Mercury Testing of Sport/Food Fishes within Humboldt Bay

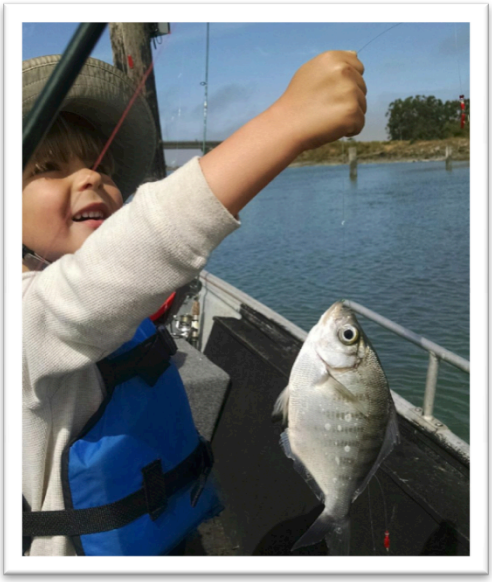
Final Report

April 2018

Jennifer Kalt, Humboldt Baykeeper, Arcata, CA
Ross Taylor, Ross Taylor & Associates, McKinleyville, CA

Prepared for Humboldt Baykeeper
600 F Street, Suite 3 #810
Arcata, CA 95521

Funded by
California Environmental Protection Agency
Environmental Justice Small Grant
State of California



Acknowledgements

Humboldt Baykeeper would like to thank the many people who contributed to the Humboldt Bay Mercury Assessment:

Ross Taylor of Ross Taylor and Associates: Consulting fisheries biologist and avid fisherman, Ross contributed to all aspects of the project, including study design, processing samples, data analysis, report writing, and outreach to sport anglers;

Jasmin Segura, Humboldt Baykeeper: Angler surveys, Spanish translation and interpretation;

Ted Hernandez, Vincent DiMarzo, Tim Nelson, and Patricia Torres of the Wiyot Tribe: Input on sampling design and recommendations, harvesting clam samples;

Mitch Farro, Darren Ward, Pat Moorhouse, Doug Epperley, Ishan Vernallis, Todd Kraemer, and Mike Wilson: Volunteer fishermen who collected most of the samples analyzed for this study;

Phil Glenn: Charter boat captain;

MaryAnn Hytken and all of her students and assistants at English Express, a non-profit English-as-a-Second Language school in Eureka, CA;

Mike Buettner: Graphic design;

Coast Seafoods Company: Oysters samples;

CEBAM Analytical, Inc. of Bothell, Washington;

the many anglers who patiently answered our questions.

Mercury Testing of Sport/Food Fishes within Humboldt Bay

Project Purpose and Need

Mercury advisories have been issued for many major waterbodies in California, including coastal areas of Northern California. Humboldt Bay is currently designated as an area in need of a site-specific fish advisory (Smith et al. 2016). In 2012, the North Coast Regional Water Quality Control Board determined that Humboldt Bay did not warrant listing for mercury impairment under Clean Water Act Section 303(d) based on mussel testing done in the 1980s (NCRWQCB 2012). However, that same year, a report was released showing that Leopard Shark from Humboldt Bay had the highest mercury levels in a statewide assessment of contaminants in coastal fish (Davis et al. 2012), indicating a need for further sampling of commonly eaten fish caught in Humboldt Bay.

Background

Fish consumption is the major route of methylmercury exposure in the United States (ATSDR 1999). For many years, mercury advisories focused primarily on which fish to avoid. A result of this approach was that many people simply eliminated fish from their diets, especially pregnant women.

There are many health benefits of eating fish that is low in mercury, PCBs, and other contaminants. Fish is high in protein and low in fat, and is an important source of omega-3 fatty acids, which support heart health and brain functions (Silbernagel et al. 2011). In recent years, concerns have been raised about generic fish advisories causing harm by encouraging people to limit their fish consumption, thereby limiting the beneficial effects of eating low-mercury fish (Verbrugge 2007).

Methylmercury is a powerful neurotoxin that can cause loss of coordination, blurred vision or blindness, and hearing and speech impairment. At lower levels of exposure, more subtle symptoms in adults are numbness or tingling in the hands, feet, and/or around the mouth. Developing fetuses are particularly sensitive, and can experience slight decreases in learning abilities, language skills, attention and/or memory function (Silbernagel et al 2011).

Methylmercury accumulates in the body, and magnifies in larger, older animals that eat higher on the food chain (Davis et al. 2012). But reducing mercury exposure from fish consumption can lower the mercury levels in blood and hair samples within a few months (Bose-O'Reilly et al. 2010). This is especially important information for women of child-bearing age, since they can reduce their babies' mercury exposure by eliminating fish with high mercury levels from their diets.

The most vulnerable populations are people who eat a lot of fish, including recreational and subsistence fishermen and their families, tribal members, Hmong and other Asian residents, Latino residents, and people with low incomes that fish to feed their families. Another group at risk includes people with high incomes who can afford to eat a lot of expensive fish such as tuna, swordfish, and sushi. There are increased concerns for people who may consume many meals from one large animal, such as recreational and subsistence users who freeze, smoke, or pressure cook and can fish to eat all year round.

Mercury is a natural element found in some rock and soil. Human activities, such as burning coal and the use of mercury to mine gold, also add mercury to the environment (Smith et al., 2016). At this time, there are no known local sources of mercury in the Humboldt Bay area. Mercury was used in historic gold mining in the Klamath, Trinity, and Russian Rivers, but is not known to have occurred near Humboldt Bay or in the adjacent Eel and Mad River watersheds. The mercury in the Humboldt Bay region is thought to originate from coal-burning power plants in Asia and elsewhere, which is emitted into the atmosphere and deposited across western North America. A recent study found that coastal fog deposits mercury at higher levels than rainwater in Central California (Weiss-Penzias et al. 2012).

Previous Studies in the Region

As previously mentioned, a 2012 report found the highest levels of mercury in California coastal waters in Humboldt Bay Leopard Shark (Davis et al. 2012). The average mercury levels in these Leopard Shark from Humboldt Bay was 1.66 parts per million (ppm) – more than three times Office of Environmental Health Hazard Assessment's (OEHHA) "do not consume" level for women under 45 and children (Klasing and Brodberg, 2008) and more than twenty times the advisory level used to define subsistence fishing (Gassel and Broberg 2005). On a statewide level, survey results indicate that there is significant mercury contamination in coastal areas to cause risks to humans wherever they catch and eat long-lived predator fish (Klasing and Brodberg, 2008).

In 2005, Humboldt Baykeeper teamed up with the Waterkeeper Alliance and the Environmental Quality Institute at University of North Carolina, Asheville to sample three important local fish species: Chinook Salmon, Albacore Tuna, and Lingcod (Evenson 2006). The Chinook Salmon were caught in the Pacific Ocean just west of Humboldt Bay. The Albacore were caught approximately 90 miles west of Eureka and ranged in size from 22 to 31 pounds. Lingcod were caught off the coast of Cape Mendocino, relatively far from any known industrial source of mercury pollution, and these fish ranged from 6 to 25 pounds in size. Results of Humboldt Baykeeper's previous mercury testing are included in the Results section of this report.

