UNIVERSITY OF CALIFORNIA, DAVIS

BERKELEY • DAVIS • IRVINE • LOS ANGELES • MERCED • RIVERSIDE • SAN DIEGO • SAN FRANCISCO • SANTA BARBARA • SANTA CRUZ

DEPARTMENT OF ENVIRONMENTAL SCIENCE AND POLICY
ONE SHIELDS AVENUE
DAVIS, CALIFORNIA 95616-8576

March 31, 2010

Pamela Creedon and Regional Board Members:

Thank-you for this opportunity to comment on the Draft TMDL and Basin Plan Amendment for Methylmercury in the Delta. I have been involved in this issue for the last 10 years. I conducted the longest-running and most extensive survey of anglers in the Delta. I am a researcher at UC Davis specializing in aquatic ecology and policy. These comments are my own and do not represent the University, its staff & faculty, or the Regents.

I include here for reference 3 documents that are relevant to the development of the TMDL, but which are not obviously used in the current draft. The first is an article that was recently published in the scientific journal "Environmental Research" describing the results of a 2 & ½ year fish consumption study in the Delta of over 500 anglers and family members (Attachment A). Although Regional Board staff has known about this study since its inception, was informed of its findings last year, and was given the accepted manuscript prior to publication, the findings are noticeably absent from consideration in the TMDL and BPA. The second is a study commissioned by the Regional Board determining how many people are at risk from consuming mercury-contaminated fish in the Delta (Attachment B). This study should be useful in determining the urgency for immediate action in the Delta to reduce methyl-mercury, rather than waiting for 9 years to take significant action. The third is a stakeholder survey commissioned by the Regional Board and the California Department of Public Health to determine the appropriate role for community organizations in planning and implementing actions to reduce exposure of fish-consumers to mercury (Attachment C). This survey found that 30 stakeholders unanimously placed community organizations at the center of decision-making and implementation, but the recent TMDL "stakeholder process" made no serious efforts or provisions to include community groups.

I have several conclusive remarks to make regarding the TMDL as currently crafted:

1) The fish consumption rates used to set recommended fish tissue targets are too low for two reasons: a) the mean values and 95th percentile rates are drawn from studies outside the Delta and are much lower than the rates found in the attached study (Attachment A, Shilling et al., 2010); b) using mean or average values of fish consumption, rather than 95th percentile rates from local studies to set targets results in the higher consuming 50% of the population NOT being protected by the fish tissue target.

2) The State Water Resources Control Board has clearly set the policy of protecting the most sensitive of beneficial uses within TMDLs. This is reflected in TMDL examples, such as the one for pathogenic bacterial contamination of Southern California beaches. The current TMDL and BPA does not use this

standard. It uses a standard of protecting the lower 50% of sensitivity of uses, based on the use of average fish consumption rates, assuming the rates were correct.

3) Approximately 50,000 anglers and their family members, including women and children, are affected right now by mercury contamination of Delta fish (attached study). Waiting 8 or 9 years to implement actions under the TMDL will result in continued harm and no diminishment in this harm to this population.

3) The “stakeholder process” was well-funded, but mis-managed. It included excessive representation by the regulated parties and virtually no representation of impacted communities. This essentially set up a partnership between the regulated and regulator parties, to the exclusion of the communities and their representatives actually impacted by mercury in Delta fish. This is almost the opposite of what one would expect from a stakeholder process where those with a health and well-being stake would be front and center and those with only a management interest would be included as a minority party. Based on stakeholder process sign-in sheets, dischargers and agencies represented >90% of participants. This process was dysfunctional and distracting. It should not be looked to for any guidance about how the TMDL should be implemented, though it does provide a good summary of how regulated parties feel about the TMDL.

Adoption of the TMDL and BPA as recommended by staff will be a decision against protecting the most sensitive of beneficial uses – the subsistence fishing person feeding their family.

Sincerely,

[signed]
Fraser Shilling, Ph.D.
Department of Environmental Science & Policy
University of California, Davis
fmshilling@ucdavis.edu
530-752-7859

Encl.

Attachment A

Environmental Research ∎ (∎∎∎∎) ∎∎∎–∎∎∎

Contents lists available at ScienceDirect

Environmental Research

journal homepage: www.elsevier.com/locate/envres

Contaminated fish consumption in California's Central Valley Delta ☆

Fraser Shilling [a,*], Aubrey White [b], Lucas Lippert [a], Mark Lubell [a]

[a] Department of Environmental Science and Policy, University of California, One Shields Ave, Davis, CA 95616, USA
[b] Department of Human and Community Development, University of California, Davis, CA 95616, USA

ARTICLE INFO

Article history:
Received 17 February 2009
Received in revised form
26 January 2010
Accepted 2 February 2010

Keywords:
Fish contamination
Mercury
Fish consumption
Subsistence fishing
TMDL
Clean Water Act

ABSTRACT

Extensive mercury contamination and angler selection of the most contaminated fish species coincide in California's Central Valley. This has led to a policy conundrum: how to balance the economic and cultural impact of advising subsistence anglers to eat less fish with the economic cost of reducing the mercury concentrations in fish? State agencies with regulatory and other jurisdictional authority lack sufficient data and have no consistent approach to this problem. The present study focused on a critical and contentious region in California's Central Valley (the Sacramento–San Joaquin Rivers Delta) where mercury concentrations in fish and subsistence fishing rates are both high. Anglers and community members were surveyed for their fish preferences, rates of consumption, the ways that they receive health information, and basic demographic information. The rates of fish consumption for certain ethnicities were higher than the rates used by state agencies for planning pollution remediation. A broad range of ethnic groups were involved in catching and eating fish. The majority of anglers reported catching fish in order to feed to their families, including children and women of child-bearing age. There were varied preferences for receiving health information and no correlation between knowledge of fish contamination and rates of consumption. Calculated rates of mercury intake by subsistence anglers were well above the EPA reference dose. The findings here support a comprehensive policy strategy of involvement of the diverse communities in decision-making about education and clean-up and an official recognition of subsistence fishers in the region.

1. Introduction

The present study provides critical data to support decision-making to reduce fish contamination, involve diverse stakeholder communities, and encourage safer fishing and eating patterns in California's Delta. The US Department of the Interior estimates that 10% of Californians engage in sport and subsistence fishing (USDI et al., 2003), many of whom fish in the watersheds of the Sacramento–San Joaquin Rivers Delta and San Francisco Bay. Subsistence fishing in areas with fish contamination creates the need for immediate policy initiatives, both to educate anglers about contamination and to speed the rate of remediation of the contamination. In California, fish contamination from mercury, polychlorinated biphenyls (PCBs), and other chemicals threatens fish consumption as a part of the daily diet. There has never been an economic evaluation of the cost of reducing fish contamination in California, though it is popularly thought to be high. Because of this perceived high cost of remediation, public agencies in California have proposed reducing fish consumption to reduce risk and exposure. There are actually several policy strategies that are available: (1) clean up environmental contamination in accordance with the Clean Water Act and California'a Porter-Cologne Act, (2) educate subsistence anglers about fish contamination, allowing them some choice, and (3) the combination of (1) and (2), developing pollution remediation plans that comprehensively deal with clean-up, new discharges, angler education, and inclusion of impacted communities. Currently, there is insufficient knowledge of fish consumption practices in California's Delta to make an informed choice among policy options.

California's growth was based initially on a gold-mining boom. Mercury mined in the Coast Ranges was used in the Coast and interior ranges to improve gold recovery (Alpers and Hunerlach, 2000). The watersheds of the Central Valley contain thousands of legacy mercury and gold mining features. Mercury also originates from natural geothermal activity, soil, atmospheric deposition,

Abbreviations: ANOVA, analysis of variance; CDFG, California Department of Fish and Game; CVRWQCB, Central Valley Regional Water Quality Control Board; FFQ, Food Frequency Questionnaire; PCBs, polychlorinated biphenyls; SAAC, Southeast Asian Assistance Center; SFEI, San Francisco Estuary Institute; TMDL, total maximum daily load; USDA, US Department of Agriculture; USEPA, US Environmental Protection Agency

☆ *Funding Sources and Research Approval*: This research was supported by a combination of grants from the Sacramento Regional County Sanitation District (2005–2007) and The California Endowment (2007–2008). Evidence of meeting requirements for research involving human subjects is attached.

* Corresponding author. Fax: +530 752 3350.
E-mail addresses: fmshilling@ucdavis.edu (F. Shilling), aubreywhit@gmail.com (A. White), llippert@ucdavis.edu (L. Lippert), mnlubell@ucdavis.edu (M. Lubell).

0013-9351/$ - see front matter © 2010 Published by Elsevier Inc.
doi:10.1016/j.envres.2010.02.002

industrial and domestic waste-water, and unknown sources. Inorganic mercury enters the food chain primarily through bacteria-mediated mercury methylation (reviewed in Benoit et al., 2003) and bio-accumulates in organisms of higher trophic levels (Clarkson, 2002; Gilmour et al., 1998; May et al., 2000). Predatory fish (e.g., striped bass) tend to have the highest tissue concentrations of mercury (Wiener et al., 2003) and are favored by anglers.

Subsistence fishing is prevalent throughout the world, but tends not to be viewed as a behavior characteristic of urban communities. Urban California contains broad ethnic diversity, including many recently arrived immigrants who appear to have retained the cultural and economic practice of subsistence fishing. There is very high ethnic and language diversity in the Delta region of the Central Valley. Recently arrived Hmong, Cambodian, Vietnamese, Russian, and Mexican populations are common in Central Valley urban areas (Fujimoto, 1998). Many of these diverse communities relied on fishing as a cultural and economic practice in their countries of origin and have brought that practice with them. In addition, the social structure and accepted pathways of communication are quite different from the host culture (Fujimoto, 1998). This can make effective communication for education and/or decision-making particularly challenging—a problem that is poorly addressed in California state policy. There are also many California-born anglers and fish consumers in the Delta region who subsistence fish.

The Central Valley Regional Water Quality Control Board (hereafter the Regional Board) has developed a draft total maximum daily load (TMDL) for methyl-mercury in the Delta because of impairment to fish consumed by humans and wildlife (Central Valley Regional Water Quality Control Board, 2008). Because the consumption of fish by wildlife and humans is legally protected in these waters as a beneficial use under the Clean Water Act, legally, the state must develop a plan to resolve this impairment, which by strict definition means reducing mercury concentrations in fish. The Clean Water Act requires the development of TMDLs as science and policy guides for reducing particular types of waterway pollution. In the presence of subsistence fishing this is particularly challenging, because protecting their use would require potentially greater political and financial investments.

We used a food frequency questionnaire to study fish consumption patterns. Survey respondents were asked for a 30-day recall of fish intake from local waters and commercial sources. The vast majority of comparable studies using FFQs have reported accurate findings using this approach among a wide range of nationalities and ethnicities (Villegas et al., 2007; Quandt et al., 2007; Sullivan et al., 2006; Kuster et al., 2006; McNaughton et al., 2005). In cases where the FFQ has been less accurate, it tended to under-estimate actual consumption (Hudson et al., 2006; Lee et al., 2002). Anglers and community members were interviewed in English or the respondents' native language. A statistical description of fish consumption patterns is presented for the North Delta region of the Central Valley over 3 years (2005–2008), including information about individual fish species and ethnic communities. This information, combined with existing information about fish tissue concentrations of mercury is used as the basis for an exposure analysis. Findings are presented showing the diverse mechanisms through which anglers receive health related information. Finally, actual mercury exposure is compared to assumptions made in current policy-development for mercury remediation.

2. Methods

2.1. Study area

The study area comprised the North, South, and West Delta regions of the Central Valley, stretching from the cities of Sacramento and Stockton to the city of Fairfield (Fig. 1). The waterways included the Sacramento River (the largest in California), the Port of Sacramento Shipping Channel, Montezuma Slough, and the San Joaquin River. Specific sites for surveying along the Sacramento River were: Garcia Bend City Park, Freeport, Clarksburg, and Port of Sacramento shipping channel. These sites were chosen as sites likely to be popular with anglers after an expert review of CDFG creel survey data by river mile and pre-surveying site visits (Fig. 1). These areas were also chosen because fish tissue concentrations of mercury are high in the vicinity of the sites (within 10 river miles).

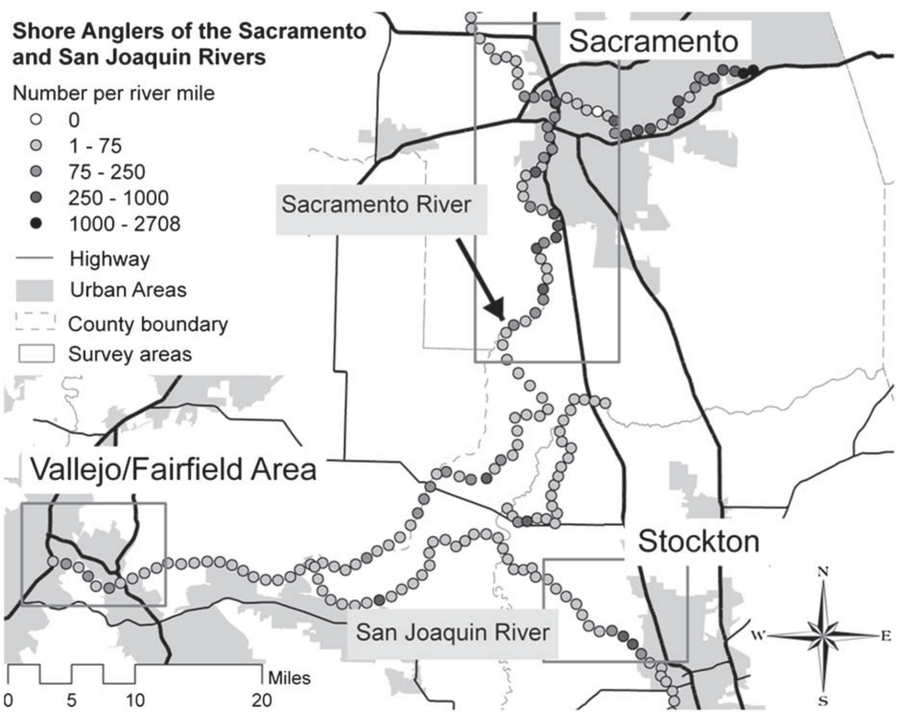


Fig. 1. Annual angling intensity in study area. Data from the California Department of Fish and Game creel survey program, 2000. Angler surveying areas for the present study.

2.2. Survey instrument, sample, and protocol

The survey instrument was designed to cover target fish species, fish consumption rates, health communication, and household demographics. It was designed in 2003 and 2004 in collaboration with the California Department of Public Health and the California Office of Environmental Health Hazard Assessment and is nearly identical to the instrument used in the recently published study of women attending clinics in Stockton, CA (Silver et al., 2007). There were 17 questions and the questionnaire took about 10 min to administer. Answers were recorded on the questionnaire, coded, and transferred to a computer spreadsheet. Fish filet models were used representing 3 different cooked weights of fish filet (1.5, 4.5, and 7.5 oz) in order to allow estimates of actual fish consumption rates.

Anglers were chosen for interviews as they were encountered along the river-bank by surveyors. All or the vast majority of anglers were interviewed as they were encountered, reducing bias in selection of the sampled population. However, the angler interviews were only conducted in English, which resulted in a failure to interview about 5% of those approached. 373 shore anglers were interviewed during biweekly to monthly site visits between September 2005 and June 2008. All days of the week were represented roughly equally in sampling; sampling was conducted primarily in the early morning and late afternoon when anglers were more likely to be present. In July and August, surveyors went into the field, but very few anglers were encountered when surveyors were present, which may be related to anglers fishing at different times of day, or night, during these hotter months. Encounters were initiated by the surveyor approaching the anglers and beginning a conversation about fishing. Anyone reporting that they had been previously interviewed was not interviewed again. On the vast majority of sampling days, all anglers observed fishing were interviewed. Community members were chosen for interviews based on prior knowledge of Southeast Asian Assistance Center (SAAC) staff that an extended family member fished, but without specific knowledge of how often they fished or ate fish. All such people identified by the SAAC staff were interviewed. SAAC staff live in the communities they serve and have access to households because of community familiarity with the organization. 137 community members were interviewed between December 2006 and June 2008.

Subjects were told that the survey was about fishing activity along the river and was being conducted to better understand what kinds of fish people were catching and eating. They were not told in advance that the survey was related to concerns about fish contamination.

2.3. Spatial and creel survey data

Fish contamination data up to 2006 were obtained from the California Regional Board, covering almost 30 years of measurements of mercury in various fish species, and from the San Francisco Estuary Institute (SFEI) for 2005–2007. Mean mercury concentrations (parts per million or micrograms/gram) were calculated for each target species using values for legal-sized or edible fish at or near the angler survey sites. In the case of striped bass, this corresponded to lengths >18 in, for sturgeon this corresponded to lengths >48 in and for all other fish species lengths >12 in, except sunfish, bluegill, and crappie where lengths >6 in were used.

Creel survey data covering 1999–2001 (the most recent and comprehensive available) were obtained from the California Department of Fish and Game in computer spreadsheets and in written reports to the US Fish and Wildlife Service. The survey covered fishing effort, types and numbers of fish caught, and location of fishing. The creel survey data were attributed to river mile points along the Sacramento River using ArcView 3.2 (Fig. 1). The river mile points were manually measured using ArcView 3.2 along the center-line of the river using geo-referenced digital photographs. These data were used to choose sites for surveying and to compare fishing activity of the surveyed population in this study with the creel survey population.

2.4. Survey data analysis

Fish consumption rates (g/day) were calculated for each individual based on 30-day recall of how much and how often individual types of fish (e.g., catfish) were eaten. Anglers were grouped by major race/ethnicity (e.g., Hispanic) according to Census Bureau classification. Minor ethnicity (e.g., Lao) was also recorded when the survey respondent provided sufficient information for the classification. Rates of mercury intake were calculated for individuals based on individual consumption rates determined through surveying for specific fish types and the regional mean mercury concentrations for those fish types, which is based on fresh weight. Because the cooked weight of fish, represented by the fish filet models used in surveying, is about 75% of the fresh weight, the calculated rates of mercury intake here are a conservative estimate of actual rates. Mean and 95th percentile fish and mercury consumption rates were calculated for all interviewees and median rates calculated for all recent consumers. Data were organized in MS Excel and all statistical analysis was done using the commercial software SPSS 16.0. Trends analysis was performed using the Seasonal Kendall test software developed by the US Geological Survey (Hirsch et al., 1982; Hirsch and Slack, 1984; Helsel et al., 2006).

3. Results

3.1. Context: fish contamination and angling intensity

Concentrations of mercury in commonly eaten fish were calculated using a combination of the Regional Board and SFEI datasets (Table 1). Fish sizes ranged from >6 in (bluegill) to >48 (sturgeon) and mean wet tissue concentrations ranged from 0.052 ppm (shad) to 0.772 ppm (largemouth bass) wet tissue weight.

Creel survey data collected by the California Department of Fish and Game (CDFG) indicate that the primary target fish species for all anglers, regardless of ethnicity, in the Northern region of the Central Valley Delta were striped bass, salmon, shad, and catfish (Murphy et al., 1999, 2000; Schroyer et al., 2001). This is similar to the targeted species in the present study (Table 2), with inter-ethnic differences in fish preferences. For all commonly caught fish there were mercury concentration data available in the study region (Table 1).

Table 1
Mercury concentrations of commonly eaten fish in the Northern Delta region, in size ranges sought by anglers.

Fish species (common name)	N	Mercury concentration (Mean ppm)	SD	Length (in)	Location
Shad	19	0.052	0.023	> 15	AR, Delta
Bluegill	10	0.208	0.125	> 6	SR, SRSC
Carp	30	0.309	0.197	> 15	SR
Catfish	44	0.424	0.251	> 12	SR, Delta
Crappie	5	0.309	0.104	> 8	SR, Delta
Chinook Salmon	25	0.09	0.03	> 26	AR, FR, SR
Largemouth Bass	63	0.774	0.324	> 12	AR, SR
Sacramento Pike Minnow	42	0.763	0.525	> 12	AR, SR
Split-tail	1	0.37		16	SR
Sacramento Sucker	38	0.22	0.117	> 12	AR, SR
Rainbow Trout/Steelhead	12	0.061	0.014	> 18	AR, SR
Striped Bass	47	0.545	0.318	> 18	AR, Delta, SR
Sturgeon	11	0.271	0.241	> 48	SR
Sunfish	14	0.182	0.097	> 8	SR

AR=American River, FR=Feather River, SR=Lower Sacramento River. Data from the Central Valley Regional Water Quality Control Board database and San Francisco Estuary Institute reports online (http://www.sfei.org).

Please cite this article as: Shilling, F., et al., Contaminated fish consumption in California's Central Valley Delta. Environ. Res. (2010), doi:10.1016/j.envres.2010.02.002

Table 2
Ethnicity-specific targeting of fish species. Shown are the fish species most commonly eaten and the fish species eaten in largest quantity. Ranks determined from survey for all respondents.

Ethnicity	Target	
	1st choice Frequency/amount	2nd choice Frequency/amount
African-American	SB/SB	CF/CF
SE-Asian	SB/SB	CF/CF
Lao	CF/SB	SB/SF
Hmong	SB/SB	CF/Stur
Asian/Pacific Islander	SB/SB	CF/CF
Hispanic	SB/SB	CF/CF
Native American	CF/LMB	CF/KS
White	SF/SB	SB/Stur
Russian	Carp/Carp	CF/CF

Carp=carp, CF=catfish, SF=sunfish, KS=Chinook salmon, LMB=largemouth bass, SB=striped bass, Stur=sturgeon.

