RTD-233

Background Information for a Central Valley Fish Consumption Study

Geographic Information System and Relational Database for Fish Tissue Mercury and Creel Survey Data

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Mercury Pollution in Northern California
Delta Tributaries Mercury Council

SACRAMENTO RIVER WATERSHED PROGRAM

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Acknowledgments

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I Summary

In order to support the development of a fish consumption study for the Bay-Delta watershed, a relational database was assembled of creel survey and fish tissue Hg concentrations. The creel data came from the Department of Fish and Game and fish tissue mercury concentrations from various sources (assembled by Central Valley Regional Water Quality Control Board; Michelle Wood, WoodM@rb5s.swrcb.ca.gov). In addition, a geographic information system was created containing the creel survey and fish tissue Hg data, which facilitates choice of sites and communities for the fish consumption study and exposes gaps in knowledge and data for fish tissue Hg concentrations. The zip code of origin of angler groups fishing in areas with high concentrations of mercury in fish tissue was used to identify community areas and their demographic composition. The information developed here provides the necessary context for the development of pilot fish consumption studies. The combination of this study, the Department of Health Services' companion needs assessment, and pilot consumption studies should be sufficient background for the design and implementation of a comprehensive fish consumption study for the Bay-Delta watershed. The information is also useful for planning monitoring programs for creel surveying and mercury concentrations in fish tissue and for developing targeted outreach and education to anglers and their families in the Delta watershed.

II Introduction and Background

Various fish species and populations in the Bay-Delta watershed have high enough mercury concentrations to warrant concerns about public health. These concerns have been primarily for the women of child-bearing age and children who might consume fish caught from regions with high concentrations of mercury in fish tissue. Methyl-mercury in dietary freshwater and marine fish is the primary pathway of exposure to humans for this neurotoxin (USEPA, 1997; Mahaffey, 1999). Despite years of concern about mercury in fish in the Bay-Delta watershed, there has not previously been a description of how fishing intensities overlapped with mercury concentrations in fish. This overlap, combined with the "needs assessment" conducted by the Department of Health Services, constitutes part of the background information for a potential fish consumption study in the Bay-Delta watershed.

Fish consumption surveys are conducted in places where there is a risk to public health from contamination of fish by waterway pollutants. These can involve direct interaction with anglers at points of access (Meredith and Malvestuto, 1996), home or clinic interviews (Dewailly et al., 2002), or phone interviews (Stern et al., 1996). Many states have engaged in large-scale fish consumption surveys to understand exposures to mercury and other contaminants (New Jersey: Stern et al., 1996; Alabama: Meredith and Malvestuto, 1996; Michigan: Murray and Burmaster, 1994; Wisconsin, Illinois, Indiana, Ohio, and Michigan: Hanrahan et al., 1999). California is notably absent from the list of heavily populated states that have an identified fish contamination problem that have also conducted large-scale fish consumption surveys. Surveys have been conducted in the San Francisco and Santa Monica Bays.

In the recent "Mercury Strategy for the Bay-Delta Ecosystem" (Wiener et al., 2003), one of the Core Components was "monitoring of mercury in fish, health-risk assessment, and risk communication" which addressed the Management Goal "protect human health by providing informed guidance for reducing dietary exposure to methylmercury in fish." This goal included as objectives the following: "*(2) To assess health risks of fish consumption to humans*. This objective would be facilitated by the development of an effective data management system for storage and retrieval of data on mercury in fish, shellfish, and other edible aquatic biota. *(3) To provide fish-consumption advice to the public*. Fish-consumption advisories can be effective for reducing exposure of humans to methylmercury. Existing and monitoring data should be analyzed to determine if a single regional fish-consumption advisory is appropriate or whether spatial variation in contamination of fish warrants multiple advisories across the region. *(4) To transfer information through public outreach.* The public benefits of this program would be enhanced by active public outreach and by communication of findings to environmental health professionals. Monitoring data, combined with information from special studies, can be used to identify priority areas and target groups for outreach and education efforts, which should also communicate the health benefits of eating clean fish. *(5) To perform special studies needed to support health-risk assessment and risk communication*. Ancillary studies may be needed to estimate rates and patterns of fish consumption, to identify and characterize groups with potentially high levels of exposure, to identify optimal methods for communicating advice, and to evaluate the effectiveness of fish-consumption advisories."

The present study was intended to assess the fishing intensity and mercury concentrations in fish tissue data that are currently available. This assessment will inform this goal of the CALFED Mercury Strategy as well as the goal of the Delta Tributaries Mercury Council to reduce the risk of mercury exposure of humans and wildlife. In order to serve these goals, critical information includes the relative distribution of fishing intensity and fish concentrations of mercury and knowledge of the communities from which anglers are originating.

III. Objectives of Study

This study was conducted in order to assemble information critical to conducting a fish consumption survey and related monitoring and public education and outreach programs. The three objectives of this study were to: 1) Assemble a relational database in order to support queries of fishing intensity data and fish tissue Hg concentrations; 2) Construct a geographic information system was constructed to show where in the Bay-Delta watershed fishing intensity and fish tissue concentrations of Hg are both high as well as to aid in determining the communities of origin of anglers in areas with high relative risk from mercury; 3) Expose data and knowledge gaps which will aid in the development of future programs monitoring mercury concentrations and fishing activities that may put anglers and their families at risk.

IV. Methods

a. Databases

i. Creel survey data

Creel survey data for reservoirs and certain stretches of Central Valley rivers were obtained as Excel files from the California Department of Fish and Game (CDFG) for the years 1999-2001. The data included information about the location (river mile), number of anglers, their zip code of origin, number of fish caught and released, and the types of fish caught (see Appendix A). The data were collected by the CDFG by counting and interviewing anglers in rivers and reservoirs and stored in a relational database in MS Access. CDFG staff queried the database for the DTMC study, using the fields for river mile, number of anglers, fish species caught and kept or released, and zip code of anglers.

ii. Fish tissue Hg data

The Regional Water Quality Control Board – Central Valley region researched and collected all available data for mercury concentrations in fish tissue for sampling points within the Delta watershed. These data were combined within a single database in MS Excel and made available for this study (described in Appendix A).

b. Geographic Information System

1) Mapping creel survey data (see Appendix B): Reservoirs for which creel survey data were available were mapped. Coordinates were obtained from two online geo-locator services: “cdec” in the Department of Water Resources and “elib” at UC Berkeley. There are 21 points on the map, each one at the dam end of the reservoir. River miles were mapped along surveyed stretches of the Sacramento, San Joaquin, Cosumnes, Stanislaus, American, Feather, and Yuba Rivers using on-screen digitizing in ArcView 3.2 at 1:14,000 scale resolution. The statewide hydrology coverage from the National Hydrography Database was used as a base-map and distances measured either along the river center-line or along the river line (if there was only one line) with measurement node intervals of 0.01 to 0.1 miles. Creel survey data were attributed to each river mile and reservoir point.

2) Mapping fish tissue Hg sampling points (see Appendix B): The sampling points were mapped from the combined-source database from the Regional Board. These points were manually checked for accuracy (position relative to known geographic reference point (e.g., river), both by F. Shilling and the Regional Board. Fish species, length group (e.g., 200 to 300 mm), and tissue Hg concentrations were attributed to the points. The distribution of points is concentrated in certain waterbodies (e.g., Cache Creek, Delta, Bear/Yuba Rivers) and notably absent or composed of a few in others (e.g., Oroville Reservoir).

c. Relational Database

The creel survey and mercury fish tissue mercury data were combined in a relational database (rdb) in MS Access. This relational database was used to support queries of river miles where fishing occurred near sampling locations that had fish tissue Hg concentrations >0.3 parts per million wet weight (ppm). It was also queried for the angler zip codes corresponding to the river miles where fish tissue Hg concentrations were high. This allowed the discovery of communities of origin of anglers who were fishing in areas that put them and consumers of their catch at risk.

The field names in the Excel files from which the data were obtained were retained in the rdb. River miles were assigned to fish tissue mercury sampling points where those points were within ½ mile of a creel survey river mile or a reservoir that had creel surveys. The relationships among fields are shown in figure 1 below.

Figure 1

V. Findings

a. Fishing Intensity in the Delta Watershed

i. Delta

The "Delta Striped Bass Recovery Program" of the California Department of Fish and Game program follows planted striped bass fingerlings and tagged fish through agency re-capture programs, as well as creel surveys at various places in or near the Bay-Delta. DFG staff interview anglers at the boat ramps and determine the size and gender of striped bass caught that day.

For this study, data were received from DFG staff as an Excel file. The creel survey has been going on since 1984 in the San Francisco Bay area and since 1986 in the vicinity of the Delta. The head of the program, Mike Harris, has cautioned that this program does not collect data in the same way as the Sacramento River creel survey program, i.e., they do not extrapolate from the surveys to regional level fishing intensity (thus the low number of fish recorded in the survey). However, he did indicate that surveyors go where they know there is fishing boat activity, which means that angler success in particular regions could reflect fishing intensity in those regions and that the number of fish returned to particular boat ramps could be used in decision-making about where to send interviewers for a fish consumption study or for outreach and education. For example, if a particular boat ramp receives anglers who fish in areas known to have high concentrations of mercury in fish tissue, then that boat ramp could be prioritized for consumption studies. They do not collect angler zip code data, so there is no way to determine the community origin of the anglers.

Two types of geographic data were collected, the boat ramp from which the anglers originated ("port of origin") and the areas where fish were caught ("recovery locations"). For "recovery location" data, the areas described are where the anglers surveyed said they caught the fish sampled.

According to CDFG staff: "*The creel clerk met the anglers at the boat ramp (the port of origin) and asked them of their striped bass success, and if they were successful, to see their catch. This is all volunteer-based, so if the angler did not wish to let us see the fish, we were out of luck. The locations are not equally visited. The creel clerks followed the fishing, so to speak, so if the clerks heard that striped bass fishing is good at certain parts, they would go there. We are trying to maximize the number of fish we see so there is no protocol on how often a site should be visited. During the summer, this often meant sampling the catch from commercial fishing party boats targeting striped bass*." (Samantha Vu, CDFG Fishery Biologist)

Figure 2

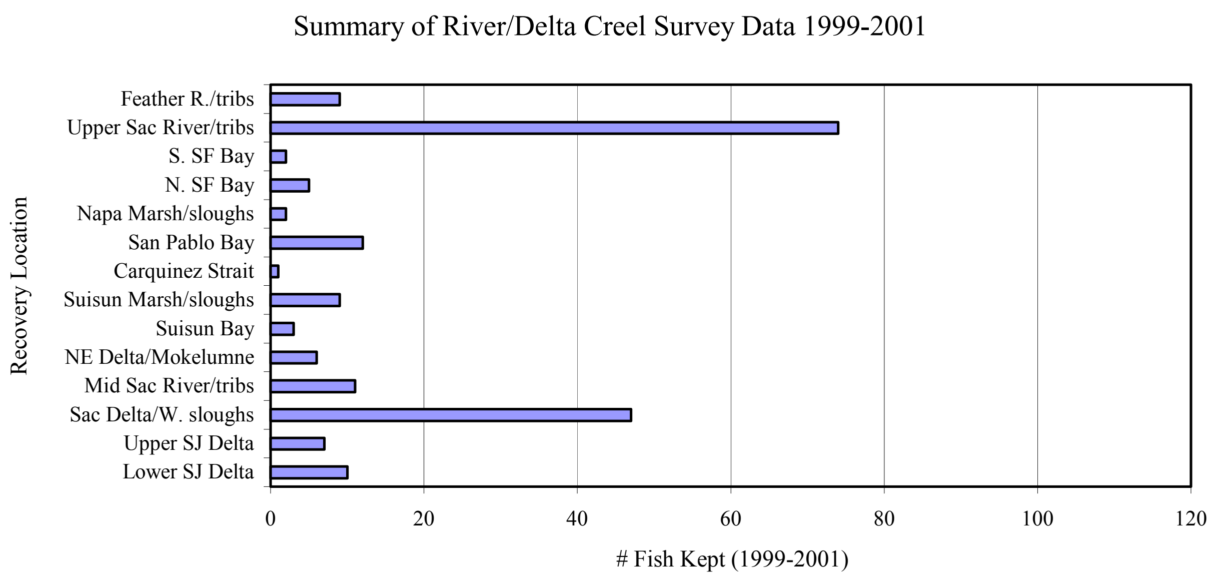
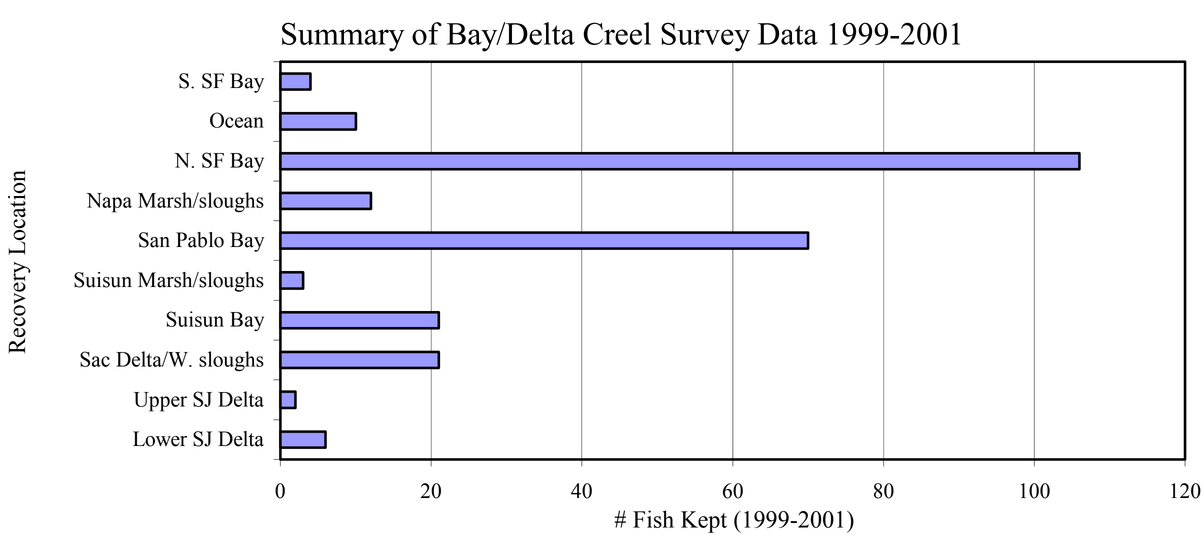


Figure 3



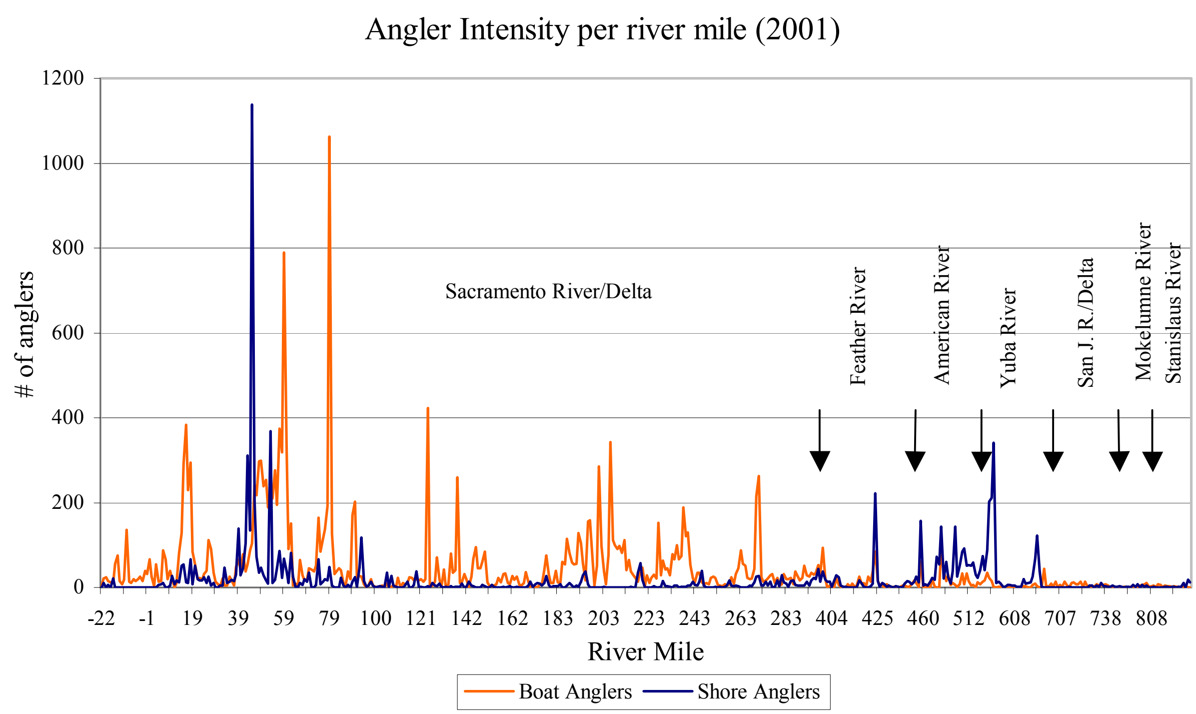
For the Sacramento River and San Joaquin River portions of the Delta and the surrounding sloughs, there were certain regions that had apparently greater fishing intensity (during December to June). These were the Sacramento River and certain tributaries above the confluence with the Feather River and the western Delta from Sacramento Point to Courtland and all Delta sloughs and channels west of the Sacramento River (figure 2). In comparison, the Bay had the greatest fishing intensity in the North San Francisco Bay, San Pablo Bay, and Suisun Bay (during June to December; figure 3).

The data were not collected with great enough intensity to permit a picture of the actual fishing pressure in each region of the Delta and tributaries. Therefore, use of the data to inform a potential fish consumption study should be limited until more such data is collected.

ii. Sacramento and San Joaquin Rivers and Tributaries

The CDFG also collects creel survey data for main-stem tributaries to the Bay-Delta (e.g., the Scramento River) under their “Salmon and Steelhead Recovery Program”. One of these data types is fishing pressure or angler numbers by river mile (figure 4 below). These data indicate that there are specific river miles where angling intensity is very high compared to other places. These are areas where high fish tissue mercury concentrations would put the most people at risk and the areas where there should be the most knowledge about mercury concentrations.

Figure 4



The CDFG also collects data about the types of fish caught, but this data is aggregated by river segment, rather than river mile. Segments are 20 to 100 miles long. The number of angler hours has been calculated per river stretch and is shown in figure C-1 (Appendix C). These data show that the most fishing effort occurs in the Sacramento River between the Carquinez Straits and Colusa, the lower Feather River, and the lower American River. Fishing for particular fish species is not uniformly distributed throughout the river system. For example, black bass and catfish fishing occurs primarily in the San Joaquin and Mokelumne Rivers (figures C-2 and C-3), striped bass fishing occurs primarily in the Sacramento, San Joaquin, Mokelumne, and Feather Rivers (figure C-4). Rainbow trout are caught and kept primarily in the upper Sacramento, Yuba, and American Rivers (figure C-5). Fishing for steelhead occurs mostly in the American and Feather Rivers (figure C-6). The majority of fishing for Chinook salmon occurs in the Sacramento, Feather, and American Rivers (figure C-7). Other fish are taken home from the lower Sacramento, San Joaquin, and American Rivers (figure C-8). One important thing to note is that the vast majority of fish recorded as caught and kept in this creel survey program are catfish, striped bass, and Chinook salmon, with black bass making up a very minor component.

iii. Reservoirs

Certain reservoirs have been surveyed by mercury specialists for the occurrence of mercury and methyl-mercury in fish tissue, especially in larger size game species. This activity arose because of the combination of mercury from abandoned mines and conditions conducive to mercury methylation in the reservoirs. Specific reservoirs, such as Camp Far West (Bear River) and Scott Flat (Deer Creek) have been identified as having fish with >1 ppm mercury in their tissue (USGS, 2001). It is possible that other Sierra Nevada and Coast Range reservoirs have similarly high fish tissue levels of mercury due to past mining activity in the watersheds.

The California Department of Fish and Game “Reservoir Program” tracks fishing activity in the state’s reservoirs in much the same ways as the Sacramento River program. They report annually to the US Fish and Wildlife Service under the Sportfish Restoration Act. For about a dozen reservoirs in the Central Valley watersheds, they collect data on number of anglers, boat ramp where interviews took place, number of hours fished, the fish-species groups caught (e.g., “catfish”), the proportion kept and released, and the zip code of origin of anglers. Dennis Lee, DFG supervisor for the program, said that the surveying results in a measure of fishing success rather than fishing intensity. For the reservoirs surveyed, the data do provide a sense of which reservoirs are more fished than others and also a way to compare reservoirs with river stretches. These data are important for both comparing among surveyed reservoirs and to a more limited extent, comparison between reservoirs and river reaches.

Angler activity

Fishing effort was measured in the reservoirs by counting anglers and estimating number of hours fished annually, for 1999 to 2001 (figure 5). This gives a measure among reservoirs of the popularity of the reservoirs and the relative intensity of fishing. Of reservoirs where upstream abandoned mines with mercury contamination exist, Oroville, Berryessa, and Folsom reservoirs had the highest level of fishing activity by these measures. Another measure of angler activity is the number of fish caught and kept. By this measure, Oroville, Berryessa, Folsom, and Bullards Bar reservoirs have the highest activity (figures C-9 & C-10). To put the angling intensity in the same perspective as the river reaches, the number of anglers in each of Berryessa, Oroville, Folsom, and New Melones reservoirs is in the same order of magnitude (thousands) as were present along the Sacramento River between Rio Vista (river mile 13) and Knights Landing (river mile 89), which was the reach with the highest number and density of anglers (figure 4).

Salmonid species (trout, steelhead, and salmon) and black bass (e.g., smallmouth bass) are of concern for tissue mercury concentration and also happen to be the most popular fish groups caught in the reservoirs; once again, Oroville, Berryessa, and Folsom are among the reservoirs with the highest activity by this index (figure C-11, C-12).

Figure 5

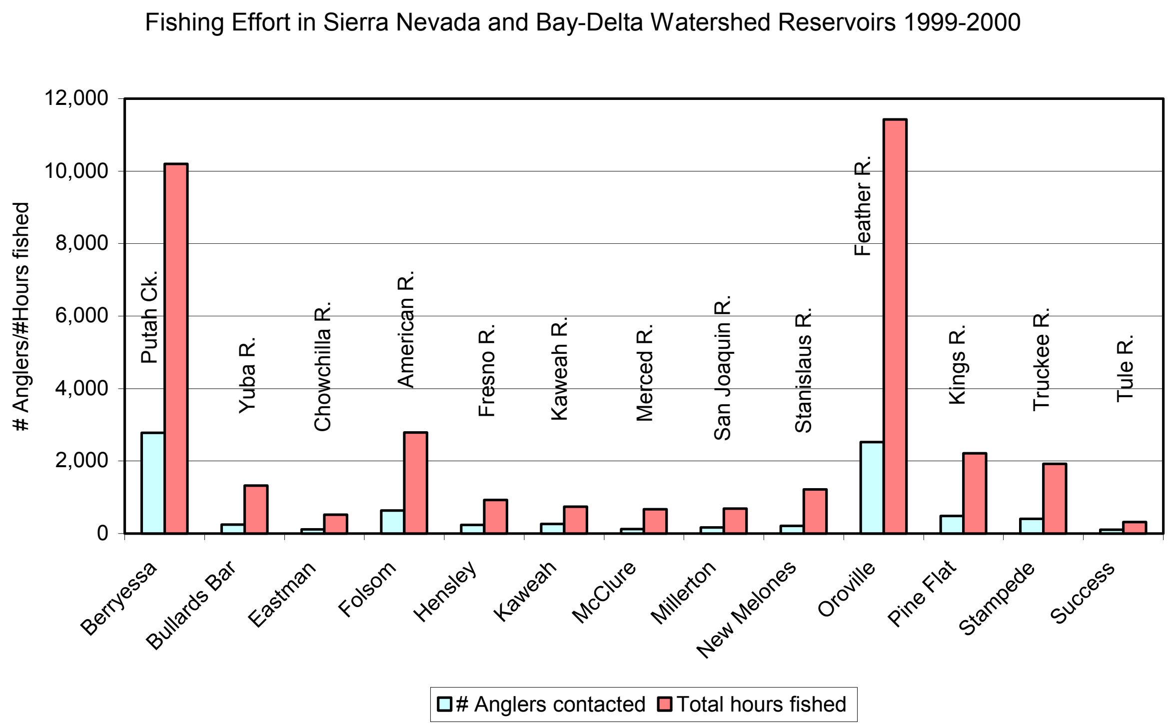
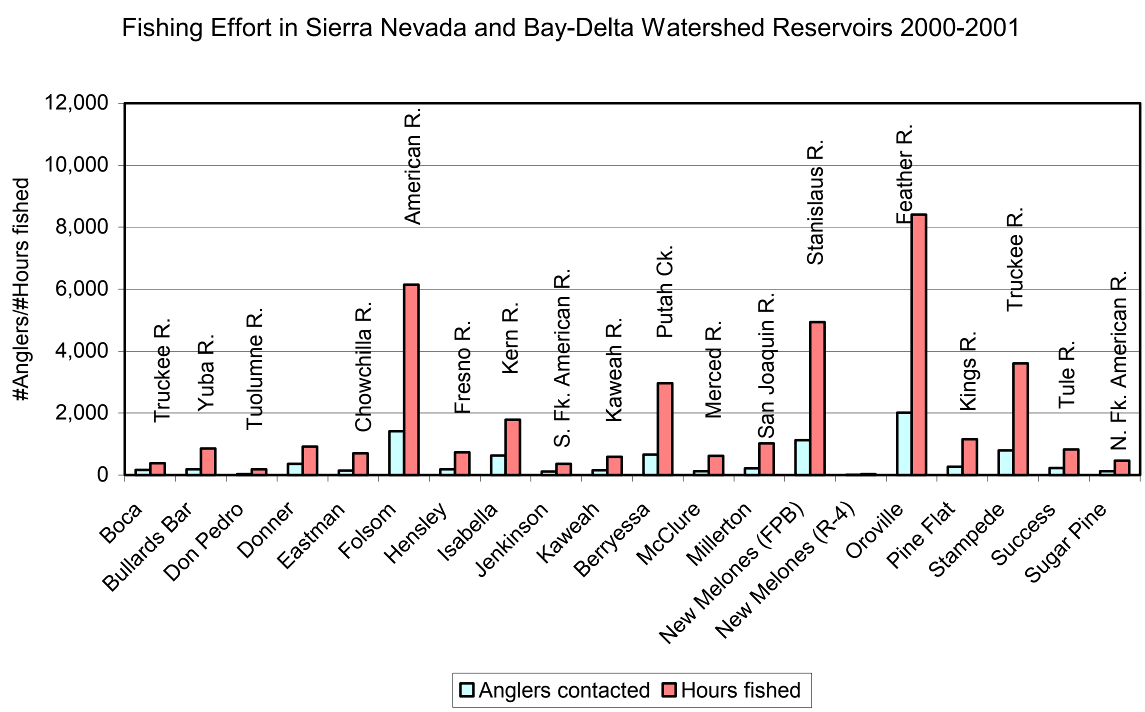


Figure 6



b. Risk to Anglers from Mercury Contamination

i. Species of Concern

There are many fish species caught by anglers in the Bay-Delta watershed that have been measured as having tissue burdens of mercury above the EPA concentration of concern (0.3 ppm wet weight). Measurements of fish tissue concentrations of mercury have been carried out under various monitoring programs and the data collected in one database by the Regional Water Quality Control Board. Fish tissue Hg concentrations in reservoirs have been monitored somewhat irregularly, though the measured concentrations are high enough to cause concern for risk to anglers and their families, depending on their consumption rates. For example, largemouth bass from Lake Berryessa can have Hg concentrations greater than 1.0 ppm (figure C-13). Fish favored by anglers from Folsom, Bullards Bar, McClure, New Melones, Don Pedro, Pardee, Amador, Stony Gorge, East Park, and Black Butte Reservoirs and Beach Lake have mercury concentrations greater than 0.3 ppm (figures C-14 & C-15).