Methods - Species Selected for Testing:

For the Humboldt Bay project the primary criteria for selection of focal fish species included:

- The species is commonly fished for in Humboldt Bay and kept as a food source.
- The species resides within Humboldt Bay for a significant part of the year.
- The species is relatively long-lived, thus more susceptible to bioaccumulation of toxins.
- The species is already associated with mercury health advisories within coastal waters of California.
- The species is an important indicator to statewide tracking of mercury levels due to its wide distribution and abundant populations.

The fish species meeting these criteria included:

Leopard Shark (*Triakis semifasciata*) – is a species of Houndshark, common in bays and estuaries along the west coast from Oregon to Mexico. They are mostly found in shallow water (<4 meters depth) and often forage on mud flats during incoming tides. Food items include clams, shrimps, crabs and bony fishes. Most Leopard Sharks have high site fidelity and tend to remain in a relatively small geographic area, which has led to genetic divergence throughout the species' distribution. Leopard Sharks are caught by both commercial and recreational fisheries, for food and the aquarium industry. When handled and processed correctly, the meat is considered excellent table fare. Leopard Sharks are slow-growing and long-lived, with females reaching maturity at 10-15 years and an estimated maximum lifespan of 30 years. Leopard Sharks are known to have high levels of mercury (Davis et al. 2012). This species is common to Humboldt Bay; often up into the Mad River Slough and the Arcata channel in the North Bay.

Bat Ray (*Myliobatis californica*) – is a species of eagle ray, common in muddy and sandy sloughs and bays from Oregon to the Gulf of California. Bat rays are euryhaline and can tolerate a wide range of salinities. Bay Rays can grow up to 200 pounds, but most fish average 20-30 pounds in weight. Common food items are mollusks, crustaceans and small fish which they forage off of the bottom. These rays can also dig down 20 cm to expose buried prey such as clams. Bay Rays are a popular sport fish in bay and pier fisheries due to their large size, fighting capabilities and are also commonly eaten. The wings have large amounts of meat that must be cleaned and processed quickly. Maximum lifespan has been estimated at 20 to 25 years. Bat Rays are known to have elevated mercury levels (Davis et al. 2012). This species is common throughout Humboldt Bay.

California Halibut (*Paralichthys californicus*) – is a large-toothed flounder species, distributed from Washington south to Magdalena Bay in Baja California. This flounder species is common in bays and near-shore waters and is an extremely popular sport fish due to its excellent table fare. Most adult California Halibut reside in water depths less than 30 meters. Juveniles

commonly rear in protected bays and adults opportunistically inhabit bays when forage fish are concentrated, such as in Humboldt during the summer of 2016. California halibut can grow upwards of 50 pounds, but most sport-caught fish are in the five to 20 pound range. Using light line and live bait is most productive when fishing for California Halibut. Females mature at about age four to five years and their maximum lifespan is approximately 30 years. California Halibut are known to have moderately elevated mercury levels (Davis et al. 2012). As previously mentioned, this species presence and relative abundance in Humboldt Bay is influenced by availability of forage fish such as anchovies and sardines. California Halibut were targeted heavily in Humboldt Bay during the summers of 2016 and 2017.

Lingcod (*Ophiodon elongatus*) – is the largest member of the greenling family, *Hexagrammidae*, and is distributed along the west coast from the Gulf of Alaska south to Baja Mexico. They are generally bottom-oriented fish associated with rocky reefs in depths of 20 to 100 meters. Lingcod are largely non-migratory. They are a popular sport fish due to their large size, aggressiveness and excellent taste. Lingcod can exceed 100 pounds in weight, but 10 to 30 pound fish are most common. Females mature at around age 3 to 5 years and can live up to 20 years. Males have a maximum lifespan of around 14 years. Lingcod are known to have moderately elevated mercury levels (Davis et al. 2012). In Humboldt Bay, Lingcod distribution is mostly restricted to the rocky habitat of the jetties and fish are caught by both shore-based and boat anglers.

Shiner Surfperch (*Cymatogaster aggregata*) – is the most widely distributed of the Surfperch species in California waters. Shiner Surfperch prefer calm waters of bays, often associated with eelgrass beds and around the pilings of docks and piers. Shiner Surfperch can also tolerate a wide range of salinities and can be found in the lower reaches of coastal rivers. These fish are not long-lived and do not feed high on the food chain, thus previous testing has shown their methyl mercury levels to be relatively low when compared to other species (Davis et al. 2012). Shiner Surfperch were included in this study because it is a popular target species of dock fishermen, is kept for food and previous studies have shown this species to be the best state-wide indicator species for bays and harbors because of its wide and common distribution (Davis et al. 2012).

These five species were originally selected as the study's focal species, yet the exact list of species tested was modified once the study was underway. Species added to the study included: Walleye Surfperch (*Hyperprosopon ellipticum*), Jacksmelt (*Atherinopsis californiensis*), Black Rockfish (*Sebastes melanops*), Horseneck (or Fat Gaper) Clam (*Tresus capx*), Pacific Littleneck Clam (*Protothaca staminea*), Martha Washington (or Butter) Clam (*Saxidomus gigantea*), and Oysters farmed in Humboldt Bay.

Walleye Surfperch were sampled instead of Shiner Surfperch because we were unable to locate any concentrations of Shiner Surfperch in Humboldt Bay, whereas the Walleye Surfperch were abundant around dock pilings where shore-based anglers were fishing. These docks and pilings were also frequented by Jacksmelt, so this species was included for mercury testing. Black Rockfish were caught while fishing for Lingcod along Humboldt Bay's jetties and were included in the sampling because this is a target species for people fishing from the jetties. The three species of clams were included by request of the Wiyot Tribe, whose members frequently harvest clams from traditional sites in southern parts of Humboldt Bay. The farmed oysters were included because of their commercial importance to the local economy.

Methods - Fish Sampling and Processing:

Fish samples for the Humboldt Bay mercury study were caught with sport-fishing tackle, following current regulations set by the California Department of Fish and Wildlife (https://www.wildlife.ca.gov/regulations). We reviewed federal and state collection methodologies which stressed the importance of proper handling and preparation of tissue samples, thus sampling was limited to a pre-screened group of fishermen that had previous experience in biological field surveys and data collection.

Methods used to handle fish and prepare samples for testing were consistent with methods described in the EPA document titled, *Guidance for Assessing Chemical Contaminant Data for use in Fish Advisories. Volume 1: Fish Sampling and Analysis* (U.S. EPA 2000). However, one deviation from the U.S. EPA methods was not testing composite samples (a mixture of flesh from more than one fish), because the use of a range of samples collected by various persons at various times and locations was potentially not suitable for composite testing. Also, testing of composite samples requires a higher level of quality control in obtaining and handling samples, as well as a more rigorous chain of custody. The exception was the shellfish; composite samples were analyzed for all four species included in the study.