In 2001, CDFG reported about 22,000 directly counted anglers at a survey rate of about one in every 4 days for all months of the year, but on different tributary rivers to the Delta (Schroyer et al., 2001). About 80% of those counted were fishing on the Sacramento River between the Feather River and the San Francisco Bay and other tributary rivers to the Delta. In 2001, of the approximately 1.2 million licensed anglers in California, 191,000 of them lived in 5 counties encompassing the Delta (Sacramento, San Joaquin, Solano, Yolo, and Contra Costa; data from the CDFG License Bureau). One interpretation of the 10-fold difference between the number of anglers counted by CDFG and the number of licensed anglers is that anglers fish about one of every 10 days on regional rivers. This is similar to the rate of fishing among anglers (one of every 4.5 days) and community members (one of every 10 days) in the present study.

3.2. *Rates of fish consumption*

Consumption rates for locally caught fish and commercially acquired fish were calculated for all respondents (Fig. 3 and Table 3). There was no significant relationship between day of the week when surveying occurred and ethnic group type, or fish consumption rate. Rates found for Southeast Asian community members were not significantly different from rates found for Southeast Asian anglers, but for other ethnic groups, community member consumption rates and angler consumption rates were significantly different. Because of this, most data analyzes on these two datasets were done separately. Consumption rates for anglers as a whole varied throughout the year, with peaks during the Fall, when both striped bass and salmon are returning to rivers to spawn (Fig. 3), and fishing activity is the highest (Fig. 2). There was no significant trend (P=0.78) in consumption of locally caught fish across the 3-year study period (2005–2008), when trend was corrected for seasonality using the Seasonal Kendall test (Hirsch et al., 1982; Hirsch and Slack, 1984; Helsel et al., 2006). The arithmetic mean and median consumption rates of *locally caught* fish were 27.4 and 17.0 g/day, respectively, for anglers—which are higher than and similar to the USEPA standard fish consumption rate of 17.5 g/day. Both the arithmetic mean and median consumption rates were used in the present study because they provide different types of information about behavior (Sechena et al., 2003). The mean and median rates of consumption of all fish (locally caught and commercial) were 40.6 and 24.1 g/day, higher than the combination of USEPA's average rate for fish consumption (17.5 g/day) and the USDA's average food intake rate for commercial fish (12.5 g/day). The corresponding mean fish consumption rates from the community member survey were 55.2 g/day (locally caught fish, median rate=21.3 g/day) and 63.4 g/day (total fish, median rate=28.4 g/day), with both types of rates being higher than the corresponding rates for anglers in the field ($P<0.05$, t-test), primarily because the majority of community members surveyed were Southeast Asians. Among the major ethnic groups, Southeast Asians ate the most locally caught fish, followed by African-Americans and Hispanics. However, there was no statistically significant difference in rates among the major ethnicities ($P>0.05$, ANOVA). Of the ethnic sub-groups, the Lao respondents had the highest mean total fish consumption rate (65.2 g/day) and locally caught fish consumption rate (57.6 g/day). Their rate of local fish consumption was significantly higher than the mean rate for all non-Lao anglers ($P<0.05$, t-test).

Women interviewed in community settings ate significantly more locally caught (54.1 g/day) and total (66.4 g/day) fish than male anglers (26.4 and 39.3 g/day; $P<0.05$, t-test) and identical amounts of commercially obtained fish. There was no statistically significant difference between male and female angler consumption rates ($P>0.05$, Table 3). There were no significant differences in consumption rates among age groups (Table 3). Rates of consumption for locally caught and total fish were significantly higher ($P<0.05$, t-test) for anglers from households with children, or from households with women of child-bearing age, than anglers from households without children or women of child-bearing age.

To represent the majority of the fish-consuming population, we also calculated the 95th percentile rates for locally caught, and total fish consumption and the corresponding mercury intake rates. By definition, 95% of fish consumers consume at or below the 95th percentile rate. These rates were compared to the rates used by the Regional Board for its Total Maximum Daily Load (TMDL) for methyl-mercury in the Delta region under different mercury load-setting "scenarios" corresponding to different assumed fish consumption rates (Central Valley Regional Water Quality Control Board, 2008). The scenarios were based on a range of consumption rates and were 17.5 g/day (scenarios A and C), 32 g/day (scenarios B and D), and 142 g/day (scenario E). All ethnicities and sub-ethnicities with sufficient "N" to calculate 95th percentile rates (exceptions=Russian and Native American) had locally caught and total fish intake rates greater than Regional Board scenarios A–D (Table 3). African-American, Lao, Vietnamese, Asian/Pacific Islander, and Hispanic anglers had 95th percentile rates greater than Regional Board scenario E (Table 3), which was the highest rate used by the Regional Board.

3.3. *Balancing locally caught and commercial sources of fish*

An important issue in understanding the economic and dietary decisions that subsistence fishing communities make when fish are contaminated, is the balance between buying and catching edible fish. Anglers and community members often consumed fish that they or someone they knew had caught as well as fish that they bought at markets or restaurants. For all ethnic groups and both genders combined, there was an inverse relationship between consumption rates of commercially acquired fish and locally caught fish (Fig. 4). There was a significant relationship between the frequency that anglers fished and the amounts of locally caught fish that they ate ($P<0.05$, Chi-square test).

3.4. *Rates of mercury consumption*

The combination of species-specific consumption rates and species-specific mercury concentrations was used to calculate the

Table 3
Mean and 95th percentile fish and mercury intake rates for different groups.

	N	Local fish intake		Local fish Hg intake		Total fish intake		Total fish Hg intake	
		Mean (g/d)	95th percentile (g/d)	Mean (µg Hg/d)	95th percentile (µg Hg/d)	Mean (g/d)	95th percentile (g/d)	Mean (µg Hg/d)	95th percentile (µg Hg/d)
Ethnicity									
African-American	32	31.2 [21.3]	242.3	15.7 [9.0]	127.8	48.3 [21.3]	252.0	20.8 [7.7]	130.6
Southeast Asian	152	32.3 [17.0]	129.4	14.0 [7.0]	62.8	42.8 [24.1]	180.2	17.1 [9.5]	74.7
Hmong	67	17.8 [14.9]	89.6	6.9 [6.2]	33.6	22.3 [19.1]	89.6	8.3 [8.3]	37.7
Lao	30	57.6 [21.3]	310.4	26.5 [10.5]	161.4	65.2 [24.1]	317.5	28.8 [9.5]	163.5
Vietnamese	33	27.1 [21.7]	152.4	11.9 [5.0]	77.4 [36.1]	55.4	249.3 [12.0]	20.4	105.9
Asian/Pacific Islander	38	23.8 [15.6]	148.3	9.8 [4.8]	40.4	46.1 [35.0]	156.4	16.5 [9.2]	49.5
Hispanic	45	25.8 [19.1]	155.9	10.8 [7.8]	48.1	36.3 [14.2]	169.5	13.9 [6.7]	54.1
Native American	6	6.5	ND	2.3	ND	69.9 [108.4]	ND	20.8 [33.3]	ND
White	57	23.6 [21.3]	138.9	8.8 [6.7]	43.8	34.7 [28.4]	139.2	12.1 [7.5]	46.8
Russian	17	23.7 [17.7]	ND	7.8 [5.6]	ND	36.1 [35.5]	ND	11.5 [9.6]	ND
All Anglers	373	27.4 [19.7]	126.6	11.4 [6.7]	51.5	40.6 [26.1]	147.3	15.4 [8.1]	56.6
Southeast Asian[a]	286	40.8 [17.0]	128.5	17.6 [7.3]	58.0	50.3 [25.5]	144.5	18.7 [7.9]	70.2
Hmong[a]	130	21.3 [14.9]	102.1	8.1 [4.6]	38.7	26.5 [17.0]	119.7	9.7 [4.5]	42.9
Lao[a]	54	47.2 [17.0]	265.8	20.4 [6.7]	117.8 [28.4]	54.4	267.0 [10.8]	22.6	118.8
Demographic Group									
Age									
18–34	143	32.0 [24.6]	138.9	13.0 [8.9]	55.6	44.9 [25.2]	151.5	16.8 [8.5]	66.7
35–49	130	22.7 [14.2]	120.5	9.8 [6.9]	51.2	36.8 [24]	143.9	14.0 [7.7]	57.5
> 49	87	30.6 [17.0]	207.0	12.8 [5.4]	92.3	44.3 [24.1]	217.2	17.0 [8.4]	95.4
Gender									
F	35	38.2 [22.5]	226.8	15.9 [8.4]	94.7	53.9 [24.6]	263.1	20.6 [8.2]	105.4
M	336	26.4 [19.5]	129.3	11.0 [6.5]	54.3	39.3 [26.1]	146.6	14.9 [8.1]	56.9
Household contains									
Woman 18–49 y-o	217	33.0 [21.2]	142.2	14.1 [7.3]	59.5	46.6 [7.3]	158.1	18.2 [8.8]	71.8
Children	174	35.1	142.8 [22.2]	15.4	61.2 [7.8]	49.2	171.9 [27.1]	19.6	78.3 [9.3]
Awareness									
0	172	24.7 [18.2]	121.6	10.4 [6.6]	51.9	35.5 [23.0]	143.5	13.7 [7.5]	56.6
1	44	42.8 [28.0]	361.1	19.5 [12.3]	187.5	52.9 [28.5]	361.1	22.5 [10.7]	187.5
2	115	28.4 [21.3]	139.6	11.0 [6.3]	61.2	45.8 [28.0]	151.7	16.2	63.3
3	35	12.2 [13.8]	62.4	5.1 [4.0]	32.1 [20.8]	28.1	95.6[6.0]	9.9	35.9
4	7	57.1 [36.1]	ND	24.3 [7.6]	ND	65.0 [39.0]	ND	26.7 [8.9]	ND

ND stands for "not determined" because of insufficient data. All data shown are for angler surveying, except for the data indicated as from combined angler and community surveys.
In the "mean" columns, the first value for a group is the arithmetic mean for all interviewees, the second value below it in "[ ]" is the median for recent consumers.

[a] Rates from combined angler and community surveys.

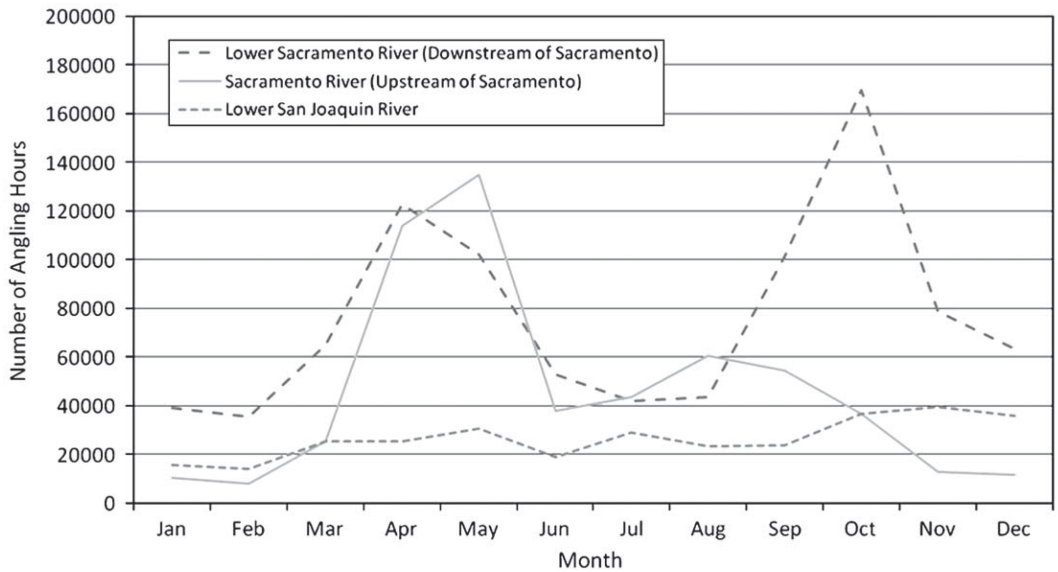


Fig. 2. Fishing intensity as angling hours varying by season and location on the Sacramento River and San Joaquin River. Data from the California Department of Fish and Game creel survey program, 2000.

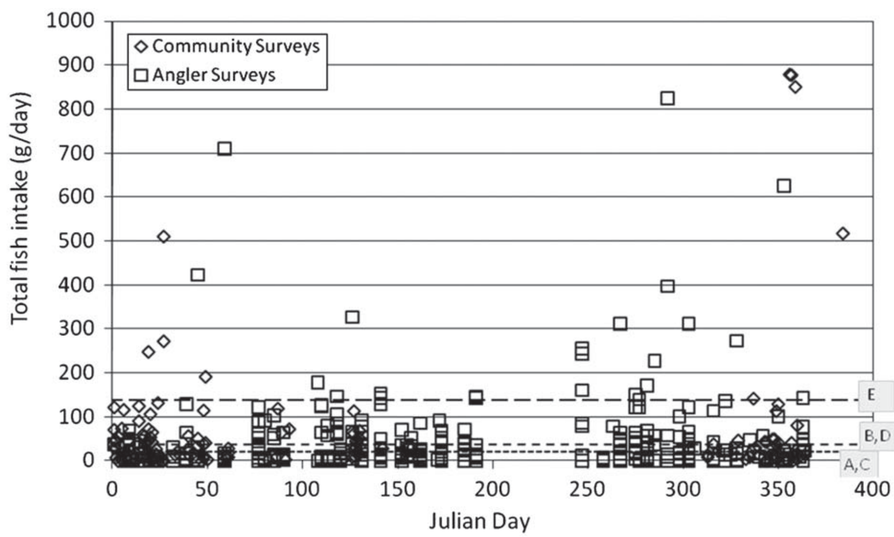


Fig. 3. Total fish consumption rates over the year (Julian Day 1=January 1). Each symbol represents an individual interviewee. The lines at the bottom represent the scenarios for fish consumption rates used by the Central Valley Regional Water Quality Control Board's TMDL for methyl-mercury in the Delta. A, C=17.5 g/day; B, D=32 g/day; E=142 g/day of fish consumed.

mercury intake rates of each surveyed angler and community member (Table 3, Fig. 5). Predictably, higher rates of mercury intake corresponded to higher rates of fish consumption because the types of fish consumed are similar across the range of consumption (Fig. 5), with the notable exception of two anglers (circled) who selectively consumed trout and salmon, which have low mercury concentrations in this region. Mean rates of mercury intake for individual ethnicities were compared to the USEPA reference dose (0.1 micrograms mercury/kg-body-weight/day) and to the grand mean of all intake rates. Approximately 5% of anglers had a mercury intake rate at least 10 times higher than the USEPA reference dose, the mercury intake rate 1/10 of the rate associated with measurable health impacts. The reference dose (7 micrograms/individual/day) was calculated using an average adult body-weight of 70 kg (Finley et al., 1994; USEPA, 1997). The mean total mercury intake rate for the whole sampled population is significantly greater than the USEPA reference dose ($P<0.05$, t-test). Similarly, the mean mercury intake rates for Southeast Asian, Vietnamese, Lao, and Asian/Pacific Islander were all significantly higher than the USEPA reference dose ($P<0.05$). For African-American, Lao, and Vietnamese anglers, 95th percentile local fish mercury intake rates were higher than 10 times the USEPA reference dose, and for these groups, as well as Southeast Asian anglers as a whole, the 95th percentile rates of mercury intake from total fish consumption were greater than 10 times the USEPA reference dose. Among ethnic groups, Lao and Vietnamese had mean mercury intake rates that were significantly higher than the grand mean rate for all anglers ($P<0.05$).

Anglers from households with children had mercury intake rates that were significantly higher ($P<0.05$) than the USEPA reference dose and higher than households without children

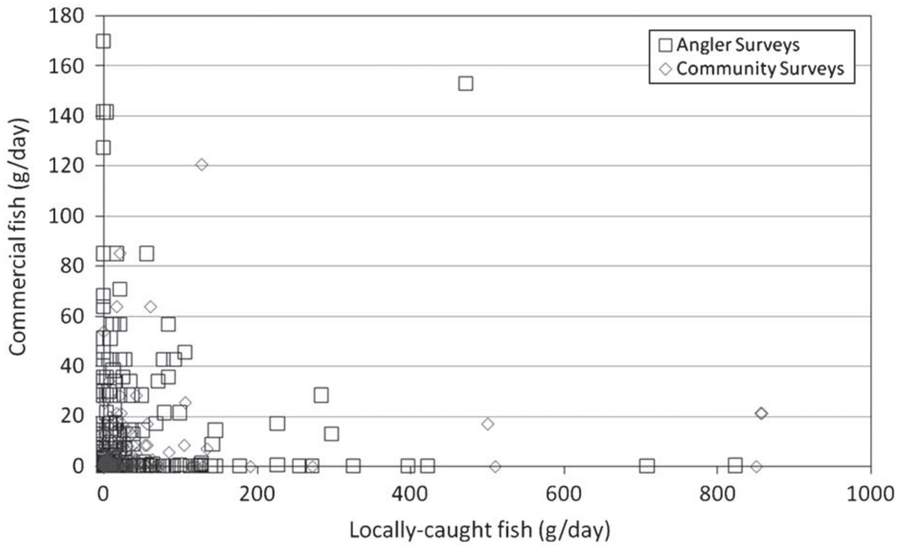


Fig. 4. Relationship between consumption rates for locally caught and commercially acquired fish.

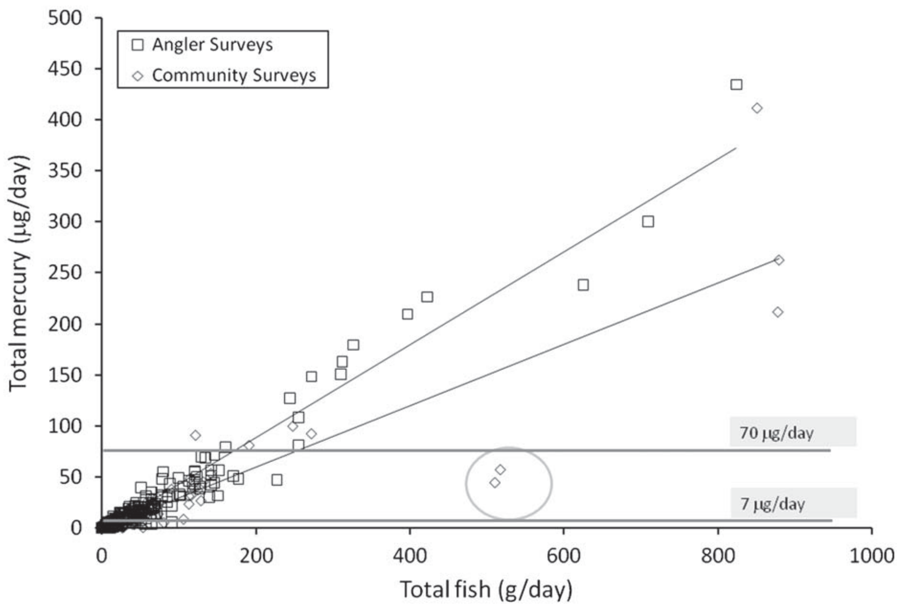


Fig. 5. Calculated mercury intake rates per interviewee compared to total fish consumption rate. The lines corresponding to 7 and 70 μg/day are the USEPA mercury reference dose for adults and ten times the dose, respectively. The circled pair of symbols represent surveyed community members who were consuming large amounts of low-mercury fish (salmon and trout). The upper line represents the least-squares regression fit for the angler survey results and the lower line, the corresponding fit for the community survey results.

(Table 3). Anglers from households with women of child-bearing age had higher rates of mercury intake than anglers from households without women of child-bearing age, but with only marginal significance ($0.05 < P < 0.10$).

The fish filet models used in surveying represented cooked fish, which has about 75% the mass and volume of fresh fish. Mercury concentrations are calculated and used here for fresh fish. Therefore, the mercury intake rates calculated here represent a conservative estimate of actual rates, where actual rates could be 1.33 times higher than those reported.

3.5. *Awareness of fish contamination*

Respondents were asked about their awareness of warnings about fish contamination and their responses coded according to accuracy and completeness of the response (range=0, no awareness, to 4, high awareness and accurate recall, Table 4). Angler awareness (Table 5) was highest among White respondents (mean=1.9), followed by Native Americans (mean=1.6), and African-Americans (mean=1.4). Awareness was also highest in middle-aged respondents (compared to other age groups) and higher in men than women. There was significantly lower ($P < 0.05$, *t*-test) awareness of warnings about fish consumption among Southeast Asians interviewed in community settings than for Southeast Asian anglers interviewed while fishing.

Awareness was compared to fish consumption and various demographic parameters (Table 3). Anglers that were more aware of warnings about fish contamination did not have statistically different rates of fish consumption or corresponding mercury intake than anglers with low awareness ($P > 0.05$, *t*-test). Awareness in households with children present (mean=0.97) was significantly ($P<0.05$, ANOVA) lower than in households without children (mean=1.2). There was no significant difference in awareness correlated to the presence or absence of a woman of child-bearing age in the household.

3.6. Pathways for communication of health information

Because state and local governments are considering informational campaigns about fish contamination and in some places have started them, we tested the fishing populations for awareness of this issue. Among African-Americans, Hispanics, Native Americans, and Russians, a sign at a fishing location was the main source of information about fish contamination (Table 5). Among Southeast Asians, Asian/Pacific Islanders, and Whites, television was the main source of information (Table 5). Secondary sources of information included friends and family and community clinics (Table 5). When sources of warnings about eating fish were compared among ethnicities, Asian, Southeast Asian, and White groups reported warnings from different sources than all other groups ($P<0.05$, Chi-square test). Similar results were found when trusted sources of health information were compared among groups. Asian, Southeast Asian, Hmong, and White groups reported trusting different sources for health information than all other groups ($P<0.05$, Chi-square test). There were no differences among age groups for trusted sources of health information. Males and females both recalled warnings primarily from television, but women also relied on friends and family as an important source.