The data for individual and small groups of fish were also mapped by sampling location in order to show the distribution of Hg concentrations and sizes of fish in the Bay-Delta watershed. The number of individual fish represented per dot ranges from 1 to over 10. No mapping of sample size per point was done, but the data are available in the database. The maps are shown in Appendix C at the end of this report. According to the CDFG "Freshwater Sport Fishing Regulations Booklet" (3/1/2003 – 2/28/2004) the relevant legal size limits by species or fish group are: 1) black bass – range between no limit and 22 inches (559 mm); 2) striped bass – 18 inches (457 mm); 3) trout and other salmonids – no limit across most of study area; 4) all others – no limit.

1) Bluegill and sunfish (Centrarchidae) have been sampled widely and values are shown in figure C-16. The majority of measured concentrations are below 0.3 ppm and about half are below 0.1 ppm. This is primarily for fish that are <200 mm (8 inches) with a notable exception in the Cache Creek watershed. Concentrations >0.3 ppm have been measured in the Bear River, Cache Creek, Putah Creek, Cosumnes River, and southwestern Delta watersheds.

2) White and black crappie (Centrarchidae) have been sampled mostly right around the Delta where the majority of concentrations are <0.3 ppm (figure C-17) and most fish sampled have been <200 mm (8 inches). Concentrations >0.3 ppm have been measured in Greens Lake and the lower Delta, as well as the Cache Creek, Bear River, and San Joaquin River watersheds.

3) Sampling for largemouth bass (Centrarchidae) has been carried out throughout the Bay-Delta watershed, the majority of concentrations have been >0.3 ppm (figure C-18) and most fish sampled have been >200 mm (8 inches). Concentrations >0.3 ppm have been measured in fish sampled from the following river and creek watersheds: Sacramento, Feather, Yuba, Bear, American, Mokelumne, Stanislaus, Tuolumne, Merced, and San Joaquin Rivers and Stony, Cache, and Putah Creeks. There have also been fish sampled with concentrations >0.3 ppm from sloughs and creek in other locations, including within the Delta itself.

4) Smallmouth and white bass (Centrarchidae) have been moderately sampled throughout the Delta watershed (figure C-19), the majority of concentrations have been >0.3 ppm and most

fish have been >200 mm (8 inches). Concentrations >0.3 ppm have been found in fish from the Yuba, Bear, American, Sacramento, Tuolumne Rivers and Putah and Cache Creek watersheds.

5) Spotted bass (Centrarchidae) have been seldom sampled, with collected fish being >200 mm (8 inches) and the majority of concentrations >0.3 ppm (figure C-20). High concentrations have been measured in the Yuba, Bear, and Feather Rivers and Cache Creek watersheds.

6) Carp (Cyprinidae) have been sampled widely outside of the Delta, with most fish being >300 mm (12 inches, figure C-21). Concentrations of mercury are mostly <0.3 ppm, with higher concentrations (0.3 – 1.0 ppm) in the Yuba River, Feather River, Putah Creek, Stanislaus River, and San Joaquin River watersheds.

7) Hardhead and Sacramento blackfish (Cyprinidae) have been sampled in few locations, the majority of concentrations are <0.3 ppm (figure C-22), and most fish sampled have been <400 mm (16 inches). Concentrations >0.3 ppm have been measured in the Yuba River, Cache Creek, and Sacramento River watersheds.

8) Roach and hitch (Cyprinidae) have been sampled in the Cache and Putah Creek watersheds and the southern Delta (figure C-23). Most fish have been small (<8 inches), but about half of the concentrations have been >0.3 ppm.

9) Red and golden shiners (Cyprinidae) have been sampled primarily in the Delta (figure C-24), tend to be <200 mm (8 inches), and all concentrations have been <0.3 ppm.

10) Sacramento pike minnow (Cyprinidae) have been sampled throughout the Sacramento River watershed (figure C-25). The fish sampled were mostly >200 mm (8 inches) and the majority of Hg concentrations were >0.3 ppm. High concentrations (>0.3 ppm) were found in the Feather, Yuba, American, Mokelumne Rivers and Cache and Putah Creeks watersheds.

11) Black and brown bullhead (Ictaluridae) have not been sampled widely and are shown in figure C-26. Most sampling has been done for fish between 200 and 400 mm (8 and 16 inches) and values have been mostly below 0.3 ppm. One value was >0.3 ppm (0.580 ppm) in Colusa Drain at Abel Road.

12) Channel and white catfish (Ictaluridae) have been sampled widely in the tributaries to the Delta (figures C-27 and C-28). The vast majority of fish sampled were >200 mm and most were 400 – 600 mm (16 to 24 inches). Concentrations in the mainstem Sacramento River and the Delta were <0.3 ppm for channel catfish and >0.3 ppm for white catfish. Concentrations were often >0.3 ppm in fish from the Sacramento River, Bear River, Feather River, Cache Creek, Putah Creek, Mokelumne River, Stanislaus River, and San Joaquin River watersheds.

13) Suckers (Catostomidae) have been widely sampled throughout the Sacramento River watershed (figure C-29), but not the San Joaquin River watershed. Most fish were >200 mm. Most concentrations were <0.3 ppm, with concentrations >0.3 ppm in the Delta and the Cache Creek, Putah Creek, American River, Yuba River, and Feather River watersheds.

14) Striped Bass (Moronidae) have been sampled primarily in the mainstems of the Sacramento and San Joquin Rivers and major tributaries (figure C-30). Most fish sampled were

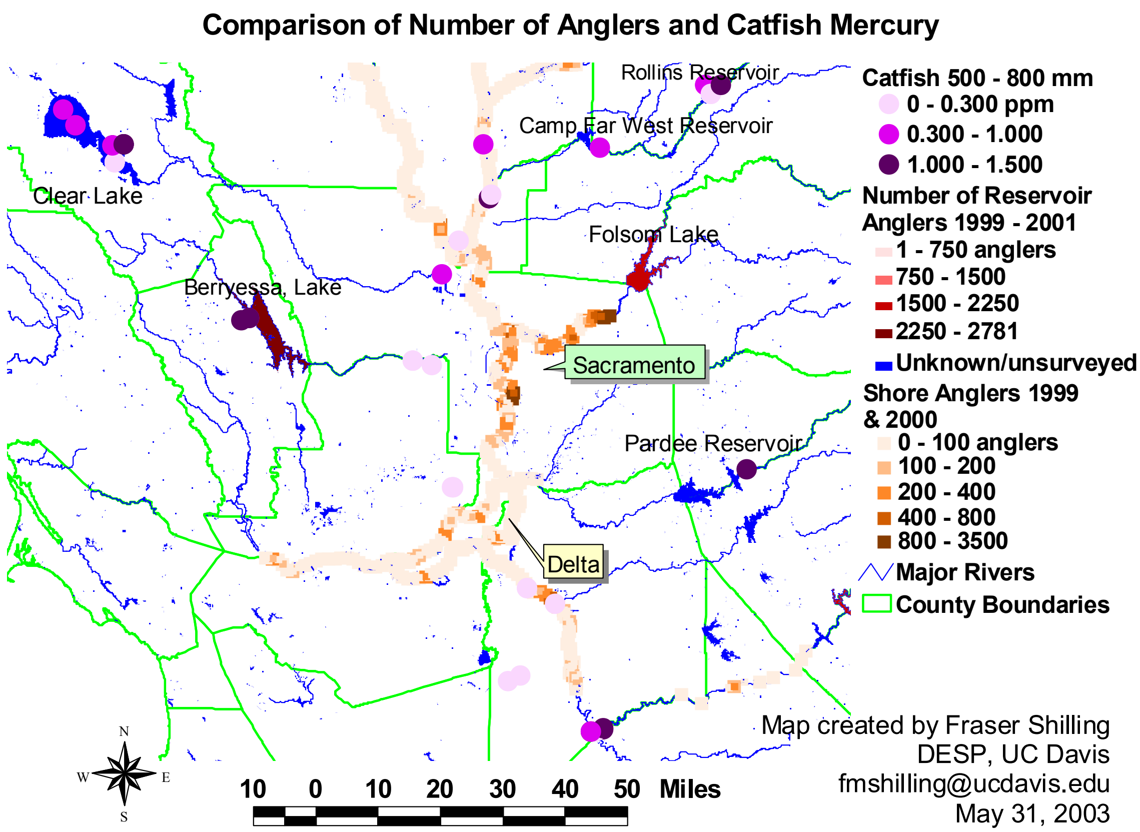
>400 mm and had mercury concentrations >0.3 ppm. The highest concentrations (>1.0 ppm) were in the San Joaquin and Feather Rivers.

ii. Overlap Between Angling and Contamination

The river mile locations for fish tissue concentrations higher than 0.3 ppm were used to find angling locations where anglers might be at risk. The relational database was queried for river mile locations where there were nearby sampling sites where fish tissue Hg concentrations had been measured to be greater than 0.3 ppm. There were many sampling sites with fish tissue Hg concentrations >0.3 ppm where there were no river miles, which are locations where there is no creel surveying.

The map below (figure 7) shows the overlap between catfish (white and channel) contamination and number of anglers in reservoirs and fishing from the shore of the Sacramento River and tributaries.

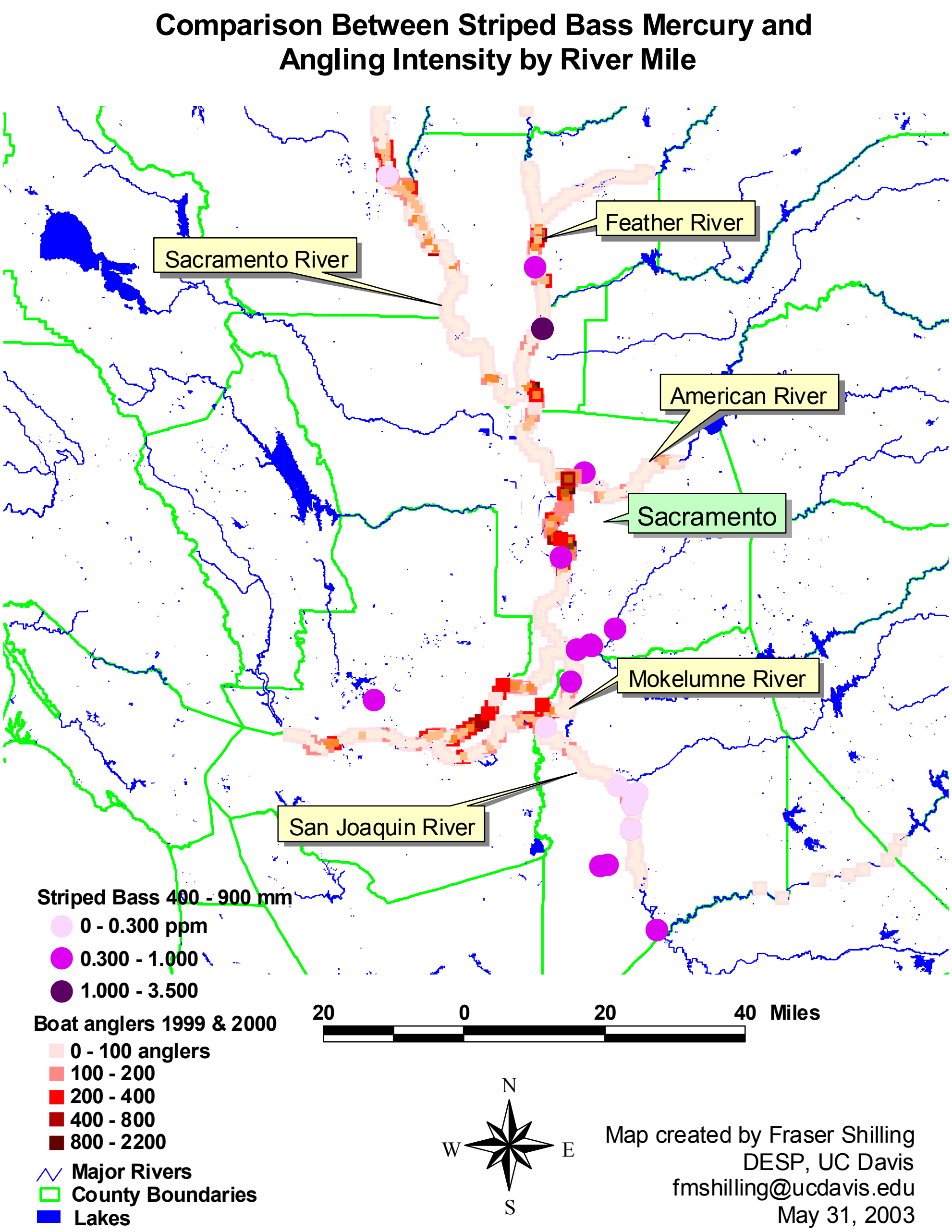
Figure 7



According to reports from CDFG, most fishing for catfish occurs year-round in the lower Mokelumne and San Joaquin Rivers, with some but much less fishing in the lower Sacramento River. So, although there is overlap between fish sampling points and river reaches surveyed for fishing activities, there are also many places where one was measured (fish tissue Hg or fishing intensity) and not the other. Lake Berryessa is an obvious place where high Hg concentrations and fishing intensity have coincided making it a logical place for concern.

Fishing for striped bass is one of the most popular sports angling choices in the Delta tributaries, after fishing for Chinook salmon. There are two peaks of striped bass fishing with low levels in between. Most of the activity occurs on the lower Sacramento River (below Red Bluff) with moderate fishing on the Feather, San Joaquin, and Mokelumne Rivers. The map below (figure 8) shows the areas of overlap and non-overlap between fishing activity and mercury concentrations in striped bass. There are obviously areas (near Sacramento) where fish tissue Hg concentrations and fishing intensity are both high. There are also areas of high fishing intensity with no measurements of fish tissue Hg.

Figure 8



iii. Communities of origin of anglers

The angler zip codes of origin for the river miles (including reservoirs) with $[Hg]_{fish}$ >0.3 ppm were queried from the relational database and the number of anglers from each zip code counted. The CDFG creel survey data included zip codes of anglers interviewed at each river mile. The top 40 zip codes (in terms of number of anglers/angler groups) are listed in the table below, along with the county and city names.

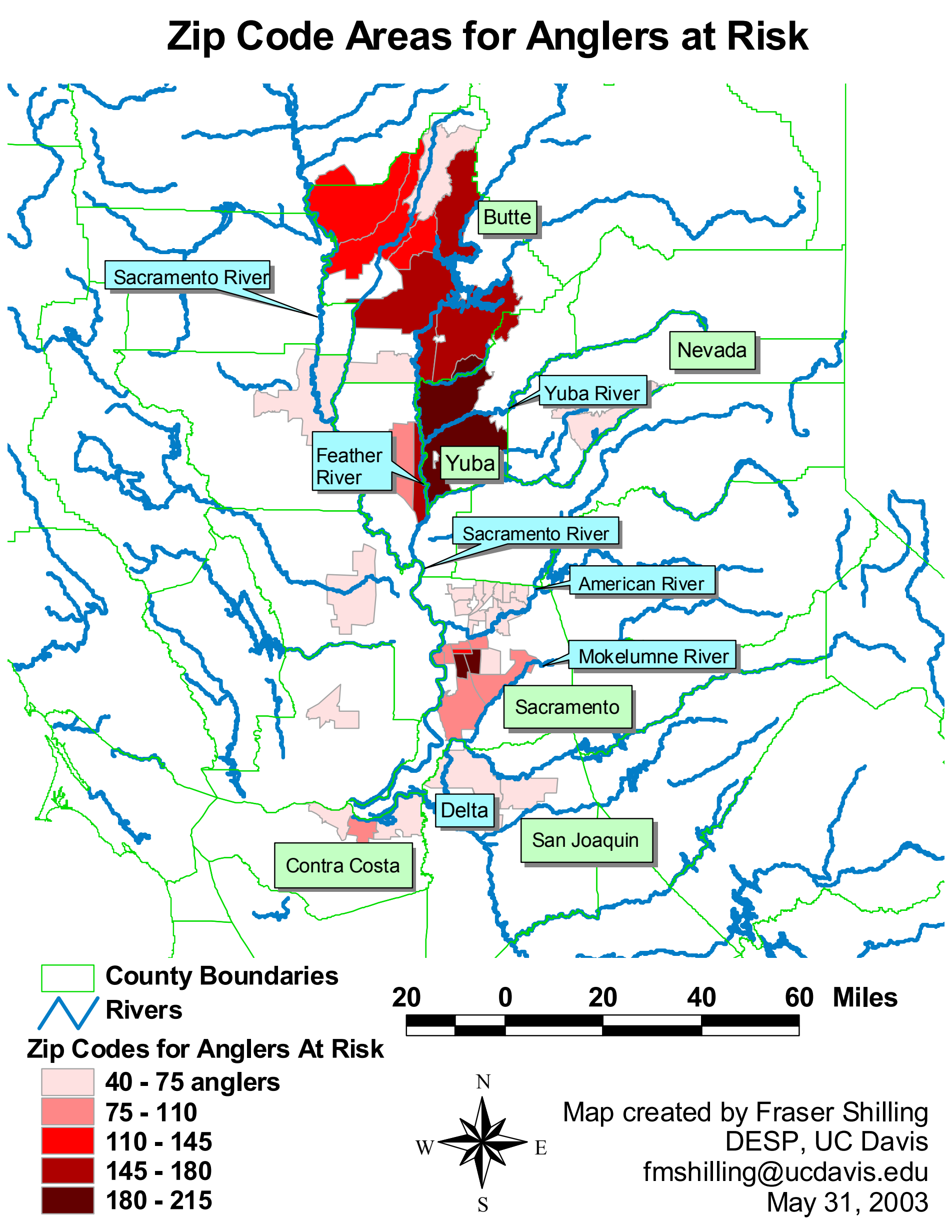
Table 1 Frequency of angler zip codes from river miles with high mercury concentrations (>0.3 ppm) in fish tissue. The top 40 are listed, along with city and county names.

ZIP CODE	*COUNTY NAME*	*CITY NAME*	*ANGLER ZIP CODE COUNT*
95823	Sacramento	SACRAMENTO	209
95828	Sacramento	SACRAMENTO	194
95901	Yuba	MARYSVILLE	181
95991	Sutter	YUBA CITY	177
95966	Butte	OROVILLE	168
95965	Butte	OROVILLE	167
95926	Butte	CHICO	126
95969	Butte	PARADISE	126
95928	Butte	CHICO	123
95824	Sacramento	SACRAMENTO	117
94509	Contra Costa	ANTIOCH	107
95831	Sacramento	SACRAMENTO	103
95624	Sacramento	ELK GROVE	100
95820	Sacramento	SACRAMENTO	100
95826	Sacramento	SACRAMENTO	95
95758	Sacramento	ELK GROVE	93
95993	Sutter	YUBA CITY	89
95822	Sacramento	SACRAMENTO	86
95945	Nevada	GRASS VALLEY	72
95207	San Joaquin	STOCKTON	68
95209	San Joaquin	STOCKTON	68
95825	Sacramento	SACRAMENTO	65
95948	Butte	GRIDLEY	65
95821	Sacramento	SACRAMENTO	57
95954	Butte	MAGALIA	57
94565	Contra Costa	PITTSBURG	56
95608	Sacramento	CARMICHAEL	56
95240	San Joaquin	LODI	54
95838	Sacramento	SACRAMENTO	54
95687	Solano	VACAVILLE	52
95829	Sacramento	SACRAMENTO	50
95210	San Joaquin	STOCKTON	48
95621	Sacramento	CITRUS HEIGHTS	48
95628	Sacramento	FAIR OAKS	48
95695	Yolo	WOODLAND	47
95932	Colusa	COLUSA	46

95610	Sacramento	CITRUS HEIGHTS	45
95842	Sacramento	SACRAMENTO	45
95660	Sacramento	NORTH HIGHLANDS	44
95242	San Joaquin	LODI	43

These zip codes are the communities of origin of anglers from 3 years of surveying where the anglers fished in areas where edible fish had been measured to have $[Hg]_{fish}$ >0.3 ppm. These communities are logical starting points for community-based fish consumption surveys and education and outreach. They span 10 counties adjoining the Sacramento and San Joaquin Rivers above and within the Delta, with the exception of Nevada county (figure 9 below).

Figure 9



One consideration to make when designing fish consumption studies, or education and outreach programs, is the demographic make-up of the communities of concern. In this study, the zip codes for anglers fishing in high-risk areas were used to aggregate race and ethnicity data from the census blocks within the zip codes. Census tracts were not used because some of them are larger than the zip codes themselves. There was a wide range of proportions of ethnicities in the zip code areas from figure 9. These are show in the table below.

Table 2 Proportion of different races and ethnicities for the zip codes with the highest frequencies of anglers in river locations with high Hg concentrations (>0.3 ppm) in fish tissue. The percents given are percents of total population.