One of the most important aspects of this project was how fish were handled upon capture, as exemplified by the following paragraph in the U.S. EPA document: *The primary QA consideration in sample collection, processing, preservation, and shipping procedures is the preservation of sample integrity to ensure the accuracy of target analyte analyses. Sample integrity is preserved by prevention of loss of contaminants already present in the tissues and prevention of extraneous tissue contamination.*

These steps, as recommended by the U.S. EPA, were followed when handling and processing fish caught in Humboldt Bay for testing:

1. All fish kept for a tissue sample were caught alive and were free of cuts, lacerations, tumors and other open wounds. We released any fish that appears wounded. All fish that were not of legal size were also released.
2. All equipment used for measuring, holding, processing and storing fish and/or tissue samples were cleaned with detergent and rinsed with distilled water prior to processing each fish/tissue sample.
3. To avoid contamination with melting ice in coolers, sampled fish and/or filets were placed in waterproof (zip-lock) bags.
4. Although the U.S. EPA discourages field processing of fish (i.e. filleting and bagging), when this was done, extra care was taken to avoid contamination with any sources of gasoline, diesel, oils and grease. All knives, cleaning boards and gloves were thoroughly washed between field processing of tissue samples.
5. Individual fish of the selected target species were rinsed in ambient water to remove any foreign material from the external surface. Large fish were stunned by a sharp blow to the base of the skull with a wooden club or metal rod. This club was used solely for the purpose of stunning fish, and was cleaned to prevent contamination of the samples.
6. Once stunned, the fish's total length was measured in cm or mm (Figure 1). For Bat Ray, measure body length, less tail/whip. Whole fish were weighed with either a digital hanging scale or a digital tray scale.
7. Photos were taken of each processed fish. At least one photo had something in the photo for scale (such as person or measuring device).
8. Field processing was done immediately and filleting was conducted by an experienced fisheries biologist. Prior to filleting, hands (or gloves) were washed with soap and rinsed thoroughly in ambient water, followed by distilled water. Specimens came into contact with non-contaminating surface only. Fish were filleted on a Polytetrafluoroethylene (PTFE) cutting board that was cleaned properly between each processed fish. Care was taken to avoid contaminating filet tissues with material released from inadvertent puncture of internal organs. Any dark muscle tissue in the vicinity of the lateral line should not be separated from the light muscle tissue that constitutes the rest of the muscle tissue mass.
9. After filleting and skinning the fish, we cut off a piece close to eight ounces to one pound in size (225 to 450 grams), weighed this sample, blot dried, wrapped it in aluminum foil, taped it, and placed the sample in sealed zip-lock bag. This bag was then stored in a clean cooler on ice. The samples bags were positioned in the cooler so that melted ice-water was unable to infiltrate the bags. The bags were also clearly marked with species and capture information (fish species, total length, weight of sample,

capture date, capture location) with a tag consistent with the U.S. EPA protocol (Figure 2). This tag was inserted into each sample's zip-lock bag.

10. After a day of field sampling, all zip-lock bags of tissue samples were stored in a freezer (at -20^{o}C or -4^{o}F). For methylmercury testing, CDFW standards stated that samples can be frozen for up to six months prior to laboratory testing (EPA 2000).
11. Field data sheets – we used the U.S. EPA field form with one modification: numbering the fish individually (such as, Lingcod #01) and ignore the "composite sample" section of the data sheet. Also, weight of the whole fish and tissue sample weight was entered. Data sheets were printed on water-proof paper for field use. After each field day, the data sheets were scanned and saved as PDF's.
12. Field Equipment list –the Humboldt Bay project used a list consistent with the U.S. EPA recommendations for collection of tissue samples in the field (Appendix A).

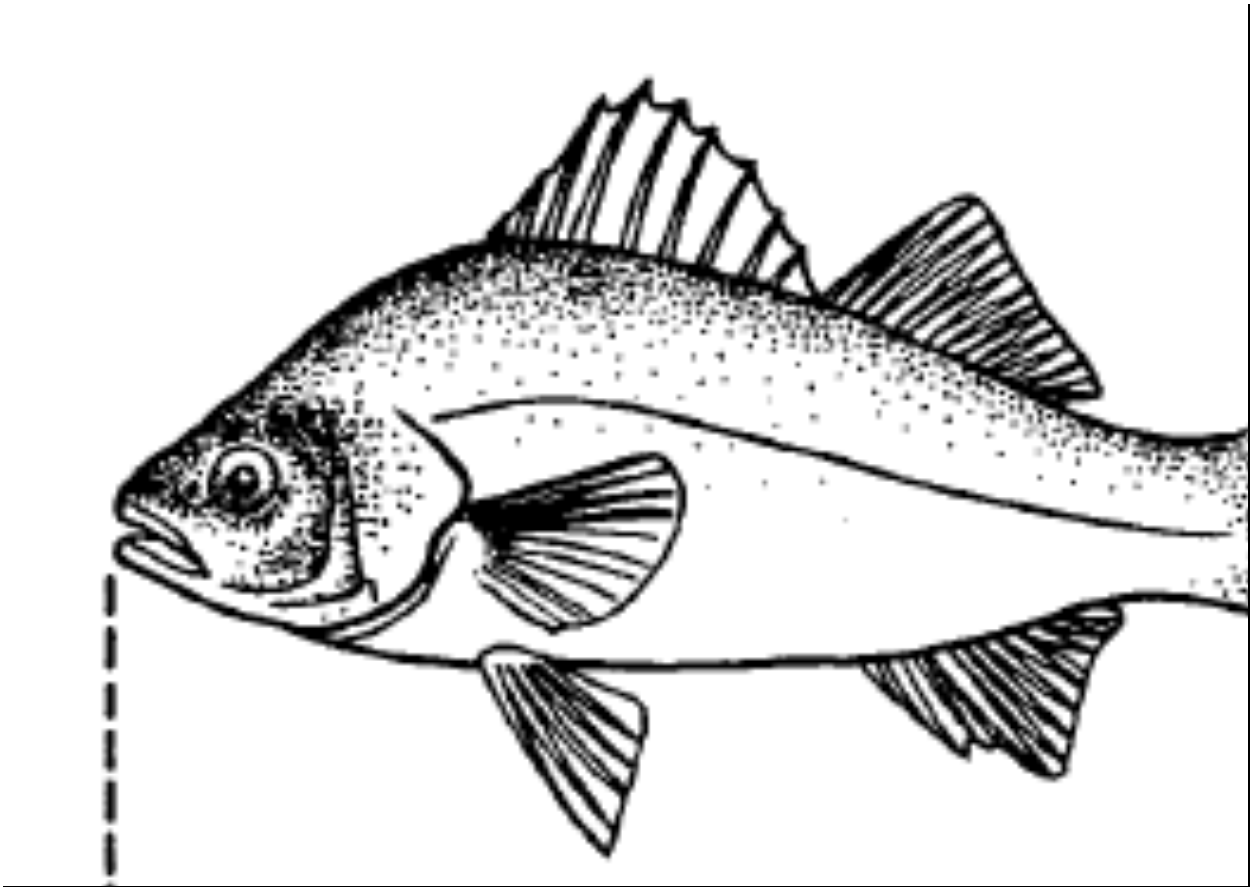


Figure 1. Example of measurement of total length (from U.S. EPA 2000).