The primary trusted source of health information for African-American, Southeast Asian, Asian/Pacific Islander, Hispanic, and White populations was health providers (Table 5). For Native Americans, family and friends were the primary source of health information (Table 5). Secondary sources for all groups included family and friends, television, radio, newspaper/magazines, and community centers (Table 5). For all age groups and genders, the primary source of health information was from medical providers. Secondary sources included family and friends and television.

Table 4
Coded awareness of health warnings about eating fish.

Code	Categories of responses
0	No awareness of health warnings
1	Report awareness of pollution, toxicity, some non-specified problem with fish
2	Awareness of one of the following: mercury contamination, OR specific contaminated fish species, OR specific recommended amounts of fish per time period, OR warnings about children and pregnant women fish consumption
3	Awareness of two of the issues in (2)
4	Accurate recall of mercury contamination, specific fish, frequency of consumption (1 meal/month), and warnings about children and pregnant women consumption

4. Discussion

This study shows that anglers in the Sacramento/San Joaquin Rivers Delta may be exposed to mercury in amounts well above the USEPA reference dose. This exposure is in part because the consumption rates of locally caught fish (primarily) are relatively high (compared to the USEPA average value), including being higher than the rates used by state agency staff to develop pollution control plans. In addition, the exposure is concentrated in non-white, primarily immigrant populations, though many ethnicities are affected. Rates of fish consumption vary seasonally, based primarily on fish availability, affecting the accuracy of mercury intake calculations from short-term studies.

4.1. Consumption rates compared to other studies

The fish consumption rates in the present study vary to some degree by ethnicity. This has been found to be true for a comparable study in a nearby area (Silver et al., 2007) and other areas. Fish consumption rates for certain ethnicities in the Delta region are similar to the rates found for Asian American and Asian Pacific Islanders in Washington (117.2 g/day; Sechena et al., 2003), for Yakama Nation members (58.7 g/day; Columbia River

Table 5
Mean awareness, sources of warnings about fish consumption, and trusted sources of health information for different groups of anglers.

Ethnicity	*N*	Awareness Mean (0=none, 4=high)	Source of warning 1st, 2nd choice	Trusted health sources 1st, 2nd choice
African-American	32	1.4	3, 4	1, 3
Southeast Asian	152	0.40	1, 4	1, 3
Hmong	67	0.58	1, 4	1, 3
Lao	30	0.67	1, 3	1, 5/10
Vietnamese	33	1.1	1, 4	1, 4
Asian/Pacific Islander	38	1.2	1, 4	1, 4
Hispanic	45	1.0	3, 1	1, 4
Native American	5	1.6	3, 4	3
White	57	1.9	1, 3	1, 3
Russian	17	0.8	3, 7	4, 7
All Anglers	373	1.1	1, 3	1, 3
Age				
18–34	83	0.9	4, 1/3	1, 4
35–49	82	1	1, 8	1, 4
>49	54	0.6	8, 1	1, 3
Gender				
F	23	0.6	1, 4	1, 3
M	198	0.9	1, 8	1, 3
Household				
With woman 18–49	142	1.13	1, 3	1, 3
With children	116	0.97	1, 3	1, 3

For warning sources: 1=television, 3=sign at fishing location, 4=friend or family, 7=community clinic, 8=other. For trusted sources of health information: 1=health care provider, 3=family or friend, 4=television, 5=radio, 7=newspaper or magazine, 10=community center.

Please cite this article as: Shilling, F., et al., Contaminated fish consumption in California's Central Valley Delta. Environ. Res. (2010), doi:10.1016/j.envres.2010.02.002

Inter-Tribal Fish Commission, 1994), New Jersey adults (50.2 g/day; Stern et al., 1996), and the 99th percentile consumption rates found in national surveys (USEPA, 2001). The rates presented here are the first measured for local angling populations in the Delta.

The mean consumption rates observed for certain ethnic groups of Delta anglers (Table 3) are several times higher than the default consumption rate (17.5 g/day) the USEPA recommended for public agency planning, based on the 90th percentile rate from USDA nation-wide consumption surveys (USEPA, 2001). This consumption rate was used by the USEPA to set the target methyl-mercury concentration for fish tissue at 0.3 mg/kg fish tissue. The rates found here are also several times higher than the mean daily consumption rate (4.58 g/day) for the general US population (USEPA, 2002). These USEPA rates of consumption and the consumption rate calculated for San Francisco Bay anglers (95th percentile rate=32 g/day), are used by the Regional Board to set target fish tissue concentrations for the Delta through the TMDL process (Central Valley Regional Water Quality Control Board, 2008; described in more detail below). In all cases, the average and 95th percentile rates used in proposed pollution regulation are less than mean local fish consumption rates we found for Lao and the combined Southeast Asian fish consumers (Table 3). The consumption rates of locally caught fish that sometimes have multiple contaminants, especially near urban areas and near the San Francisco Bay, indicate that many fish consumers in the Delta have exposure levels of immediate public health concern.

4.2. Mercury intake

Few studies have calculated mercury intake from subsistence fishing using local measurements of mercury concentrations in fish (Stern et al., 1996). Other studies have compared fish consumption rates with mercury body load (e.g., blood; Cole et al., 2004). Our study provides the first accurate estimates of mercury intake for various populations eating multiple species of locally caught fish in California's Central Valley Delta, which can be compared in future studies to measured mercury body loads. These intake rates indicate that most fish consumers may be taking in greater than the USEPA maximum of 0.1 micrograms/kg-body-weight/day. About 5% of consumers are consuming more than 10 times the maximum recommended dose. This number could be higher by 1.33-fold because the rate of mercury intake was conservatively calculated (see Section 2). Certain ethnic groups are on average consuming several times greater than the USEPA reference dose. Ethnic group-specific 95th percentile rates for fish and mercury intake are higher than the highest rates used by the Regional Board for pollution control planning (Central Valley Regional Water Quality Control Board, 2008) and near to or greater than 10 times the USEPA reference dose. All of these findings pose complex, but straightforward policy questions about who should be protected and to what degree.

4.3. Policy issues

4.3.1. Disproportionate health impacts of mercury intake

The USEPA has determined that a dose of 0.1 microgram/kg body-weight/day of mercury is the maximum that children and women of child-bearing age should consume to protect fetal and child brain development (USEPA, 2004). This reference dose is approximately one tenth the intake rate that has been found to result in measurable health effects in various studies. For a 70 kg (154 lb) person (average adult body-weight), the rate would be 7 micrograms of mercury/day. Stern et al. (1996) calculated the mean rate of mercury intake for New Jersey adults, based on fish consumption rates (mean=50.2 g/day), as 7.5 micrograms of mercury/day.

In the present study, the rates of mercury intake were calculated for all respondents (Fig. 4) and are shown in Table 3 by ethnicity, gender, and age group. For none of the groups were calculated mean mercury intake rates from fish consumption less than the reference dose. The Lao respondents had the highest mean mercury intake rate (28.8 micrograms/day), 4 times higher than the reference dose. The vast majority of this mercury intake was from locally caught fish (26.5 micrograms/day). Of the different ethnic groupings, only Lao had mean mercury intake rates that were significantly higher than the reference dose (t-test, $P<0.05$).

4.3.2. Impacts of state regulatory response

In their interpretation of the Clean Water Act, the state has developed a draft TMDL for methyl-mercury in edible fish (Central Valley Regional Water Quality Control Board, 2008). The implementation is intended to be a combination of reduction of methyl-mercury in sediments and water column through waste-load allocations and changes in fish-eating behavior in at-risk human populations. The first phase of implementation includes developing education and outreach programs directed at communities eating fish from the Delta. The draft Delta TMDL states: "*Beneficial use protection in the case of mercury pollution, therefore, must be accomplished by a combination of cleanup and education. Education is a needed part of a TMDL implementation plan until effects of all mercury reduction efforts are reflected in fish tissue levels*." State agencies recognize this as a critical part of their overall strategy. For example, a New Jersey study found that a reduction in fish consumption rates was correlated with exposure to state warnings and advisories (Burger, 2008). This is intended to be the short-term "risk-reduction" program paralleling mercury controls, in order to protect human health until fish tissue targets (for mercury) are achieved. One danger of this approach is that TMDL attainment for humans may be achieved through changing human behavior (reducing fish consumption), rather than controlling mercury in the system. However, our study found no relationship between knowledge of fish contamination and fish consumption rates.

For subsistence fishing populations, simply trying to encourage less fish consumption may be infeasible and if successful, may pose heavy cultural and economic burdens on the population. In the case of the Delta methyl-mercury TMDL, if in a future TMDL amendment, fish consumption rates have dropped because of effective communication by agencies, then fish tissue target concentrations could be raised higher than they would have to be now to protect high-intake fish consumers. Because correcting impairment is the purpose of TMDLs under the Clean Water Act, it remains to be seen whether or not risk-reduction through fish consumption reduction can be legally defended as a TMDL implementation strategy. State responsibility also extends to protecting piscivorous birds and mammals. Fish tissue targets that take into account this responsibility may end up remaining relatively protective of high-intake human consumers as well.

4.4. Effectively protecting beneficial uses

A critical issue at the interface between state pollution policy and science is the method used to determine actionable risk. In this study and in most similar studies, the mean fish consumption rate is calculated to indicate the relative risk faced by consumers of contaminated fish. In many studies, the 90th or 95th percentile rates are also calculated as a way to track high-intake consumers. Consideration of 95th percentile rates of mercury intake is more protective of most of the population than measures of central tendency, is likely to lead to the most protective public policy, and is the strategy chosen by the Regional Board. The high 95th percentile mercury intake rates calculated for African-American, Southeast Asian, Lao, and Vietnamese put these groups at risk of measurable health effects from mercury consumption. Any policy response and pollution remediation plan (such as a Total Maximum Daily Load under the Clean Water Act) developed to deal with mercury contamination of edible fish in the Delta should include consideration of the 95th percentile rates.

In the staff report accompanying the TMDL and testimony to the Regional Board itself (Shilling, personal observation; CVRWQCB, 2008) staff suggest that the low fish tissue targets (~0.05 ppm) corresponding to the higher "subsistence" rates (142 g/day) are not realistic and instead suggest targets that are more attainable. In contrast to this assertion, current concentrations of mercury in American shad, rainbow trout, and other species in the Delta and tributary rivers are comparable to 0.05 ppm (Table 1 and unpublished data from the Regional Board). The more attainable targets suggested by the Regional Board (0.24–0.29 ppm; CVRWQCB, 2008) correspond to estimated fish consumption rates of 17.5–32 g/day, which are relatively low compared to fish consumption rates found for certain ethnicities in the present study. Because the estimated consumption rates used as the basis for TMDL standards do not account for high rates of fish consumption among certain groups, the TMDL is unlikely to be protective of beneficial uses and therefore may not be compliant with the Clean Water Act or California's Porter-Cologne Act.

4.5. Fish consumption patterns for health benefits

Balancing fish consumption for health benefits with concerns about contamination requires consideration of type and size of fish, frequency of consumption, and amount consumed. Species-specific contaminant concentrations, means that rates of contaminant intake can depend as much on total fish intake as on the pattern of fish species consumption. However, by changing patterns of consumption, it is possible to retain the value of eating fish from a health point-of-view, while avoiding the neuorological harm from mercury intake (Oken et al., 2005). In this case, consuming fish with lower mercury concentrations (smaller and/or low trophic level) can result in net health benefits (e.g., see Fig. 5). Because it is unlikely that many anglers and communities will stop or reduce fish consumption, patterns of consumption could be addressed. People could contribute to their exposure-reduction by eating fish in the palette of preferred types that are low in contaminants, by catching them from places known to have lower contaminant concentrations, and/or by focusing more on smaller fish that have lower concentrations of bioaccumulative toxins. Because anglers surveyed in this study showed willingness to eat fish species with low concentrations of mercury (e.g., salmon, shad, trout), it is possible that in general, changes in eating patterns are possible. However, ethnic-specific preferences for different species may pose a barrier to this type of change.

4.6. Community responsibility

In other areas where fish contamination has been approached from a public health perspective, the success of changing consumers' behavior has been variable. Based upon our findings, the learning process for this behavioral change is unlikely to originate directly from state agencies; rather trusted community sources (community organizations, family and friends, health providers) and certain mass media are likely to be more effective. This suggests that well-advertized community-based programs that develop and implement policies related to fish consumption behavior will be the most successful model. In the present study, there were inter-ethnic group differences in both the source of recalled warnings about fish consumption and for trusted sources of health information. A single cookie-cutter approach to communication of risk information may not be appropriate for the highly diverse angling communities of California's Central Valley Delta region. An approach that is more likely to reflect the needs and communication pathways of these diverse communities is one originating from the communities themselves and possibly initiated by trusted community organizations and community health providers (Shilling et al., 2008). In a recent study, Castello et al. (2008) provided evidence that the involvement of fishers in fishery management can result in significant improvements in fish populations and fishery quotas. A similar approach to fish contamination where impacted subsistence fishers were involved in solution-building would be a significant improvement over the current approach.

4.7. Environmental justice

The California Bay-Delta Authority has been the entity responsible for coordinating understanding of environmental problems in the Bay-Delta and coordinating and leading responses to these problems. This body has been criticized for its lack of inclusion of environmental justice practices (Shilling et al., 2009), lack of public input, and lack of clear connections between science and policy (Little Hoover Commission, 2005). Fish contamination is very much an environmental justice issue in the Bay-Delta and the Central Valley in general because of disproportionate impacts to the ethnically diverse fish consumers and the lack of involvement of these impacted consumers in decision-making. Community organizations that the authors have collaborated with have expressed interest and have active involvement in decision-making around attainment of target concentrations of mercury in fish. As will probably be the case for effective communication and community education about fish contamination, an effective strategy for attainment of mercury standards would be one that included the knowledge and activities of groups representing the impacted communities.

Acknowledgments

We thank Laura Leonelli and staff at the Southeast Asian Assistance Center for input on communicating with anglers, assistance with interviews, and translations. We thank LaDonna Williams (People for Childrens' Health and Environmental Justice), Alyce Ujihara (California Department of Public Health), Bob Brodberg (California Office of Environmental Health Hazard Assessment), Janis Cooke and Michelle Wood (Central Valley Regional Water Quality Control Board) for various contributions. The article was improved by the suggestions of two anonymous reviewers.

References

Alpers, C.N., Hunerlach, M.P., 2000. Mercury contamination from historic gold mining in California. U.S. Geological Survey Fact Sheet FS-061-00, Sacramento, CA.

Benoit, J., Gilmour, C., Heyes, A., Mason, R.P., Miller, C., 2003. Geochemical and biological controls over methylmercury production and degradation in aquatic ecosystems. In: Chai, Y., Braids, O.C. (Eds.), Biogeochemistry of Environmentally Important Trace Elements. American Chemical Society, Washington, DC, pp. 262–297.

Burger, J., 2008. Fishing, fish consumption, and awareness about warnings in a university community in central New Jersey in 2007, and comparisons with 2004. Environmental Research 108, 107–116.

Castello, L., Viana, J.P., Watkins, G., Pinedo-Vasquez, M., Luzadis, V.A., 2008. Lessons from integrating fishers of Arapaima in small-scale fisheries management at the Mamiraua Reserve, Amazon. Environmental Management 43 (2), 197–209.

Central Valley Regional Water Quality Control Board (CVRWQCB), 2008. Sacramento–San Joaquin Delta Estuary TMDL for methylmercury. Draft Staff Report. Central Valley Regional Water Quality Control Board.

Clarkson, T.W., 2002. The three modern faces of mercury. Environmental Health Perspectives 110, 11–23.

Cole, D.C., Kearney, J., Sanin, L.H., Leblanc, A., Weber, J.-P., 2004. Blood mercury levels among Ontario anglers and sport-fish eaters. Environmental Research 95, 305–314.

Columbia River Inter-Tribal Fish Commission, 1994. A fish consumption survey of the Umatilla, Nez Perce, Yakama and Warm Springs Tribes of the Columbia River Basin. CRITFC Technical Report No. 94-3, Portland, Oregon.

Finley, B., Proctor, D., Scott, P., Harrington, N., Paustenbach, D., Price, P., 1994. Recommended distributions for exposure factors frequently used in health risk assessment. Risk Analysis 14, 533–553.

Fujimoto, I., 1998. Building Civic Participation in California's Central Valley, Book One: Getting to Know the Central Valley. California Institute for Rural Studies.

Gilmour, C.C., Riedel, G.S., Ederington, M.C., Bell, J.T., Benoit, J.M., Gill, G.A., Stordal, M.C., 1998. Methylmercury concentrations and production rates across a trophic gradient in the northern Everglades. Biogeochemistry 40, 327–345.

Helsel, D.R., Mueller, D.K., and Slack, J.R., 2006. Computer program for the Kendall family of trend tests. U.S. Geological Survey Scientific Investigations Report 2005–5275.

Hirsch, R.M., Slack, J.R., Smith, R.A., 1982. Techniques of trend analysis for monthly water quality data. Water Resources Research 18, 107–121.

Hirsch, R.M., Slack, J.R., 1984. A nonparametric trend test for seasonal data with serial dependence. Water Resources Research 20, 727–732.

Hudson, T.S., Forman, M.R., Cantwell, M.M., Schatzkin, A., Albert, P.S., Lanza, E., 2006. Dietary fiber intake: assessing the degree of agreement between food frequency questionnaires and 4-day food records. Journal of the American College of Nutrition 25 (5), 370–381.

Kuster, C., Vuki, V.C., Zann, L.P., 2006. Validation of the accuracy of household reporting of subsistence fishing catch and effort: a Fijian case study. Fisheries Management and Ecology 13 (3), 177–184.

Lee, K.Y., Uchida, K., Shirota, T., Kono, S., 2002. Validity of a self-administered food frequency questionnaire against 7-day dietary records in four seasons. Journal of Nutritional Science and Vitaminology 48 (6), 467–476.

May, J.T., Hothem, R.L., Alpers, C.N., and Law, M.A., 2000. Mercury bioaccumulation in fish in a region affected by historic gold mining: the South Yuba River, Deer Creek, and Bear River watersheds, California, 1999. U.S. Geological Survey Open File Report 00-367, Sacramento, CA.

McNaughton, S.A., Mishra, G.D., Bramwell, G.A., Paul, A., Wadsworth, M.E.J., 2005. Comparability of dietary patterns assessed by multiple dietary assessment methods: results from the 1946 British Birth Cohort. European Journal of Clinical Nutrition 59 (3), 341–352.

Murphy, K., Hanson, L., Harris, M., and Schroyer, T., 1999. Central Valley Salmon and Steelhead Harvest Monitoring Project—1999 Angler Survey. California Department of Fish and Game, unpublished annual report.

Murphy, K., Schroyer, T., Massa, D., 2000. Central Valley Salmon and Steelhead Harvest Monitoring Project—2000 Angler Survey. California Department of Fish and Game, unpublished annual report.

Oken, R.O., Kleinman, K.P., Bellinger, D., Amarasiriwardena, C.J., Hu, H., Rich-Edwards, J.W., Gillman, M.W., 2005. Maternal fish consumption, hair mercury, and infant cognition in a U.S. cohort. Environmental Health Perspectives 113 (10), 1376–1380.

Quandt, S.A., Vitolins, M.Z., Smith, S.L., Tooze, J.A., Bell, R.A., Davis, C.C., DeVellis, R.F., Arcury, T.A., 2007. Comparative validation of standard, picture-sort, and meal-based food-frequency questionnaires adapted for an elderly population of low socio-economic status. Public Health Nutrition 10 (5), 524–532.

Schroyer, T., Massa, D., and Murphy, K., 2001. Central Valley Salmon and Steelhead Harvest Monitoring Project—2000 Angler Survey. California Department of Fish and Game, unpublished annual report.

Sechena, R., Liao, S., Lorenzana, R., Nakano, C., Polissar, N., Fenske, R., 2003. Asian American and Pacific Islander seafood consumption—a community-based study in King County, Washington. Journal of Exposure Analysis and Environmental Epidemiology 13, 256–266.

Shilling, F.M., London, J.K., Levanos, R., 2009. Marginalization by collaboration: environmental justice as a third party in and beyond CALFED. Environmental Science and Policy 12, 694–709.

Shilling, F.M., Sommer, S., Leonelli, L., Shimoum, D., 2008. Community-based strategies to reduce mercury exposure in Delta fishing communities. Report for the California Department of Public Health and the Central Valley Regional Water Quality Control Board.

Silver, E., Kaslow, J., Lee, D., Lee, S., Tan, M.L., Weis, E., Ujihara, A., 2007. Fish consumption and advisory awareness among low-income women in California's Sacramento–San Joaquin Delta. Environmental Research 104, 410–419.

Stern, A.H., Korn, L.R., Ruppel, B.E., 1996. Estimation of fish consumption and methylmercury intake in the New Jersey population. Journal of Exposure Analysis and Environmental Epidemiology 6 (4), 503–525.

Sullivan, B.L., Williams, P.G., Meyer, B.J., 2006. Biomarker validation of a long-chain omega-3 polyunsaturated fatty acid food frequency questionnaire. Lipids 41 (9), 845–850.