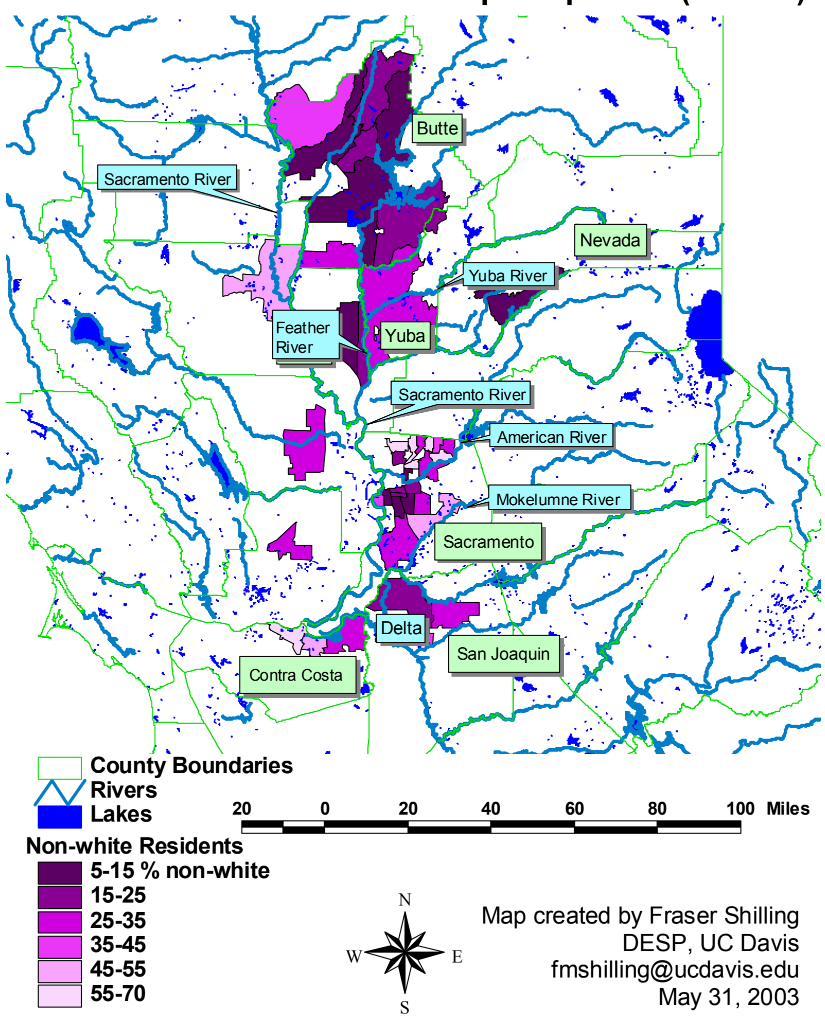
ZIP	*City Name*	*County Name*	*%Amer. Ind.*	*%Asian*	*%Black*	*%Hawaiian Pac. Isl.*	*%Hispanic*	*%Multi-ethn*	*%Other ethn*	*%White*
95823	Sacramento	Sacramento	0.95	3.68	1.73	0.14	6.46	3.38	1.73	87.59
95828	Sacramento	Sacramento	0.94	2.86	2.57	0.35	8.81	4.33	2.69	85.28
95901	Marysville	Yuba	2.52	20.35	1.52	0.17	12.16	4.23	6.69	65.10
95991	Yuba City	Sutter	2.02	5.51	1.59	0.14	12.86	3.51	5.92	81.05
95966	Oroville	Butte	3.66	2.96	1.62	0.16	10.91	3.85	4.81	84.50
95965	Oroville	Butte	3.72	1.01	0.24	0.09	4.26	2.80	1.18	92.47
95969	Paradies	Butte	1.20	6.18	2.65	0.29	8.64	5.13	3.38	77.65
95926	Chico	Butte	1.10	9.08	2.04	0.29	26.88	5.38	15.69	64.49
95928	Chico	Butte	1.28	0.64	0.23	0.11	3.87	2.14	0.74	94.48
95824	Sacramento	Sacramento	1.51	2.77	1.68	0.29	11.27	5.17	5.46	82.11
94509	Antioch	Contra Costa	1.00	17.61	10.31	0.56	24.43	6.50	11.15	52.01
95831	Sacramento	Sacramento	0.54	8.19	11.60	0.51	13.50	7.06	5.58	64.91
95820	Sacramento	Sacramento	2.13	3.70	5.68	0.44	11.56	5.28	4.57	77.96
95624	Elk Grove	Sacramento	0.90	30.50	10.32	0.27	10.17	4.96	3.45	48.96
95826	Sacramento	Sacramento	1.12	3.07	2.84	0.31	10.21	4.84	3.66	83.41
95758	Elk Grove	Sacramento	0.79	8.40	9.76	0.39	11.13	5.63	4.76	69.29
95993	Yuba City	Sutter	0.94	0.61	0.33	0.11	4.75	2.23	0.99	93.58
95822	Sacramento	Sacramento	1.32	3.69	2.88	0.21	7.07	4.06	2.11	85.16
95945	Grass Valley	Nevada	1.13	0.80	0.17	0.06	5.98	3.08	1.41	92.34
95209	Stockton	San Joaquin	0.60	4.03	5.01	0.30	24.26	6.04	10.95	71.88
95207	Stockton	San Joaquin	0.87	10.85	16.87	0.97	35.07	7.27	18.27	44.10
95948	Gridley	Butte	1.46	9.39	3.40	0.26	20.20	6.02	12.09	65.33
95825	Sacramento	Sacramento	1.02	2.66	1.07	0.21	6.61	3.74	1.73	88.64
95954	Magalia	Butte	1.16	4.79	2.07	0.09	7.63	3.91	2.84	81.64
95821	Sacramento	Sacramento	1.37	15.89	21.76	1.92	18.57	6.55	9.80	41.21
95608	Carmichael	Sacramento	0.89	4.28	12.27	0.44	16.47	5.34	6.44	69.31
94565	Pittsburg	Contra Costa	0.68	34.31	12.39	0.55	24.83	6.98	11.72	32.42
95838	Sacramento	Sacramento	1.87	3.60	1.14	0.21	17.25	4.15	7.09	81.86
95240	Lodi	San Joaquin	0.98	4.86	0.48	0.12	31.95	5.15	17.33	70.08
95687	Vacaville	Solano	0.94	9.38	8.90	0.55	12.87	5.65	5.09	68.30
95829	Sacramento	Sacramento	0.81	6.64	10.67	0.40	12.55	6.27	5.12	68.86
95628	Fair Oaks	Sacramento	0.75	27.13	9.55	0.66	34.62	6.48	18.06	35.60
95621	Citrus Heights	Sacramento	0.91	19.82	24.37	1.34	24.89	7.18	13.44	31.91
95210	Stockton	San Joaquin	0.63	20.13	8.69	0.58	17.32	6.21	7.47	55.32

95695	Woodland	Yolo	1.71	7.46	8.55	0.44	15.29	6.23	7.18	68.12
95932	Colusa	Colusa	4.28	8.69	2.82	0.04	41.42	2.63	28.47	54.59
95842	Sacramento	Sacramento	1.03	2.57	1.24	0.14	34.08	4.53	17.44	71.36
95610	Citrus Heights	Sacramento	0.88	16.59	9.93	0.47	15.12	6.22	5.85	59.15
95660	North Highlands	Sacramento	1.17	25.45	15.32	0.70	17.34	6.96	8.85	40.78
95670	Rancho Cordova	Sacramento	0.77	16.10	5.92	0.34	12.66	6.36	4.46	65.00
95242	Lodi	San Joaquin	0.62	8.72	1.41	0.34	14.85	3.75	7.71	76.45
95673	Rio Linda	Sacramento	1.52	19.42	19.31	1.53	22.32	6.71	10.98	39.73
94561	Oakley	Contra Costa	0.79	6.40	8.89	0.33	21.59	6.75	9.02	66.62
95662	Orangevale	Sacramento	0.96	10.65	5.04	0.37	12.72	6.41	6.03	69.60

When all non-white ethnicities are aggregated, the variation among zip codes becomes more obvious (figure 10), the lowest proportion being 5% non-white and the highest 70%.

Figure 10

Percent Non-White Residents per Zip Code (At Risk)



c. Informing the Department of Health Services' Needs Assessment

In an earlier phase of this project, a combination of creel survey and fish tissue mercury levels was used to prioritize regions and counties where fishing intensity was high and mercury contamination in fish tissue was also high. This information was intended for California Department of Health Services to use in their selection of priority counties for conducting needs assessment. It was an incomplete study in that there were zip code data missing and the GIS portion had not been started. However, the results did give an indication of which river stretches and counties might have the highest risk associated with consumption of fish caught in rivers tributary to the Bay-Delta.

River sections were first prioritized by number of fish caught of species of concern (having been found to accumulate mercury), then where those places corresponded to areas where fish tissue concentrations of mercury were >0.5 ppm, and finally the zip code groups of anglers fishing in those areas. From zip codes, counties of origin could also be determined.

Top 10 counties of origin for anglers at river sections with high mercury risk

These data are from the creel survey program for the Sacramento River and tributaries only, not for the Delta or reservoirs. The numbers are for angler groups surveyed, a fraction of the total angling population. County of origin was determined from a database of zip codes in each county.

Table 3 Counties of origin for anglers with the highest frequencies in the Sacramento River, San Joaquin and tributaries creel survey program.

County	#angler groups
Sacramento	242
San Joaquin	167
Placer	63
Stanislaus	49
Yolo	36
El Dorado	35
Contra Costa	35
Santa Clara	27
Solano	26
Butte	18

Recommended Counties:

First priority: Sacramento, San Joaquin, Placer, Stanislaus, Yolo
These counties were selected based on angling intensity for target fish species (e.g., black bass and striped bass) in areas where fish tissue levels of mercury are measured to be high (>0.5 ppm). Both urban and rural counties were desired to reflect the diversity in the Delta watershed. Stanislaus and Yolo could be considered "rural" counties in some respects, though they have obvious urban centers.

A second tier of counties was recommended for future needs assessment work, including Butte county. The Department of Health Services used this list to select counties for a several-month long needs assessment involving interviews with county health officers (and other staff) and community groups. This list could be refined now based on the information in (b), ii "Communities of origin of anglers" to include counties such as Butte, Yuba, and Sutter and to exclude Placer.

d. Focal Points for Anglers

i. River Miles

In order to make fish consumption studies efficient, investigators usually focus effort on locations where risk has been determined and many anglers are present. The following river miles are where the most anglers were present on the shore or on boats for 1999, 2000, and 2001. These are places to prioritize when conducting education and outreach or studying fish consumption.

Table 4 River miles with the highest frequencies of shore anglers. River miles (RM) and rivers were ranked by numbers of anglers for 3 years where creel surveying had been conducted by CDFG.

RM 1999	River	RM 2000	River	RM 2001	River
523	American	459	Feather	45	Sacramento
459	Feather	523	American	53	Sacramento
45	Sacramento	522	American	39	Sacramento
522	American	45	Sacramento	523	American
46	Sacramento	93	Sacramento	43	Sacramento
93	Sacramento	46	Sacramento	46	Sacramento
736	San Joaquin	521	American	424	Feather
521	American	39	Sacramento	521	American
464	Feather	520	American	93	Sacramento
500	American	513	American	459	Feather
707	San Joaquin	500	American	500	American
43	Sacramento	464	Feather	506	American
47	Sacramento	510	American	42	Sacramento
39	Sacramento	74	Sacramento	44	Sacramento
510	American	514	American	619	Yuba
735	San Joaquin	506	American	57	Sacramento
53	Sacramento	18	Sacramento	47	Sacramento
737	San Joaquin	43	Sacramento	62	Sacramento
513	American	519	American	510	American
92	Sacramento	736	San Joaquin	38	Sacramento

Table 5 River miles with the highest frequencies of boat anglers. River miles (RM) and rivers were ranked by numbers of anglers for 3 years where creel surveying had been conducted by CDFG.

RM 1999	River	RM 2000	River	RM 2001	River
79	Sacramento	79	Sacramento	79	Sacramento

271	Sacramento	59	Sacramento	59	Sacramento
59	Sacramento	271	Sacramento	60	Sacramento
46	Sacramento	46	Sacramento	124	Sacramento
270	Sacramento	459	Feather	57	Sacramento
459	Feather	425	Feather	16	Sacramento
7	Sacramento	270	Sacramento	58	Sacramento
425	Feather	49	Sacramento	271	Sacramento
49	Sacramento	7	Sacramento	206	Sacramento
500	American	58	Sacramento	201	Sacramento
124	Sacramento	500	American	48	Sacramento
8	Sacramento	6	Sacramento	49	Sacramento
58	Sacramento	8	Sacramento	18	Sacramento
803	Mokelumne	14	Sacramento	15	Sacramento
6	Sacramento	60	Sacramento	55	Sacramento
60	Sacramento	13	Sacramento	46	Sacramento
427	Feather	400	Feather	51	Sacramento
5	Sacramento	16	Sacramento	138	Sacramento
400	Feather	47	Sacramento	270	Sacramento
9	Sacramento	124	Sacramento	50	Sacramento

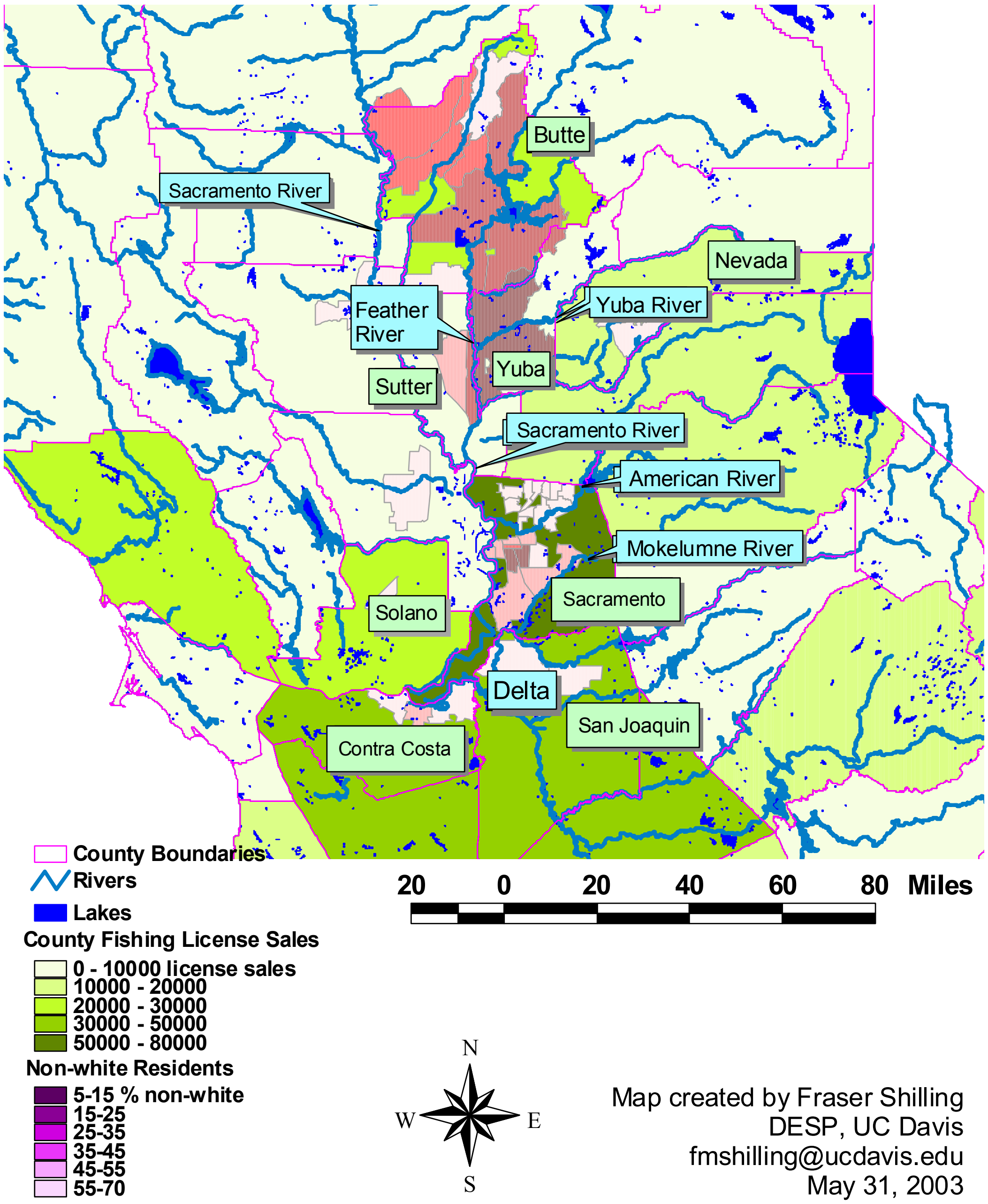
Information about fishing intensity and fish tissue Hg concentrations should allow fish consumption surveys that are associated with angling to be focused. There are river miles that consistently show up from year to year as high activity places. Some of these may be associated with salmon runs and may vary with size and timing of the runs. These places are not considered critical for this study. Other places may be places where there are many anglers catching any fish available. There are differences between the high intensity fishing river miles for boat anglers and those for shore anglers, both in terms of specific river stretches and whole rivers. In most cases, both shore and boat anglers are accessible by boat, in terms of surveying. Boat ramps and marinas are other places where anglers concentrate. Those facilities nearest river stretches with high Hg concentrations in fish could be chosen first for consumption surveying.

ii. License Sales

The License and Revenue Branch of the CDFG keeps track of fishing license sales by distributor, county, and year (http://www.dfg.ca.gov/licensing/statistics/statistics.html). The Branch has a queryable database (by city, county, zip code) for license purveyors, which was not functioning at the time of the writing of this report (http://www.dfg.ca.gov/lrbweb/jsp/). However, the license sales by county were available, which are displayed below (figure 11). This shows that for certain counties there seems to be overlap between the number of licenses sold and the zip codes for the highest number of anglers at risk (e.g., Sacramento and Butte Counties). For other counties, there is no such overlap (e.g., Sutter County). These license data are therefore probably not the best indicator of an overlap between fishing intensity and risk from mercury in fish, expect at the statewide scale where county borders are less important. However, the database of license sale locations may be useful as points of contact with anglers, assuming the sellers were interested in cooperating.

Figure 11

County Fishing License Sales (2001)



e. Data and Knowledge Gaps

i. Fishing Intensity

Fishing intensity has been measured on over 500 miles of river per year (varies with year) and about 20 reservoirs (varies with year) in the Bay-Delta watershed. However, there are stretches of river, sloughs, and canals and whole reservoirs where fishing occurs and there is no regular

creel and fishing intensity surveying. In the context of mercury, waterways that have had measured fish contamination would be the priority for surveying. California Department of Fish and Game biologists know the particular waterways that have fishing activity but are not being surveyed. The following major waterways have high likelihood of fishing activity due to their size and/or proximity to urban areas and have had fish tissue mercury concentrations >0.3 ppm measured in them:
Upper American River
Steelhead Creek/Natomas E Main Drain
Bear River
Big Chico Creek
Cache Creek
Colusa Drain
Cosumnes River
Deer Creek (Yuba tributary)
Kings River
Merced River
Mill Creek
Morrison Creek
Putah Creek
Sacramento Slough
Stony Creek
Sutter Bypass
Tuolumne River
Upper Yuba River

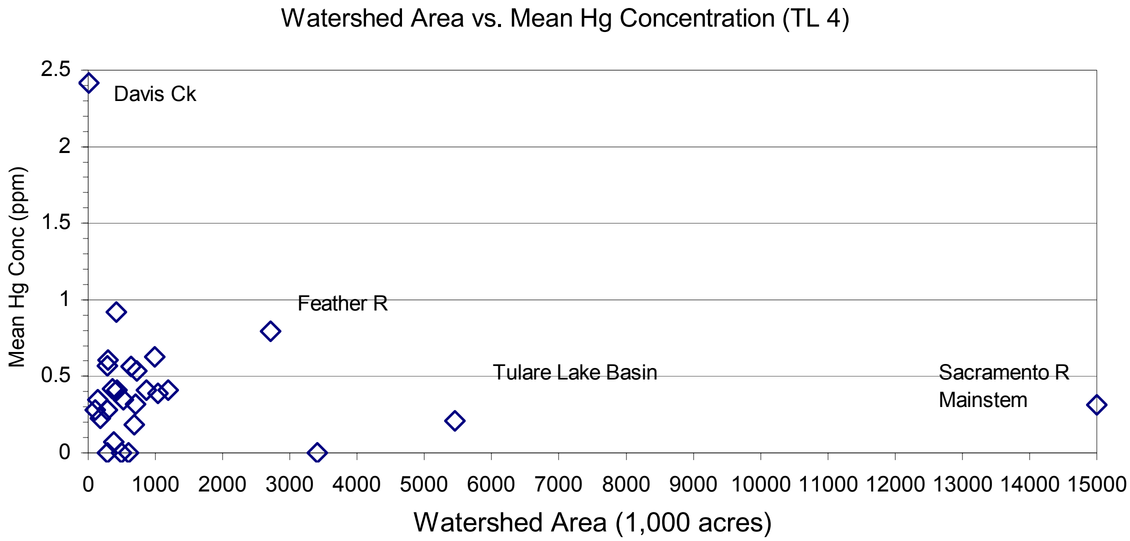
The California Department of Fish and Game is the primary agency for creel and fishing activity surveying. They have been undergoing program reductions due to budget cuts. Surveying the waterways indicated would require at least a doubling of the original un-reduced program for the Sacramento River, San Joaquin River, and several major tributaries.

The absence of information about fishing intensity, the size and species of fish being kept, and the communities from which the anglers originate means that the state has little information on which to base assessments of risk from mercury (and other contaminants) to public health. These data are as important as the measurement of contaminant concentration in the fish, unless direct measures of fish consumption were made.

ii. Mercury Contamination

In order to analyze gaps in information for mercury concentration in fish, data for mercury in fish tissue were summarized for various watershed and data attributes. Hg concentrations in trophic level 4 fish (e.g., largemouth bass, striped bass, Sacramento pike minnow) were compared to watershed area (figure 12), which showed that there was no obvious linear relationship between these two parameters. This means that watershed size has not been a factor in watershed monitoring. Watershed area was obtained from the Calwater 2.2 database.

Figure 12



However, there did seem to be potential for an exponential decay in the measured concentrations vs. watershed area, with larger watersheds (e.g., Sacramento River) having much lower concentrations than specific smaller watersheds (e.g., Davis Creek). This may be due to the occurrence of Hg sources and conditions conducive to mercury methylation in specific creeks or river segments, with dilution of the effect over the whole river system.

The number of samples taken for all trophic levels and for trophic level 3-4 and 4 fish was compared to mean Hg concentration (figure 13 & 14, respectively). Watersheds with moderate fish tissue Hg concentrations were heavily sampled, whereas waterbodies with higher concentrations had lower sampling numbers.

Figure 13

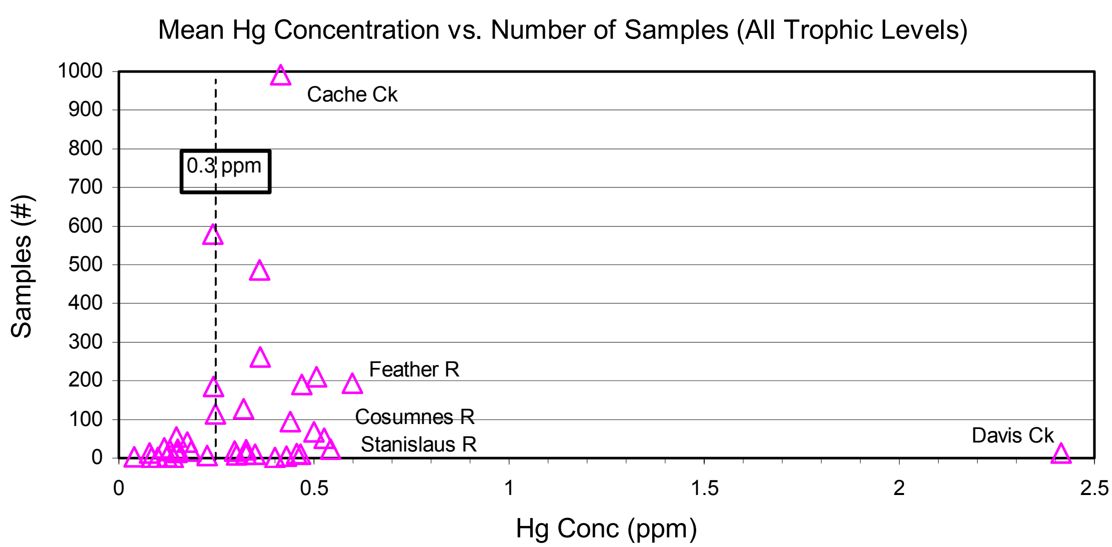
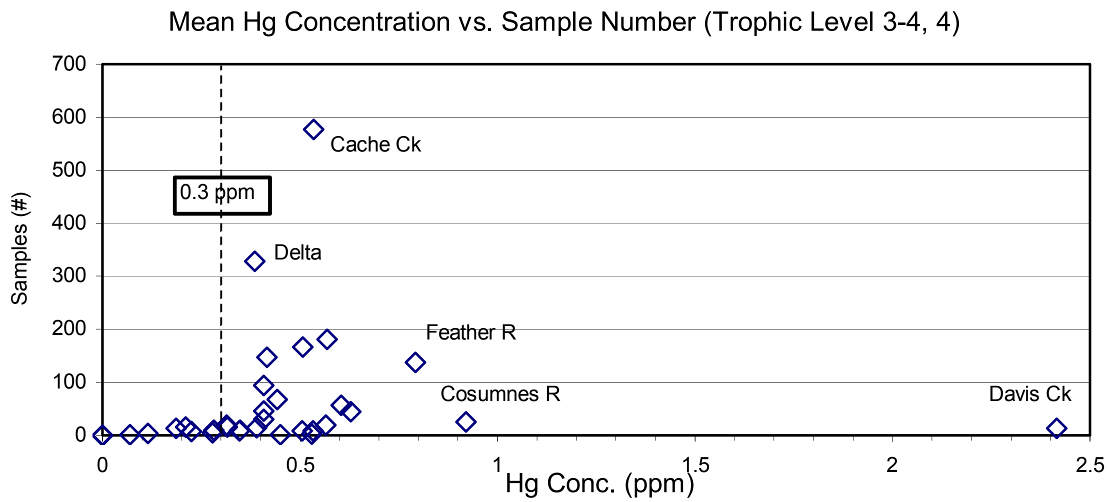
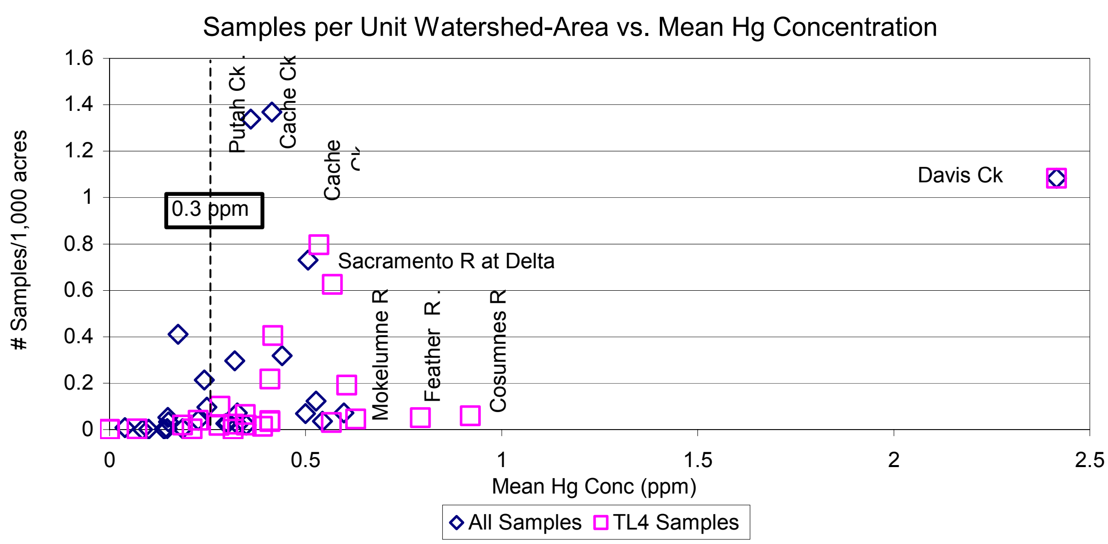


Figure 14



In order to correct for the possible effect of watershed size on sampling effort, the number of fish tissue samples for all trophic levels and for only trophic levels 3-4 and 4 were expressed per 1,000 acres of watershed and compared to mean Hg concentrations in the fish (figure 15). Putah and Cache Creek and the Sacramento River in the Delta had relatively high numbers of samples, with moderate mean Hg levels. Davis Creek had relatively high sampling intensity per unit area and the highest measured Hg concentrations in fish tissue. In comparison to these watersheds, the Cosumnes, Feather, and Mokelumne Rivers had very low sampling intensity and relatively high concentrations of Hg in fish tissue.