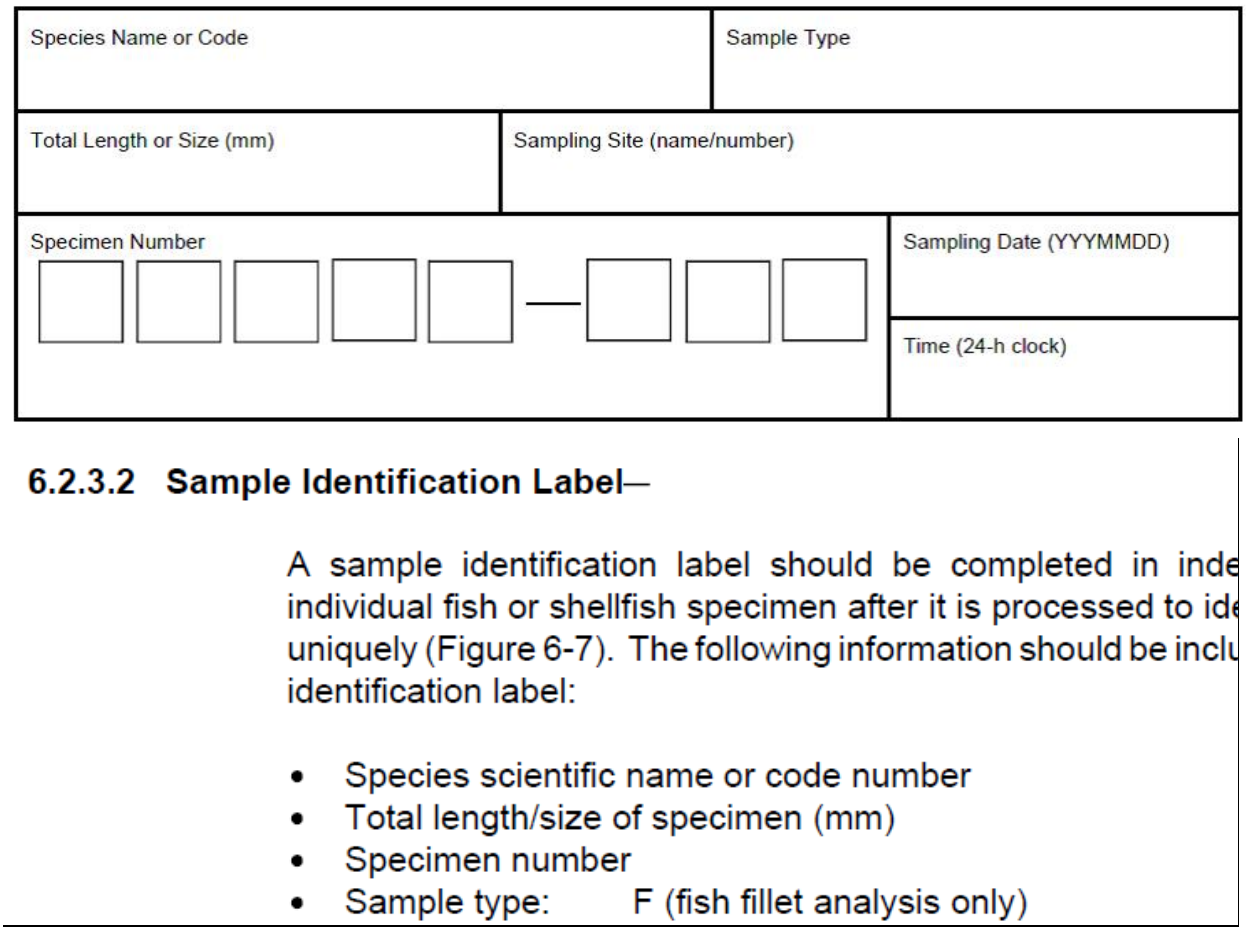


Figure 2. Example of U.S. EPA sample ID label and label instructions (from U.S. EPA 2000).

For the most part, skinless filets of fish were tested, consistent with the flesh normally consumed by the Humboldt Bay angling community. The U.S. EPA (2000) states that, "*using skinless fillets for assessing mercury exposures for members of the general population and most recreational fishers is most conservative. Because mercury is differentially concentrated in muscle tissue, leaving the skin on the fish fillet actually results in a lower mercury concentration per gram of skin-on fillet than per gram of skin-off fillet. In addition, few consumers in the general population eat the skin of the fish, which justifies its removal for analysis, particularly when monitoring concerns are directed solely at mercury contamination."* However, the exception was testing skin-on meat of Walleye Surfperch and Jacksmelt due to their relatively small size and the fact that these fish are usually prepared with skin-on. The tissue sample size of a filet from each captured fish was between eight ounces and one pound and was weighed with a digital tray scale. Again, the exceptions were the Walleye Surfperch and Jacksmelt because of their small size – each sample from these fish consisted of a headed and gutted

carcass, similar to how these species would be cleaned prior to cooking. These headed and gutted carcasses were weighed to the 0.1 pounds on a digital tray scale.

Methods - Tissue Sample Testing and Reporting:

Tissue samples were sent to CEBAM Analytical, Inc., located in Bothell, Washington. CEBAM Analytical was founded in 1995 by Dr. Lian Liang and specializes in the analysis and speciation of mercury in various samples using modified EPA 1630 and EPA 1631 Methods. The Humboldt Bay tissue samples were analyzed for both methylmercury and total mercury. Of the total amount of mercury found in fish muscle tissue, methylmercury often comprises more than 95 percent and is also the more toxic form (Bloom, 1992). Several studies have generally shown that as fish age, mercury concentrations in their flesh increase, including concentrations of methylmercury (U.S. EPA 2000). Because of these reasons, total mercury is usually analyzed for most fish studies and assumed to be 100 percent methylmercury for the purposes of conservative risk assessment (Smith et al. 2016; Davis et al. 2012). The fish sampled from Humboldt Bay had methylmercury values that were 81% to 96% of the total mercury. Our results are reported as levels of total mercury in parts per million (ppm), consistent with other recent assessments completed in California coastal waters by the Surface Water Ambient Monitoring Program (Davis et al. 2012) and the Office of Environmental Health Hazard Assessment (Smith et al. 2016).

The total mercury thresholds used for the Humboldt Bay study were consistent with Advisory Tissue Levels (ATLs) developed by OEHHA and SWAMP (Klasing and Brodberg 2008; Davis et al. 2012; Smith et al. 2016). The OEHHA fish advisory process considers both the health benefits of fish consumption and the risk from exposure to the chemical contaminants found in fish. Benefits are included in the advisory process because there is considerable evidence and scientific consensus that fish should be part of a healthy, well-balanced diet. Thus, the ATLs consider both the toxicity of the chemical and the potential health benefits of eating fish. OEHHA uses the ATLs to determine the maximum number of servings per week that consumers can eat, for each species and at each location, to limit their exposure to these contaminants. The OEHHA established three ATL thresholds based age and sex because fetuses and children are more sensitive to the toxic effects of methylmercury. The ATLs for the sensitive population, including women who might become pregnant (typically 18 to 45 years of age) and children are lower than for women over 45 years old and men. The lower ATL values for the sensitive population provide additional protection to allow for normal growth and development of the brain and nervous system of unborn babies and children (Smith et al. 2016).

The “do not consume” mercury ATL for children and women up to age 45 is 0.44 ppm and for women over age 45 and men is 1.31 ppm. The “consume no more than one serving per week” ATL for children and women up to age 45 is between 0.15 and 0.44 ppm. For an adult, one

serving is considered an eight-ounce uncooked skinless filet (four ounces cooked). A serving for a child is half that (four ounces uncooked and two ounces cooked).OEHHA's third ATL for mercury is 0.07 ppm was a lower bound threshold until the ATL table was updated in November 2017. The new table added ATLs for four, five, six, and seven servings per week (Klasing and Brodberg 2008).