USDI (U. S. Department of the Interior), Fish and Wildlife Service and U.S. Department of Commerce, U.S. Census Bureau, 2003. 2001 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation (California), FHW/01-CA-Rev., Revised March 2003.

USEPA1997. Exposure Factors Handbook, vol. 1, General Factors. U.S. Environmental Protection Agency, National Center for Environmental Assessment, Washington, DC. EPA/600/P-95/002Fa.

USEPA, 2001. Water Quality Criterion for Protection of Human Health: Methylmercury. U.S. Environmental Protection Agency, Office of Science and Technology (USEPA). EPA-823-R-01-001.

USEPA, 2002. Estimated Per Capita Fish Consumption in the United States. U.S. Environmental Protection Agency, Office of Science and Technology (USEPA). EPA-821-C-02-003.

USEPA, 2004. Joint Federal Advisory for Mercury in Fish. What You Need to Know about Mercury in Fish and Shellfish. Online at: 〈http://www.epa.gov/waterscience/fishadvice/advice.html〉.

Villegas, R., Yang, G., Liu, D.K., Xiang, Y.B., Cai, H., Zheng, W., Shu, X.O., 2007. Validity and reproducibility of the food-frequency questionnaire used in the Shanghai Men's Health Study. British Journal of Nutrition 97 (5), 993–1000.

Wiener, J.G., Krabbenhoft, D.P., Heinz, G.H., Scheuhammer, A.M., 2003. Ecotoxicology of mercury. In: Hoffman, D.J., Rattner, B.A., Burton Jr., G.A., Cairns Jr., J. (Eds.), Handbook of Ecotoxicology. 2nd edition CRC Press, Boca Raton, FL, pp. 409–463 (Chapter 16).

Please cite this article as: Shilling, F., et al., Contaminated fish consumption in California's Central Valley Delta. Environ. Res. (2010), doi:10.1016/j.envres.2010.02.002

Attachment B

UNIVERSITY OF CALIFORNIA, DAVIS

BERKELEY • DAVIS • IRVINE • LOS ANGELES • MERCED • RIVERSIDE • SAN DIEGO • SAN FRANCISCO • SANTA BARBARA • SANTA CRUZ

DEPARTMENT OF ENVIRONMENTAL SCIENCE AND POLICY
ONE SHIELDS AVENUE
DAVIS, CALIFORNIA 95616-8576

May 29, 2009

Janis Cooke, Environmental Scientist
Regional Water Quality Control Board, Central Valley Region
11020 Sun Center Drive, #200
Rancho Cordova, CA 95670

Dear Dr. Cooke:

Please find here a report prepared for the Central Valley Regional Water Quality Control Board, Central Valley Region, under SWRCB contract # 06-447-300-0, entitled: "Data synthesis and research on emerging Bay-Delta issues, including the Pelagic Organism Decline". The report estimates the number of anglers and their family-members at risk from consuming mercury in fish from the Delta. There are approximately 10,000 anglers and 40,000 associated family members who are consuming greater than 10 times the USEPA recommended dose of mercury, which puts them at immediate risk of neurological and other harm. The report provides support for the numbers based on my research in this area, where for the last 3 years my graduate students and I have surveyed anglers and community members in the Delta region. This work was conducted in partnership with staff of the Southeast Asian Assistance Center, a service organization for Southeast Asians and others in the Sacramento area. The study constitutes the largest set of interviews, greatest geographic extent, and longest running study of its kind in the Delta.

I am available to address and clarify any outstanding issues related to this report.

Sincerely,

Fraser Shilling, Ph.D., Staff Research Associate
Department of Environmental Science & Policy
University of California, Davis
fmshilling@ucdavis.edu
530-752-7859

Memorandum

Characterizing High Mercury Exposure Rates of Delta Subsistence Fishers

Report to the Central Valley Regional Water Quality Control Board
Fraser Shilling, Ph.D., Department of Environmental Science and Policy, University of California, Davis
May 29, 2009

Summary

Fish consumption is the primary pathway for mercury ingestion among the general public. My recent research at UC Davis has shown that approximately half of anglers and their families in the Sacramento San Joaquin River Delta may consume more than the USEPA reference dose for mercury (a safe dose unlikely to result in health effects) and 5 to 6% of anglers may consume 10 times the reference dose. A rate of intake that is ten times the reference dose places them and their families at immediate risk of mercury-related health impacts. These findings resulted from a survey of over 500 anglers and community members between 2005 and 2008 throughout the Delta. The survey included quantification of consumption rate of individual fish species which, when combined with average mercury concentrations for these species, allowed for calculation of mercury intake rates. There are approximately 170,000 licensed anglers in the Delta, meaning that up to 10,000 anglers and their families may be exposed to poisonous levels of mercury in their fish intake. This memorandum characterizes this high-intake rate population and briefly describes analyses that can improve knowledge of both rates of mercury intake and ethnic and geographic diversity associated with elevated rates.

This report was prepared for the Central Valley Regional Water Quality Control Board (SWRCB contract # etc.)

Background

The US Department of the Interior estimates that 10% of Californians engage in sport and subsistence-fishing (USDI et al. 2003), many of whom fish in the watersheds of the Sacramento-San Joaquin River Delta and San Francisco Bay. Subsistence fishing in areas with fish contamination creates the need for immediate policy initiatives, both to educate anglers about contamination and to speed the rate of remediation of the contamination. In California, fish contamination from mercury, polychlorinated biphenyls (PCB**s**), and other chemicals threatens fish consumption as a part of the daily diet.

Subsistence fishing is prevalent throughout the world, but tends not to be viewed as a behavior characteristic of urban communities. Urban California contains broad ethnic diversity, including many recently-arrived immigrants who appear to have retained the cultural and economic practice of subsistence fishing. There is very high ethnic and language diversity in the Delta region of the Central Valley. Recently-arrived Hmong, Cambodian, Vietnamese, Russian, and Mexican populations are common in Central Valley urban areas (Fujimoto 1998). Many of these diverse communities relied on fishing as a cultural and economic practice in their countries of origin and have brought that practice with them. In addition, the social structure and accepted pathways of communication are quite different from the host culture (Fujimoto 1998). This can make effective communication for education and/or decision-making particularly challenging – a problem that is poorly addressed in California state policy. There are also many California-born anglers and fish-consumers in the Delta region who subsistence fish.

The Central Valley Regional Water Quality Control Board (hereafter the Central Valley Water Board) has developed a draft total maximum daily load (TMDL) for methyl-mercury in the Delta because of impairment to fish consumed by humans and wildlife (Central Valley Regional Water Quality Control Board 2008). Because the consumption of fish by wildlife and humans is legally protected in these waters as a beneficial use, legally, the state must develop a plan, which is approved by the USEPA, to resolve this impairment. One definition for impairment resolution is reductions of mercury concentrations in fish.

Method of Exposure Analysis

This study relies on previous research on mercury exposure via fish consumption. In this previous research, we used a food frequency questionnaire (FFQ) to study fish consumption patterns. Survey respondents were asked for a 30-day recall of fish intake from local waters and commercial sources. The vast majority of comparable studies using FFQs have reported accurate findings using this approach among a wide range of nationalities and ethnicities (Villegas et al. 2007; Quandt et al. 2007; Sullivan et al. 2006; Kuster et al. 2006; McNaughton et al. 2005). In cases where the FFQ has been less accurate, it tended to under-estimate actual consumption (Hudson et al. 2006; Lee et al. 2002). Anglers and community members were interviewed in English or the respondents' native language. A statistical description of fish consumption patterns was presented for the North Delta region of the Central Valley over 3 years (2005-2008), including information about individual fish species and ethnic communities. This information, combined with existing information about fish tissue concentrations of mercury was used as the basis for an exposure analysis.

Study Area

The study area comprised the North, South, and West Delta regions of the Central Valley, stretching from the cities of Sacramento and Stockton to the city of Fairfield (Figure 1). The waterways included the Sacramento River (the largest in California), the Port of Sacramento Shipping Channel, Montezuma Slough, and the San Joaquin River. Specific sites for surveying along the Sacramento River were: Garcia Bend City Park, Freeport, Clarksburg, and

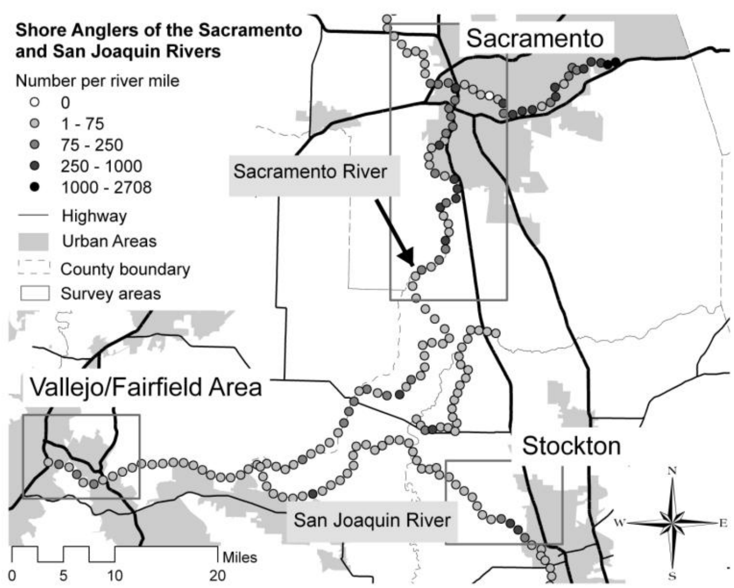


Figure 1 Study areas in the Delta (rectangles) and angler effort (dots).

Port of Sacramento Shipping Channel. These sites were chosen as high activity sites after a review of CDFG creel survey data and site visits (Figure 1). These areas were also chosen because fish tissue concentrations of mercury are high in the vicinity of the sites (within 10 river miles).

Survey Instrument, Sample, & Protocol

The survey instrument was designed to cover target fish species, fish consumption rates, health communication, and household demographics. It was designed in 2003 and 2004 in collaboration with the California Department of Public Health and the California Office of Environmental Health Hazard Assessment and is nearly identical to the instrument used in the recently-published study of women attending clinics in Stockton, CA (Silver et al. 2007). There were 17 questions and the questionnaire took about 10 minutes to administer. Answers were recorded on the questionnaire, coded, and transferred to a computer spreadsheet. Fish filet models were used representing 3 different cooked weights of fish filet (1.5 oz., 4.5 oz., and 7.5 oz) in order to allow conservative estimates of actual fish consumption rates.

Anglers were chosen for interviews as they were encountered along the river-bank by surveyors. No bias was present in the selection. However, the angler interviews were only conducted in English, which resulted in a failure to interview about 5% of those approached. 373 shore anglers were interviewed during biweekly to monthly site visits between September 2005 and June, 2008. Community members were chosen for interviews based on prior knowledge of Southeast Asian Assistance Center (SAAC) staff that an extended family member fished, but without specific knowledge of how often they fished or ate fish. SAAC staff members live in the communities they serve and have access to households because of community familiarity with the organization. 137 community members were interviewed between December, 2006 and June, 2008.

Subjects were told that the survey was about fishing activity along the river and was being conducted to better understand what kinds of fish people were catching and eating. They were not told in advance that the survey was related to concerns about fish contamination.

Spatial and Creel Survey Data

Fish contamination data up to 2006 were obtained from the California Regional Board, covering almost 30 years of measurements of mercury in various fish species, and from the San Francisco Estuary Institute (SFEI) for 2005 to 2007. Mean mercury concentrations (parts per million or micrograms/gram) were calculated for each target species using values for legal-sized or edible fish at or near the angler survey sites. In the case of striped bass, this corresponded to lengths >18 inches, for sturgeon this corresponded to lengths >48” and for all other fish species lengths >12”, except sunfish, bluegill, and crappie where lengths >6” were used.

Survey Data Analysis

Fish consumption rates (g/day) were calculated for each individual based on 30-day recall of how much and how often individual types of fish (e.g., catfish) were eaten. Anglers were grouped by major race/ethnicity (e.g., Hispanic) according to Census Bureau classification. Minor ethnicity (e.g., Lao) was also recorded when the survey respondent provided sufficient information for the classification. Rates of mercury intake were calculated for individuals based on individual consumption rates determined through surveying for specific fish types and the regional mean mercury concentrations for those fish types, which is based on fresh weight. Because the cooked weight of fish, represented by the fish filet models used in surveying, is about 75% of the fresh weight (Jackson et al., 1999), the calculated rates of mercury intake here are a conservative estimate of actual rates. Data were organized in MS Excel and all statistical analysis was done using the commercial software SPSS 16.0. Trends analysis was performed using the Seasonal Kendall test software developed by the US Geological Survey (Hirsch and Slack 1984; Helsel et al. 2006).

Findings

Fish Contamination

Concentrations of mercury in commonly-eaten fish were calculated using a combination of the Regional Board and SFEI datasets (Table 1). Fish sizes ranged from >6" (bluegill) to >48" (sturgeon) and mean wet tissue concentrations ranged from 0.052 ppm (shad) to 0.772 ppm (largemouth bass) wet tissue weight.

Table 1. Mercury concentrations of commonly-eaten fish in the Northern Delta region, in size ranges sought by anglers. AR = American River, FR = Feather River, SR = Lower Sacramento River. Data from the Central Valley Regional Water Quality Control Board database and San Francisco Estuary Institute reports online (Melwani et al., 2007; http://www.sfei.org)..

Fish Species (Common Name)	N	Mercury Concentration		Length	Location
		(Mean ppm)	SD		
Shad	19	0.052	0.023	>15"	AR, Delta
Bluegill	10	0.208	0.125	>6"	SR, SRSC
Carp	30	0.309	0.197	>15"	SR
Catfish	44	0.424	0.251	>12"	SR, Delta
Crappie	5	0.309	0.104	>8"	SR, Delta
Chinook Salmon	25	0.09	0.03	>26"	AR, FR, SR
Largemouth Bass	63	0.774	0.324	>12"	AR, SR
Sacramento Pike Minnow	42	0.763	0.525	>12"	AR, SR
Split-tail	1	0.37		16"	SR
Sacramento Sucker	38	0.22	0.117	>12"	AR, SR
Rainbow Trout/Steelhead	12	0.061	0.014	>18"	AR, SR
Striped Bass	47	0.545	0.318	>18"	AR, Delta, SR
Sturgeon	11	0.271	0.241	>48"	SR
Sunfish	14	0.182	0.097	>8"	SR

Angling Activity

Creel survey data collected by the California Department of Fish and Game (CDFG) indicate that the primary target fish species for all anglers, regardless of ethnicity, in the Northern region of the Central Valley Delta were striped bass, salmon, shad, and catfish (Murphy et al. 1999, 2000; Schroyer et al. 2001). This is similar to the targeted species in the present study (Table 2), with inter-ethnic differences in fish preferences. For all commonly-caught fish there were mercury concentration data available in the study region (Table 1). Knowing angler preferences for certain fish species is important for both understanding current consumption patterns and advised patterns, in terms of balancing trophic level 3 and 4 fish.

Table 2. Ethnicity-specific targeting of fish species: Locally-caught fish species most commonly eaten/fish species eaten in largest quantity. Ranks determined from survey for all respondents. Carp = carp, CF = catfish, SF = sunfish, KS = Chinook salmon, LMB = largemouth bass, SB = striped bass, Stur = sturgeon.

Ethnicity		Target	
		1st choice	2nd choice
		Frequency/amount	Frequency/amount
African-American		SB/SB	CF/CF
SE-Asian		SB/SB	CF/CF
	Lao	CF/SB	SB/SF
	Hmong	SB/SB	CF/Stur
Asian/Pacific		SB/SB	CF/CF
Hispanic		SB/SB	CF/CF
Native American		CF/LMB	CF/KS
White		SF/SB	SB/Stur
	Russian	Carp/Carp	CF/CF

In 2001, CDFG reported about 22,000 directly-counted anglers at a survey rate of about one in every 4 days for all months of the year, but on different tributary rivers to the Delta (Schroyer et al. 2001). About 80% of those counted were fishing on the Sacramento River between the Feather River and the San Francisco Bay and other tributary rivers to the Delta. In 2005, of the approximately 1.1 million licensed anglers in California, 170,000 of them lived in 5 counties encompassing the Delta (Sacramento, San Joaquin, Solano, Yolo, and Contra Costa; data from the CDFG License Branch). One interpretation of the 8-fold difference between the number of anglers counted by CDFG and the number of licensed anglers is that anglers fish about one of every 8 days on regional rivers. This is similar to the self-reported rate of fishing among anglers (one of every 4.5 days) and community members (one of every 10 days) in the present study.

Rates of Fish Consumption

To understand and potentially influence rates of mercury intake, it is important to separately quantify consumption of locally-caught and commercially-acquired fish. Consumption rates for locally-caught fish and commercially-acquired fish were calculated for all respondents (Figure 2 and Table 3). There was no significant relationship between day of the week when surveying occurred and ethnic group type, or fish consumption rate. Rates found for Southeast Asian community members were not significantly different from rates found for Southeast Asian anglers, but for other ethnic groups, community member consumption rates and angler consumption rates were significantly different. Because of this, most data analyses on these two datasets were done separately. Consumption rates for anglers as a whole varied throughout the year, with the highest rates peak during the Fall and Winter (Figure 2), when both striped bass and salmon are returning to rivers to spawn and fishing activity is the highest (Figure 3).

An important finding from the surveying of fish consumption was that people consuming at the highest rates are primarily eating locally-caught fish, not commercially-acquired fish (Table 3). This means that, a primary way to reduce the mercury intake for these high-consumers will be to reduce the mercury in locally-caught fish.

Rates of Mercury Intake

Rates of mercury intake were calculated for each interviewee by multiplying the rate of consumption of specific fish by the average mercury concentration for that fish species in the region of surveying. These individual-specific rates were aggregated into different groups (Table 3) for calculation of mean and 95th percentile rates of consumption. These rates were also compared to the USEPA reference dose (RfD) for mercury intake, 0.1 micrograms mercury/kg body-weight per day. For the comparison with the RfD, an average body weight of 67 kg was assumed, meaning that variation around this mean weight will cause variation in actual individual exposure. "*The reference dose (RfD) is an estimate of the highest daily dose of a chemical that the most sensitive in the population can be exposed to over a lifetime of exposure without experiencing an adverse effect.*" (Center for Food, Nutrition, and Agriculture Policy, University of Maryland Web site)

The rates of mercury intake presented here are likely to be an under-estimate of actual rates. The fish filet models presented to interviewees were of cooked fish, which are approximately 75% of the weight of fresh fish. The mercury concentrations used in this study were determined for fresh fish, not cooked fish. To compensate for this difference, all mercury intake rates were multiplied by a factor of 1.3. When this was done, 50% and 34% of all respondents were found to have total fish and local fish (respectively) derived mercury intake rates greater than the EPA reference dose. More seriously, 6% of all respondents were found to have mercury intake rates from <u>total</u> fish consumption greater than 10 times the EPA reference dose and 5% of all respondents had mercury intake rates from <u>local</u> fish consumption greater than 10 times the EPA reference dose.

The EPA reference dose represents a conservative and protective standard for protecting the health of children <17 years-old and women who are bearing or may bear children. The dose was calculated as 1/10 the rate of mercury intake that was likely to lead to detectable learning impairments and other neurosystem related problems Consuming mercury at a rate greater than the reference dose may pose harm to children or fetuses of women consuming fish. Consuming mercury at a rate greater than 10 times the reference dose is likely to lead to neuorological and other harm (NRC, 2000; Trasande et al., 2005; USEPA, 2000). The highest-consuming groups (e.g., Lao people) had 95th percentile rates up to 30 times the reference dose and the highest consuming individuals consumed at ~60 times the reference dose.

Whole Population Exposure to Fish-Tissue Mercury

There are about 170,000 licensed anglers in the counties containing the Delta (data from License Branch, Department of Fish and Game for 2005). Although there are anglers that are likely to visit from other counties and un-licensed anglers, this represents an approximation of the base angler base for the region. The number of anglers consuming mercury from fish meals at rates greater than the EPA reference dose is about 85,000, with 75,000 of these reaching that level from local fish consumption alone. The number of anglers consuming mercury at rates greater than 10 times the EPA reference dose and therefore exposed at toxic levels to mercury, is 10,200, with 8,500 of these reaching that exposure level through local-fish consumption alone.

Anglers are one group that may be expected to eat fish in large quantities, but there are other people in the communities around the Delta who may also be expected to consume large amounts of fish, including family members and friends of anglers. Women interviewed in community settings ate significantly more locally-caught (54.1 g/day) and total (66.4 g/day) fish than male anglers (26.4 g/day and 39.3 g/day; $P<0.05$, t-test) and identical amounts of commercially-obtained fish. There was no statistically significant difference between male and female angler consumption rates ($P>0.05$, Table 3). There were also no significant differences in consumption rates among age groups (Table 3). Rates of consumption for locally-caught and total fish were significantly higher ($P<0.05$, t-test) for anglers from households with children, or from households with women of child-bearing age, than anglers from households without children or women of child-bearing age. Given these results, it is likely that the findings from angler surveys approximately represent a larger population of members of subsistence and recreational fishing households. Therefore, the number of anglers can be multiplied by a "family factor" (of 4 for a family of four) to obtain a more realistic estimate of the population exposed to mercury from fish consumption. This would mean that the 10,200 anglers exposed to mercury at 10 times the EPA reference dose, may represent 40,800 (family of 4) to 61,200 (family of 6) people in the Delta region.