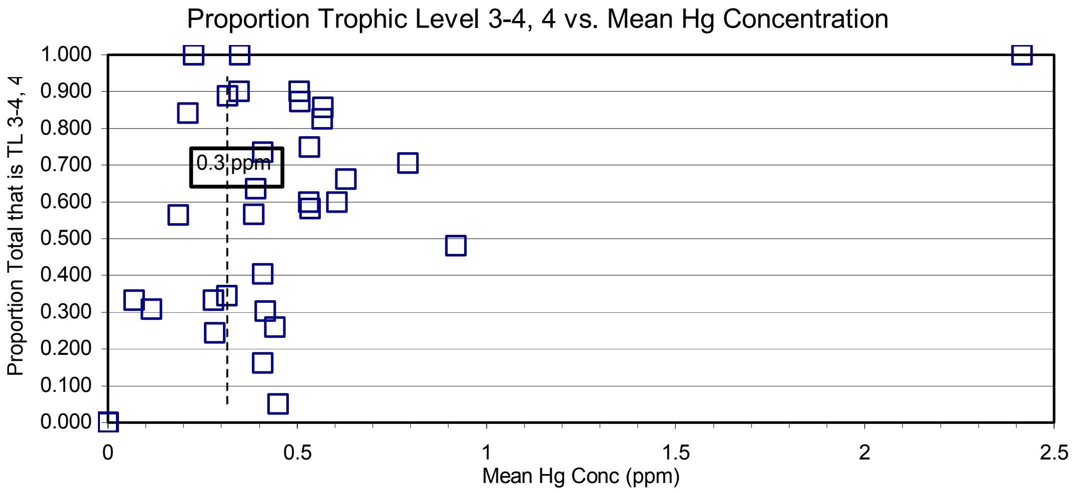
Figure 15



The observations in the previous three graphs point to a need for monitoring programs to increase the rate of sampling in rivers and creeks where there have been few previous measurements and those have shown high Hg concentrations (e.g., the Mokelumne, Feather, and Cosumnes Rivers).

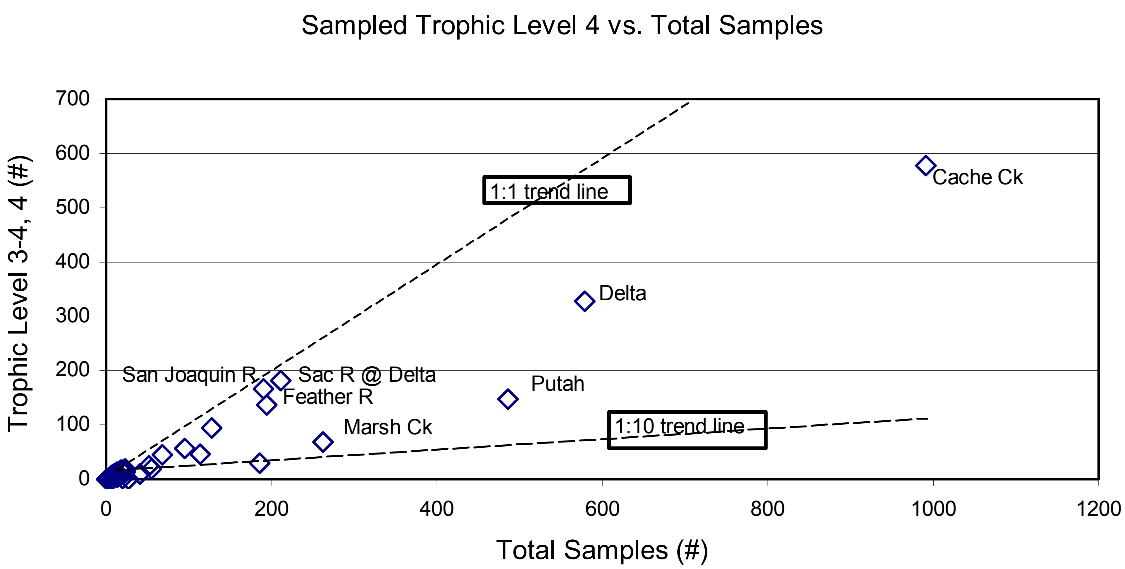
The proportion of all samples that were for trophic level 3-4 or 4 fish were compared to mean Hg concentrations (figure 16). This was in order to get an indication of how sampling was conducted in different waterways for higher trophic level fish that tend to be caught and consumed by humans.

Figure 16



There was no apparent linear relationship between these two parameters. However, it would be worth examining monitoring intensity relative to the nature of the monitoring need (e.g., subsistence fishing vs. biomagnificaition) in each waterway. For example, the highest concentrations measured were in the Davis Creek watershed and all samples were taken in trophic level 4 fish. Figure 17 shows the relationship between sampling for trophic level 4 fish relative to total sampling effort, which are not independent variables. Two lines are shown for reference indicating whether 100% or 10% of sampling effort was devoted to trophic level 3-4 and 4 fish. Cache and Putah Creeks and the Delta had the highest numbers of samples and relatively even distributions of sampling effort between trophic levels. In contrast, certain waterways, (e.g., the Yuba River watershed) had good sampling, but a low proportion of these were in trophic level 3-4 or 4 fish. This is a watershed where consumption of sport-fish is of concern.

Figure 17



A high proportion of sampling dedicated to trophic level 4 fish is appropriate for places where subsistence/sport-fishing or piscivorous wildlife occur, but may be less appropriate where one wishes to understand the amplification of Hg through trophic levels. Similarly, in heavily-fished waterbodies, one may want to have a relatively high proportion of sampling focused on trophic level 4 fish, though not an exclusive focus.

Not all waterways and watersheds have been equally sampled for fish tissue mercury. Certain waterbodies have received significant sampling intensity, while having lower mercury concentrations than other waterbodies with very low sampling intensity. Rivers originating from the Sierra Nevada that are tributary to the Sacramento and San Joaquin Rivers and the Delta have received low levels of sampling relative to the mean concentrations of mercury found in fish tissue (all trophic levels and trophic level 4) in what could be considered pilot studies. Decisions about supporting subsequent studies should take into account these distributions and carefully consider the types of questions the monitoring and measurements are intended to address.

iii. Social and Ethnic Considerations

There are a variety of communities in the Bay-Delta watershed that rely on fish caught from nearby waterways for economic or cultural reasons. These may have different types of response to surveying efforts, either because of language, perceptions of the role of the surveyors, or cultural divides between the surveyors and the surveyed populations. The creel survey data available is for mainstems of large rivers and reservoirs. According to CDFG staff, there is also considerable subsistence fishing activity for a variety of fish (e.g., splittail and black bass) in sloughs, canals, creeks, and unsurveyed reaches of major rivers in the Bay-Delta watershed. Many of these are in areas where there are high concentrations of Hg in fish tissue. There are suggestions of the ethnic diversity of communities from the combination of creel survey zip code data and census data. However, there is little information about the risk the communities face due to their choice of fishing location, their frequency of consumption, and who is consuming the fish. A recent nationwide survey found that blood mercury levels varies with race and ethnicity among women and children (Schober et al., 2003), which may be related to varying patterns of fish consumption across ethnicities. Surveying conducted under pilot studies for a comprehensive fish consumption study should be distributed evenly across the communities at high risk of exposure to Hg. Alternatively, there could be over-sampling of communities at the highest risk (e.g., subsistence fishers). A major data gap for this study was that there was not readily-available demographic data for census blocks (smaller than zip codes), as compared to census tracts (often larger than zip codes) for which there are such data. This gap meant that a grouping like "Asian" could not be disaggregated into component ethnicities, such as Vietnames, Cambodian, Taiwanese, etc. These data may be available commercially from vendors who specialize in these kinds of data manipulations.

VI. Conclusions and Recommendations

The primary conclusion is that angling populations are at risk in a variety of locations around the Bay-Delta watershed due to a combination of fish species, fish size, fish tissue Hg concentration, and fishing intensity. This risk seems to be spread throughout the watershed, with the concentration being greatest in a ring around the Bay-Delta encompassing valley-floor to foothill elevations and stretching from Butte County in the north to Merced County to the south. The center of the Delta actually seems to have lower risk, based on the lower concentrations of Hg in fish tissue in the center of the Delta.

There is not sufficient information to determine risk for all anglers and communities in the watershed because of incomplete creel survey and fish sampling data. However, there is sufficient information about mercury in fish tissue and fishing intensity in the Bay-Delta watershed to support the development of pilot fish consumption surveys. The combination of pilot surveys and data from expanded fish sampling for mercury and creel surveys may be enough information on which to found an understanding of the distribution of fish consumption patterns, a comprehensive fish advisory and public education, and estimated exposure rates for different consumption patterns. However, it is still not clear what form a Central Valley fish consumption study will take.

Recommendations

1) *Support the California Department of Fish & Game's creel survey programs for the Delta, reservoirs, and the Delta tributaries. Expand the programs to target species and areas with high concentrations of toxins such as methylmercury that put public health at risk*. Fishing intensity is a basic set of data for making many mercury-related decisions. For example, sampling fish for mercury contamination and conducting fish consumption surveys and education and outreach about health risk are best founded on adequate data about fishing intensity and other data from creel surveys.

2) *Base future monitoring of mercury in fish tissue on a combination of gaps in the spatial and temporal distribution of samples, the fish species caught, and the measured or estimated use of fish by human and animal consumers*. Patterns of sampling should reflect an informed and considered set of decisions about where fishing intensity is high, where past sampling has identified high concentrations of Hg, and where there may be high concentrations but no measurements have been taken. CALFED and other agencies should ensure that these connections are made with future sampling programs. In addition, the choice of fish species monitored for Hg should reflect at least in part, the distribution of fish caught by anglers, for which there is some information from CDFG.

3) *Increase the rate of fish tissue and angling monitoring in the San Joaquin River watershed.* There are comparatively few fish tissue samples for mercury concentration in the San Joaquin River watershed. For all fish species sampled, the majority of samples were taken in Delta or the Sacramento River watershed. This did not seem to be based on the apparent concentration of Hg in fish tissue and may instead by a sampling/sampler bias. There is also much less creel surveying done in this watershed than the Sacramento River watershed.

4) *Develop pilot fish consumption surveys in communities that span the geographic and demographic range of communities that are at risk from eating fish containing mercury. These surveys should also span the range of risk levels, from high-end consumers from places with high concentrations of mercury in fish (e.g., Cache Creek or Bear River watersheds) to moderate consumers in areas with relatively low concentrations of mercury in fish (e.g., the upper Sacramento River watershed)*. The Bay-Delta watershed is demographically diverse, which can be a confounding factor in determining risk of exposure from fish tissue by measuring fish consumption rates. In order to understand the boundaries on the risk to public health from mercury in fish tissue, pilot fish consumption surveys should include as a wide a range as possible of consumption patterns and fish sources.

4) *Support disconnected fish consumption surveys and fish consumption education and outreach. Support public education about risks from Hg in fish tissue in heavily-fished areas when that information becomes available, not just when fish advisories are developed*. By combining fish consumption studies and education about the potential risks from eating fish from certain areas, investigators may bias their understanding of the consumption rates in particular communities. There are many areas in the Bay-Delta watershed where there are past measurements of high concentrations of Hg in fish and observed fishing activity, but no advisory has been declared. If the responsible agency (OEHHA) cannot generate an advisory due to time, resource, or data limitations, there may still be a risk to public health that could be shared through public education without obvious liability for the agency responsible for educating the angling public. There should also be a balancing between advisories about fish consumption based on contaminants and the health benefits of fish consumption.

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Appendix A

Excel Files

ANGLINTENS9902.xls

Creel survey data for the years 1999-2002 are contained within this database. The original data collected included the information below (Table 1). Information on river mile, fish species kept and released, number of anglers on the shore and in boats, and the zip code of origin for a member of the angling group were obtained by querying the CDFG MS Access relational database. The queried data were entered into “ANGLINTENS9902.xls”.

Table A-1 Types of data collected in the California Department of Fish and Game’s angler survey database – Central Valley Region

PHYSICAL DATA

Survey Date	
Day type	- weekday or weekend day
Count weather	- weather conditions at start
Count start	- time survey was started
Count finish	- time survey completed
Interview weather	- weather conditions mid-way through interview
Interview start	
Interview finish	
Air temperature	
Water temperature	
Clerk name	

CATCH DATA

River mile	
Organism code	- species
Fork length	- for salmon and very few sturgeon and stripped bass
Mark or tag	
Condition	- salmon and steelhead (bright or dark)
Comments	- tag information

CATCH NUMBER

Organism code	-species
Kept	- number of fish kept (based on interview)
Released	- number of fish released (based on interview)

COUNT DATA

River mile	
Time	-record time spent at each river mile
Number boat	-number of boats observed
B_anglers*	-anglers fishing from boats
S_anglers*	-anglers fishing from shore

*represents all anglers observed during the observation period (approximately 2 hours).

INTERVIEW DATA

River mile	
Number anglers	- this represents the number of anglers in a group (1 or more) interviewed
Target species	- anglers are questioned regarding the species they are trying to catch
Method	- boat or shore
HrsFished	- recorded by the ¼ hr.
Zip code	- only one zip code per interview (even if a group is interviewed).
Done	- anglers are asked if they are finished fishing for the day, rarely do Fish and Game staff find this to be the case.

2003Feb25_RegBrd5-FishHgData.xls

The field names listed below are from the original database from the Regional Board. Not all fields were retained in subsequent work files (e.g., "FishHgDatabyWatershed.xls") and some were slightly modified.

Table A-2 Field names and definitions from the Regional Boards database for mercury in fish tissue.

"SITES" & "DATA" Column Heading Definitions

Regional Board staff has adapted the use of these fields from the CCAMP database.

Util – This "number" field is included as the first column of each spreadsheet. It can be used for numerous purposes. For example, if the user wants to sort a data set, but then return it to its original order, UTIL can be filled with sequential numbers (1,2,3…) prior to the sort, so that the initial order can easily be restored. *[Regional Board staff use "util" to sort "DATA" records by the order the samples were originally listed in reports/electronic files.]*

ProjID - Project ID - This "text" field contains an abbreviated project name, for use in project pick lists, map labels, project file naming, etc. This should correspond exactly to the ProjID entry in the Projects sheet. The ProjID can be combined with the "SiteName" to form a unique identifier for every sampling location. *[Note, some Project reports presented compilations of data that included data presented in other reports by the same or different agencies. Regional Board staff made a good faith effort to delete such "duplicate" records from this data set; however, the user should carefully review data for duplicates before conducting analyses.]*

WatershedTag – This "number" field contains the Hydrologic Sub Area number for this particular site. *[Regional Board staff used the State Board's GIS ArcView HSA coverage to determine WatershedTag. If the HSA number indicated by the GIS ArcView coverage differed from the Tag determined by the TSM for TSM sites (e.g., the site was near a HSA boundary), Regional Board staff used the TSM tag.]*

SiteTag – This "text" field contans a short alphanumeric tag used to identify sites on maps, sampling sheets, etc. *[Regional Board staff uses the TSMP tag convention. Each station is identified by a unique seven-digit number derived from the State Water Board's hydrologic basin planning maps. The first digit of a station number signifies one of the nine Regional Water Boards. The second and third digits represent a hydrologic area, while the fourth and fifth digits identify a hydrologic subarea. The sixth and seventh digits represent the distance in miles above the downstream hydrologic boundary. For example, station 519.21.01 is in Region 5, hydrologic area 19, subarea 21, and is one mile upstream from the hydrologic unit boundary. Not all mileage indicators are accurate, however. In certain instances, it was necessary to assign an arbitrary mileage indicator. For example, the arbitrary designation is used when two or more stations within the same hydrologic subarea are located within the same number of miles of the hydrologic boundary, resulting in the same station number. In this case, one or more of the stations is arbitrarily assigned a mileage designator. ***As of 11 February 2003, Regional Board staff has not completed the development of an updated set of Site Tags for all sampling locations for programs other than the TSMP.**** Note: the CCAMP protocol is to attach a three-letter acronym to the Hydrological Unit number (for example, 309DAV). Regional Board staff is NOT using this convention.]

RiverMile - This "number" field contains the distance in miles above the downstream terminous of a river or creek. Regional Board staff cited the river miles noted on USGS 7.5' topographic quads, when river miles were illustrated. For smaller waterways where the USGS did not note river miles, staff approximated the distance using the ArcView "Measure" tool and USGS 7.5' topographic quads images. Sites that fall between River Miles 0 and 1 are labelled "0"; sites that fall between River Miles 1 and 2 are labelled "1", and so forth. Regional Board staff uses river mile values to correlate fish tissue mercury data to CDFG creel survey data, which is organized by river mile. This number may or may not equate to the distance in miles above the downstream hydrologic unit boundary, which is used for the SiteTag. *[Note, Regional Board staff has not entered all possible river mile information for the Delta as of 11 February 2003; this task is a work in progress.]*

H2OBody - This field provides the name of the watershed in which the samples was collected.

DeltaSubRegion - Regional Board staff divided the Delta into subregions based on mercury levels in biota and tributary Hg sources. This is a preliminary assignment that staff will refine as TMDL analyses continue.

SiteName - Regional Board staff listed the site names more or less as listed in the original studies. The ProjID can be combined with the "SiteName" to form a unique identifier for every sampling location.

SiteDesc - Site description.

StreamOrder - For some waterbodies, Regional Board staff indicated the upstream-to-downstream order that sites occurred.

SampleYear - This "number" field contains the year the sample was collected. *[In at least one project included in this file, UCDavis1, the data set included only a range of years, e.g., 1997-1999, rather then the specific date each sample was collected. Therefore, the "Year" is expressed as the most recent year in the range, and the "DateTime" is expressed as a range for such samples.]*

DateTime - This is the Date and Time the sample was taken, expressed in the following date format: 5/30/97 15:30. *[This format is not compatible with much of the available fish data sets. For example, much of the available data sets provide only the year sampled, or the month and year sampled. This field may contain either "numbers", "dates", or "text" and will not import easily into Access.]*

Purpose – This column is left blank for all routine sample data. Other information about the sample can be stored in this data sheet by identifying its purpose in this field. Placing characters in this column causes the program to ignore data in the corresponding data fields when calculating averages, time trends, etc. As an example, if both PQLs and MDLs are recorded for each sample, three lines of data will be required for a given site at a given date and time, one for the data itself, and one each for the MDL and PQL information. For some data sets, PQLs, MDLs, method number, or equipment IDs do not change frequently. For any given project, the program will assume the most recent information applies to data entered after that point. Hence, if MDLs do not change for a given parameter, they need be entered only once for a given project, at the date and time the data is first collected.

Routine Sample Data – Leave field blank

FD - Field Duplicate

LD - Lab Duplicate

FB - Field Blank

LB - Lab Blank

LS - Lab Spike

PQL – Practical Quantification Limit

MDL – Minimum Detection Limit

Method or Equipment ID – defined on the Methods worksheet. Use the actual method number for lab methods, and a unique user defined ID for a specific piece of equipment (for example, a serial number)

Matrix –Matrix choices are listed below (Note: in Options you can select display of either Resident or Transplanted tissue). You can select from the control menu for all tissue data, but if you want to look at more specific tissue types (MATRIX1), you need to select these in Options. *[This "All Fish Data" file contains only "TIS" data.]*

SED (Sediment)
H2O (Water)
TIS (Tissue)
EFF (Effluent)
INF (Influent)
STO (Stormwater)
OT (Other)

MATRIX1 – A more detailed description of tissue types. *[Bold text indicates categories used by Regional Board Staff; filling in this column is a work in progress.]*

FF - Freshwater Fish
IV - Invertebrate (crayfish, shrimp, amphipods, isopods)
MO - Mollusk (clams and mussels)
MF - Marine Fish
OT - Other (e.g., bullfrog tadpoles)
BNC - Bent Nosed Clam
CM - California Mussel
FC - Freshwater Clam
GLY - Sand worm (Glycera spp.)
IS - Insect (caddis fly larvae)
LNC - Littleneck clam (Protothaca sp.)
OYS - Oyster
PAC - Shore crab (Pachygrapsus crassipes)
POD - Jingle shell (Pododesmus spp.)
BM - Bay Mussel
RBP - Benthic Invertebrates
ROA - California Roaches
SCR - Sand Crab (Emerita analoga)

TisSourc – This field is used to record whether tissue is from resident organisms or organisms that have been transplanted from some other location. *[TSM includes this information with its sample results; Regional Board staff has not attempted to discern such information for other published studies.]*

SampleID – This field is for recording lab identification numbers associated with the sample

WtType – This column is used to indicate whether data is being expressed as dry weight, wet weight, or lipid weight. *[Regional Board staff has not used this column; instead, staff included separate columns for dry weight mercury, wet weight mercury, dry weight methylmercury, and wet weight methylmercury, as well as associated data qualifiers for each analyte.]*

dw – Dry Weight
ww – Wet Weight
lw – Lipid Weight

QAQC – This field can be used to turn off the automatic data-checking tool that is available on the CCAMP Analytes worksheet. *[Regional Board staff has not used this field but may in the future.]*

Sampler – Name of person doing sampling

Notes – Information about conditions at a site on a given sampling day. For example, "Cows standing in creek immediately upstream of site"

For Tissue Chemistry Data only:

These fields are consistent with the State Mussel Watch Program and Toxic Substances Monitoring Program data formats.

Genus

Species

Common – common name

TrophicLevel - This "text" field indicates trophic level (TL) designations based on each organism's feeding habits using the following criteria: TL1 - Phytoplankton; TL2 - Zooplankton and benthic invertebrates; TL3 - Organisms that consume zooplankton, benthic invertebrates and phytoplankton; and TL4 - Organisms that consume TL3 fish. These TL definitions are used in the USEPA's 1997 Mercury Study Report to Congress and in the Regional Board's 2001 Clear Lake TMDL for Mercury Numeric Target Report.

TLAssigner - The last name of the person, or the citation, that evaluated the trophic level of a particular species. Anastasia Stanish [Stanish] and Michelle Wood [Wood], both Regional Board Environmental Scientists, based their evaluations on information provided in: Moyle PB, 2002. Inland Fishes of California. Berkeley: University of California Press. "Harnly et al., 1997": Harnly, M., S. Seidel, P. Rojas, R. Fornes, P. Flessel, D. Smith, R. Kreutzer, and L. Goldman. 1997. Biological monitoring for mercury within a community with soil and fish contamination. Environmental Health Perspectives, 105(4): 424-429.

Age - This "text" field indicates fish age in years.

Number – number of individuals in composite

Individual&Composite - An "x" in this column indicates that the same fish was included in both an individual sample and a composite sample, with the results for both included in this dataset as separate records. The UCDavis3 project included such data, and more may be included in the future. When analyzing the enclosed data, the user should be certain not to "double-count" the same fish if it is included in both individual and composite samples.

Weight – Weight of sample in grams.

Length – Length of organism in millimeters (average length of sample is a composite)

Length Type – Type of length measurement: **FL** (fork length), **Car** (Carapace), **TL** (total length). *[Length values for composite samples are typically reported as average length. However, UCDavis3 reported median values with no indication of type of length measurement. This is indicated by "median" in this column. Also, some studies indicated subjective measurements, e.g., "small" or "large"; such descriptors are included in this field.]*

Tissue – Part of body sampled:

- **W** – Whole
- **F** – Fillet
- **L** – Liver
- **ST** – Soft Tissue (e.g., clams minus shells)
- **O** – Ova (fish eggs)

Pwater – Percentage water by weight.

Plipid – Percentage lipids by weight.

Duration – Length of time deployed in field.

Specific Analyte Columns - Regional Board staff included separate columns for dry weight mercury, wet weight mercury, dry weight methylmercury, and wet weight methylmercury concentrations, as well as columns for data qualifiers for each analyte. All results are presented in parts per million (ppm). If results were below the method detection limit (DL) or reporting limit (RL) and the data source provided the DL or RL value, staff included that value in the results field and qualified the results in the associated "Qual" column. If no DL or RL value was available, staff left the results field blank and qualified the results in the associated "Qual" column.

FishHgDatabyWatershed.xls

Fish tissue Hg data from Regional Board were sorted by river or creek watershed into separate worksheets for the following waterways: American River, Arcade_SteelheadCk, Bear R, Big Chico Ck, Butte Ck, Cache Ck, Calaveras R, Clear Ck, Colusa (Trough), Cosumnes R, CottonwoodCk, Misc, Davis Ck, Deer Ck-Yuba, Deer Ck, Delta, Dry Ck, Feather R, Marsh Ck, McCloud R, Merced R, Mill Ck, Mokelumne R, Morrison Ck, Natomas E Dr, Pit R, Pope Ck, Putah Ck, Sacramento R @ Delta, Sacramento R main-stem, Sacramento Slough, San Joaquin R @ Delta, San Joaquin R main-stem, Stanislaus R, Stony Ck, Sutter Bypass, Tulare Lk Basin, Tuolumne R, and Yuba R

The database also contains a worksheet that compares measured fish tissue Hg with size of watershed, trophic level, and sampling effort (“HgSummSheds”). There are several graphs derived from this worksheet that compare Hg concentrations to watershed area (“HgvsWatershedArea”), number of samples per unit watershed area (“HgvsAreaCorrSample#”), proportion of sampled fish that were trophic level 3-4 or 4 (“PropTL4vsHg”), proportion of total sampled fish that were trophic level 3-4 or 4 (“TL4vsTotalSamples”), number of sampled trophic level 3-4 and 4 fish (“HgvsSampTL4”), total number of sampled fish (“HgvsAllSample”).