Results – Mercury Levels of Fish Tested from Humboldt Bay

In August of 2016, Humboldt Baykeeper enlisted the services of Captain Phil Glenn and his boat the Bluefin to assist in collecting fish for the study. On two half-day trips we caught five legal-sized California Halibut, three Bat Rays and one Leopard Shark. Numerous undersized halibut and Brown Smooth-hound Sharks were caught and released. Additional sampling in September of 2016 conducted by Ross Taylor and Associates (RTA) resulted in samples from two more Bat Rays and a Lingcod. Clam samples were collected in South Humboldt Bay with the assistance of the Wiyot Tribe on March 30, 2017. Additional sampling by RTA occurred on July 3rd, 21st and 27th and on September 24th and 29th of 2017. During these five sampling efforts the following samples were obtained: four Lingcod, two Black Rockfish, five Walleye Surfperch, two Jacksmelt, and one California Halibut. Farmed oysters were harvested in North Humboldt Bay by Coast Seafoods Company in Eureka.

The six California Halibut tested ranged in size from 4.8 pounds to 36 pounds in total weight (Table 1 and Figure 3). Five of these fish were caught north of the Samoa Bridge, and the sixth fish was captured south of the Samoa Bridge near the Coast Guard Station (Table 1 and Figure 3). These six fish (including duplicate tests) had total mercury levels between 0.094 and 0.354 ppm, and an average of 0.204 ppm (Table 1 and Figure 3). Most of these values are within the "no more than one serving per week" ATL range for children and women under the age of 45.

Five Bat Rays were tested and these fish ranged in size between 7.6 pounds and 48 pounds in total weight (Table 1 and Figure 3). All five Bat Rays were caught north of the Samoa Bridge. These five fish (including duplicate tests) had total mercury levels between 0.121 and 0.423 ppm, and an average of 0.276 ppm (Table 1 and Figure 3). Most of these values are within the "no more than one serving per week" ATL range for children and women under the age of 45.

Five Lingcod were caught while fishing along the north and south jetties at the entrance to Humboldt Bay. These fish ranged in size between 3.6 pounds and 9.2 pounds in total weight (Table 1 and Figure 3). These five fish (including duplicate tests) had total mercury levels between 0.1459 and 0.5405 ppm, and an average of 0.3157 ppm (Table 1 and Figure 3). Four of these values are within the "no more than one serving per week" ATL range for children and women under the age of 45 and the fish that weighed 9.2 pounds exceeded the ATL of 0.44 ppm (do not consume for children and women up to age 45). The five Lingcod caught along the

Humboldt Bay jetties had consistent increases of total mercury with increased body weight (Table 1 and Figure 3). Humboldt Baykeeper tested the total mercury levels of four Lingcod caught in 2005 in the ocean near Cape Mendocino. These fish ranged in size from 6.2 pounds to 25.4 pounds in total weight and had total mercury values between 0.362 and 0.910 ppm (Table 1 and Figure 3). The three largest fish were above the ATL of 0.44 ppm, the do not consume level for children and women up to age 45.

Five Walleye Surfperch were caught from the Humboldt Bay Redwood Terminal Dock, located on the west side of the bay, south of the Samoa Bridge. These five fish ranged in size between 2.2 ounces and 2.8 ounces, with relatively low total mercury values of 0.1004 to 0.1360 ppm (Table 1 and Figure 3).

Two Black Rockfish were caught along the south jetty at the entrance to Humboldt Bay. These two fish weighed 2.4 and 2.1 pounds, with relatively low total mercury values between 0.1320 and 0.1340 ppm (Table 1 and Figure 3).

One Leopard Shark was caught in the north section of Humboldt Bay in the channel that heads north towards Arcata. This fish had a total weight of 20.4 pounds and a total mercury level of 1.292 ppm (Table 1 and Figure 3). This Leopard Shark had the highest level of total mercury of the 34 samples tested from fish caught within Humboldt Bay (Table 1 and Figure 3). Other recent studies that tested Leopard Sharks caught in California all resulted in high levels of total mercury (Smith et al. 2016; Davis et al. 2010).

We also included the total mercury levels of five Chinook Salmon tested by Baykeeper in 2005 because the importance of the ocean salmon fishery to Northcoast anglers. These five salmon ranged in size from 4.7 pounds to 8.5 pounds and all had relatively low total mercury values between 0.027 and 0.051 ppm (Table 1 and Figure 3).

The average mercury concentration in the Albacore caught off Humboldt County coast was 0.110 ppm. These results are consistent with a study of albacore caught in Oregon in 2003, which found average mercury concentrations of 0.14 ppm (Morrissey et al. 2008).

The shellfish tested for mercury included Horseneck, Littleneck, and Martha Washington clams and oysters cultured in Humboldt Bay. All the shellfish samples tested were below 0.07 ppm and considered “safe to eat” in regards to total mercury (Figure 4).

Table 1. Humboldt Bay mercury testing results for eight fish species.

Collection Date	Species	Lab's Tissue Sample ID #	Total Length (inches)	Whole Weight (pounds)	Total Mercury (ppm)	Sample Location and Description
8/24/2016	California Halibut	CAHAL-001	24.0	5.4	0.130	North of Samoa Bridge in west channel
8/24/2016	California Halibut	CAHAL-001-D	24.0	5.4	0.138	North of Samoa Bridge in west channel
8/24/2016	California Halibut	CAHAL-002	23.6	5.4	0.094	North of Samoa Bridge in west channel
8/24/2016	California Halibut	CAHAL-003	22.8	4.8	0.206	North of Samoa Bridge in west channel
8/24/2016	California Halibut	CAHAL-004	22.8	5.1	0.152	North of Samoa Bridge in west channel
8/24/2016	California Halibut	CAHAL-005	24.8	5.7	0.354	North of Samoa Bridge in west channel
8/24/2016	California Halibut	CAHAL-005-D	24.8	5.7	0.342	North of Samoa Bridge in west channel
9/24/2017	California Halibut	CAHAL-006	45.5	36.0	0.220	Near Coast Guard Station
8/20/2016	Bat Ray	BATRY-001	28.3	48.0	0.396	North of Samoa Bridge in west channel
8/20/2016	Bat Ray	BATRY-002	15.0	7.6	0.160	North of Samoa Bridge in west channel
8/24/2016	Bat Ray	BATRY-003	23.2	24.4	0.383	North of Samoa Bridge in west channel
8/24/2016	Bat Ray	BATRY-003-D	23.2	24.4	0.423	North of Samoa Bridge in west channel
8/26/2016	Bat Ray	BATRY-004	19.3	15.2	0.322	North of Samoa Bridge in west channel
8/26/2016	Bat Ray	BATRY-005	20.1	15.8	0.121	North of Samoa Bridge in Arcata channel
8/26/2016	Bat Ray	BATRY-005-D	20.1	15.8	0.128	North of Samoa Bridge in Arcata channel
10/20/2016	Lingcod #1	LCOD-001	22.5	3.6	0.1459	South jetty
10/20/2016	Lingcod #1 duplicate	LCOD-001-D	22.5	3.6	0.1461	South jetty
7/21/2017	Lingcod #2	LCOD-002	29.1	9.2	0.5405	North jetty
7/21/2017	Lingcod #3	LCOD-003	26.0	6.8	0.4055	North jetty
7/21/2017	Lingcod #3 duplicate	LCOD-003-D	26.0	6.8	0.4198	North jetty
7/29/2017	Lingcod #4	LCOD-004	25.3	4.9	0.2681	South jetty
9/27/2017	Lingcod #5	LCOD-005	26.4	6.5	0.2839	South jetty

Table 1 (continued). Humboldt Bay mercury testing results for eight fish species.