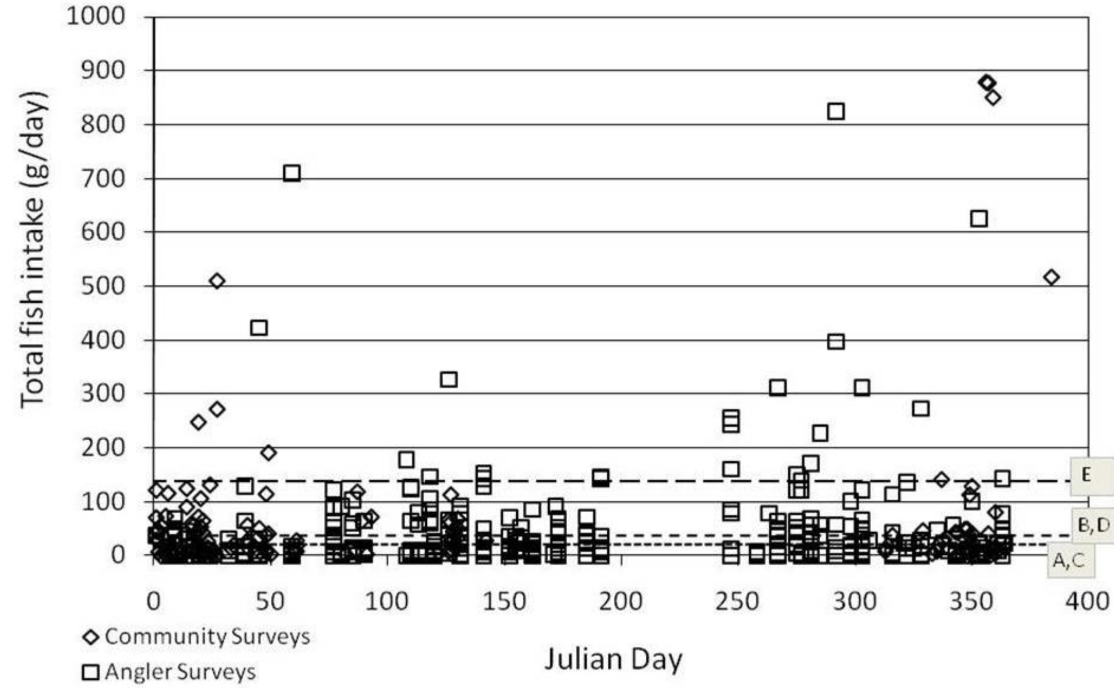


Figure 2 Total fish (commercial + local) consumption rates over the year (Julian Day 1 = January 1st). Each symbol represents an individual interviewee. The lines at the bottom represent the scenarios for total fish consumption used by the Central Valley Regional Water Quality Control Board's TMDL for methyl-mercury in the Delta. A,C = 40 g/day; B,D = 44.5 g/day; E = 142 g/day of fish consumed.

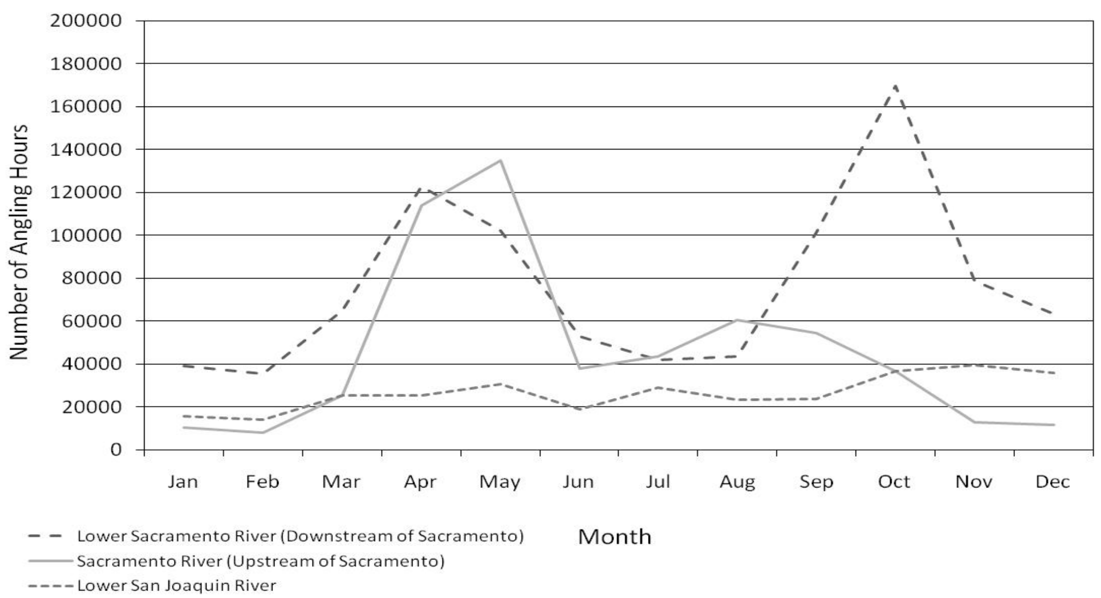


Figure 3 Fishing intensity as angling hours varying by season and location on the Sacramento River and San Joaquin River. Data from the California Department of Fish & Game creel survey program, 2000.

Table 3. Mean and 95th percentile fish and mercury intake rates for different groups. ND stands for "not determined" because of insufficient data. All data shown are for angler surveying, except for the data indicated as from combined angler and community surveys.

		N	Local Fish Intake		Local Fish Hg		Total Fish Intake		Total Fish Hg	
			Mean (g fish/d)	95th Percentile (g fish/d)	Mean (micro-g Hg/d)	95th Percentile (micro-g Hg/d)	Mean (g fish/d)	95th Percentile (g fish/d)	Mean (micro-g Hg/d)	95th Percentile (micro-g Hg/d)
Ethnicity										
African-American		32	31.2	242.3	15.7	127.8	48.3	252.0	20.8	130.6
Southeast Asian		152	32.3	129.4	14.0	62.8	42.8	180.2	17.1	74.7
	Hmong	67	17.8	89.6	6.9	33.6	22.3	89.6	8.3	37.7
	Lao	30	57.6	310.4	26.5	161.4	65.2	317.5	28.8	163.5
	Vietnamese	33	27.1	152.4	11.9	77.4	55.4	249.3	20.4	105.9
Asian/Pacific Islander		38	23.8	148.3	9.8	40.4	46.1	156.4	16.5	49.5
Hispanic		45	25.8	155.9	10.8	48.1	36.3	169.5	13.9	54.1
Native American		5	6.5	ND	2.3	ND	44.2	ND	13.6	ND
White		57	23.6	138.9	8.8	43.8	34.7	139.2	12.1	46.8
	Russian	17	23.7	ND	7.8	ND	36.1	ND	11.5	ND
All Anglers		373	27.4	126.6	11.4	51.5	40.6	147.3	15.4	56.6
Southeast Asian (combined surveys community + angler)		286	40.8	128.5	17.6	58.0	50.3	144.5	18.7	70.2
	Hmong	130	21.3	102.1	8.09	38.7	26.5	119.7	9.7	42.9
	Lao	54	47.2	265.8	20.4	117.8	54.4	267.0	22.6	118.8
Age	18-34	143	32.0	138.9	13.0	55.6	44.9	151.5	16.8	66.7
	35-49	130	22.7	120.5	9.8	51.2	36.8	143.9	14.0	57.5
	>49	87	30.6	207.0	12.8	92.3	44.3	217.2	17.0	95.4
Gender	F	35	38.2	226.8	15.9	94.7	53.9	263.1	20.6	105.4
	M	336	26.4	129.3	11.0	54.3	39.3	146.6	14.9	56.9
Household contains	Woman 18-49 y-	217	33.0	142.2	14.1	59.5	46.6	158.1	18.2	71.8
	Children	174	35.1	142.8	15.4	61.2	49.2	171.9	19.6	78.3
Awareness	0	172	24.7	121.6	10.4	51.9	35.5	143.5	13.7	56.6
	1	44	42.8	361.1	19.5	187.5	52.9	361.1	22.5	187.5
	2	115	28.4	139.6	11.0	61.2	45.8	151.7	16.2	63.3
	3	35	12.2	62.4	5.1	32.1	28.1	95.6	9.9	35.9
	4	7	57.1	ND	24.3	ND	65.0	ND	26.7	ND

Differential Exposure

There were wide ranges of consumption both within ethnic groups and among groups. When poor, disenfranchised, and/or non-white communities are disproportionately affected by environmental contamination then the issue is one of environmental justice. In the case of consumption of contaminated fish by major ethnic groups, white anglers had the lowest mean and 95th percentile consumption rates of locally-caught fish and all fish, though in comparison to other major ethnic groups, these rates were only statistically different from Southeast Asians as a major ethnic sub-group.

Southeast Asian anglers and community members reported similar rates of fish consumption and had the highest rate of mercury intake among large ethnic/national-origin groups. The rates measured in our study (Table 3)were similar to rates found in countries of origin for first and second generation Southeast Asians by the Food and Agriculture Organization of the United Nations for Lao people (48 g/day) and Mekong Basin residents (107 g/day; FAO, 2003). It is more appropriate to go beyond traditional Census Bureau designation and refer to ethnicities separately. There are many Hmong, Lao, and Iu Mien people in the Delta region who originated in this or previous generations from countries in Southeast Asia. Many Lao people in Laos and Cambodia live at lower elevations near fish-bearing streams and rivers, whereas Hmong people in Vietnam and Thailand live in mountainous areas. These origins may help to explain the higher rates of fish consumption among Lao when compared to Hmong.

Survey Sufficiency

Most of the findings here depend upon sufficient power in the statistical analysis, based on the amount of data available for the analysis. When used this way, power refers to the likelihood that a Type II error (rejecting a false null hypothesis) will be avoided. Power analysis is related to the size of the effect or difference sought and the number of samples. Sample size analysis is a related calculation that can help determine how many samples may be needed to determine an effect or difference.

Because of the number of ethnicities fishing in the Delta region, it is challenging to conduct a survey with sufficient power to differentiate between groups or between mean fish consumption rates for a group and a standard rate, such as the rate used by the Regional Board for TMDL Scenario A/C for fish consumption (17.5 g/day). I used the information available from past surveying to determine sample sizes needed to measure the difference between the mean rates we found for local fish consumption and the rate used by the Regional Board (17.5 g/day). Despite the wide range of rates found, for all Asians and for Southeast Asians, the past surveying had sample sizes sufficient for comparison. Similarly, the statistical power was sufficient (57% to 83%) for this comparison. For all other mean rate comparisons, the sample sizes were too small to provide sufficient statistical power to compare the ethnicity-specific mean rates and the TMDL Scenario A/C rate. This would have been ever more of an issue when comparing mean rates found with 95th percentile rate from the San Francisco Bay study (32 g/day), used to develop TMDL Scenario B/D. Another way to say this is that in order to state with confidence whether or not mean rates for individual ethnicities are similar to the rates used to develop TMDL Scenarios A, B, C, and D, a larger survey would need to be performed. The sample sizes needed per group are on the order of 100 to 200 individuals for 50% power and 150 to 450 individuals for 80% power. 80% power is a commonly used standard for biostatistics.

As stated in the Delta Methyl-Mercury TMDL: "*The San Francisco Bay Mercury TMDL selected the consumption rate for the 95th percentile of anglers (32 g/day) for calculation of the San Francisco Bay fish mercury target (0.2 mg/kg) to protect people who choose to eat San Francisco Bay fish on a regular basis ….*" Table 3 above provides the 95th percentile rates for all anglers and anglers within different demographic groups. In almost all cases, the 95th percentile rates for Delta fish-consumers are greater than Scenarios A, B, C, D. As stated in the TMDL in reference to choosing subsistence level consumption rates for Scenario E: "*In selecting the 90th percentile, rather than the mean or median, the USEPA intended to recommend a consumption rate that is protective of the majority of the entire population. The USEPA recommended a consumption rate of 142.4 g/day (four to five fish meals per week) of local fish for the development of a human health criterion for anglers whose main source of protein is from locally caught fish. This value represents the 99th percentile consumption rate for all survey participants.*"

If the Regional Board chooses to use mean fish consumption rates for Delta anglers across ethnic and other demographic groupings, then sufficient surveying must be conducted to provide power to the statistical analyses in determining whether the assumed rates used in the TMDL are protective of public and individual health. In contrast the 95th percentile rates found from surveying anglers and community members in the Delta region are sufficiently different from the Scenarios A-D rates and similar to the Scenario E rates to ensure that additional surveying may not be needed to assure health-protective standards.

Conclusions and Recommendations

1) There is a population of approximately 10,000 anglers and their families, which together represent at least 40,000 people, in the Delta region who are ingesting dangerous amounts of mercury through locally-caught fish consumption. The Regional Board and responsible state and federal entities should recognize this population and their rates of fish consumption in the methyl-mercury TMDL and similar pollution control processes.

2) Ethnicity-specific rates of fish consumption, patterns of fish choice, separate health communication pathways, and different levels of awareness of fish contamination and advisories mean that measuring fish consumption rates and communicating effectively with different communities is a larger task than currently recognized among state agencies. The state and federal government should support continuing fish consumption and other dietary and health-related surveying in order to both understand practices and collaborate with communities to find ways to develop alternatives.

3) The choice of fish consumption rates for developing TMDL targets is an important exercise. Currently the rates used in the TMDL for Scenarios A-D are neither protective of 50% of the population consuming higher than the mean rates in the region, nor of the ethnicities that eat at higher rates than the central tendency. The Central Valley Regional Board should adopt the health-protection standard set by the San Francisco Bay Regional Board and recommended by the USEPA of using the 95th percentile or 99th percentile fish consumption rates *in the Delta communities* to set mercury targets in fish tissue. These rates should be based on continuing monitoring and not one-time studies that can become obsolete or incompletely reflect ethnicity-specific practices.

References

Central Valley Regional Water Quality Control Board (CVRWQCB), 2008. Sacramento – San Joaquin Delta Estuary TMDL for Methylmercury, Draft Staff Report. Central Valley Regional Water Quality Control Board.

FAO/MRC/Government of Thailand/Government of the Netherlands. 2003. New approaches for the improvement of inland capture fisheries statistics in the Mekong Basin. RAP Publication 2003/01. 145 p.

Fujimoto, I., 1998. Building Civic Participation in California's Central Valley, Book One: Getting to Know the Central Valley. California Institute for Rural Studies.

Helsel, D.R., Mueller, D.K., and Slack, J.R., 2006. Computer program for the Kendall family of trend tests: U.S. Geological Survey Scientific Investigations Report 2005–5275.

Hirsch, R.M., and Slack, J.R., 1984, A nonparametric trend test for seasonal data with serial dependence: Water Resources Research 20: 727–732.

Hudson, T.S., Forman, M.R., Cantwell, M.M., Schatzkin, A., Albert, P.S., Lanza, E., 2006. Dietary fiber intake: Assessing the degree of agreement between food frequency questionnaires and 4-day food records. Journal of the American College of Nutrition 25(5): 370-381.

Jackson, L.S., M.G. Knize, J.N. Morgan. 1999. Impact of Processing on Food Safety: [proceedings of the American Chemical Society Symposium on Impact of Processing on Food Safety, Held April 14 - 18, 1997, in San Francisco, California]. Springer, 270 pages

Kuster, C., Vuki, V.C., Zann L.P., 2006. Validation of the accuracy of huosehold reporting of subsistence fishing catch and effort: a Fijian case study. Fisheries Management and Ecology 13(3): 177-184.

Lee, K.Y., Uchida, K., Shirota, T., Kono, S., 2002. Validity of a self-administered food frequency questionnaire against 7-day dietary records in four seasons. Journal of Nutritional Science and Vitaminology 48(6): 467-476.

McNaughton, S.A., Mishra, G.D., Bramwell, G. A., Paul, A., Wadsworth, M.E.J., 2005. Comparability of dietary patterns assessed by multiple dietary assessment mehods: results from the 1946 British Birth Cohort. European Journal of Clinical Nutrition 59(3): 341-352.

Melwani, A., S. BEzalel, J. Hunt, L. Grenier, J. Davis, G. Ichikawa, B. Jakl, W. Heim, A. Bonnema, and M. Gassel. 2007. California Bay-Delta Authority Fish Mercury Project Year 2 Annual Report Sport Fish Sampling and Analysis. San Francisco Estuary Institute, 118 pages.

Murphy, K, Hanson, L., Harris, M., and Schroyer, T., 1999. Central Valley Salmon and Steelhead Harvest Monitoring Project - 1999 Angler Survey. California Department of Fish and Game, unpublished annual report.

Murphy, K, Schroyer, T., and Massa, D., 2000. Central Valley Salmon and Steelhead Harvest Monitoring Project - 2000 Angler Survey. California Department of Fish and Game, unpublished annual report.

NRC, 2000. Toxicological Effects of Methylmercury. National Academy of Sciences National Research Council Report, Committee on the Toxicological Effects of Methylmercury. Washington, DC: National Academy Press

Quandt, S.A., Vitolins, M.Z., Smith, S.L., Tooze, J.A., Bell, R.A., Davis, C.C., DeVellis, R.F., and Arcury, T.A., 2007. Comparative validation of standard, picture-sort, and meal-based food-frequency questionnaires adapted for an elderly population of low socio-economic status. Public Health Nutrition 10(5): 524-532.

Schroyer, T., Massa, D., and Murphy, K., 2001. Central Valley Salmon and Steelhead Harvest Monitoring Project - 2000 Angler Survey. California Department of Fish and Game, unpublished annual report

Silver, E., Kaslow, J., Lee, D., Lee, S., Tan, M.L., Weis, E., and Ujihara, A., 2007. Fish consumption and advisory awareness among low-income women in California's Sacramento-San Joaquin Delta. Environmental Research 104: 410-419.

Sullivan, B.L., Williams, P.G., Meyer, B.J., 2006. Biomarker validation of a long-chain omega-3 polyunsaturated fatty acid food frequency questionnaire. Lipids 41(9): 845-850.

Trasande, L., P. J. Landrigan, and C. Schecter. 2005. Public Health and Economic Consequences of Methylmercury Toxicity to the Developing Brain. Environmental Health Perspectives 113:590.

USEPA 1997 Exposure Factors Handbook (http://www.epa.gov/ncea/pdfs/efh/front.pdf)

USEPA, 2000. Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (2000). US Environmental Protection Agency Office of Water and Office of Science and Technology. EPA-822-B-00-004, October. Pg. 4-5.

Villegas, R., Yang, G., Liu, D.K., Xiang, Y.B., Cai, H., Zheng, W., Shu, X.O., 2007. Validity and reproducibility of the food-frequency questionnaire used in the Shanghai Men's Health Study. British Journal of Nutrition 97(5): 993-1000.

Vladimir and unidentified friend fishing on the Slough, 2008. Photo by Aubrey White.

Attachment C

Community-Based Strategies to Reduce Mercury Exposure in Delta Fishing Communities

Prepared by:
Fraser Shilling & Samantha Sommer
University of California, Davis
Laura Leonelli & David Shimoum
Southeast Asian Assistance Center

For:
California Department of Public Health
& Central Valley Regional Water Quality Control Board

June 2008

Table of Contents

Cover photo credits: Striped bass ("Field Guide to Fishes", National Audubon Society); community meeting about fish contamination (Foua Ly); angler in Suisun Bay (Aubrey White).

Acknowledgments and Notes

Funding for development of these strategies was provided to the authors by the Central Valley Regional Water Quality Control Board, through the California Department of Public Health. Thanks to Janis Cooke (Regional Board) and Alyce Ujihara (California Department of Public Health) for their support, review, and suggested edits for this plan. We are grateful to the stakeholders who shared their perspectives and opinions (Appendix A), without which we would not have been able to conduct the project. We are especially grateful to Andria Ventura (Clean Water Fund) and Amy Vanderwarker for coordinating the meetings of community organizations and Bay and Delta stakeholders concerned about fish contamination.

Several community organizations involved in fish contamination issues provided input for this strategic plan. They reserve the right to pursue these ideas, potentially in collaboration with others, and expect that if state agencies and others want to pursue them, they plan to equally collaborate with and support the organizations. Because of the sensitivity of this issue, future relationships with communities and community organizations, with whom participation is desired, may hinge on respecting community desires to speak for and organize themselves.

Draft 1: April, 2008; Final draft (revised based on RB and CDPH comments): June, 2008

The authors: **Laura Leonelli** (seacenter@sbcglobal.net) is the executive director of the Southeast Asian Assistance Center (SAAC, Sacramento), which has a staff dedicated to helping Southeast Asian immigrants adapt to health, legal, and economic challenges. **David Shimoum** is the fish project coordinator at SAAC, having come from working with Southeast Asian communities in Stockton. **Samantha Sommer** is a recently-graduated Master's student at UC Davis, who has expertise in community development and development of sustainable community indicators for the Central Valley. **Fraser Shilling** (fmshilling@ucdavis.edu) is an environmental scientist at UC Davis who has expertise in aquatic and systems ecology and the development of environmental indicator systems.

> *"Forget about the education process… Create alternatives!…clean up certain areas so that people can safely fish in certain cleaned and maintained areas."*
> -- Debbie Davis, Environmental Justice Coalition for Water

Executive Summary

In recognition of the broad diversity of communities and geographies involved in fish contamination, the strategic plan describes a stakeholder decision-making model that is based in impacted communities, informed by science, and with support from state institutions. It is rooted in the tacit understanding of communities that agencies will pursue environmental cleanup.

Mercury is a common contaminant of fish eaten by residents of the San Francisco Bay and the Central Valley. A legacy of the Gold-Rush era as well as a component of industrial and municipal waste, mercury accumulates up the food chain until it is consumed by people as they eat fish. This plan describes ways that exposure and therefore health impacts from mercury can be reduced for communities and individuals that eat fish caught in the Sacramento/San Joaquin River Delta. Like any strategic plan, it starts out describing the nature of the problem, where we want to end up, and how we are going to get there.