Appendix B

Geographic Information System

General Information

All spatial data are in Albers Conical Equal Area projection (Clarke 1866), North America Datum 1927.

River Miles

This map contains the river mile number and the point number. The river miles are equivalent to the Department of Fish and Game's system for numbering river miles along particular rivers that are tributary to the Bay-Delta. Only the river stretches that had creel survey data were mapped. The original map of roughly 200 river miles of the Sacramento River mainstem was obtained from Dr. Steve Greco (UC Davis). This map was augmented by extending the Sacramento River and the tributaries surveyed by CDFG. These additional points were digitized on-screen using as a guide the National Hydrography Database map of hydrography at a scale of 1:14,000. While digitizing, way points were used with intervals of 0.01 to 0.1 miles in order to retain as much natural curvature as feasible.

Final fish hg sites

This map contains the fish tissue mercury data summarized by fish class size and includes information about the sites. The field names were derived from the Regional Board's MS Excel database of fish tissue Hg (2003Feb25_RegBrd5-FishHgData.xls, see above) and include intuitively obvious titles such as "watershed" and "sitename". The fish name code fields were derived from the California Department of Fish and Game's nomenclature for California native and non-native fish. The fish name codes (e.g., BLGLL for "bluegill") are followed by numbers indicating the size class of the fish (e.g., BLGLL200 for bluegill between 100 and 200 mm in length). The following table shows the codes and common names of the fish in the database and map.

Table A-3 Fish name code and common name for the digital map of mercury concentrations in tissue from different species of fish.

Fish Name Code	Fish Common Name
BCR	Black Crappie
BLGL	Bluegill
BNT	Brown Trout
CRP	Carp
CFBNH	Brown Bullhead
CFBKH	Black Bullhead
CFCH	Channel Catfish
GOBY	Goby
GSHN	Golden Shiner
HCH	Hitch

HDH	Hardhead
KOK	Kokanee Salmon
KS	King Salmon
LMB	Largemouth Bass
PRCH	Perch
ROCH	Roach
RSHN	Red Shiner
RT	Rainbow Trout
SB	Striped Bass
SBF	Sacramento Blackfish
SCP	Sculpin
SKR	Sucker
SMB	Smallmouth Bass
SPB	Spotted Bass
SPK	Sacramento Pike Minnow
STB	Stickleback
SUNF	Sunfish
TFS	Threadfin Shad
WCF	White Catfish
WCR	White Crappie
WHB	White Bass

Appendix C

Figure C-1

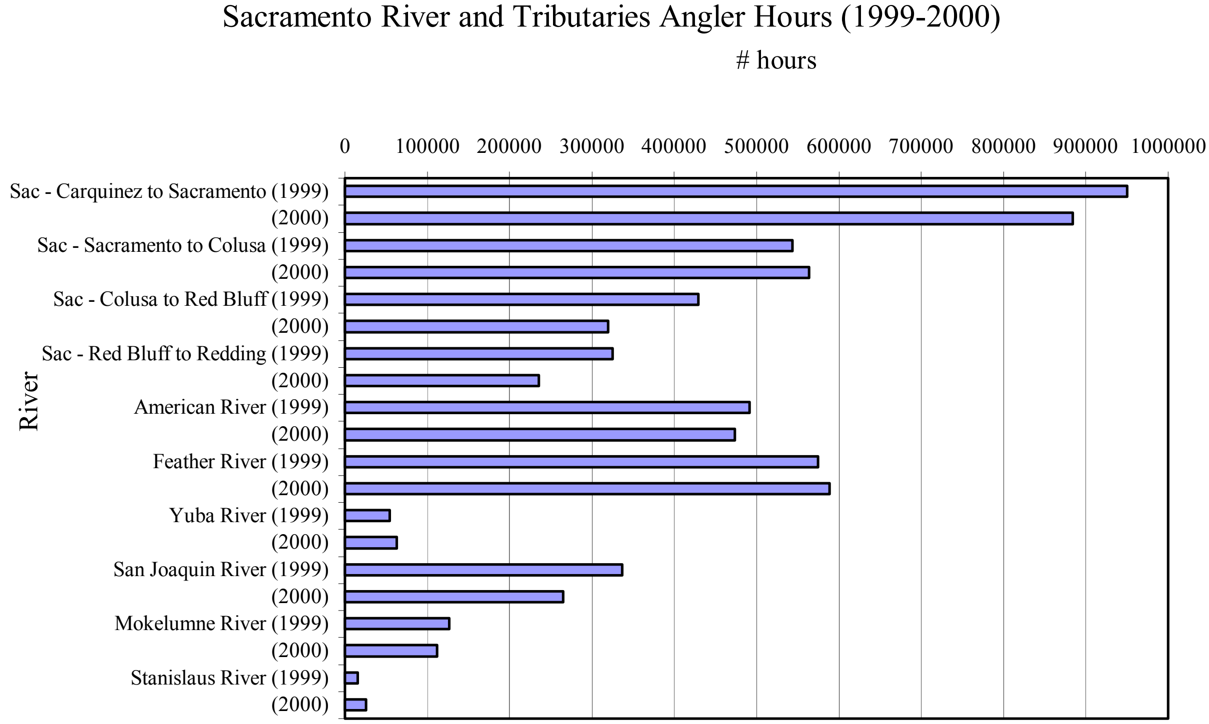


Figure C-2

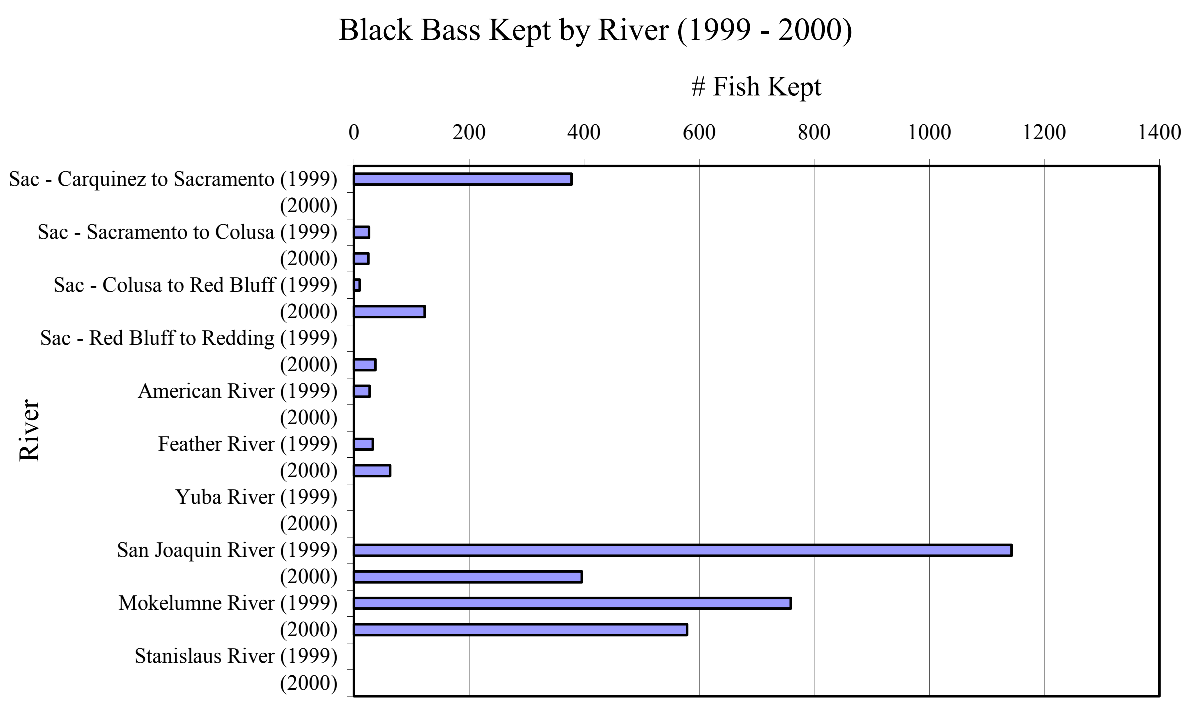


Figure C-3

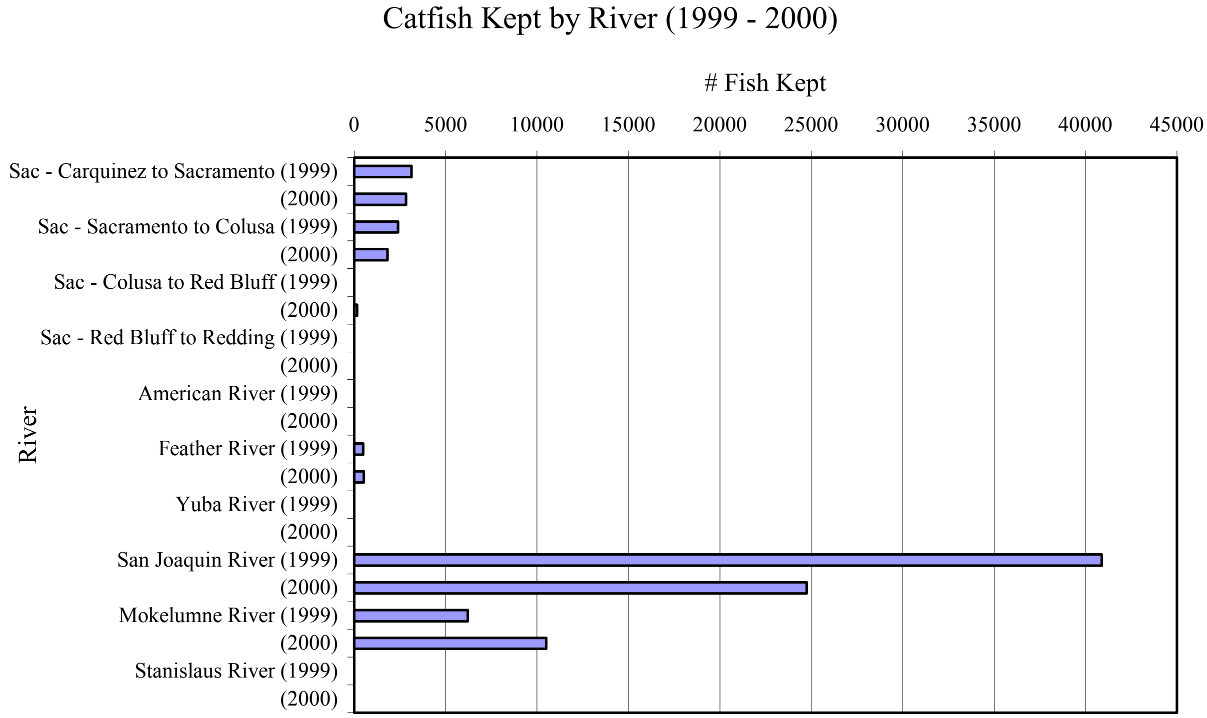


Figure C-4

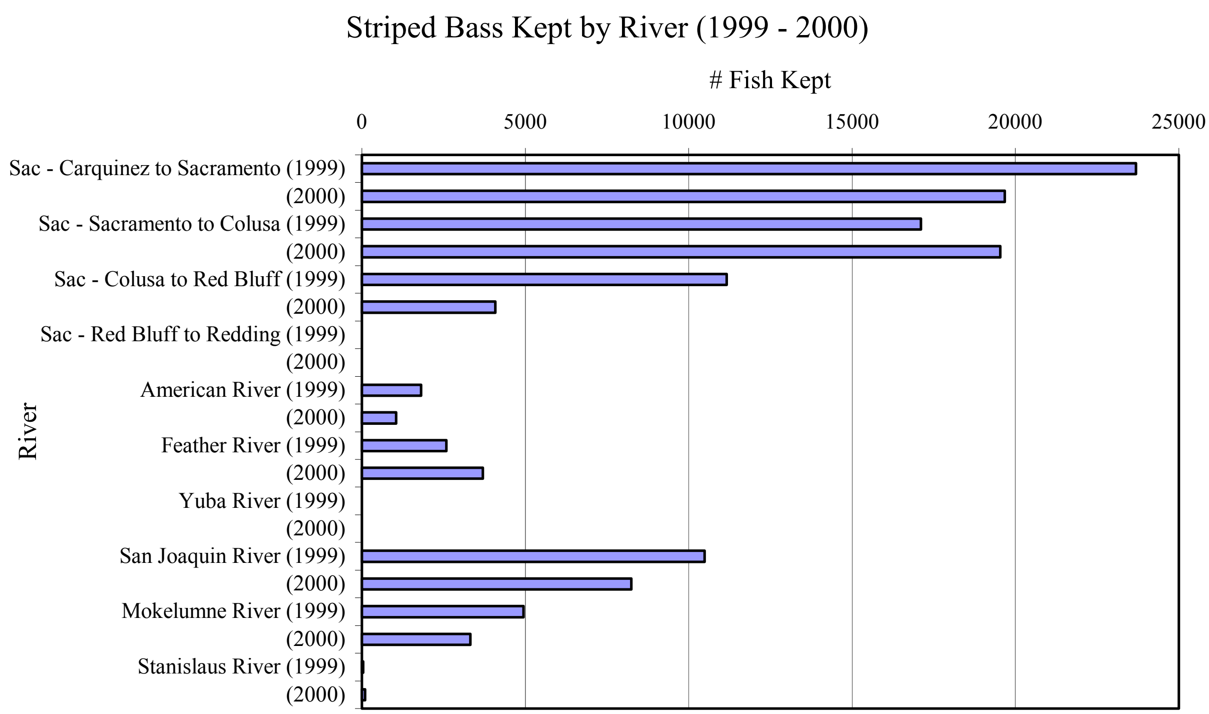


Figure C-5

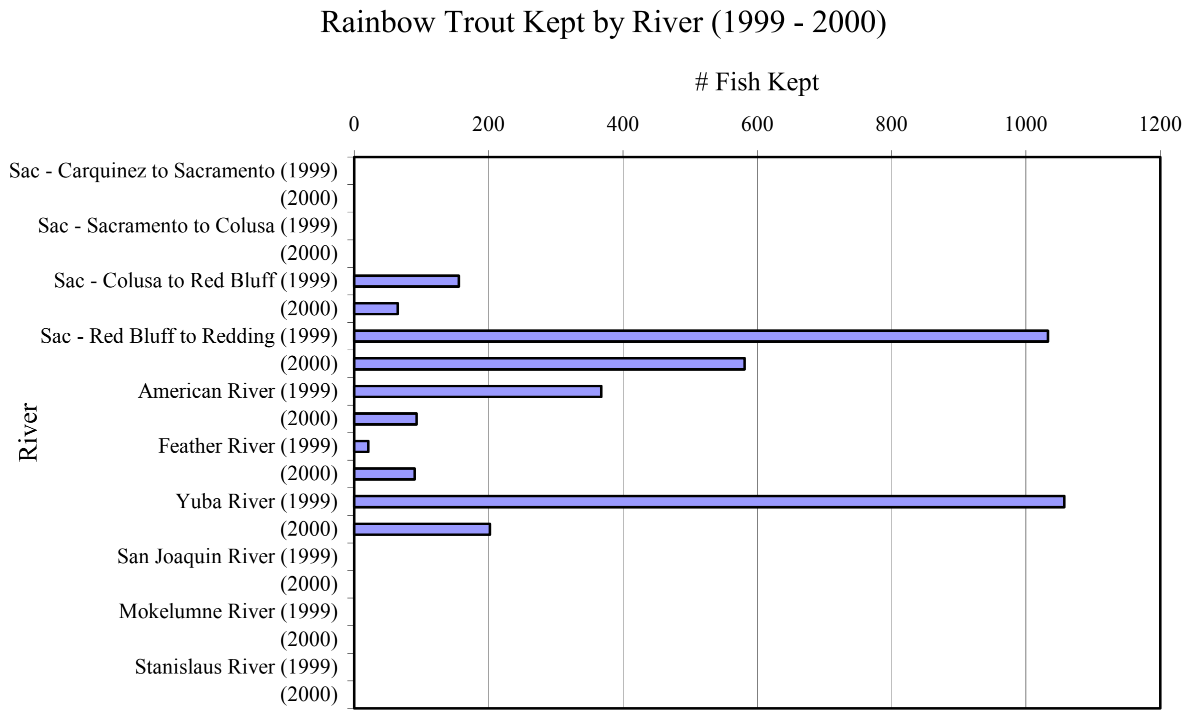


Figure C-6

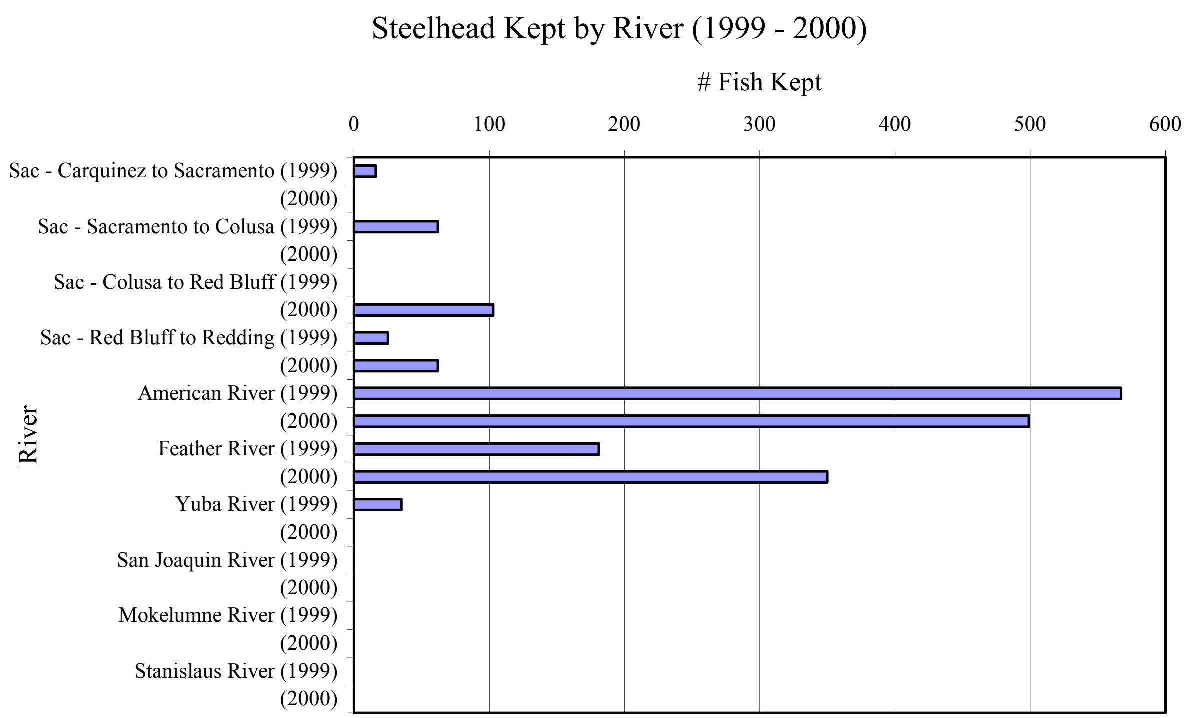


Figure C-7

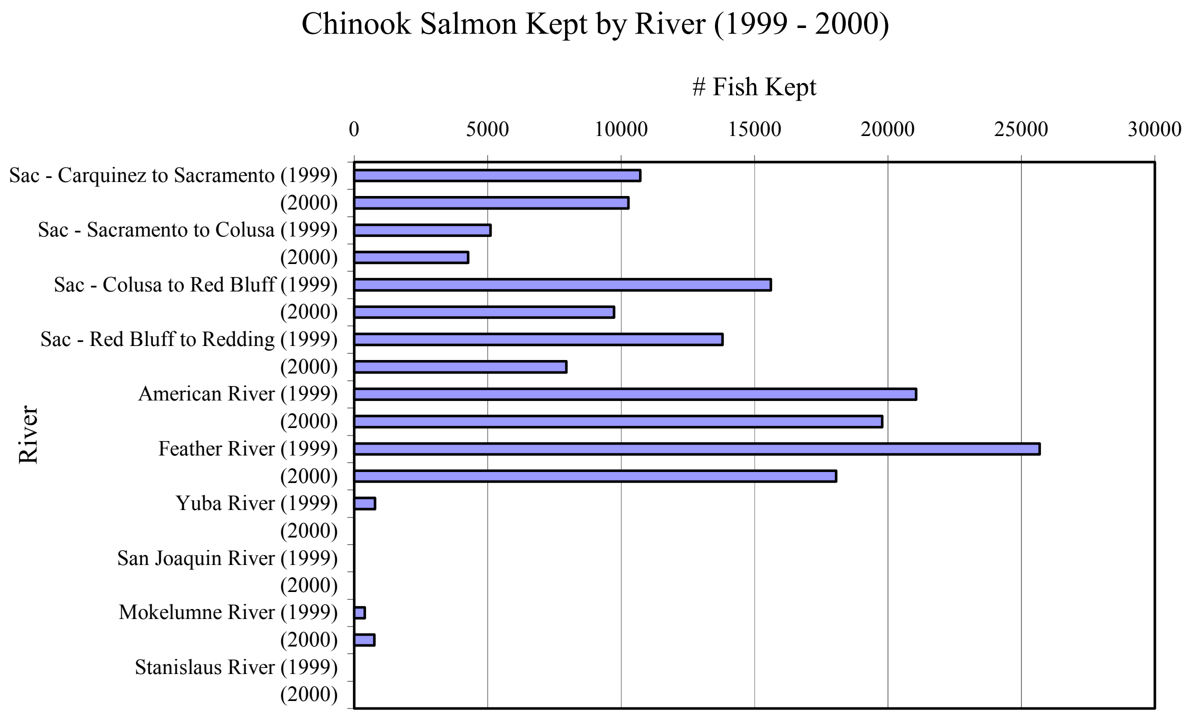


Figure C-8

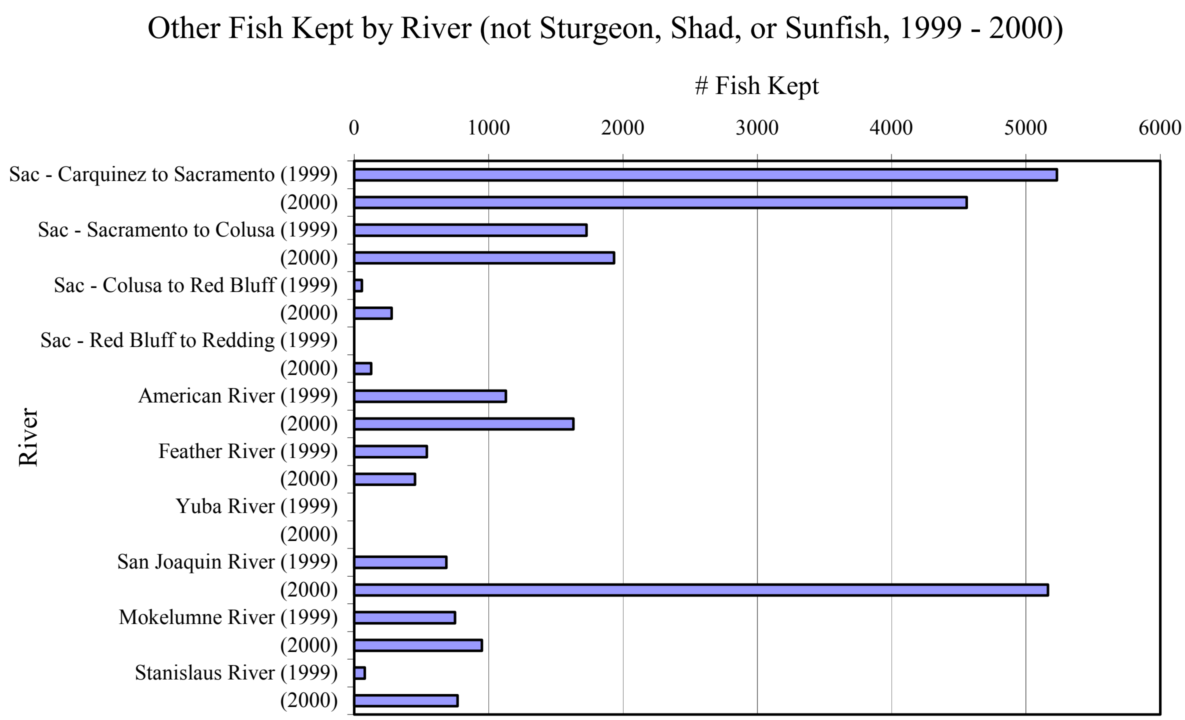


Figure C-9

Total Fish Caught and Kept in Central Valley and Sierra Nevada Reservoirs per Watershed 1999-2000