Collection Date	Species	Lab's Tissue Sample ID #	Total Length (inches)	Whole Weight (pounds)	Total Mercury (ppm)	Sample Location and Description
2005	Lingcod	LCOD-1-2005	N/A	25.4	0.910	Ocean near Cape Mendocino
2005	Lingcod	LCOD-2-2005	N/A	20.2	0.853	Ocean near Cape Mendocino
2005	Lingcod	LCOD-3-2005	N/A	10.6	0.599	Ocean near Cape Mendocino
2005	Lingcod	LCOD-4-2005	N/A	6.2	0.326	Ocean near Cape Mendocino
7/03/2017	Walleye Surfperch #1	SHSPR-001	6.9	2.6 oz.	0.1171	Redwood Terminal Dock
7/03/2017	Walleye Surfperch #2	SHSPR-002	6.5	2.8 oz.	0.1105	Redwood Terminal Dock
7/03/2017	Walleye Surfperch #3	SHSPR-003	5.9	2.2 oz.	0.1125	Redwood Terminal Dock
7/03/2017	Walleye Surfperch #4	SHSPR-004	6.4	2.3 oz.	0.1004	Redwood Terminal Dock
7/03/2017	Walleye Surfperch #5	SHSPR-005	6.1	2.4 oz.	0.1360	Redwood Terminal Dock
7/29/2017	Black Rockfish #1	BLRCO-001	14.9	2.4	0.134	South jetty
9/27/2017	Black Rockfish #2	BLRCO-002	13.3	2.1	0.132	South jetty
9/27/2017	Black RF #2 duplicate	BLRCO-002-D	13.3	2.1	0.133	South jetty
7/03/2017	Jacksmelt #1	JSMEL-001	10.6	4.6 oz.	0.0762	Redwood Terminal Dock
7/03/2017	Jacksmelt #2	JSMEL-002	11.0	6.2 oz.	0.0821	Redwood Terminal Dock
8/24/2016	Leopard Shark #1	LEOSH-001	52.0	20.4	1.292	North of Samoa Bridge in Arcata channel
2005	Chinook Salmon	CS-1-2005	N/A	4.7	0.046	Ocean - west of Humboldt Bay entrance
2005	Chinook Salmon	CS-2-2005	N/A	5.0	0.051	Ocean - west of Humboldt Bay entrance
2005	Chinook Salmon	CS-3-2005	N/A	6.7	0.045	Ocean - west of Humboldt Bay entrance
2005	Chinook Salmon	CS-4-2005	N/A	8.5	0.027	Ocean - west of Humboldt Bay entrance
2005	Chinook Salmon	CS-5-2005	N/A	6.8	0.048	Ocean - west of Humboldt Bay entrance

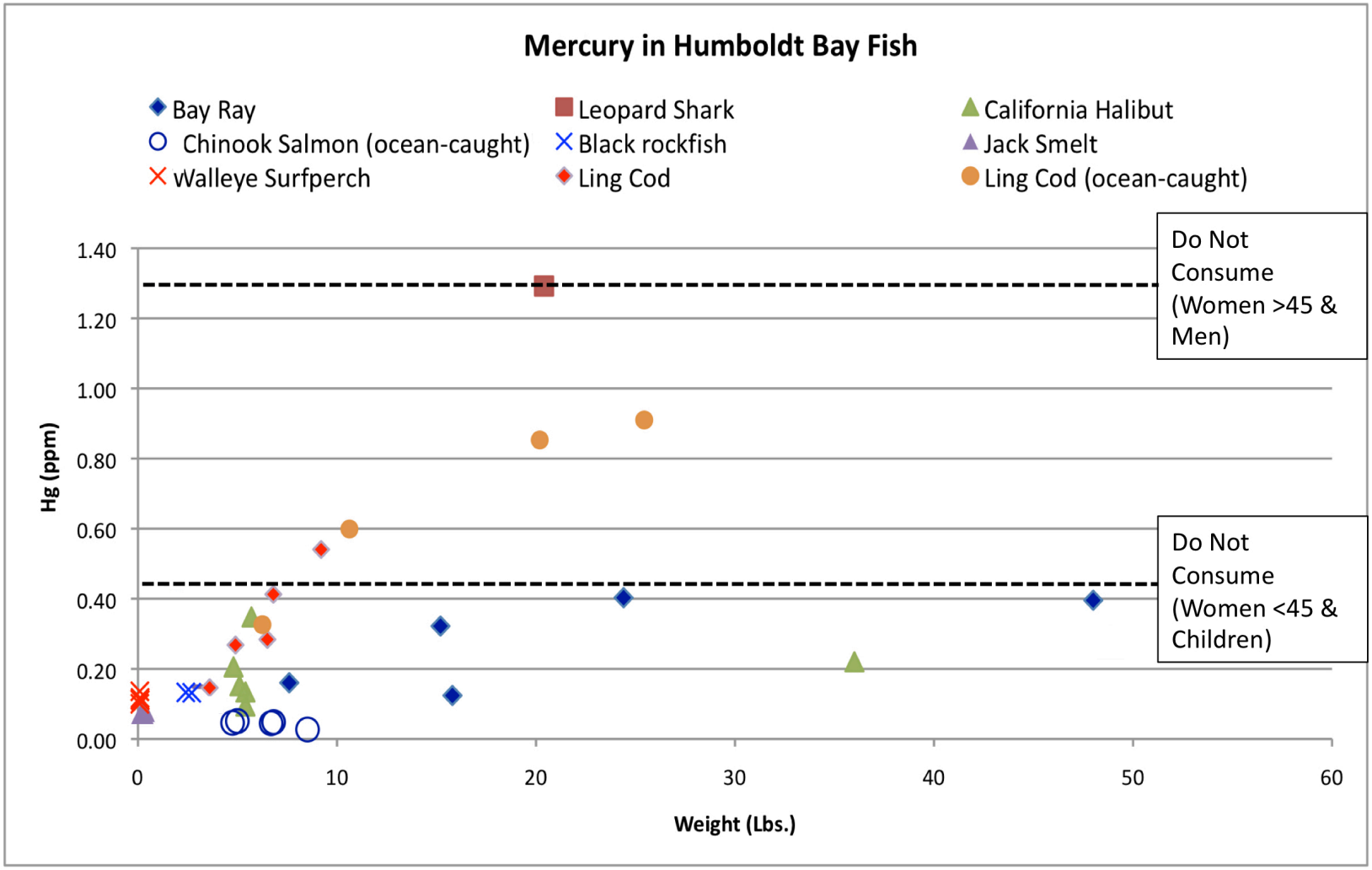


Figure 3. Humboldt Bay mercury testing results for eight fish species.