California state agencies have been involved with the challenge of reducing exposure of subsistence anglers to legacy and contemporary pollutants. This has consisted of several pilot studies and plans to clean up legacy mercury and educate anglers about fish contamination. The knowledge base about mercury cycling and accumulation has been steadily increasing, improving the likely efficacy of programs to reduce total mercury entry into waterways, as well as methylation of mercury in the environment. Remediation of mercury in waterways consists of addressing both total and methyl-mercury entry from terrestrial sources as well as methylation conditions exacerbated or created by reservoir operation, agricultural discharge, and municipal waste water. Reducing exposure in the short-term (while clean-up operations get under way) is considered by staff from certain state agencies interviewed in this study (OEHHA, Department of Fish & Game), and the Regional Board, to also involve reduced fish consumption by subsistence anglers and their families. Because this view is not shared among subsistence anglers, at least in practice, there is an unresolved tension between state goals and public goals and practices. Recent findings show that mercury concentrations can go up and down significantly from year-to-year, suggesting that our assumptions about mercury cleanup taking decades may be wrong.

This plan is intended to support the overall goal of reducing mercury exposure among members of the public consuming locally-caught fish. It is based on the assumption that cleanup and abatement activities will proceed through processes such as the TMDL and that while that is occurring, communities will decide how to respond to fish contamination. The plan was formulated based on the combined expertise of the UC Davis and Southeast Asian Assistance Center staff, as well as the interview responses from 30 stakeholders in the Delta region (agency and organization representatives). These stakeholders were each asked 15 questions relating to their understanding of fish contamination by mercury, potential strategies and actions that could help solve fish contamination, and roles their organizations and others could play in helping reduce fish contamination with mercury.

The plan is organized into 5 parts, each dealing with a particular aspect of reducing mercury exposure and serving as a gage for our effectiveness as agencies and institutions in dealing with this pollutant. It is intended to complement and overlap other discussions among engineers and scientists about the technical aspects of cleaning up mercury contamination in the environment and reducing new inputs of mercury from municipal and industrial waste and processes. The first part of this strategy covers monitoring fish tissue and fish consumption patterns as related processes. The second part deals with approaches for assessing mercury exposure in a culturally sensitive manner. The third part goes into detail about developing effective programs for educating and involving impacted community members. The fourth part talks about developing fish consumption advisories that are understandable to the diverse communities eating fish from regional waterways. The fifth and final part is the business plan for implementing the strategy, based on a decision-making model that necessarily places impacted communities at the center of deliberations about fish contamination and partners in implementing strategic solutions.

1) Monitoring fish and fish consumption

These two processes have been largely disconnected in the Bay-Delta, where fish contamination has been monitored by biologists and fish consumption has largely been monitored by social scientists and community health experts. Ideally, there would be close coordination between these activities, except for fish monitoring associated with bioaccumulation and similar studies. There are many ethnicities who consume locally-caught fish from the Delta region, so measuring consumption patterns is complicated by language, culture, and trust. Several of the interviewees are experts in this area. The plan describes how Universities, agencies, and community organizations can collectively and individually plan and implement monitoring of fish contamination and consumption.

Strategy Community organizations lead the design and implementation of fish tissue and fish consumption monitoring, aided by academic and agency scientists.

2) Assessing mercury exposure.

There have been few studies of either calculated exposure (based on frequency or amount of fish consumption) or actual exposure (based on blood-mercury concentrations). In California, a pilot study by CDPH revealed complicated results for the combination of fish consumption rates and blood-mercury concentrations (A. Ujihara, “Fish Forum” 2007). There are also cultural and community concerns about exposure monitoring, addressed by several of the stakeholder-interviewees. The plan addresses how agencies and others can collectively or individually calculate or directly address mercury exposure in diverse fish-consuming populations.

Strategy Community organizations, in partnership with agency and academic health professionals calculate or measure actual mercury exposure and community organizations lead communication of findings to communities and individuals.

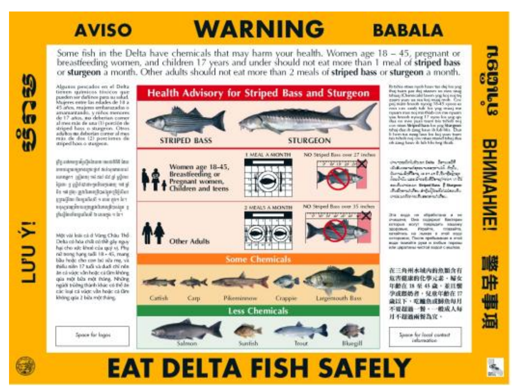
3) Effective education and outreach.

Community organizations, the Department of Public Health, and UC Davis have all engaged anglers and community members in discussions about fish consumption, have developed educational programs and materials, and have collectively reached thousands of anglers and other fish consumers. Recent research has elucidated possible opportunities and barriers to effective communication with fish consumers. Several stakeholder interviewees are expert in this area. The plan describes how state agencies and others can individually and collectively organize and support education and outreach activities to both inform people about fish contamination and provide them with avenues to communicate with decision-makers about this problem.

Strategy Community organizations lead the design and implementation of education and outreach programs to communities and individuals eating large amounts of locally-caught fish, aided by academic and agency scientists.

4) Consumption advisories.

These are developed by the Office of Environmental Health Hazard Assessment (OEHHA) and federal agencies, with a variable level of collaboration with other agencies and academic scientists. The advisories are intended for communities with high linguistic, ethnic, and cultural diversity, so their development and implementation could take advantage of experts in this area of diversity in order to make the advisories effective. The plan describes how advisories can be developed by OEHHA in collaboration with others to provide science-based *and* diversity-based advisories.



Strategy Community organizations, in partnership with agency and academic health professionals and scientists, design fish-consumption guidelines that are accessible to the diverse cultures and communities in the Delta region.

5) Decision-making & implementation model

The current approach or model used for state decision-making vis-à-vis fish contamination features state agencies on the funding and funded sides of the equations, has state agencies as the primary or sole decision-makers, and has resulted in challenges to implementation of an exposure reduction strategy. Feedback from all Delta stakeholders suggest that a strategic decision-making model is needed to reduce mercury exposure in Delta fish-consumers. To improve effectiveness, this model features organizations from impacted communities at the center of decision-making and implementation, partnering with state institutions in support roles.

I. Essential Background

Fish contamination by mercury and other pollutants is common throughout the Delta region and San Francisco Bay. Mercury from legacy, waste-stream, atmospheric, and natural sources enters the food-chain and accumulates into fish that people and wildlife eat (Wood et al., 2008). Concentrations of mercury are high enough in fish commonly-caught in the Delta region (e.g., catfish in North Delta and striped bass everywhere) to pose health risks to people consuming fish more often than once per week. As cleanup and pollution abatement plans are developed and implemented, state agencies and community organizations have been interested in helping people to keep enjoying the health benefits of eating fish, while reducing their exposure to mercury.

In 2003, CALFED commissioned a "Mercury Strategy" from a panel of national experts (Wiener et al., 2003). They combed the literature, the knowledge of Californian experts and stakeholders, and the data available to support decision-making. They described the sources of mercury and conversion to methyl-mercury in the Delta and its watersheds. They described the primary challenge in the Delta as "*to avoid increasing – and to eventually decrease – biotic exposure to methylmercury"*. They recommended 6 linked core components to the overall strategy: (1) Quantification and evaluation of mercury and methylmercury sources, (2) remediation of mercury source areas, (3) quantification of effects of ecosystem restoration on methylmercury exposure, (4) monitoring of mercury in fish, health-risk assessment, and risk communication, (5) assessment of ecological risk, and (6) identification and testing of potential management approaches for reducing methylmercury contamination. Although this study and plan effectively covered the science of mercury "production", transport, methylation, and fate, it only superficially described the social and health implications of mercury or strategies that could be taken in relation to these considerations. The current strategy builds upon the "Mercury Strategy" and fleshes out core component #4, emphasizing community involvement and education in what has been primarily an agency-driven process.

Community groups, agencies, and other stakeholders have expressed a common desire to pursue clean-up of mercury and other pollutants in the Delta watershed. They also hold a common desire to inform communities about the problem of fish contamination in order to permit anglers of many ethnicities to enjoy the beneficial use of local fish consumption while protecting their health. This strategic plan is based on in-depth interviews with 30 stakeholders about how to implement these visions. It describes specific approaches and steps to understanding the problem of consumption of contaminated fish and education and involvement of very diverse communities in reducing mercury exposure. Based on broad stakeholder input for improving effectiveness, the plan includes a model for decision-making that places impacted communities at the center, while recognizing the important scientific and funding roles of state and federal agencies. The plan provides an environmental justice solution to an environmental justice problem.

II. Problem Setting

1) Geography

Waterways leading to the Delta carry mercury in various forms and oxidative states (Domagalski, 1998 & 2001). The Delta in turn delivers the bulk of the water to the San Francisco Bay. Anglers tend to live and fish in greater numbers nearer urban areas than in the rural parts of the Sierra Nevada, Coast Range, or Central Valley (Shilling, 2003, 2004). In other words, the problem of mercury contamination originates from throughout the Delta's and Bay's watershed, but is expressed in the more urbanized areas around the Delta and Bay Area.

In the Central valley, anglers are distributed diffusely along major rivers and streams, on and around certain reservoirs, and at certain concentrated locations when other access points are limited (Williams, Shilling, Leonelli, Shimoum, and White, personal observations). Unfortunately, through an accident in geography, anglers tend to co-occur with places where frequencies of fish contamination are among the highest in California – the major rivers and reservoirs feeding into the Delta and Bay, as well as the Delta and Bay themselves (Shilling, 2003, 2004).

The Central Valley Regional Water Quality Control Board, CALFED's Ecosystem Restoration Program, and others have funded years of extensive surveying of fish tissue mercury concentrations (e.g., Davis et al, 2003). Two major and relevant findings from this work are that there are many places where mercury concentrations in certain fish species are high (e.g., catfish in the Sacramento and San Joaquin Rivers). An equally significant finding is that there are also places and fish species where concentrations are relatively low (e.g., higher-elevation creeks and trout). Although these occurrences of low and high mercury concentrations in various fish and in various places is still being defined, the upshot is that there are so-called "cool spots" where catching and eating fish may not be harmful.

2) Cultural, policy, and management setting

Individual community organizations have long been aware of the importance of fishing and fish consumption among their clients (Williams, personal communication; Leonelli, personal observation; Norris, personal communication). Recently, there have been several studies that have revealed the ethnic variety of anglers throughout the Delta region (Shilling, 2004; Silver, 2007; Shilling et al., 2008). These observations and studies have led to the conclusions that many ethnicities are involved in frequent fishing and fish consumption in the North Bay and Delta and that there is a true subsistence fishing population that crosses ethnic boundaries. The importance of these observations and conclusions is that a single management or policy approach to exposure reduction may not be effective.

Strategies for reducing mercury exposure

There are a variety of economic activities and legacy processes that impact who must remediate mercury contamination and how. State and federal agencies have statutory authority and responsibility to limit discharge of pollutants into waters of California and US. In the case of mercury and methyl-mercury, point sources of inorganic mercury, sources of methyl-mercury, and sites of methylation are reasonable targets for cleanup and abatement activities. The Clean Water Act requires the use of policy tools such as National Pollutant Discharge Elimination System (NPDES) permits and Total Maximum Daily Load (TMDL) determinations to reduce pollutant discharge to US waters. The Regional Board provides NPDES permits to dischargers and calculates TMDLs for individual pollutants for individual water-bodies. These are two possible tools that the Regional Board can use to reduce inorganic and organic mercury into waterways as well as to reduce pollutant discharge that contributes to methylation conditions. Dam and reservoir operations that are part of hydropower generation are regulated by the Federal Energy Commission. FERC has the power to require reservoir operators to limit environmental damage (including pollution discharge) from their facilities. Other state and federal regulatory powers exist to require polluters to abate (methyl)mercury inputs and remediate past inputs.

Federal lands and certain state lands contain many of the abandoned mines that continue to contribute inorganic mercury to waterways that drain to the Central Valley, Delta, and Bay. Federal land managers have not obtained sufficient funds to begin cleanup and abatement activities in any meaningful way on these lands and they remain sources of mercury in the Delta watershed. Mine features are also present on private lands, but very little cleanup has been attempted there because of landowner concerns about liability. However, they remain a source of mercury, as significant a source as public lands. Agricultural lands contribute large amounts of organic carbon, sediment, and nutrients to Central Valley waterways. These contributions are likely to increase the number and activity of methylation environments in benthic sediments, slow-moving channels, and inundated lands (e.g., rice fields). Municipal discharge is a relatively minor contributor of mercury, but may exacerbate in-stream and down-stream mercury methylation conditions (e.g., by introducing nutrients into waterways). Recent findings in Delta tributaries that tissue contamination of certain fish species can vary significantly (going up AND down) from month to month and year to year suggest that reducing mercury inputs and/or remediating methylation environments can provide short-term benefits as well as long-term benefits (Slotton, unpublished observations from Fish Mercury Project).

A critical feature of the context for this strategy is the current approach or model used for state decision-making vis-à-vis fish contamination. This approach features state agencies on the funding and funded sides of the equations, has state agencies as the primary or sole decision-makers, and has resulted in challenges to implementation of an exposure reduction strategy. This approach (shown in Figure 1) includes the Office of Environmental Health Hazard Assessment, the California Department of Public Health, and the Regional Board in decision-making roles. The thickness of the arrows indicates movement of information or material support dealing with fish contamination and barriers are shown as star shapes. According to community organizations, they have a minor advisory role, compared to the core, funded team and received a small percentage (<5%) of the total funding for the Fish Mercury Project for their work. Key stakeholders in this process and interviewed here expressed dissatisfaction with this model, with the strongest feelings being expressed by community organizations. Even state agency representatives have pointed to problems with implementing such an approach. This has primarily been because of the broad ethnic diversity disproportionately affected by fish contamination and the high barriers associated with state agencies leading outreach and education efforts through official advisories and other modes of communication. Disaffected community organizations have become more common, obscuring the positive outcomes that have accompanied state agency involvement, such as funding, research, and policy formulation.

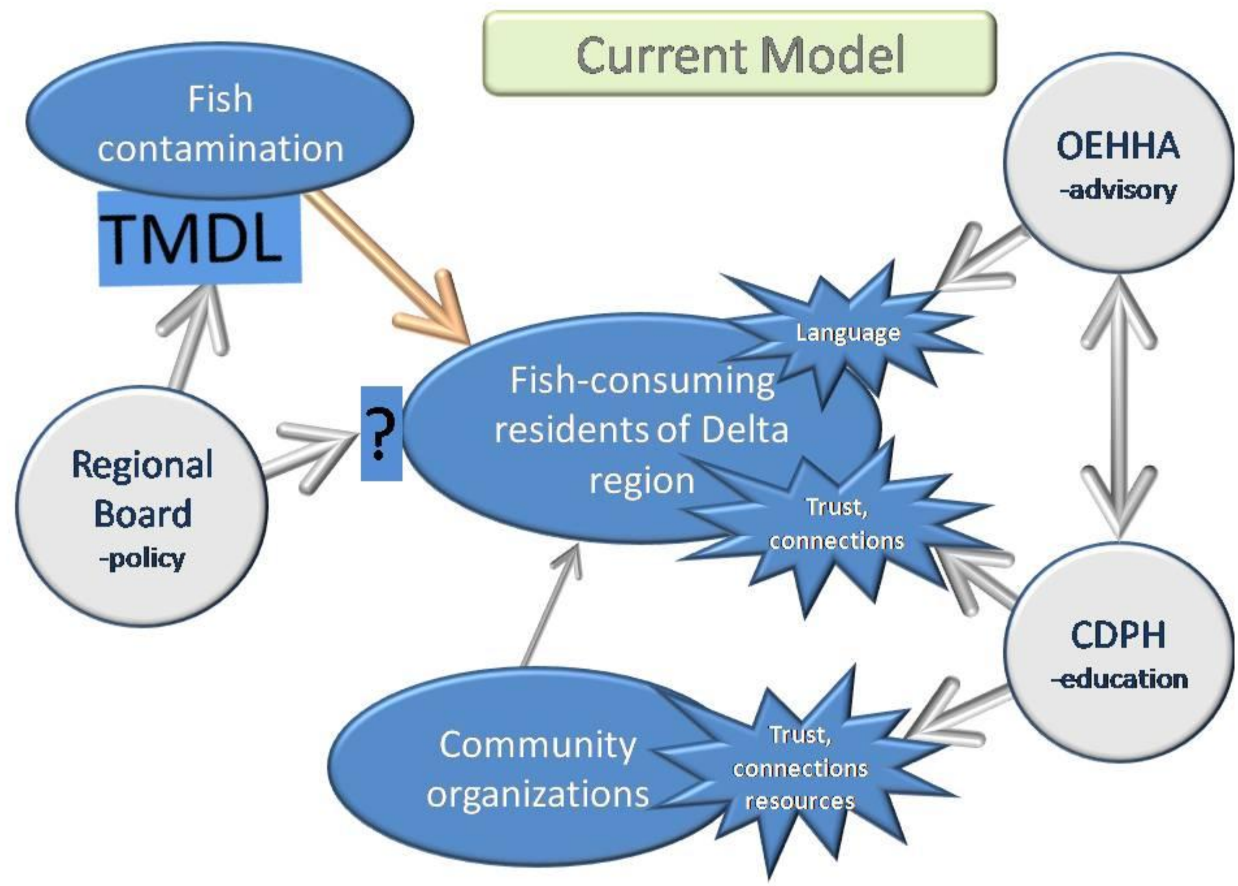


Figure 1 Decision-making and implementation model currently used in Delta fish contamination programs. Barriers are represented by the star shapes. Not all possible interactions and organizations are shown, only the primary ones. "Fish" refers to fish contamination, edible

III. Core Strategies for Exposure Reduction

Development of Strategies

This plan describes strategies for reducing mercury exposure in fish-consumers developed using a stakeholder-based process. A combination of expert-stakeholder interviews, focal groups, and stakeholder meetings led to the implementable strategies described here. The strategies are based on 3 core values expressed by stakeholders – clean-up and reduce mercury and methyl-mercury inputs, educate fish-consumers to improve their choices, and provide alternatives to consuming contaminated fish.

1) Monitoring fish and fish consumption

These two processes have been largely disconnected in the Bay-Delta, where the majority of fish contamination has been monitored by biologists and fish consumption has largely been monitored by social scientists and community health experts. Ideally, there would be close coordination between these activities, except for fish monitoring associated exclusively with bioaccumulation and similar studies. There are many ethnicities who consume locally-caught fish from the Delta region, so measuring consumption patterns is complicated by language, culture, and trust. Several of the interviewees are experts in this area. The plan describes how Universities, county and state agencies, and community organizations can collectively and individually plan and implement monitoring of fish contamination and consumption. A model for this approach has already been carried out by tribes, state agencies, and university researchers in the Great Lakes region (Dellinger, 2004).

A Model approaches

Since 2002, advocates for healthy fish consumption have canvassed and communicated with anglers about their fish consumption – People for Children's Health and Environmental Justice (PCHEJ) with African American and other ethnicities and California Indian Environmental Alliance with tribes. In the absence of state support for their efforts, they have relied on private foundation and non-state agency support. More recently, UC Davis scientists and community organizations (Southeast Asian Assistance Center & PCHEJ) have developed a unique collaborative project that was initially funded by the Sacramento Regional County Sanitation District and is currently funded by the California Endowment ($100,000 planning grant). This project is called "*Community Capacity to Reduce Fish Contamination*" (hereafter *Community Collaborative*). One goal of this project is to develop scientific studies of fish consumption and contamination exposure, with community organizations involved in decision-making roles.

The project includes surveying hundreds of anglers and community members about fish consumption patterns, holding community engagement meetings, developing education and outreach materials, and developing a community action plan for each of Sacramento and the Vallejo-area. The *Community Collaborative* is advised by a technical advisory committee composed of equal numbers of agency and non-agency members. Proponents of the project point to the inexpensive development of a spatially and temporally diverse evaluation of consumption patterns, the inter-validation of UCD and community science results, the basis of the project in environmental justice principles, the control of the project by community organizations, and the support role of the state partner (UC Davis). The *Community Collaborative* is part of a regional coalition that has formed in the Delta and Bay, a "**Healthy Fish Coalition**" that has a well-developed capacity to take on mercury exposure reduction.

As part of a large three-year study of mercury in fish in the Delta region (the *Fish Mercury Project, FMP*), the San Francisco Estuary Institute measured mercury concentrations in fish that anglers were likely to eat and the California Department of Public Health (CDPH) surveyed hundreds of potential fish consumers at a community clinic in Stockton about their consumption patterns. CDPH also developed education materials, held two "Fish Forums", gave out mini-grants to community organizations to help with community outreach and education, and was advised by a Local Stakeholder Advisory Group (LSAG). Proponents of the project point to its collaborative nature, the large amount of data collected about fish contamination, the mini-grant program, and the involvement of the LSAG. Critics of the program, who were also members of the LSAG: 1) described it as not supportive of environmental justice principles because community organizations had a traditional advisory role, but not decision-making power; 2) said that the mini-grants were not particularly helpful to the organizations themselves in terms of

Special Issue: Remediation, science, and exposure

Many stakeholders expressed strong opinions about state and federal agencies needing to more aggressively pursue mercury and methyl-mercury cleanup and reduction. Effective reduction in mercury exposure through remediation requires an understanding of the system to be treated. In recent studies, mercury concentrations in individual fish species have varied widely between years, within one watershed. This suggests that intentional management actions could have rapid effects on fish tissue concentrations at the scale of rivers tributary to the Delta. Control and management of both inputs of mercury (e.g., from legacy mines or oil refineries) and exacerbation of methylation environments (e.g., by agricultural and municipal discharge) may be possible. Many stakeholders felt that it was important to continue investigating the links between environmental mercury and human health, but they also felt that there was sufficient knowledge to proceed with remediation. There was tacit approval for moving forward to limit legacy and contemporary inputs, while conducting research about mercury sources, fates, transport, and cycling.

