers may use this increased understanding to evaluate a broad range of dietary information before making decisions about whether or not to eat contaminated fish.

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