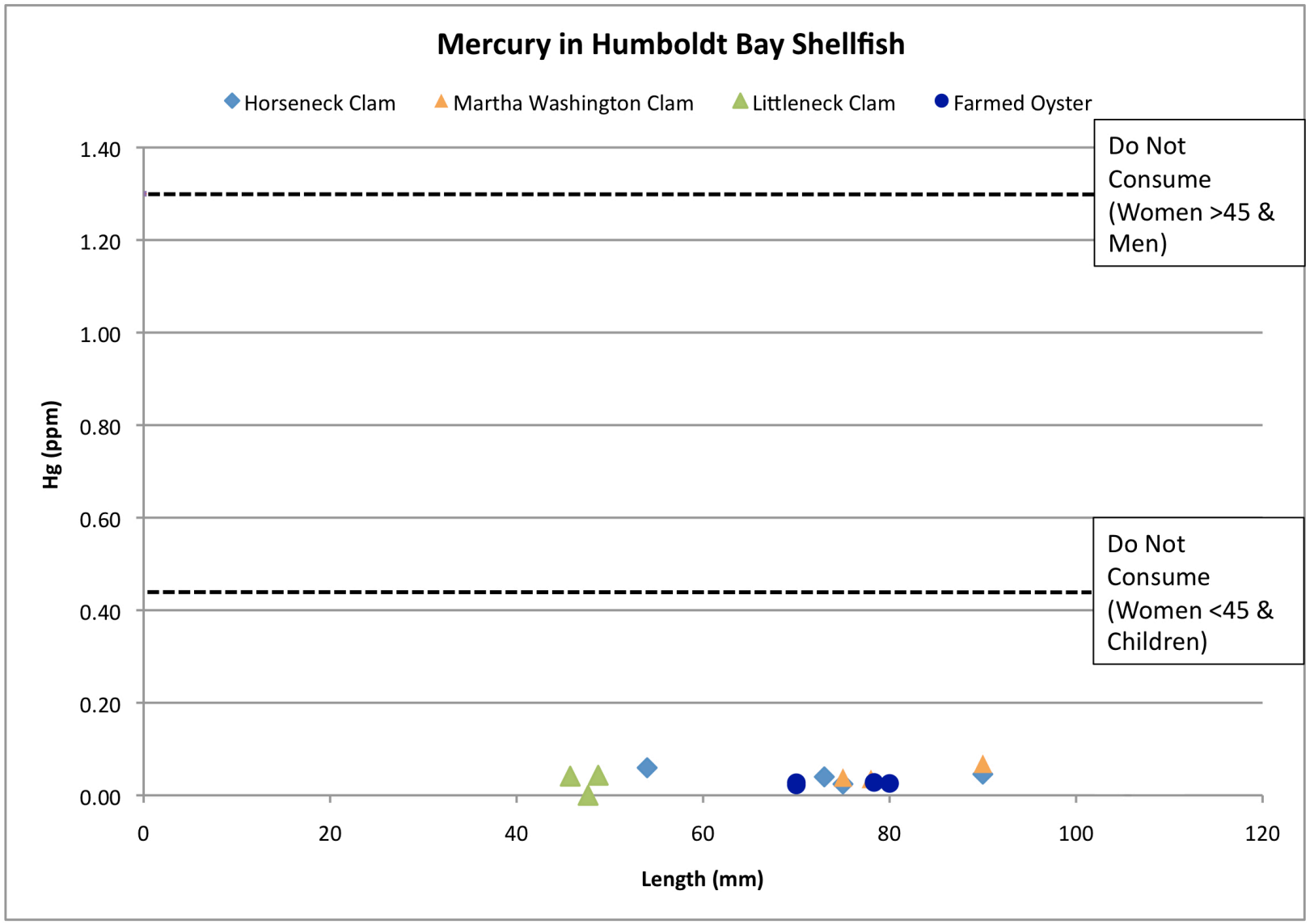


Figure 4. Humboldt Bay mercury testing results for four shellfish species.

Results – Anger Surveys:

A total of 80 shore-based anglers were interviewed to find out which fish species people catch and eat most frequently from Humboldt Bay. These surveys focused on the Del Norte Street Pier and several docks in Eureka, the North Jetty in Samoa, and the Mad River Slough Bridge in Manila. The Del Norte Street Pier is the only public fishing pier in Humboldt Bay, and is a very popular fishing spot (Figure 5**)**. In addition, angler surveys were conducted in Spanish at a bilingual health fair in Fortuna and at English-as-a-Second-Language (ESL) classes in Eureka. Angler surveys were also posted online in both Spanish and English.

Figure 5. The Del Norte Street Pier in Eureka is the only public fishing pier in Humboldt Bay, and was the site of the majority of angler surveys conducted for this study. The City of Eureka estimates that 10 to 15 anglers use the Del Norte Street pier a day.

Most people eat what they catch or feed it to their families, although some are fishing for bait to fish in ocean waters. Of the 80 anglers surveyed, five said they eat leopard shark from Humboldt Bay. The majority (62) said they eat shellfish from the bay; of those, 55 eat Dungeness crab and rock crab, 41 eat oysters**,** 24 eat clams, and 19 eat mussels. When asked, "How many times did you eat fish from Humboldt Bay in the last 30 days?" the answers ranged from 0 to 13. The number of years anglers surveyed had been fishing in Humboldt Bay ranged from "this is my first time" to "my whole life" (Figure 6).

The cooking methods people used included deep fry, pan fry, bake, grill, and boil. Of the 63 respondents who said they cook fish they catch in oil, only four said they reused the oil. Only eight respondents said they freeze, can, or smoke fish to be eaten throughout the year. The majority (57) removed the skin, while seven did not. A fisherman from Shelter Cove who was interviewed said he had elevated blood levels of mercury from consuming fresh, frozen, and canned fresh rockfish 3-4 times a week. His doctor advised eliminating all fish from his diet for three months, after which his blood levels of mercury declined.