Recommended Strategies

1) To improve public trust, develop large "total removal" remediation projects to reduce regional and localized fish tissue mercury concentrations.
2) Pursue control of activities, through regulation, that could increase methylation environments.
2) Continue to study how mercury moves through the system and into edible fish.

their increased capacity to be involved in the overall problem; and 3) said that the CDPH and other state agencies would be best positioned as support agencies in an effort led by community organizations. There are aspects of the *FMP* approach that could be wrapped into a collaboration with community organizations to strengthen the abilities of both.

B Fish Consumption Patterns

Fish consumption pattern investigation are critical to understanding who is fishing, where people are fishing, what kinds of fish people are eating, how much of each kind of fish is eaten, and what role fish plays in their overall diet and health choices. They are and should continue to be both the basis for water quality control planning and health communication planning.

Community organizations in the *Community Collaborative*, UC Davis, and the *FMP*-CDPH use essentially the same approaches for evaluating fish consumption patterns. One approach is the combination of a survey instrument with fish models, developed in collaboration between CDPH and UC Davis in early 2004 (with valuable input from OEHHA and the Regional Board), which both use for surveying large numbers of people who eat fish. CDPH's largest use of this tool was at a Women Infants & Children (WIC) clinic in Oct. 2004, where approximately 500 women were interviewed. WIC clinics provide dietary and health advice to poor communities otherwise unable to receive pre- and post-natal care while not all WIC recipients are eligible for the Comprehensive Perinatal Services Program [which provide perinatal care to low-income women in California] many of them are). The *Community Collaborative* has been using this approach for continuous surveying of anglers in the field and community members at home, with over 600 interviews since 2005 – the majority in 2007-2008. The survey instrument includes questions about fishing, fish consumption, knowledge of warnings about fish contamination, pathways for health communication, and demographics.

The *FMP* included a pilot investigation of fishing activity and fish consumption using boat-based surveying, in cooperation with the Department of Fish and Game (DFG). The DFG regularly surveys boat and shore anglers about their catch and provide a great resource because of their expertise about the location and activity of anglers. The DFG itself cautions about this approach, though, due to the formal nature of their physical presence and survey approach.

Both CDPH and the *Community Collaborative* have also used focal or expert group interviews to conduct a different type of information gathering. In both cases, investigators have conducted in-depth interviews of community experts to explore how people engage in fish consumption, make choices about fish, choose where to fish, and receive health-related information. Through this preliminary investigation, clear differences have become apparent about ethnic variation in fish consumption patterns and perception of health-related messages. Interviewed stakeholders felt that these approaches were important to compensate for possible inaccuracies (under-estimates) in consumption reporting in questionnaire-based approaches.

Two important findings of these fish consumption pattern investigations are that 1) almost all ethnicities catching fish in the Delta region are consuming those locally-caught fish at a mean rate much higher than thought by Regional and State Board staff (e.g., 32 g/day rate used in Delta methyl-mercury TMDL) and 2) community organizations and academic researchers find similar consumption patterns for the same communities. In the first case, one conclusion is that state agencies should make sure that the initial rates used in planning are accurate and periodic measurement of consumption patterns will be important for tracking pollution control and advisory program effectiveness. In the second case, a reasonable conclusion is that either community groups or academic researchers could conduct these investigations, but because of both cost and linguistic diversity, community groups are well-positioned to determine consumption patterns for their own communities. One evolving strategy in the Delta *Community Collaborative* is the development of a citizen fish monitoring program to accompany the fish surveying. Under this program, fish tissue samples will be collected at the same time as fish consumption surveying and the samples sent to a lab for analysis.

C Recommended Strategies

i) To inform cleanup and help people make choices, support fish tissue sampling by the organizations themselves or with the direct guidance from community organizations about what fish people are catching.

ii) Investigate fish consumption patterns from a combination of angler and community surveying methods and statistical tests.

iii) Carry out analyses in collaboration with community organizations and private and county health providers so that interpretation of the results has broad understanding and buy-in.

> *"The public should know where the mercury hot spots are and we can do enough sampling to delineate the areas that have hot spots or seasonal hot spots. We need to warn them to not use those areas, especially the constant hot spots. We need to do this in addition to the standard fish consumption advisories."*
>
> -- Dave Lawler, USDI Bureau of Land Management

2) Assessing mercury exposure

Consuming fish contaminated with mercury leads to increased mercury concentrations in blood and other tissues. This increase is both the vehicle for effects to nervous systems and the indicator of potential impacts. By measuring individual body burdens of mercury and other pollutants in diverse communities eating fish, state agencies can improve understanding of the *potential* effects of fish contamination. People can also get the information they need to balance protecting their health by eating some fish, while not ingesting health-impacting levels of pollutants.

There have been few studies of either calculated exposure, based on frequency or amount of fish consumption (Stern et al., 1996), or actual exposure, based on blood-mercury concentrations (Gobeille et al., 2006; Schober et al., 2003). In California, a pilot study by CDPH revealed complicated results for the combination of estimated fish consumption rates and blood-mercury concentrations (A. Ujihara, presented at “Fish Forum” 2007). The authors of the study point to the incompleteness of the study. There are also cultural and community concerns about exposure monitoring, which were addressed by several of the interviewees.

Blood and hair mercury levels have been used to measure exposure of adults and potential or actual exposure of children (Budtz-Jorgensen, 2004; Dellinger, 2004). Hair monitoring tells us about long-term exposure to mercury in our diet, while blood mercury is more informative about short-term exposure (months). Interpretation of these results are complicated by the possibility of individually-variable sensitivity to mercury and changing hair/blood ratios of mercury concentrations with age (Budtz-Jorgensen, 2004). However, this is often the best way to find out potential health impacts to *populations* from consuming fish.

There are several factors that must be considered when measuring exposure: 1) the role of low and moderate individual mercury concentrations in the context of the overall body burden of toxic chemicals; 2) the response of different ethnicities to different possible ways of sampling for mercury exposure – blood vs. hair; and 3) communicating the findings back to the individuals and communities sampled. In both cases, community health organizations can provide a doorway for regional and state organizations to gain access to and serve individuals and communities.

Cultural/ethnic responses to mercury exposure testing

According to community organization staff, certain ethnicities, including most Asian ethnic groups, may have a deep resistance to blood tests and sampling, and the perceived need for this testing and guaranteed benefit would have to be well established by parties well-known and trusted by the individual ethnicities. According to one interviewee, the person taking the blood sample would need to be from the same tribe to be trusted in this way. Hair monitoring would be less invasive, but many people have never heard of this method and its effectiveness would have to be explained. Native Americans in particular would find this method of sampling invasive and would be concerned about the process. Most people are not aware of the effects of mercury on the body, and the connection between mercury and their health should be explained and documented. Usually this requires citing proof in the form of published testing, both human bodies and fish. Once people are aware and convinced of the health impacts of mercury, and convinced that mercury is present in the fish they eat, they are willing to take preventive or corrective measures. This information is especially effective in communicating with women, who as mothers and preparers of family meals, can choose what their families consume.

Communicating findings to tested individuals and communities

People say that their own doctors are trusted sources of health information. Most people would want to receive their own individual health information – the products of mercury testing – in the privacy of a regular doctor’s appointment. Otherwise, a trusted health or service provider would be a reasonable choice for conveying individual testing results. In general, stakeholders suggest, any mercury testing information must be part of an overall chemical-burden analysis to give it context. Other professionals, such as a college professor or public official (e.g., county public health officer) are also credible sources of health information. If these credible sources are interviewed or heard on the ethnic language radio (e.g., PSAs) then this would be an effective message delivery strategy for the community. It is often assumed that limited-English-speakers are literate in their own languages, which is not always the case. Communities of a certain size have their own ethnic media, usually radio broadcasts which are very popular. Often community organizations either sponsor a radio program, or use radio to communicate all kinds of program, health, or other information.

A Recommended Strategies

i) Regional Board should fund, or support funding, community organizations and private/county health providers to provide guidance and co-lead (with academic, agency, and medical scientists) projects recruiting individuals for blood testing in clinical settings to examine exposure to mercury and other fish and environment contaminant.

ii) Community organizations/health providers collaboratively play the lead role in interpreting and communicating calculated or actual mercury exposure results for tested individuals and communities-of-origin of the tested individuals, in the context of overall chemical body burdens.

iii) Community organizations, in collaboration with scientists provide alternative strategies for fish consumption (e.g., fishing in areas that are not as contaminated).

3) Effective education and outreach

The Department of Public Health and *Community Collaborative* have both engaged anglers and community members in discussions about fish consumption, have developed educational programs and materials, and have collectively reached many hundreds of fish consumers. Recent research has elucidated possible opportunities and barriers to effective communication with fish consumers (Shilling et al., 2008). Several interviewees are expert in this area and provided feedback on appropriate strategies

Special Issue: Changing consumption patterns

Stakeholders reported that they are afraid that there are more and more indications of state agencies pursuing a strategy of encouraging people to eat less fish as an efficient and cheaper way to deal with mercury pollution. This is evident in the Regional Board TMDL process and comments from two interviewed state agency staff in this study. However, this strategy does not explicitly recognize the cultural, spiritual, economic, dietary, and recreational value of fishing and fish consumption to a wide variety of ethnicities and communities in the Delta region. Stakeholders interviewed were concerned about this approach by the state, while recognizing the importance of telling people about some of the risks of eating certain fish caught from certain places.

Recommended Strategies

1) Temper any attempts to change fish consumption patterns by describing how the state is also vigorously pursuing cleanup.
2) Build trust with fish-consumers by showing performance of cleanup activities.

All stakeholders interviewed for this plan felt that it was critical to inform people of risks from fish contamination. There was concern that the information not scare people away from eating fish, that the process be culturally-appropriate, and messaging occur via trusted communicators. There are several key components to a successful strategy of engaging with communities: a) involve community groups and members in decision-making about remediation and fish consumption advisories, b) identify who is to be engaged and thus how, c) identify the mechanisms likely to be effective in involving community leaders and the community at large, and d) collaboratively develop messages with community groups and representatives.

A Involve community in decision-making

Many of the communities involved in eating large amounts of locally-caught fish have not traditionally been represented in decision-making about how to best communicate with them. The *FMP* made in-roads in this area, but was hampered by not being set up to be a process based on environmental justice principles. Organizations and other representatives of communities have the expertise to provide guidance about effective education and outreach on fish contamination. Many of the groups below have been involved in one way or another in this issue for several years.

Group/organization	Community	Previous role with pollution issues
Southeast Asian Assistance Center	Southeast Asian and Russian immigrants	Angler and community surveying, health communication, exposure reduction strategy, *Community Collaborative*
People for Children's Health and Environmental Justice	African-American, Hispanic	Angler and community surveying, health communication, exposure reduction strategy, environmental justice policy, *Community Collaborative*
United Cambodian Families	Cambodian immigrants	Health communication about fish contamination
Lao Family Community of Stockton	Laotian immigrants and others	Health communication about fish contamination
Todos Unidos	Hispanic	Health communication about fish contamination
West County Toxics Coalition	African-American	Advocacy, health strategies
Lao Khmu Association	Laotian immigrants	Health communication about fish contamination

Surveying by the CDPH and the *Community Collaborative* provides preliminary guidance for which organizations and communication avenues may provide the most connection with the diverse fishing communities about health effects of fish contamination. For example, Hispanic anglers and fish consumers prefer medical providers, friends & family, or TV; African-American anglers prefer medical providers, friends & family, and the newspaper; and Southeast Asians prefer medical providers, friends & family, radio spots, and community groups (Williams, Leonelli, Shimoum, personal observations; Shilling et al., 2008). Other ethnicities also report trusting these and other mechanisms for receiving health-related information. There are over 20 ethnicities catching and eating fish in the Delta region (Shilling et al., 2008). In order to communicate effectively with all of them, a very diverse communication strategy will have to be pursued. Most stakeholder-interviewees felt that this was best done by community organizations which already had the trust of these communities.

B Recommended Strategies

i) Support regional meetings on fish contamination coordinated and facilitated by a neutral facilitator (several stakeholders recommended Deb Marois, debmarois@sbcglobal.net).

ii) Support regional organizers, funded by state funds and working for and with communities an possibly counties to provide trainings on fish contamination – remediation and exposure reduction – and to build capacity of CBOs where needed.

iii) Health professionals (ideally from the same ethnicity) and/or academics work with community organizations to develop accurate, effective messages about health effects of mercury, where it is encountered, and how to avoid it.

iv) Because community stakeholders and others interviewed feel that the current model of outreach and education is ineffective, community groups should lead dissemination of the messages to key persons/leaders in each community, and in every contact with clients/community members. The message should be linked to every service provided. This could be through in-language information cards (*e.g*,, those prepared by CDPH) handed to clients, in-language radio announcements for programs or events, posters on the office/church/community center walls, and reminders in any type of regular communication (newsletter, flyer). In every case, messaging should be accompanied by in-person conveyance of information by experts trusted by the community.

> *"These communities have been approached by numerous agencies to just don't eat fish or with complicated rules. For women who are pregnant and subsistence fishers… they won't stop and education campaigns don't take this into account. They can't afford to stop and it's often a cultural thing too. Agency efforts to educate have already created distrust, education is not a feasible solution."*
>
> -- Debbie Davis, Environmental Justice Coalition for Water

4) Consumption advisories

These are developed by the Office of Environmental Health Hazard Assessment (OEHHA) and federal agencies, with a variable level of collaboration with other agencies and academic scientists. The advisories are intended for communities with high linguistic, ethnic, and cultural diversity, so their development and implementation could take advantage of experts in this area of diversity in order to make the advisories effective. Currently, most ethnicities do not report signs and other printed materials as effective ways of communicating with them about fish contamination. Most stakeholders interviewed for this plan said that current approaches to sharing advisory information are ineffective and not sufficiently extensive through communities to even be potentially effective.

OEHHA has already tried the model of developing advisories with *post-hoc* input from target communities. Because there is little opportunity to adjust the advisory after this process, another model worth considering is the development of advisories in complete collaboration with community organizations. An improved model was tried under the *FMP* where community organizations and community members were asked about the potential effectiveness of state-developed advisory messages. Stakeholders expressed mixed feelings about this model, with positive feedback about the state reaching out, while still being skeptical about the efficacy of approaches that are not led from within the community.

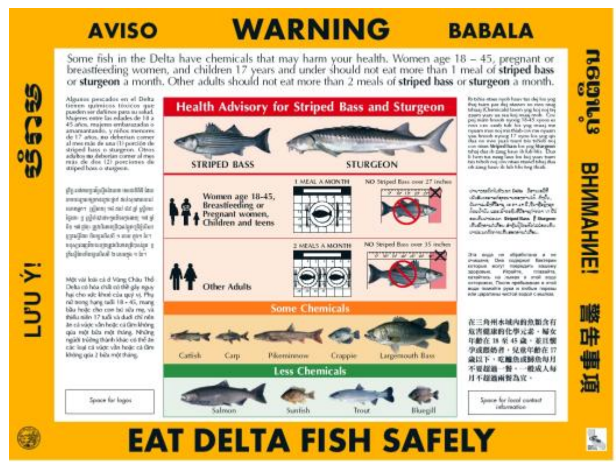


Figure 2 Multi-lingual fish advisory sign

OEHHA begins this process with the collection of information about which fish species have measured mercury concentrations above certain thresholds. The collaboration at this step could involve community groups deciding which fish are most important to consider, based on regional and ethnic preferences. In the event of insufficient information about fish species that are popular, or that with a small number of samples appear to be a problem, additional data could be collected. The next step involves determining risks associated with eating these particular fish at specific consumption rates. The collaboration at this step could involve community groups determining appropriate consumption rates to use and any considerations of seasonality, amounts consumed per fish species, and preferred sizes of fish. The third step, currently not part of the process, could involve community groups determining alternative messages that could accompany the advisory, such as which fish species may be safe to eat instead of the target fish, as well as which areas may be safer than others. The final step in the process is to craft the message into (usually) written advice in sign, brochure, or DFG manual form. Recently, the messages have also been translated and posted as signs and posters at fishing locations and other places anglers may see them. The collaboration at this step could consist of community organizations determining appropriate mechanisms for communicating with specific ethnicities (e.g., print vs. visual media), which ethnicities may need the most involvement based on specific fish consumption rates, and ways to evaluate how effective the advisory is in communicating risk and alternatives.

> *"The most effective messages come from people within the community .... The most direct strategy is to support community organizations and leaders as the primary messengers."*
> *-- Holly Brown-Williams, UC Berkeley School of Public Health*

A Recommended Strategies

i) Develop advisories collaboratively between community organizations and OEHHA to actually get the message to fishing communities in the Bay and Delta. This will require the knowledge and input from communities directly (not mediated by other institutions) as to the best and culturally specific ways to get the information out. This will also preferably be targeted to women, as there is suggestion of a large proportion of subsistence fishers are men, not women. As a result of interviewee responses, it was indicated that women would heed warnings more than men.

ii) In collaboration with community groups, test effectiveness of advisories with community follow-up.

IV. Implementation

1) *Decision-Making and Implementation Model*

Feedback from Delta stakeholders suggest that a strategic decision-making model is needed to reduce mercury exposure in Delta fish-consumers (Figure 3). This model builds on the research and work conducted by the *FMP*, the *Community Collaborative*, and other work of individual agencies and organizations. This model is a strategic response to an emerging problem – the disconnect between the growing knowledge about fish consumption as a threat to public health and the fish-consuming public themselves. It is not all-inclusive in terms of possible partners (e.g., county and federal partners) and activities.

One way that a reconnection between state and community can be supported is through the identification and creation of community advisory boards who will be composed of members in the community that have interest in developing a sustainable relationship built on trust, where the community member is respected for their knowledge just as much as the scientist for their unique contribution that they bring to the development of effective strategies of developing and social marketing advisories. A self-organizing advisory body recently formed, the Healthy Fish Council, to help fill this role.

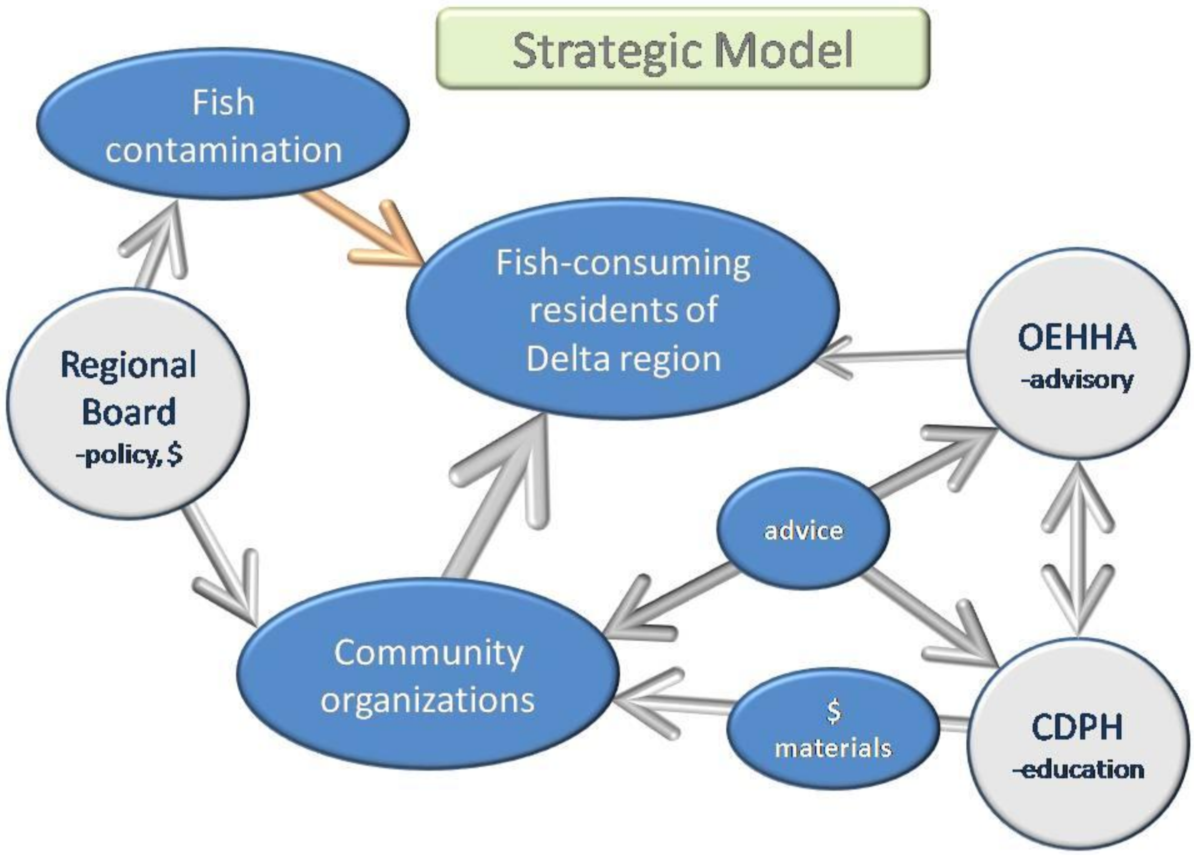


Figure 3 Strategic decision-making model for fish contamination and mercury exposure reduction. To simplify the model, not all possible interactions are included, or all possible agencies and organizations. "Fish contamination" refers to relative fish contamination among species and the activity of eating fish.