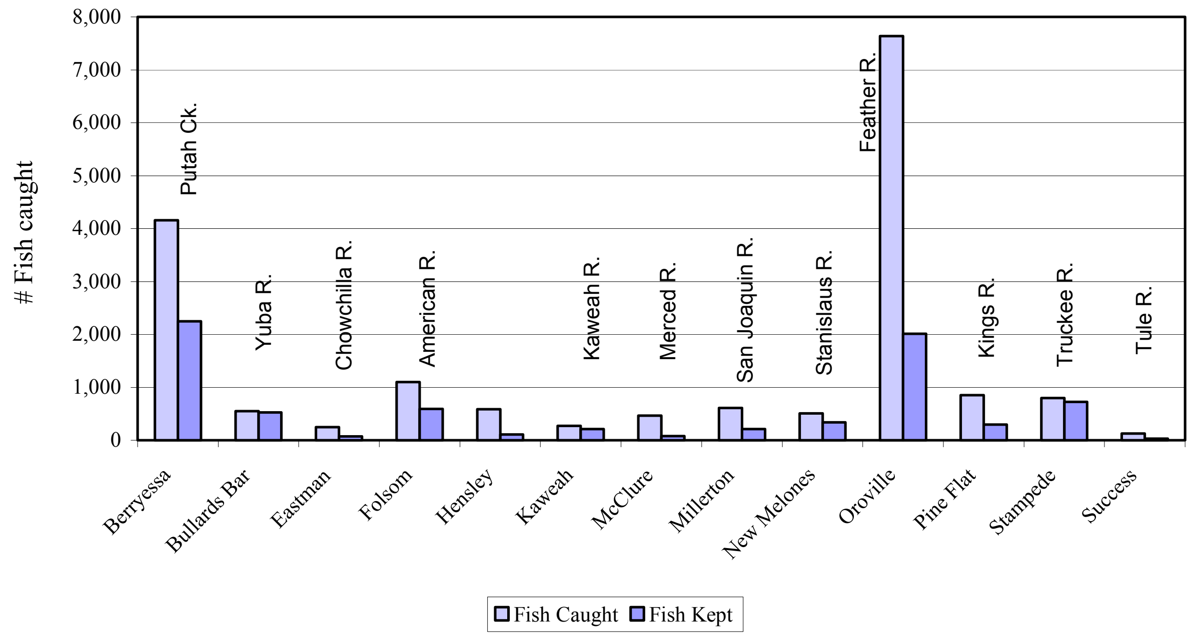


Figure C-10

Fish Caught and Kept in Central Valley and Sierra Nevada Reservoirs 2000-2001

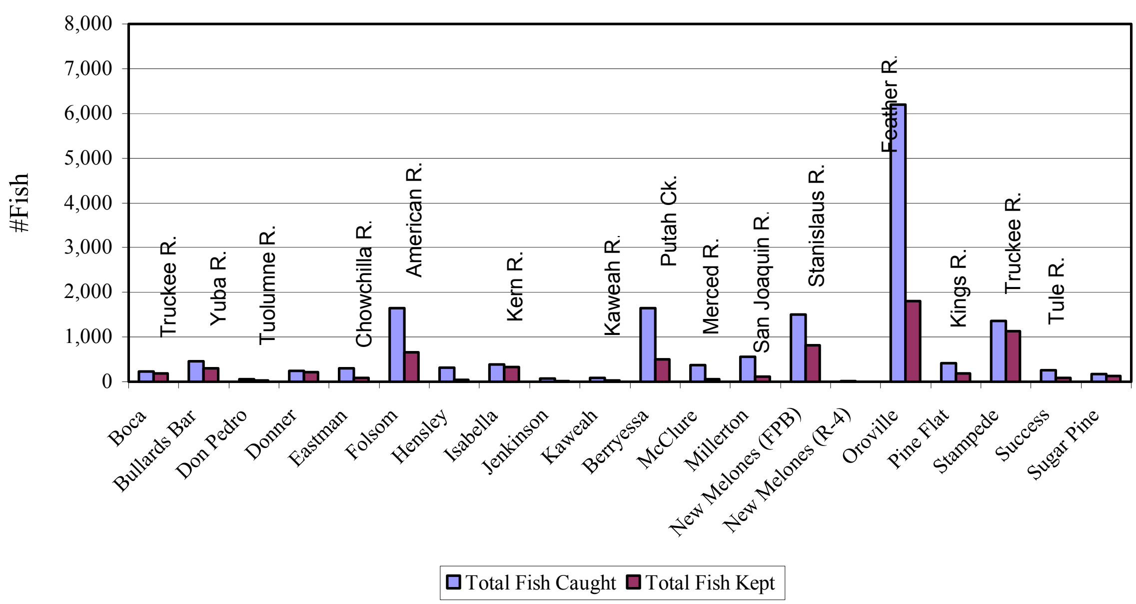


Figure C-11

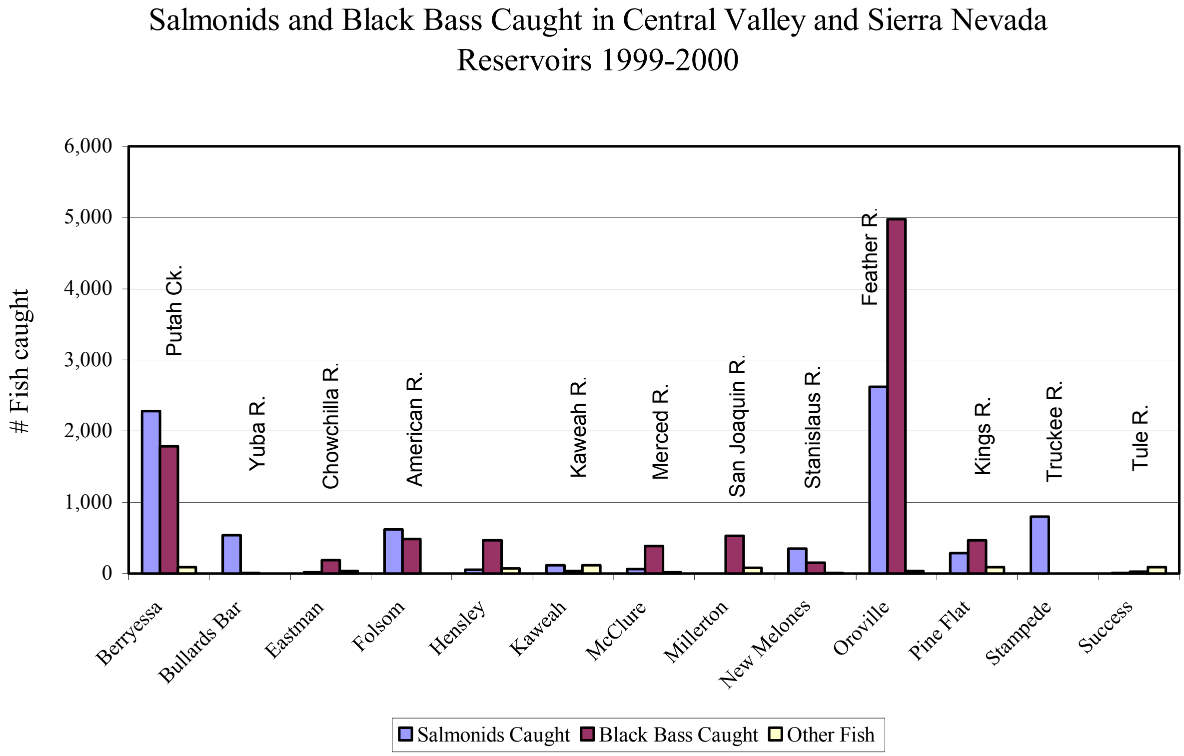


Figure C-12

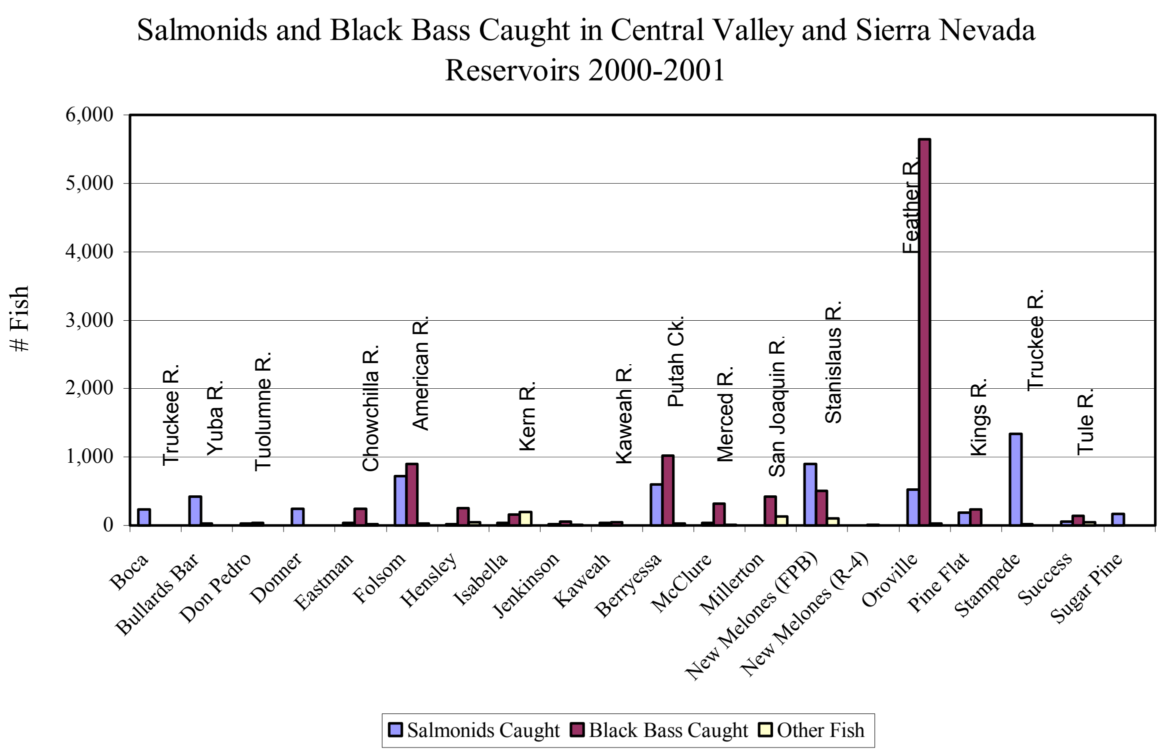


Figure C-13

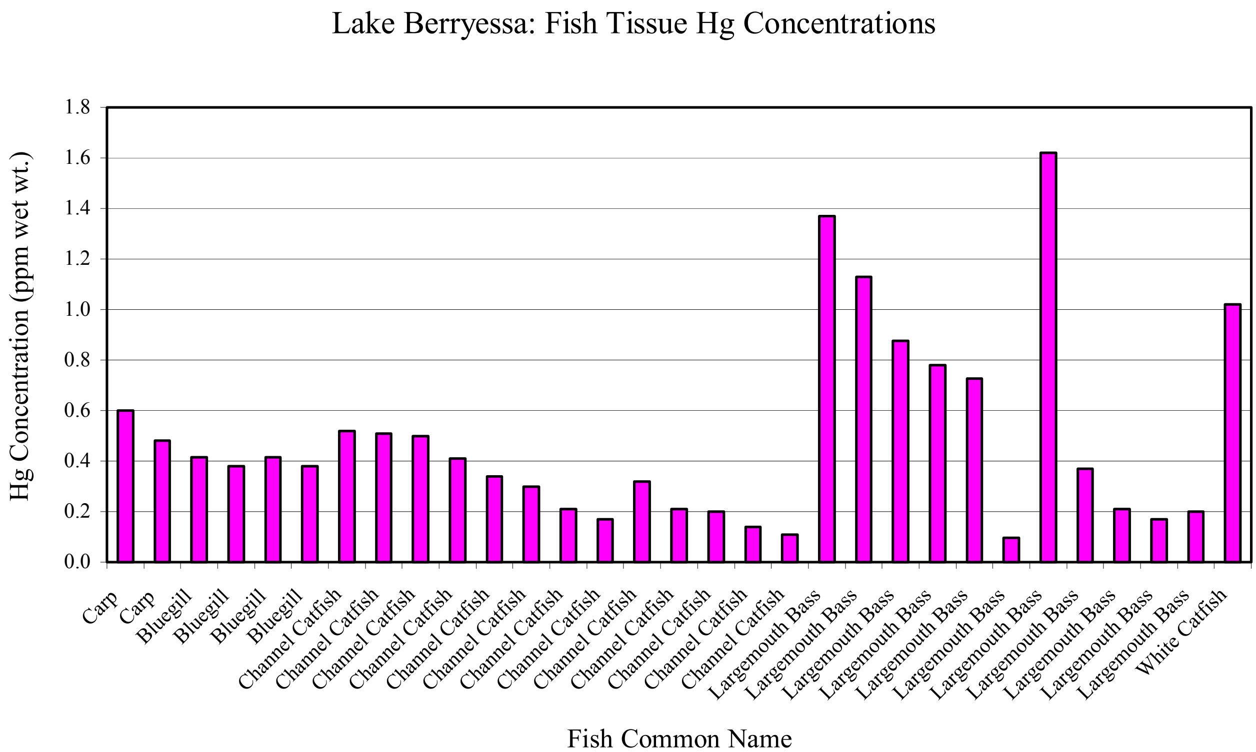


Figure C-14

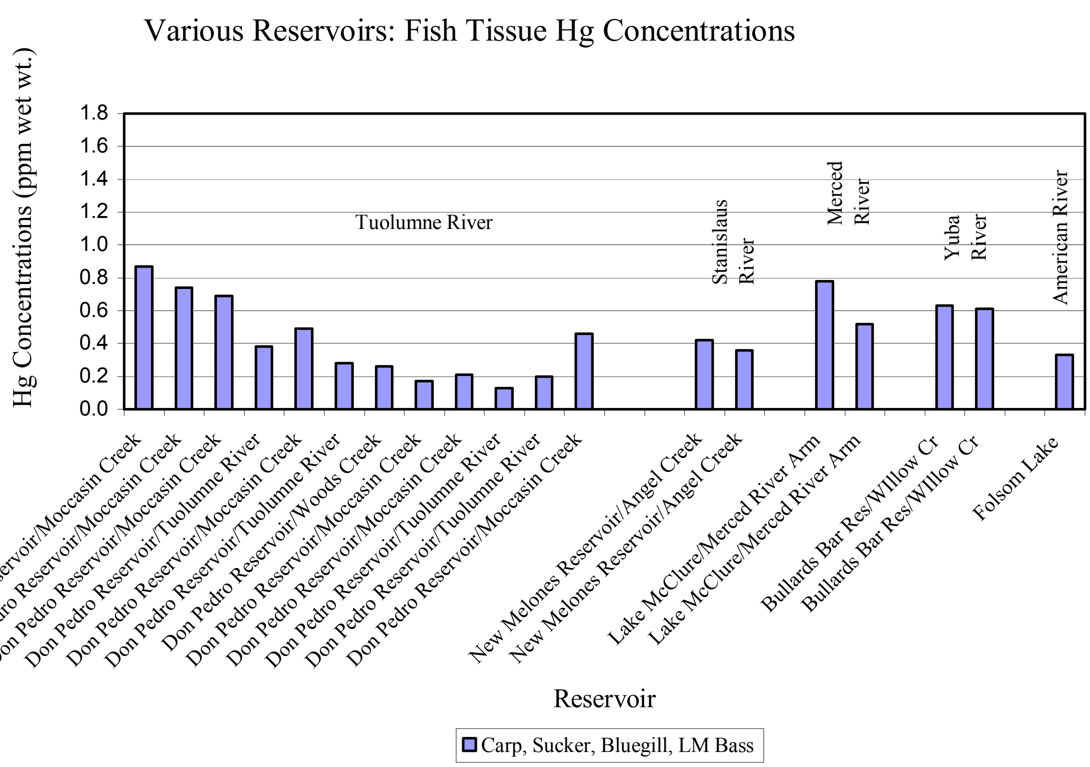
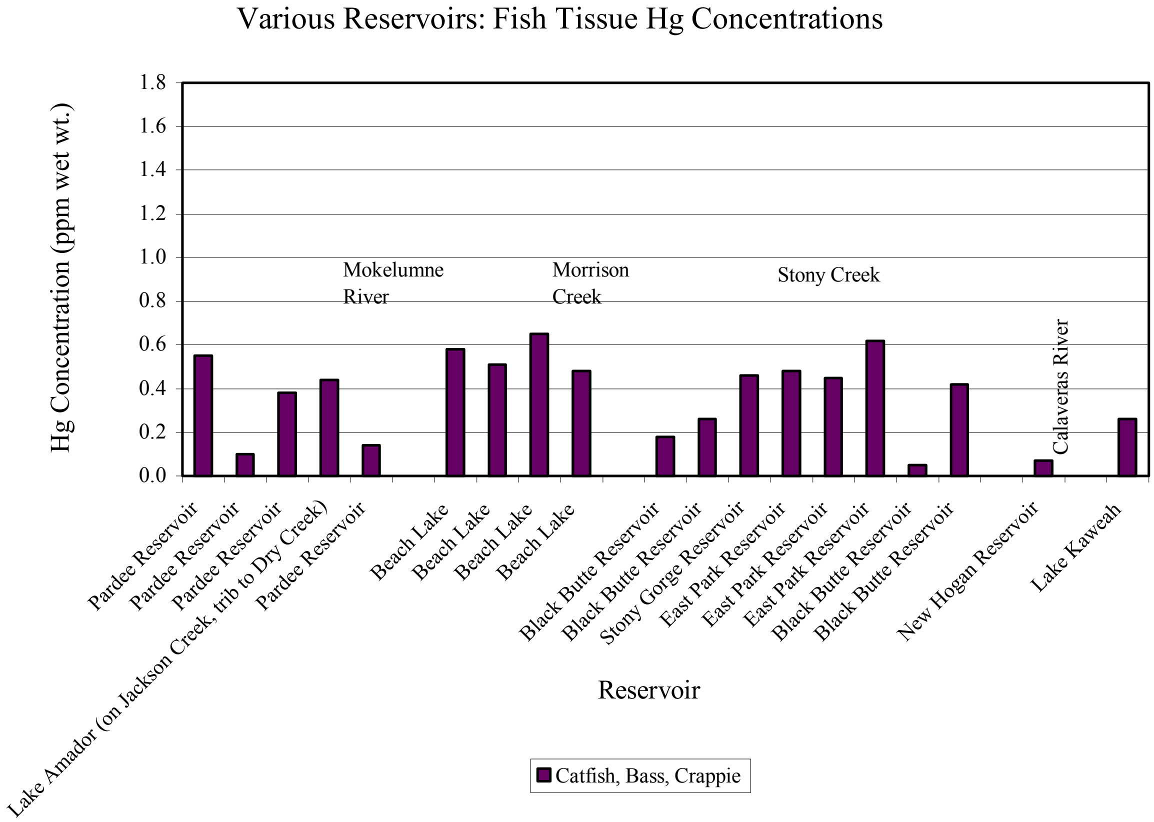


Figure C-15



Various Reservoirs: Fish Tissue Hg Concentrations
Hg Concentration (ppm wet wt.)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Mokelumne River
Morrison Creek
Stony Creek
Calaveras River
Pardee Reservoir
Pardee Reservoir
Pardee Reservoir
Lake Amador (on Jackson Creek, trib to Dry Creek)
Pardee Reservoir
Beach Lake
Beach Lake
Beach Lake
Beach Lake
Black Butte Reservoir
Black Butte Reservoir
Stony Gorge Reservoir
East Park Reservoir
East Park Reservoir
East Park Reservoir
Black Butte Reservoir
Black Butte Reservoir
New Hogan Reservoir
Lake Kaweah
Reservoir
Catfish, Bass, Crappie

Figure C-16

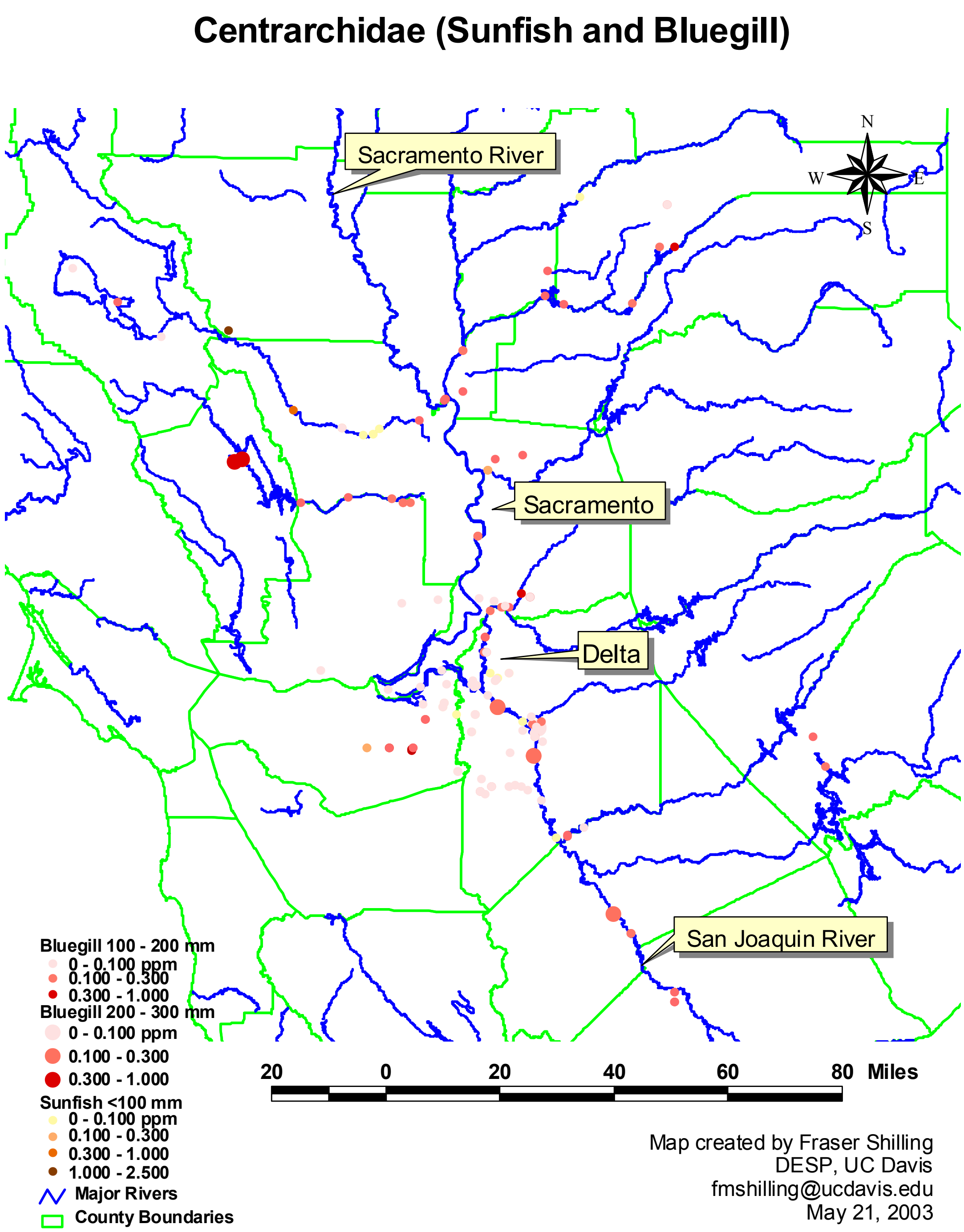

Centrarchidae (Sunfish and Bluegill)
Sacramento River
Sacramento
Delta
San Joaquin River
N
W
E
S
Bluegill 100 - 200 mm
0 - 0.100 ppm
0.100 - 0.300
0.300 - 1.000
Bluegill 200 - 300 mm
0 - 0.100 ppm
0.100 - 0.300
0.300 - 1.000
Sunfish <100 mm
0 - 0.100 ppm
0.100 - 0.300
0.300 - 1.000
1.000 - 2.500
Major Rivers
County Boundaries
20 0 20 40 60 80 Miles
Map created by Fraser Shilling
DESP, UC Davis
fmshilling@ucdavis.edu
May 21, 2003