The implementation model relies on several important factors: 1) recognition and development of the community organizations' capacity to take on this role, 2) recognition by state agencies that their statutory roles can be filled with the aid of community organizations, and 3) the movement of state agencies to a support role in education, science, and funding.

A Community capacity

Individually, dozens of community organizations in the Delta region have tackled major public health, safety, and economic problems on behalf of their client communities (e.g., lead contamination, gang violence, poverty). Individually, they have used tens to hundreds of thousands annually of private and public dollars through contracts, grants, and donations to take on these problems. Collectively, these organizations have spent millions of dollars dealing with some of the most intransigent of social and public-health problems. In doing so, these organizations have worked at the individual, neighborhood, and community level to effect change at multiple scales to an extent that few if any individual public agencies could hope to achieve. Collectively, community organizations in the Delta have the capacity to accept the funding, collaboratively make decisions, and make changes at the community level.

Community agencies have developed years of expertise in identifying individual and collective social problems, and working to solve these problems. Because of the nature of most funding mechanisms, the problem solving is considered the "outcome" and an end in itself. Learning how to prevent problems, by advocating policy and systems changes, would take this experience and skill to the next level. Community organizations would need meaningful and sustained connection to State agencies and policy makers, through funded projects, meetings, conferences and formation of local advisory groups, to develop this capacity to become the most effective and valuable partners.

> *"Scientists can describe the problem and help with education. But they don't know community; I know community. Both of us are learning and it is a two-way street."*
>
> -- David Shimoum, Southeast Asian Assistance Center

B State agency statutory role

The Office of Environmental Health Hazard Assessment (OEHHA) has a critical role in reducing mercury exposure through its development of fish consumption advisories. The effectiveness of these advisories relies entirely on the ability of anglers to understand the advisories and to use them to make decisions. OEHHA must develop the advisories based on the best available science, but there is no requirement that they must be developed with only minimal stakeholder feedback. Community organizations are ideally placed to play a consulting role in describing how advisories should be developed, who they should be targeted toward, and how they should be communicated. This is in contrast to the role to which they are usually relegated – of advisors. OEHHA can still fulfill its statutory requirements while basing certain of its decisions on this consultation

The Regional Water Quality Control Board (RB) has a critical role in encouraging and requiring clean-up of California's waterways. It functions as the main agency arbiter (besides the USEPA) of solutions to reducing mercury exposure through fish consumption. The development of solutions depends on a combination of public constituencies impacted by impairment of beneficial uses and regulatory devices to encourage or require reduction of impairment. The RB can and should recognize the key role of impacted communities as decision-makers about potential solutions as a part of effective water quality management. Interviewed stakeholders felt that the most critical roles for the Regional Board were in developing effective TMDLs for mercury and providing support to community organizations.

The California Department of Public Health (CDPH) has played a combined leadership and an assistance role so far in developing health educational materials for CDPH and community organization outreach programs. CDPH has also investigated fish consumption patterns, health risks from fish contamination, and health communication. These roles are critical feature of the implementation of mercury exposure reduction strategies. With funded consultation with community organizations, CDPH could develop materials that suit the particular communities, are produced professionally, and are in appropriate languages. In addition, CDPH could continue to pursue investigations of fish consumption patterns, under the funded leadership of community organizations.

The California Department of Fish and Game (CDFG) communicates daily with anglers through print media and in-person. The Fishing Regulations handbook has been described by many anglers as their source of information about fish contamination in certain areas. CDFG staff regularly conduct creel surveys in various parts of the Delta watershed. These advisories and surveying functions provide a two-way stream of information to and from anglers. With consultation with community organizations, the flow of information could be improved, both in terms of survey accuracy and methods for presenting advisory information.

C State institution support role for community organizations and counties

Community organizations and certain local agencies are the most likely to be effective at conducting education and outreach activities with diverse communities and functioning as intermediaries between the impacted public and state agencies. In their lead role, community organizations can ensure that development and implementation of strategies involving diverse communities are linguistically and culturally appropriate. They can be involved at the level of decision-making and at the level of implementation. County public health officials and providers are already looked to for health information.

State institutions (e.g., University of California) have an important role in this process – as providers of technical and funding resources. This provision of assistance will vary with state agency, geography, and community involved. Three kinds of basic scenarios can be foreseen and anticipated:

1) Regulation-related research support: State agencies (the Regional Board) can require that impacted communities be involved by dischargers and others seeking permits to release mercury and others that could require permits (e.g., public lands management agencies). Scientists could help community organizations with recommending additional research needed to implement the TMDL. This would improve the abilities of communities to become involved in the regulatory processes affecting their lives.

2) Technical support: Universities and state agencies have varying capacity to provide technical information to community organizations depending on their need. Community groups and others have expressed the opinion that state universities are most ideally placed in this role. They should also receive technical information from these organizations to improve their effectiveness with specific communities. For example, fish advisories are best developed with the cooperation and leadership of those familiar with the workings of the communities intended to receive or benefit from the advisories.

3) Funding support: state and federal institutions have access to funding unavailable to community organizations and fee mechanisms to develop funding resources. Because community organizations can play a critical role in reducing mercury exposure, they should be supported by general funds, bonds, impact fee-based programs, and research programs through direct contracting from agencies or grant programs. The conventional approach is to support other agencies and familiar private consultants in reducing impacts to beneficial uses. This approach is ineffective when used over large geographic areas with dozens of ethnicities.

2) Implementation of Mercury Exposure Reduction

Using a community-based model for decision-making and implementation is likely to be the most effective use of limited resources and result in the most sense of ownership and investment by fishing communities and fish consumers. A critical question is whether or not community organizations have this capacity. Given that the organizations interested in dealing with fish contamination have demonstrated this capacity incidentally with other public health issues and in direct relation, this is a non-issue. In addition, community organizations collectively have access to single contractors (e.g., UC Davis) that can receive large grants and disburse them to member groups in a coalition.

All stakeholders interviewed expressed support for the role that community organizations can play. Many of these same organizations have stressed the importance of respecting their intellectual property rights when it comes to sharing their ideas with certain state agencies and non-governmental organizations involved in the issue of fish contamination. Stakeholders and other CBOs express cautious optimism that programs from the past (e.g., *FMP*) will not be exactly repeated and that instead new collaborations will be sought where community organizations will play a role in decision-making and receive funding on par with state institutions.

Collaborative project development was supported by all interviewed stakeholders, where each party plays a role consistent with their expertise and policy role. Broadly, this consisted of state and federal agencies playing a support technical and research role to understanding and implementing mercury cleanup, mercury cycling and mercury bioaccumulation; state agencies and dischargers providing fee and other funding mechanisms for community organizations to conduct large-scale projects; county health and environmental agencies providing both technical expertise and local channels for communication; community organizations making decisions about remediation, research, and communication; and community organizations implementing various education and outreach projects.

The table below shows various activities consistent with the recommended strategies described above. It describes potential costs, estimated based on stakeholder input and the experience of the strategic plan authors (source indicated in parentheses). It also shows who should conduct these activities, the desired outcomes, and links to the TMDL as one policy nexus.

Recommended activity	Potential cost (Staff time, materials, stipends)	Responsible party	Desired outcomes	Link to TMDL
Strategic decision-making model process	$200,000/year for 10 CBOs in coalition	State-funded, one or two coalition leads	Improved collaboration between state and community, improved information sharing	Coordinated approach to decision-making, action development, and implementation
Fish consumption pattern surveying (community and anglers)	$90/surveyed individual (*Community Collaborative*) $250/individual (*FMP*/CDPH)	Community groups in collaboration with academic and/or agency scientists	Patterns of fish consumption, knowledge of fish contamination, trust	Direct measure of fish consumption behavior. Indirect measure of exposure.
Fishing and fish consumption practices (focal groups, key informants)	$100/surveyed individual, $250/focus group (*Community Collaborative*)	Community groups	Fishing and fish consumption patterns; mechanisms for receiving and using fish-related advice	Direct way of developing ethnicity-specific involvement in reducing mercury exposure
Fish monitoring	$50/sample for field sampling $100/tissue sample	Community groups collaborating with academic and/or agency scientists	Patterns of contamination in fish eaten by local populations	Direct measure of fish contamination for species eaten regionally
Mercury exposure	$75/sample for clinic sampling $100/blood sample and/or calculated exposure	Community/county health organizations in collaboration with academic and/or agency scientists	Patterns of exposure in fish-eating populations	Direct measure of human exposure
Education	$2,000/1,000 people (publication) $30,000/1,000 people (development)	Community groups and health organizations	Vast majority of fish-consumers aware of contamination	Indirect approach to changing behavior in response to risk
Outreach/In-reach	$20,000/1,000 people or 10 organizations	Community groups in collaboration with agencies	Improved communication between state agencies and communities	Improved decision-making by state agencies for mercury reduction

Consumption advisory	$50,000/regional advisory	Community groups in collaboration with academic and/or agency scientists	Advisories that resonate with the communities for which they are intended and reflect their consumption practices	Indirect approach to changing behavior in response to risk

V. Conclusions

Fish contamination has become a critical issue in the San Francisco Bay, Delta, and influent rivers because of concerns about overall health risk and disproportionate impacts to subsistence fishers, many of whom are ethnic minorities and/or poor. Stakeholders interviewed as part of this strategy plan development had the following suggested strategies and actions:

1) Include community organizations in all stages of research, education, outreach, and remediation.
2) Focus on both cleanup of contamination (legacy and contemporary) and informing people eating locally-caught fish about potential health impacts and alternatives.
3) Characterize impacts to affected populations to inform Clean Water Act related work.
4) Study the effects and effectiveness of both remediation and education and outreach approaches.

Many community organizations are already involved or aware of fish contamination as an issue for their client communities. What has been lacking to date has been the resources for them to become substantially involved in the planning, research, and education/outreach components of reducing mercury exposure from fish consumption. As these resources become available, more and more organizations will be able to become involved in planning and research, a critical part of the process of solving what is in large part an environmental justice problem.

State and federal agencies, tribes, and others are investigating ways to clean up legacy pollutants in the Delta and its watershed. This involves both reducing inputs from known sources (e.g., abandoned mines) as well as reducing the environments for mercury methylation due to degraded water quality because of agriculture, waste discharge, or water storage. In parallel, agencies and others are focusing on education and outreach to anglers to inform them of risks from eating “too much” contaminated fish. Because of the number of anglers in the Delta region and the dispersed and diverse nature of anglers, this is a challenging task. However, because of excellent connections within communities, place and ethnic-based organizations are increasingly being asked to conduct this work.

Over the last 3 years, 2 major studies have been conducted to understand fish consumption patterns. In both cases, over 500 anglers and/or community members were asked about their fishing and fish consumption behavior. Even with these large numbers of surveyed individuals, it remains to be seen if studies of this size are sufficient given the geographic and ethnic diversity of anglers and fish consumption. In parallel and prior to these studies, agencies have measured concentrations of mercury in target fish species (for consumption). The combination of fish contamination and consumption patterns helps determine risk to subsistence fishing populations.

Finally, as we collectively engage in monitoring and implementation, the need to evaluate our effectiveness becomes more apparent – for remediation and education/outreach. Effectiveness will be a product of fish consumers awareness of fish contamination (increasing), mercury and methyl-mercury cleanup (increasing), environmental methyl-mercury (decreasing), edible fish tissue concentrations (decreasing), fish consumption patterns (changing to less toxic fish), and community investment (increasing).

References

Budtz-Jorgensen, P. Grandjean, P.J. Jorgensen, P. Weihe, and N. Keiding. 2004. Association between mercury concentrations in blood and hair in methylmercury-exposed subjects at different ages. *Environmental* Research 95: 385-393.

Davis, J.A., Greenfield, B.K., Ichikawa, G., and Stephenson, M. 2003. Mercury in sport fish from the Delta region. Final Report to the California Bay Delta Authority. 60 pp. (http://loer.tamug.tamu.edu/calfed/FinalReports.htm)

Dellinger, J.A. 2004. Exposure assessment and initial intervention regarding fish consumption of tribal members of the Upper Great Lakes Region in the United States. *Environmental Research* 95: 325-340.

Domagalski, J. 1998. Occurrence and transport of total mercury and methyl mercury in the Sacramento River Basin, California. *Journal of Geochemical Exploration* 64: 277-291.

Domagalski, J. 2001. Mercury and methylmercury in water and sediment of the Sacramento River Basin, California. *Applied Geochemistry* 16: 1677-1691.

Gobeille, A.K., K.B., Morland, R.F. Bopp, J.H. Godbold, P.J. Landrigan. 2006. Body burdens of mercury in lower Hudson River area anglers. Environmental Research, 101: 205-212.

Schober, S.E., Sinks, T.H., Jones, R.L., Bolger, P.M., McDowell, M., Osterloh, J., et al., 2003. Blood mercury levels in US children and women of childbearing age, 1999–2000. J. Am. Med. Assoc. 289, 1667–1674.

Shilling, F.M. 2003. Background information for a Central Valley fish consumption study. Report for the Delta Tributaries Mercury Council. 64 pages.

Shilling, F.M. 2004. Fishing activity analysis in the Sacramento/San Joaquin Rivers Delta region. Report for the California Department of Health Services – Environmental Health Investigations Branch. 22 pages.

Shilling, F.M., L. Lippert, and A. White. 2008. Contaminated fish consumption in California's Central Valley. *In preparation*.

Silver, E., J. Kaslow, D. Lee, S. Lee, M.L. Tan, E. Weis, and A. Ujihara. 2007. Fish consumption and advisory awareness among low-income women in California's Sacramento-San Joaquin Delta. Environmental Research, 104: 410-419.

Stern, A.H., L.R. Korn, and B.E. Ruppel. 1996. Estimation of fish consumption and methylmercury intake in the New Jersey population. Journal of Exposure Analysis and Environmental Epidemiology, 6(4): 503-525.

Weiner, J.G., C.C. Gilmour, and D.P. Krabbenhoft. 2003. Mercury strategy for the Bay-Delta ecosystem: A unifying framework for science, adaptive management, and ecological restoration. Report to the California Bay-Delta Authority. 60 pp.

Williams, L., F.M. Shilling, L. Leonelli, D.P. Shimoum, and A. White. Personal observation. The afore-mentioned and others have observed the distributions of anglers throughout the Delta and its source rivers from the years 2002 to 2008.

Wood, M.L., C.G. Foe, J. Cooke, S.J. Louie, and D.H. Bosworth. 2008. Sacramento-San Joaquin Delta Estuary TMDL for Methylmercury – Staff Report (Draft). Central Valley Regional Water Quality Control Board. 193 pp.

Appendix A: Stakeholders interviewed and workshop participants during the development of the strategic plan

Community organizations and non-governmental organizations

Debbie Davis	(Environmental Justice Coalition for Water, Oakland)
David Shimoum	(Southeast Asian Assistance Center, Sacramento)
Lim Leang	(United Cambodian Families, Stockton)
Sophuth Sorn	(Seventh Day Adventist Church, Stockton)
Chan Chanthasack	(Lao Khmu Association, Stockton)
Seng Her	(Sacramento Lao Family Community)
Lawrence Lo	(Stockton Lao Family Community)
Tham Le	(Vietnamese Voluntary Foundation, Stockton)
Houa Lee	(UC Extension, Stockton)
Izzy Martin	(Sierra Fund, Grass Valley)
Andria Ventura	(Clean Water Fund)
Sherri Norris	(California Indian Environmental Alliance)

Local agencies

Julie Campbell, Chris Husing, Elizabeth Vigio, Sheri Rulon, Janet Talksy, Amelia Schendel, Patricia To,

& Teri Duarte	(Woman Infant Child Clinics – WIC, Sacramento)
Glennah Trochet	(Sacramento County Medical Officer)
Cathy Carmichael	(Sacramento Native American Health Clinic)
Jennifer Choy	(Kaiser Permanente, Sacramento)
Vicki Fry	(Sacramento Regional County Sanitation District)

State and federal agencies and universities

Robert Titus	(California Department of Fish and Game)
Robert Brodberg	(Office of Environmental Health Hazard Assessment)
Holly Brown-Williams	(UC Berkeley, School of Public Health)
Tess Shiner	(FSNEP, UC Cooperative Extension)
David Lawler	(USDI Bureau of Land Management)
Brian Bergamaschi	(US Geological Survey)

Workshop participants (Nov. 13, 2007 & Feb. 22, 2008)

Christine Cordero (Center for Environmental Health), David Shimoum & Laura Leonelli (Southeast Asian Assistance Center), Barbara Parrila-Barrigan (Restore the Delta), Savong Lam (United Cambodian Families), Michael Kent (Contra Costa County Dept. Public Health), Christina Medina (Ma'at Academy), Carlos Torres (Todos Unidos), Whitney Dotson, Benny Lee (Environmental Justice Coalition for Water), Angela Berry & Sherri Norris (California Indian Environmental Alliance), Andria Ventura & Jennifer Clary (Clean Water Fund), Amy Vanderwarker (formerly of Environmental Justice Coalition for Water), and Fraser Shilling (UC Davis)

Appendix B Questionnaire used to interview stakeholders

Structured Interview (Community-oriented) Questionnaire for Regional Delta TMDL Strategy

"*Appropriate topics for the strategy include: guidance for fish monitoring; assessment of quantities and species of fish consumed; assessment of exposure to mercury; development of educational materials; development of consumption advisories; and effective public outreach tactics. The strategy should describe the most effective and appropriate actions for the SWRCB and the Regional Board, other state and local agencies and private entities (e.g., community-based organizations and health care providers), and estimate costs*." (DPH-Regional Board Task 2 Description)

[Thank-you for agreeing to be interviewed for this project. We are developing a holistic strategy for dealing with mercury exposure in the Delta. The strategy is tied to the Delta Total Maximum Daily Load – TMDL for mercury, currently under development by the Central Valley Regional Water Quality Control Board. The TMDL is the policy used to regulate water quality and the Regional Board is the state agency responsible for regulating water quality. We would like your help in identifying ways that mercury exposure can be assessed and reduced and ways that people can become more engaged and educated about mercury exposure.]

1) How would you categorize your particular knowledge, interest, or expertise in relation to mercury contamination and exposure? OR Do you have background or knowledge on any of these topics?

☐ Legacy mercury in the environment

☐ New inputs of mercury into the environment

☐ Mercury methylation in the environment

☐ Mercury in fish

☐ Public exposure to mercury

☐ Public health issues with fish contamination

☐ Public education about fish contamination

☐ Policy development for mercury clean-up

☐ People's fishing or fish consumption activity

☐ Public health issues

How did you learn of these issues?

Strategies for reducing mercury exposure

2) Do you think there is sufficient knowledge about where mercury is coming from (sources), how it is being moved through the environment (transport) and where it is ending up (fates)? What else do you think we need to do to improve our knowledge of mercury cycling in the Delta?

Monitoring

Research

3) Eating fish contributes to health and may be culturally and economically important. However, mercury can cause a variety of brain and nervous system dysfunctions.

a) If people are consuming a lot of fish in the Delta region, do you think they should be informed of these dysfunctions?

b) Who should be responsible for sharing this information with them?

c) Who do you think they will trust and believe?

d) What are some barriers to members of (your) community receiving and understanding information about fish contamination? What health-education programs have been successful?

4) How would efforts to reduce consumption of locally-caught fish financially and culturally impact certain communities and populations?

5) Some of organizations have surveyed anglers and community members about their consumption of fish. Do you think this is a good way to find out how much fish people are eating? What are the advantages and draw-backs of this approach?

6) There are advisories from the state government for how much fish people should eat. Are you aware of these and how they are developed? Do you think they are effective? If so, what makes them effective and if not, what makes them ineffective?

7) Exposure to mercury can be measured in an individual’s blood or hair. What do you think are some limitations or advantages to doing this, with each of these methods? How should the information about mercury be share with the person giving the hair or blood sample?

8) The TMDL for mercury will focus on a combination of scientific studies, pilot mercury remediation projects, and public education and outreach programs. What kinds of public outreach and education programs do you think are most effective and how much will they cost?

9) Recently, alternative strategies have been considered to give fish consumers other fish choices and alternative locations to fish. What alternative strategies do ou think are feasible and should be considered?

10) What do you think is an appropriate role and appropriate types of actions for your organization and organizations like yours in dealing with fish contamination?

11) What do you think is an appropriate role and appropriate types of actions for state government (the Central Valley Regional Board) in dealing with fish contamination?

Strategies for reducing mercury exposure

12) How do you see your organization working within a collaborative framework involving other organizations, stakeholders or individuals to create and implement strategies or plans for mercury reduction?

13) Are you already collaborating with other organizations to incorporate diverse concerns, ideas and resources into a mercury reduction strategy?

14) How could collaboration increase the effectiveness and reduce the timeframe of a mercury reduction strategy?

15) How could scientific and non-scientific agencies and organizations work better together? [probe for specific ideas, like agency liaisons]

16) There are limited public funds available to deal with issues like environmental clean-up. Do you think the state government should invest the funds required to cleanup mercury in the environment so that people can safely eat fish? [probing for the conditions on “yes” or “no”]

17) What do you think are the trade-offs or issues between reducing mercury in the environment and in fish and trying to get people to reduce the amount of fish they eat?

Appendix C: Table of informant interview responses (see attached spreadsheet, or contact F. Shilling fmshilling@ucdavis.edu)