Figure C-17

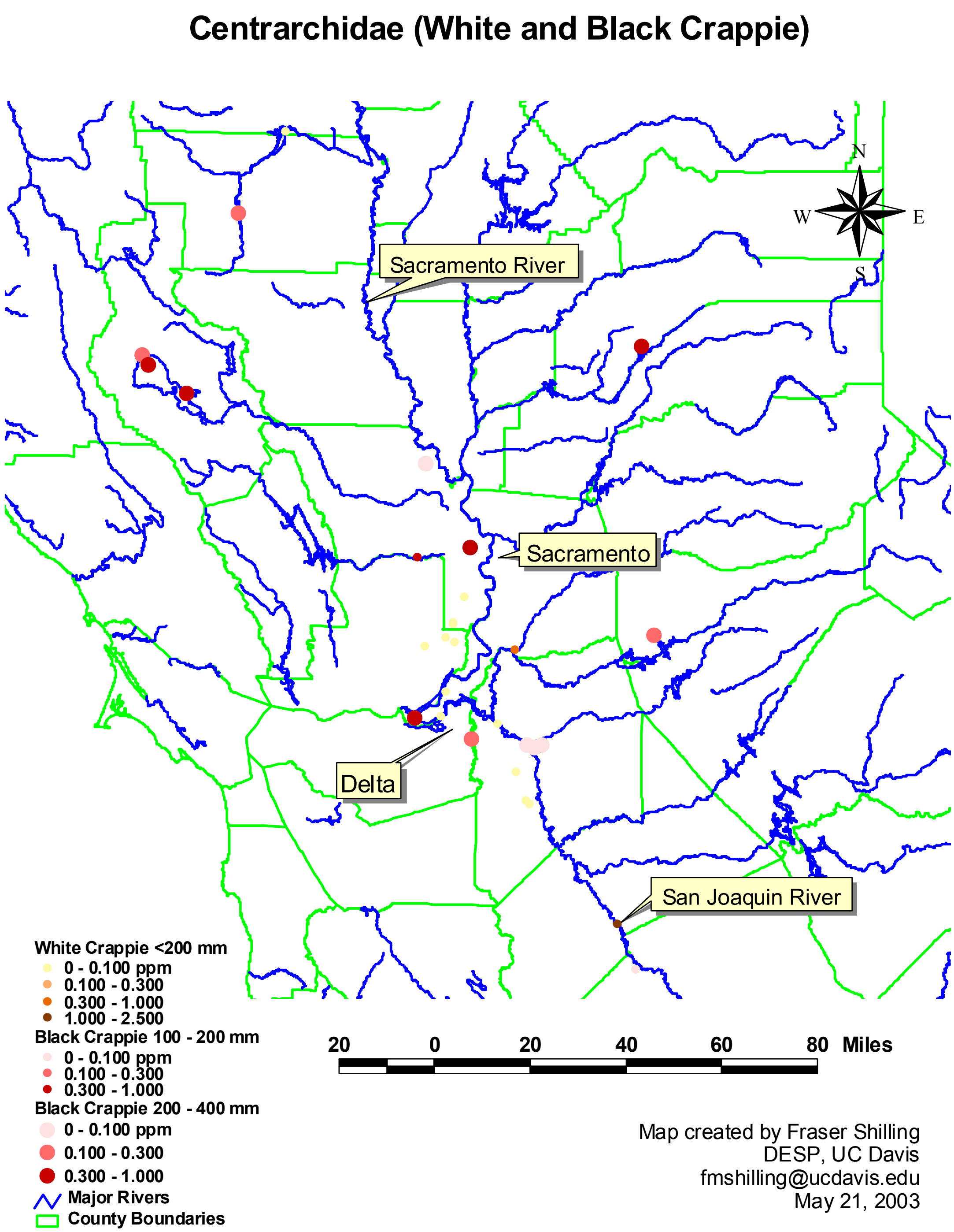

Centrarchidae (White and Black Crappie)
N
W
E
S
Sacramento River
Sacramento
Delta
San Joaquin River
White Crappie <200 mm
0 - 0.100 ppm
0.100 - 0.300
0.300 - 1.000
1.000 - 2.500
Black Crappie 100 - 200 mm
0 - 0.100 ppm
0.100 - 0.300
0.300 - 1.000
Black Crappie 200 - 400 mm
0 - 0.100 ppm
0.100 - 0.300
0.300 - 1.000
Major Rivers
County Boundaries
20 0 20 40 60 80 Miles
Map created by Fraser Shilling
DESP, UC Davis
fmshilling@ucdavis.edu
May 21, 2003

Figure C-18

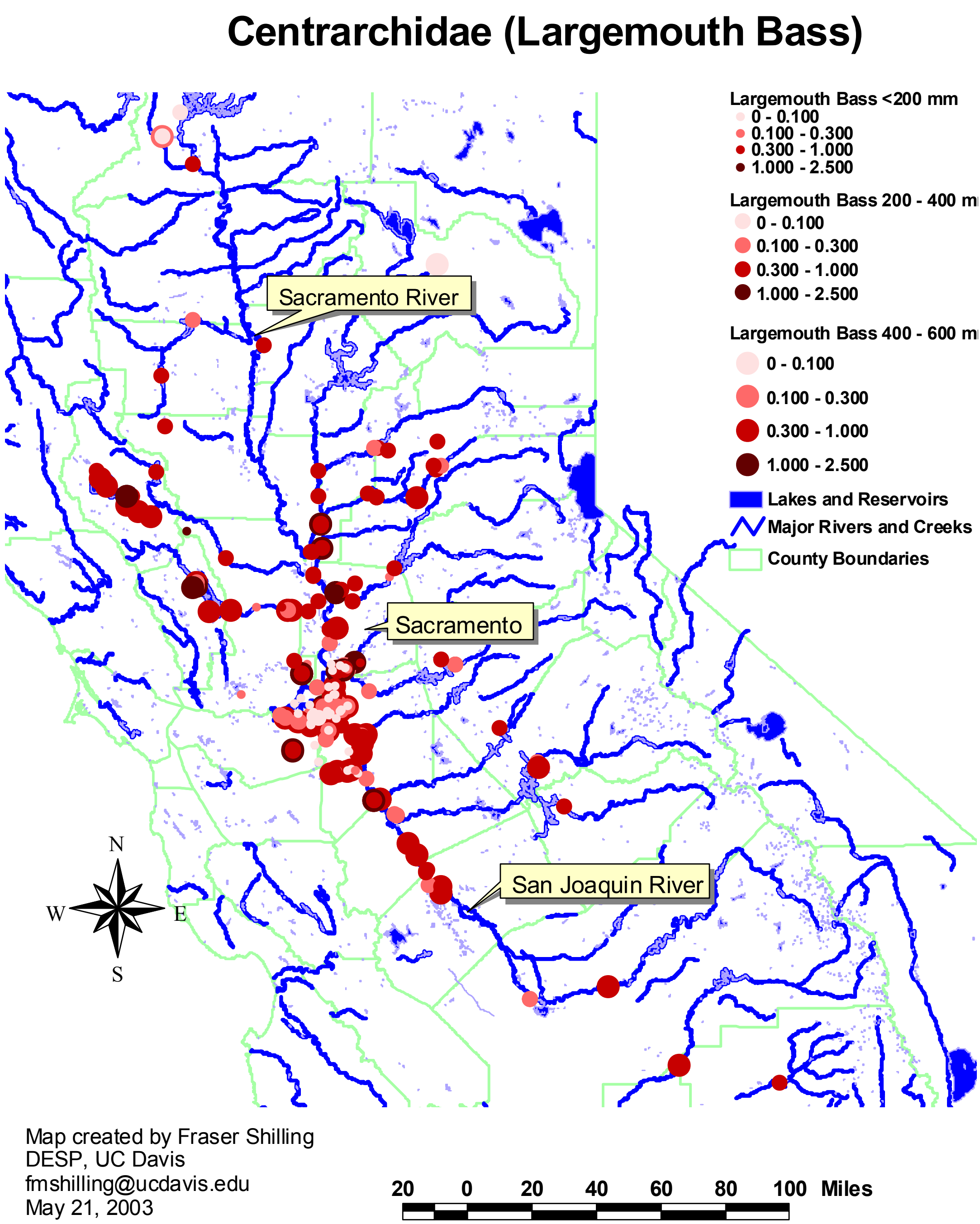

Centrarchidae (Largemouth Bass)
Largemouth Bass <200 mm
0 - 0.100
0.100 - 0.300
0.300 - 1.000
1.000 - 2.500
Largemouth Bass 200 - 400 m
0 - 0.100
0.100 - 0.300
0.300 - 1.000
1.000 - 2.500
Largemouth Bass 400 - 600 m
0 - 0.100
0.100 - 0.300
0.300 - 1.000
1.000 - 2.500
Lakes and Reservoirs
Major Rivers and Creeks
County Boundaries
Sacramento River
Sacramento
San Joaquin River
N
W
E
S
Map created by Fraser Shilling
DESP, UC Davis
fmshilling@ucdavis.edu
May 21, 2003
20 0 20 40 60 80 100 Miles

Figure C-19

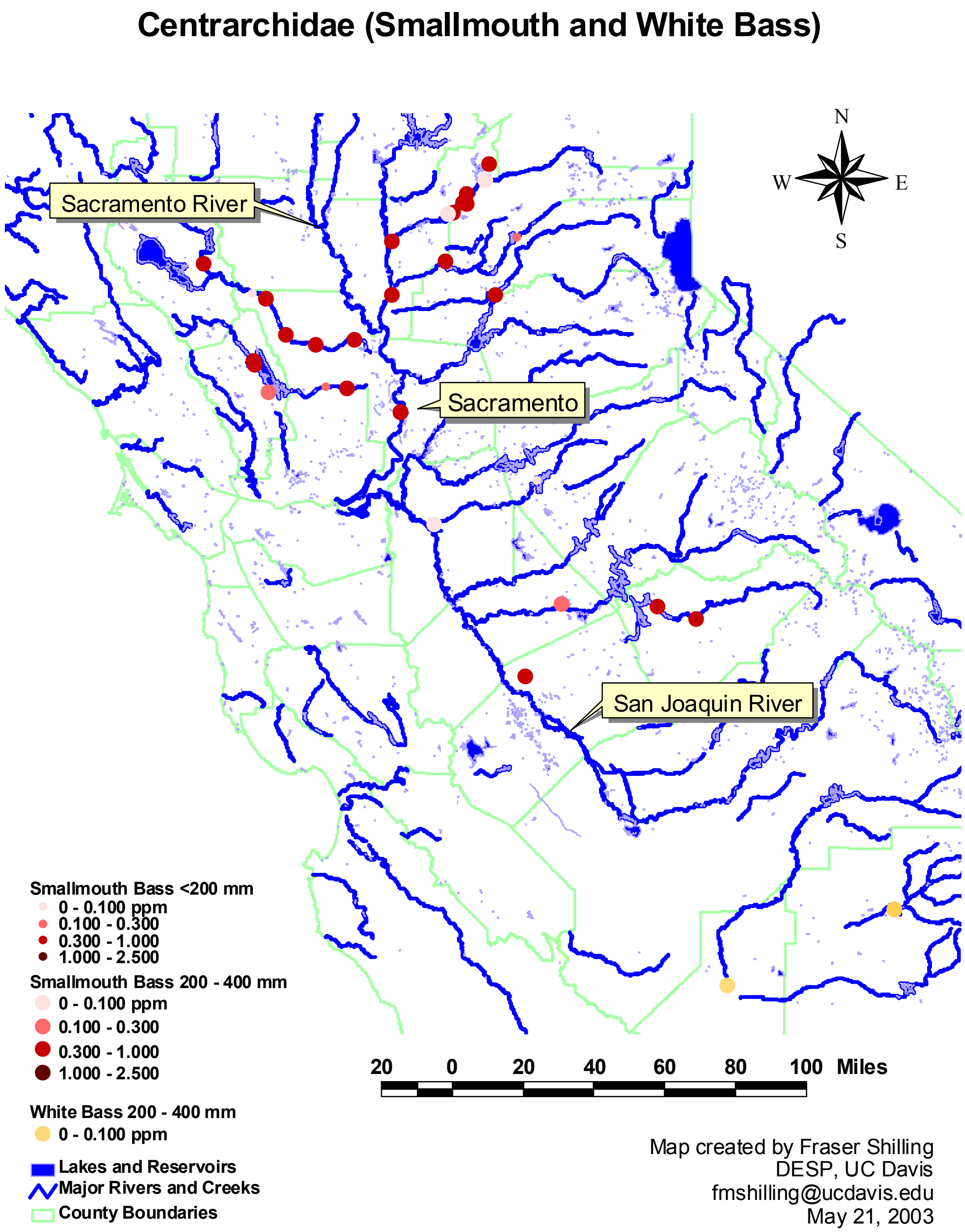


Figure C-20

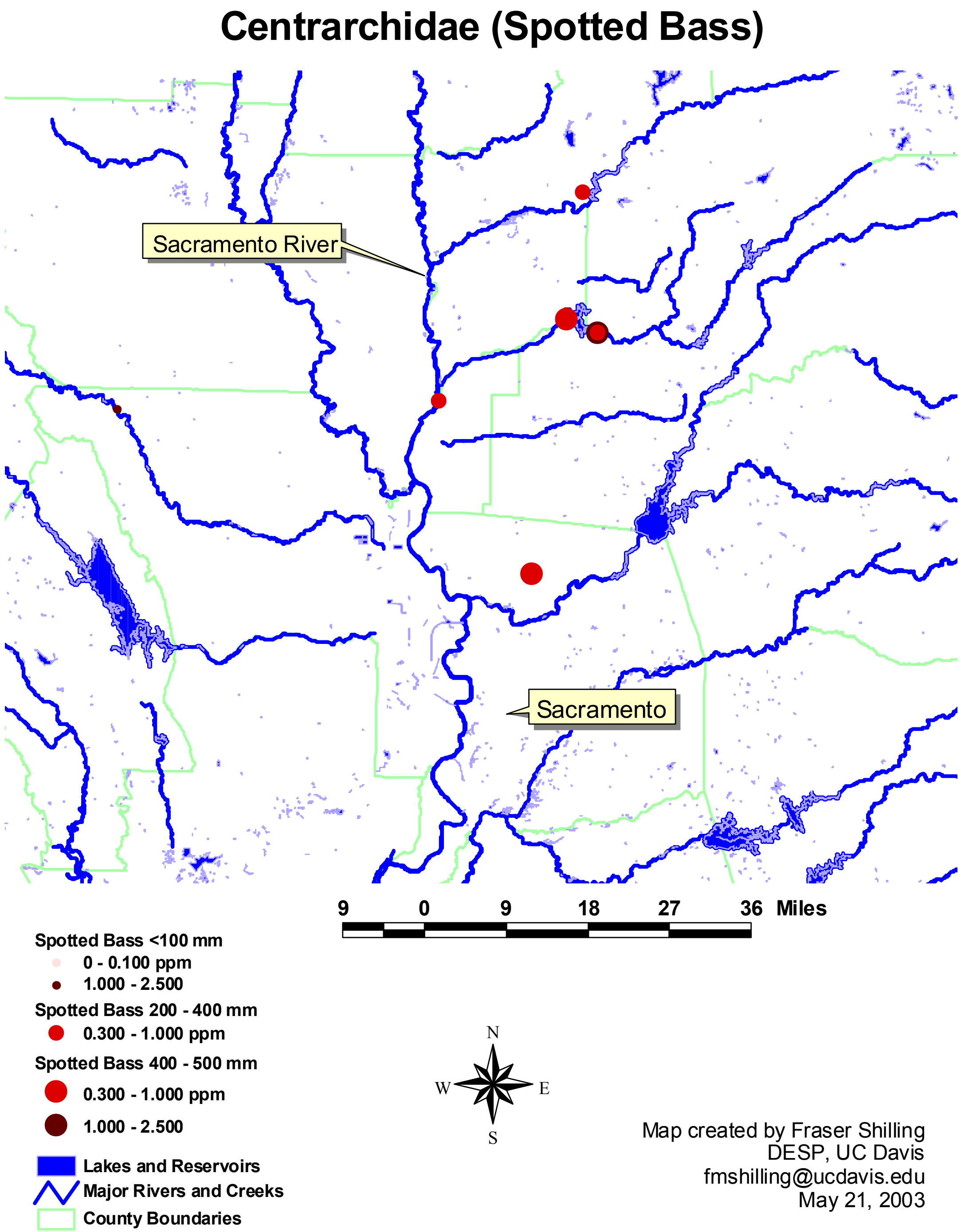

Centrarchidae (Spotted Bass)
Sacramento River
Sacramento
9 0 9 18 27 36 Miles
Spotted Bass <100 mm
0 - 0.100 ppm
1.000 - 2.500
Spotted Bass 200 - 400 mm
0.300 - 1.000 ppm
Spotted Bass 400 - 500 mm
0.300 - 1.000 ppm
1.000 - 2.500
Lakes and Reservoirs
Major Rivers and Creeks
County Boundaries
N
W
E
S
Map created by Fraser Shilling
DESP, UC Davis
fmshilling@ucdavis.edu
May 21, 2003

Figure C-21

Cyprinidae (Carp)

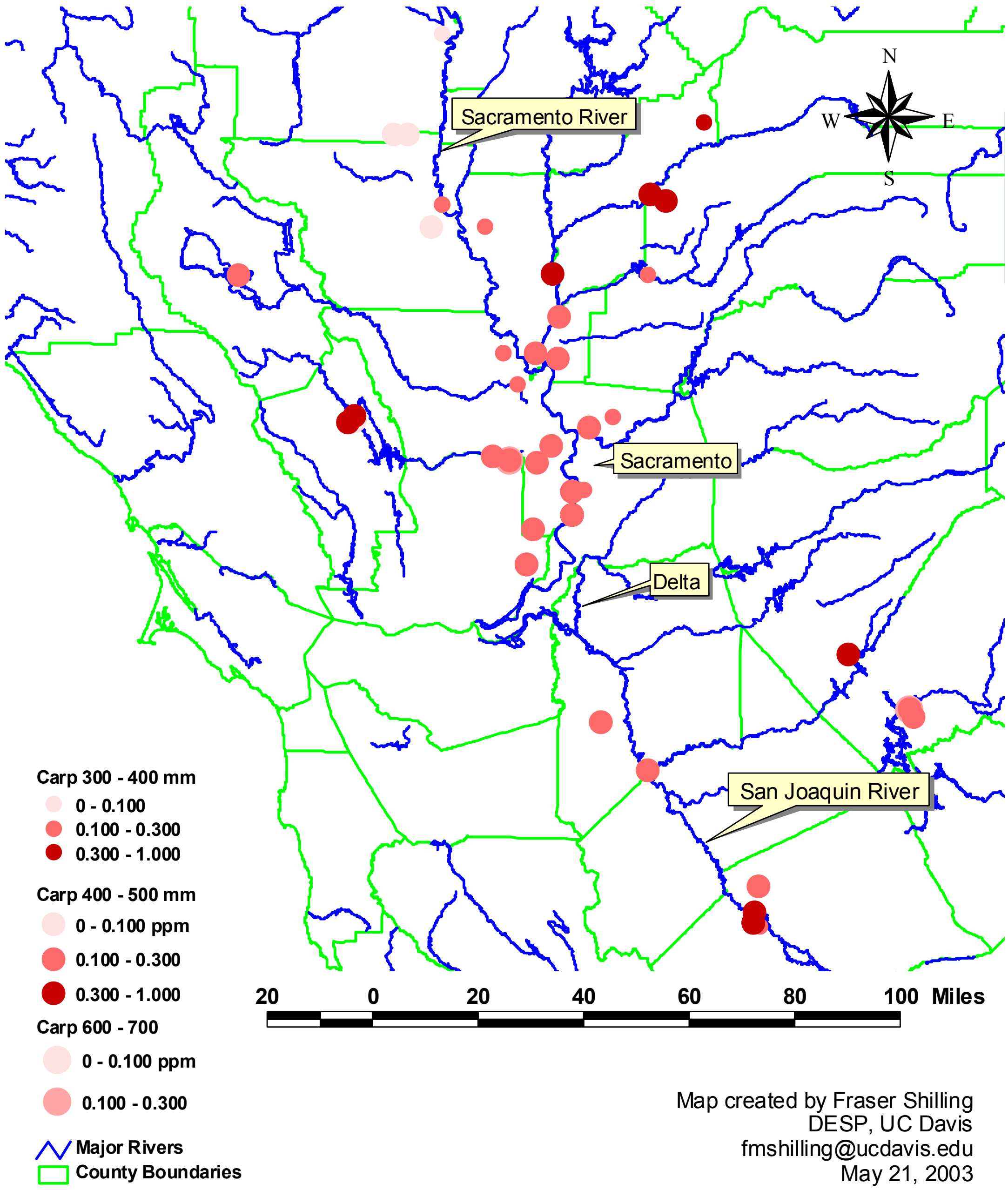


Figure C-22

Cyprinidae (Hardhead and Sacramento Blackfish)

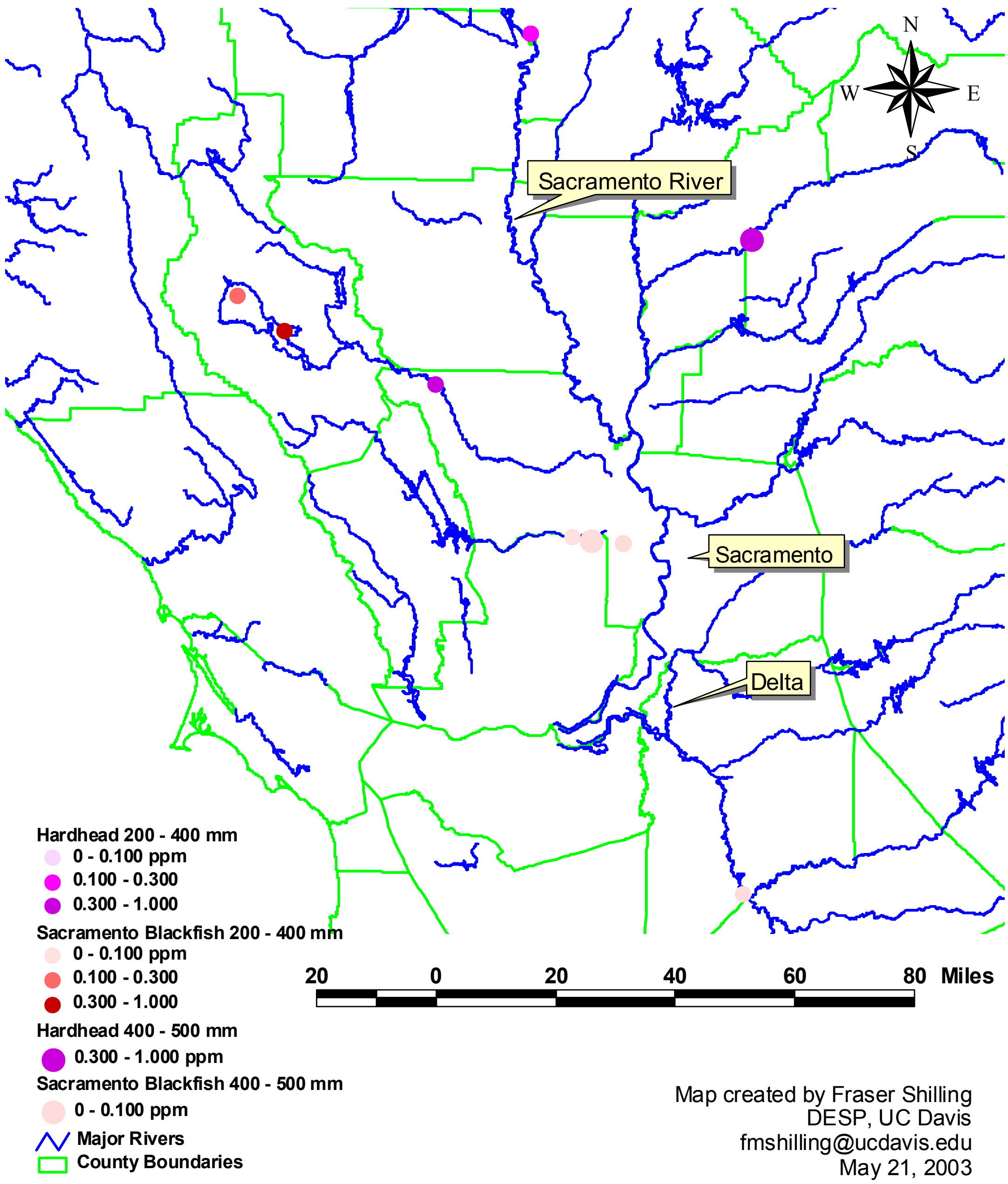


Figure C-23

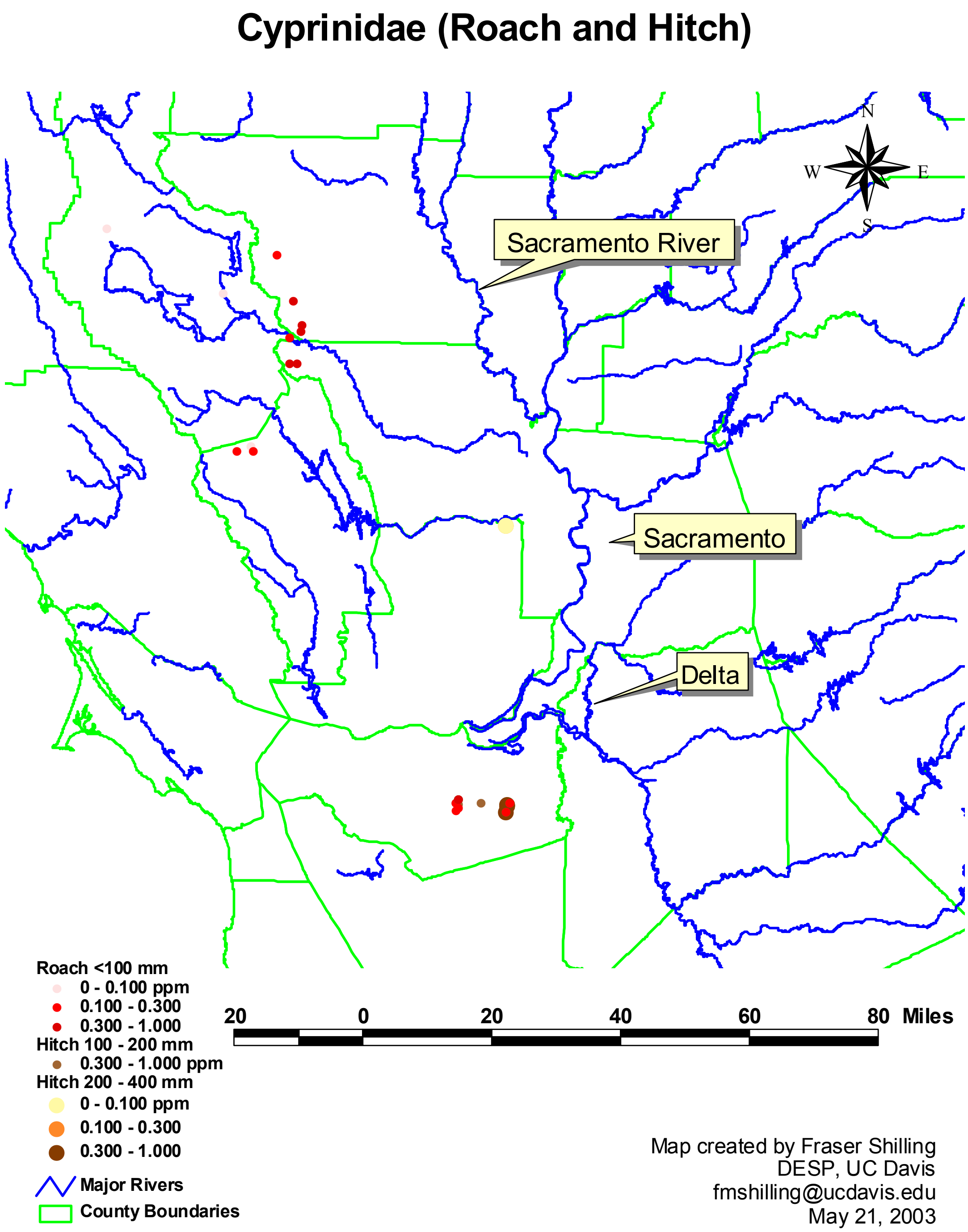

Cyprinidae (Roach and Hitch)
N
W
E
S
Sacramento River
Sacramento
Delta
Roach <100 mm
0 - 0.100 ppm
0.100 - 0.300
0.300 - 1.000
Hitch 100 - 200 mm
0.300 - 1.000 ppm
Hitch 200 - 400 mm
0 - 0.100 ppm
0.100 - 0.300
0.300 - 1.000
Major Rivers
County Boundaries
20 0 20 40 60 80 Miles
Map created by Fraser Shilling
DESP, UC Davis
fmshilling@ucdavis.edu
May 21, 2003

Figure C-24

Cyprinidae (Red and Golden Shiner)

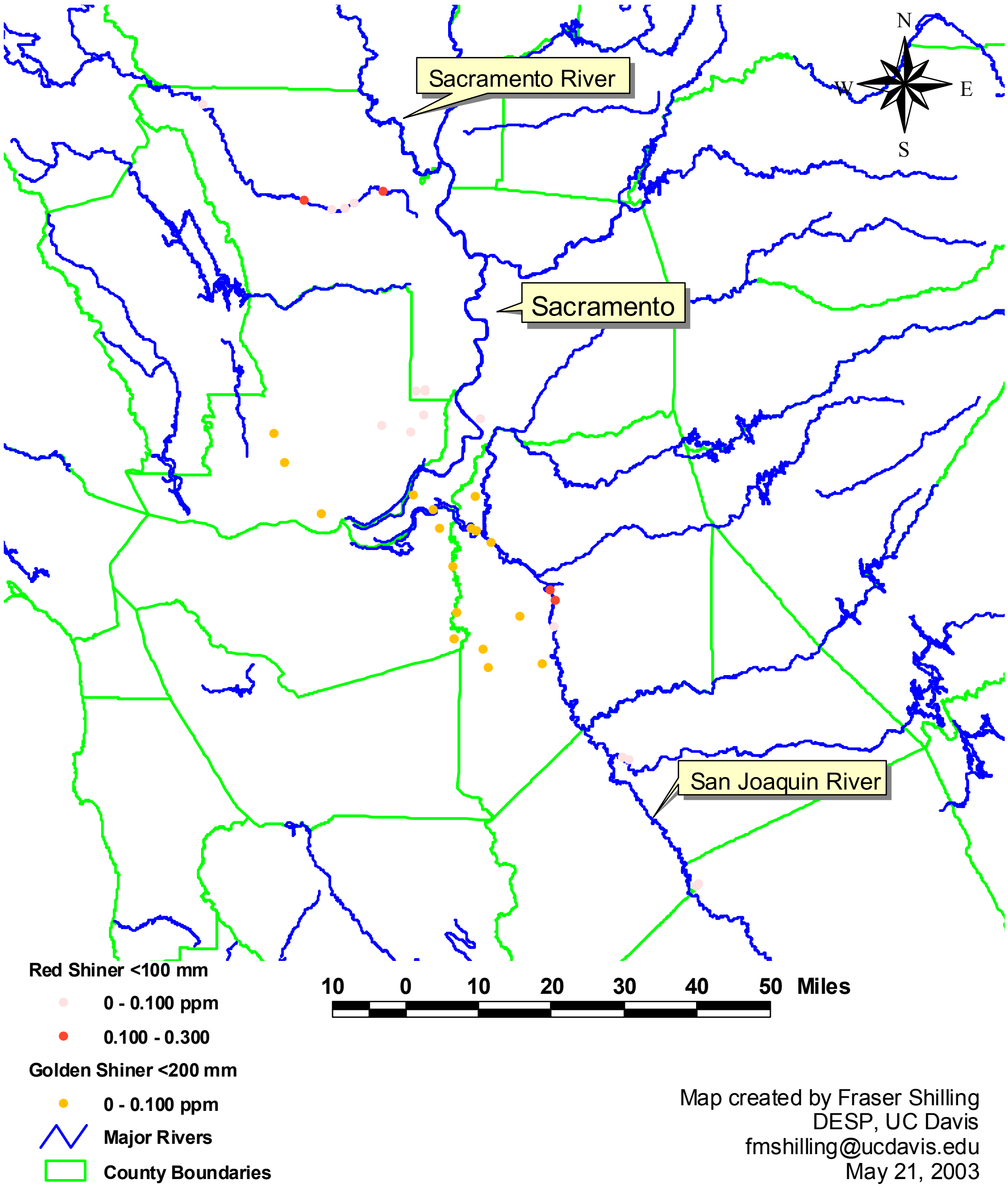


Figure C-25

Cyprinidae (Sacramento pike minnow)

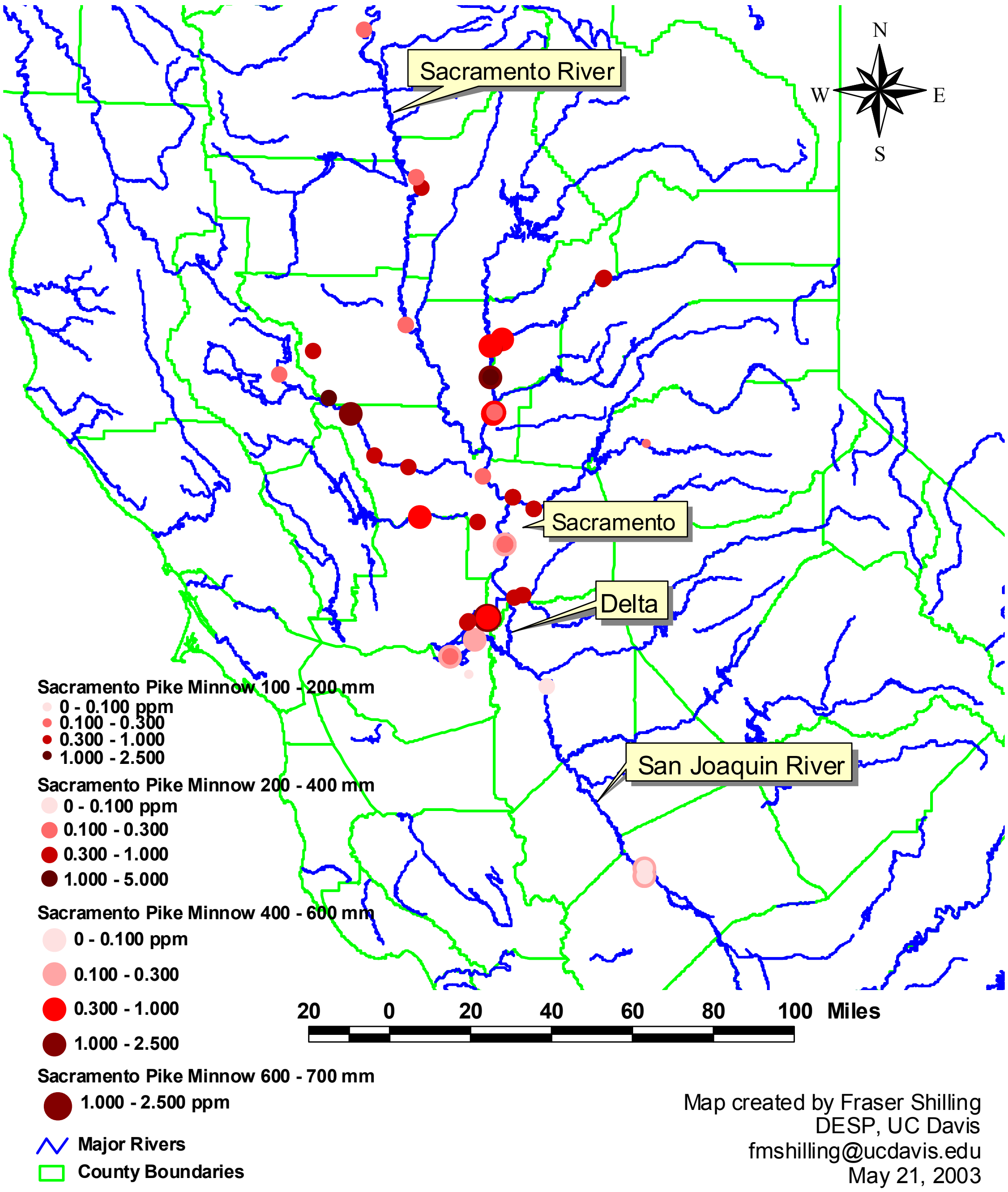


Figure C-26

Ictaluridae (Black and Brown Bullhead)

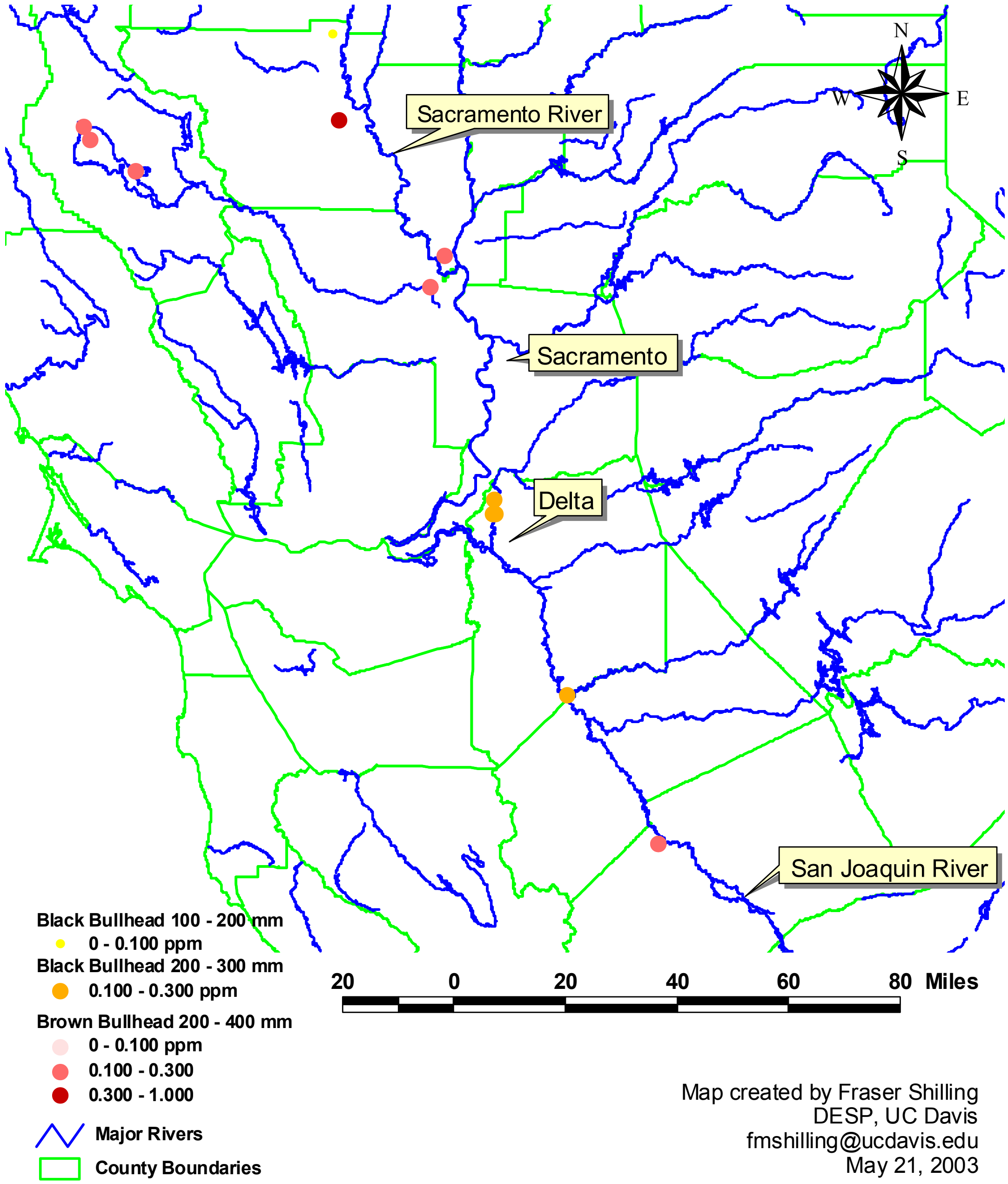


Figure C-27

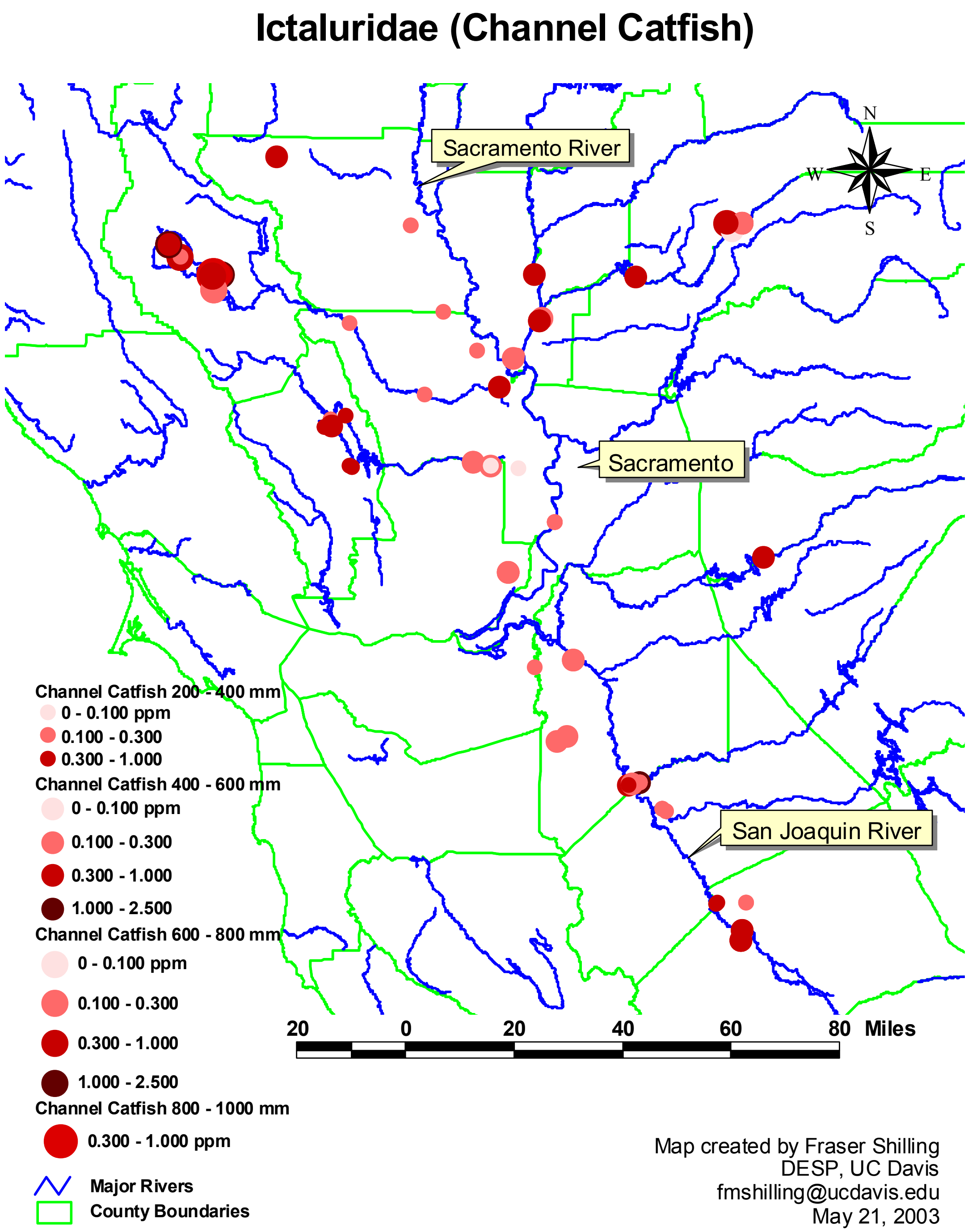

Ictaluridae (Channel Catfish)
Sacramento River
Sacramento
San Joaquin River
N
S
E
W
Channel Catfish 200 - 400 mm
0 - 0.100 ppm
0.100 - 0.300
0.300 - 1.000
Channel Catfish 400 - 600 mm
0 - 0.100 ppm
0.100 - 0.300
0.300 - 1.000
1.000 - 2.500
Channel Catfish 600 - 800 mm
0 - 0.100 ppm
0.100 - 0.300
0.300 - 1.000
1.000 - 2.500
Channel Catfish 800 - 1000 mm
0.300 - 1.000 ppm
Major Rivers
County Boundaries
20 0 20 40 60 80 Miles
Map created by Fraser Shilling
DESP, UC Davis
fmshilling@ucdavis.edu
May 21, 2003

Figure C-28

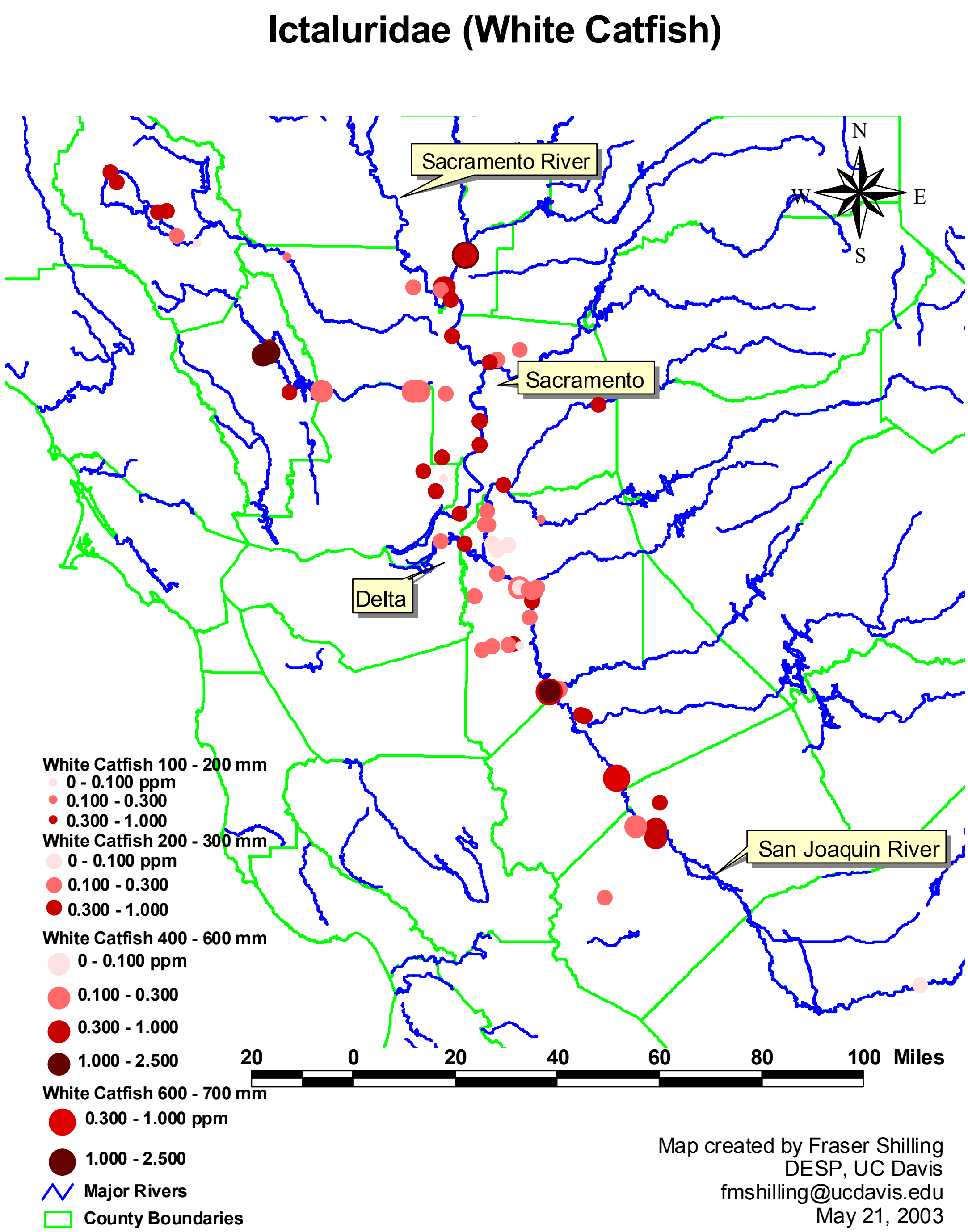


Figure C-29

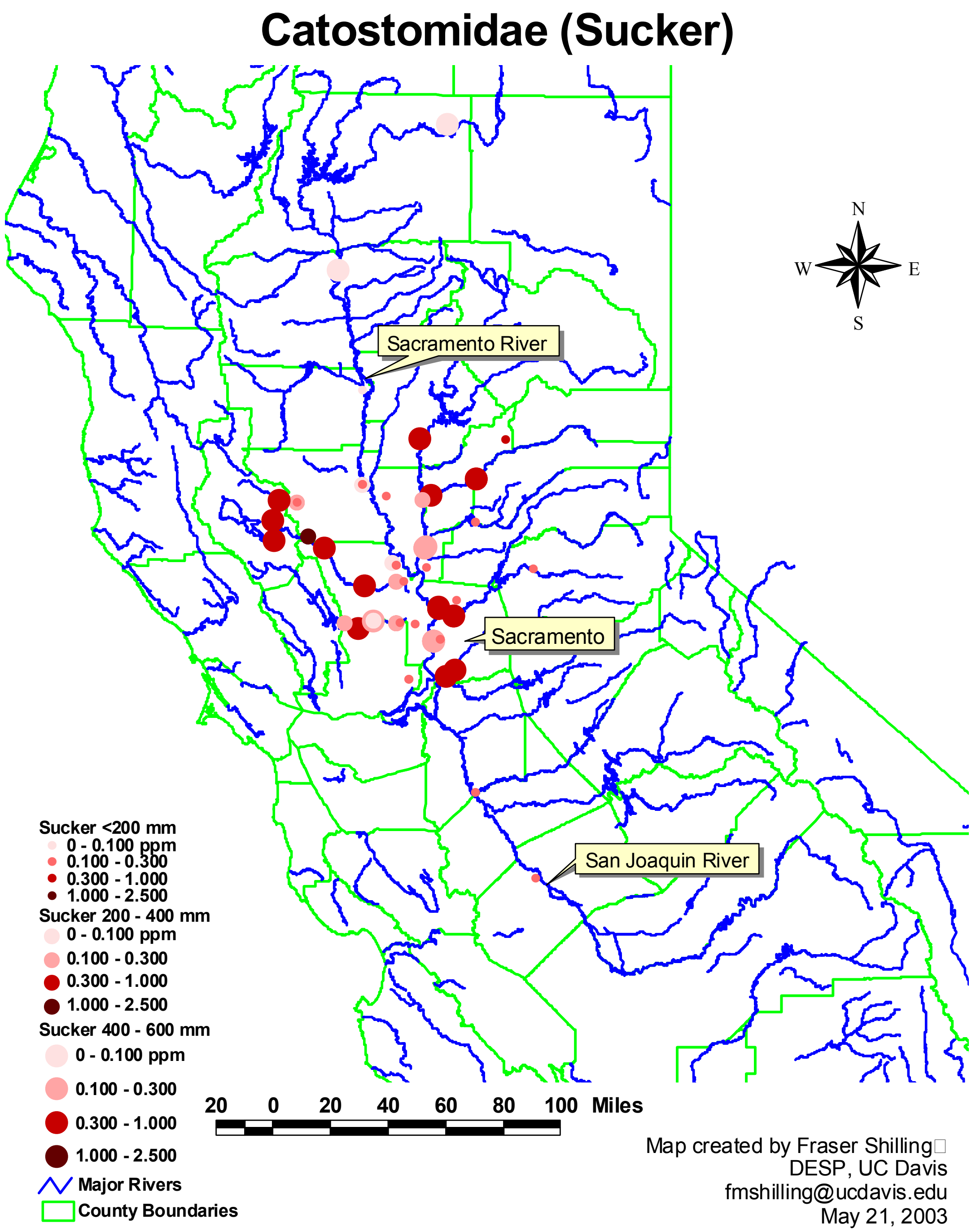

Catostomidae (Sucker)
Sacramento River
Sacramento
San Joaquin River
N
W
E
S
Sucker <200 mm
0 - 0.100 ppm
0.100 - 0.300
0.300 - 1.000
1.000 - 2.500
Sucker 200 - 400 mm
0 - 0.100 ppm
0.100 - 0.300
0.300 - 1.000
1.000 - 2.500
Sucker 400 - 600 mm
0 - 0.100 ppm
0.100 - 0.300
0.300 - 1.000
1.000 - 2.500
Major Rivers
County Boundaries
20 0 20 40 60 80 100 Miles
Map created by Fraser Shilling
DESP, UC Davis
fmshilling@ucdavis.edu
May 21, 2003

Figure C-30

Moronidae (Striped Bass)