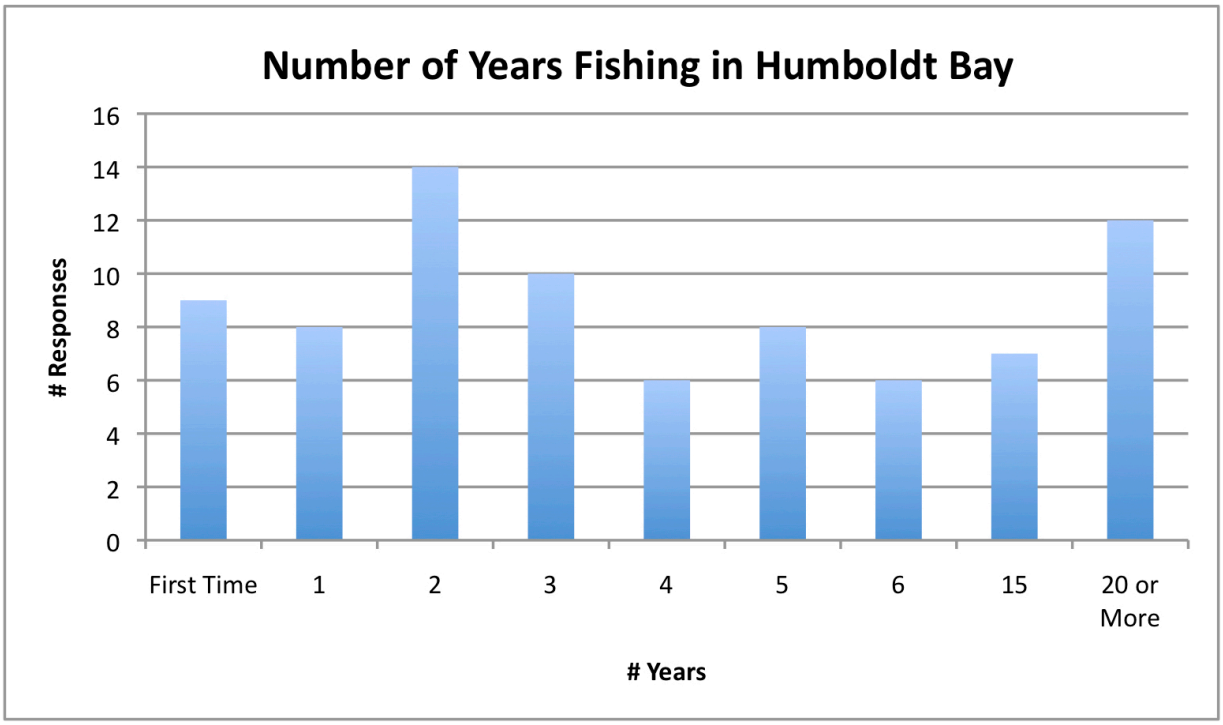


Figure 6. The number of years that respondents to the angler surveys have fished on Humboldt Bay.

Recommendations – Consumption Guidelines:

The ultimate purpose of this study is to provide the public who fish in or near Humboldt Bay information about mercury levels in the fish they and their families consume. The guidelines provided are based on OEHHA's recommended number of servings per week for the two previously mentioned populations: (1) women under the age of 45 and children, and (2) women older than 45 and men older than 18 years of age (Table 2). Ocean-caught Chinook Salmon had the lowest mercury levels of the locally tested fish and are safe to consume at a subsistence level of 20 to 28 meals per month by all people (Table 2). Because of the lower ATL's set for women under the age of 45 and children, all other fish species should be consumed at lower frequencies, and in the case of larger Lingcod and all Leopard Shark, avoided all together (Table 2).

Table 2. Average mercury levels in parts per million (ppm) for fish species caught in or near Humboldt Bay and guidelines for consumption.

Species	Average Mercury Levels, ppm	Recommended Servings* per Week, Women <45 & Children[1]	Recommended Servings* per Week, Women >45 & Men[1]
Oysters	0.026	7	7
Chinook salmon	0.043	5	7
Clams	0.045	5	7
Jack Smelt	0.079	2	7
Local Albacore	0.110	2	5
Walleye Surfperch	0.115	2	5
Black Rockfish	0.131	2	4
California Halibut	0.192	1	3
Bat Ray	0.281	1	2
Lingcod <10 lbs.	0.330	1	2
Lingcod >10 lbs.	0.787	AVOID	1
Leopard Shark	1.476	AVOID	AVOID

*Serving sizes: adults = 8 ounces uncooked (4 ounces cooked); children = 4 ounces uncooked (2 ounces cooked).

[1] Office of Environmental Health Hazard Assessment's Nov. 2017 Advisory Tissue Levels https://oehha.ca.gov/media/downloads/fish/report/atlmhgandothers2008c.pdf

Recommendations – Further Testing:

Based on the strong public interest received after we released our results via radio interview, local newsprint, tabling at several community functions, social media, and input solicited from tribal members and sport fishermen, there appears to be a need for further testing of fish consumed by Humboldt Bay sport fishers and Wiyot Tribe members. A literature review of mercury studies conducted throughout the Pacific Northwest revealed a wide range of mercury levels for fish and shellfish also present in or near Humboldt Bay (Carey et al. 2014; Davis et al. 2012; Dykstra 2008; SWRCB 1998) (Table 3).

Inquiries about the mercury levels in locally-caught Pacific Halibut have been made by Humboldt Bay-based sport fishers. Other requests have included testing of locally caught Cabezon, China Rockfish, Gopher Rockfish, and Copper Rockfish. Pacific Lamprey is a species harvested at the mouth of the Eel River by Wiyot Tribe members, and there is interest in testing lamprey for mercury. Finally, we were only able to obtain a single legal-sized Leopard Shark from Humboldt Bay and would like to test several additional fish to have a better understanding of the range of mercury values in this species.

Table 3. Average mercury levels in parts per million (ppm) for fish species tested throughout the Pacific Northwest, along with OEHHA's recommended consumption levels (Klasing and Brodberg, 2008).

Species	Average Mercury Levels, ppm	Recommended Servings* per Week, Women <45 & Children[1]	Recommended Servings* per Week, Women >45 & Men[1]
Sardines	0.013	7	7
Anchovies	0.017	7	7
Mussels	0.041	5	7
Dungeness Crab	0.074	2	7
Pacific Halibut <40 lbs.	0.202	1	3
Pacific Halibut >40 lbs.	0.606	AVOID	1
Cabezon	0.474	AVOID	1
China Rockfish	0.643	AVOID	1
Gopher Rockfish	0.760	AVOID	1
Copper Rockfish	0.835	AVOID	1

*Serving sizes: adults = 8 ounces uncooked (4 ounces cooked); children = 4 ounces uncooked (2 ounces cooked)

Literature Cited:

ATSDR. 1999. Toxicological Profile for Mercury. Agency for Toxic Substances and Disease Registry. Centers for Disease Control, U.S. Department of Health and Human Services, Atlanta, GA.

Bloom, N.S. 1992. On the chemical form of mercury in edible fish and marine invertebrate tissue. Canadian Journal of Fisheries and Aquatic Sciences 49(5):1010-1017.

Bose-O'Reilly, S., K. M. McCarty, N. Steckling, and B. Lettmeier. 2010. Mercury Exposure and Children's Health. Current Problems in Pediatric and Adolescent Health Care 40(8): 186–215.

Carey, A. J., L. A. Niewolny , J. A. Lanksbury and J. E. West. 2014. Toxic Contaminants in Dungeness crab (*Metacarcinus magister*) and Spot Prawn (*Pandalus platyceros*) from Puget Sound, Washington, USA. Washington Department of Fish and Wildlife.

Davis, J.A., J.R.M. Ross, S.N. Bezalel, J.A. Hunt, A.R. Melwani, R.M. Allen, G. Ichikawa, A. Bonnema, W.A. Heim, D. Crane, S. Swenson, C. Lamerdin, M. Stephenson, and K. Schiff. 2012. Contaminants in Fish from the California Coast, 2009-2010: Summary Report on a Two-Year Screening Survey. A Report of the Surface Water Ambient Monitoring Program (SWAMP). California State Water Resources Control Board, Sacramento, CA.

Evenson, F. 2006. Mercury Isn't Rising In North Coast Commercial Fish. Currents Magazine, Spring 2006. Humboldt Baykeeper, Eureka, CA.

Gassel, M. and R. Broberg. 2005. General Protocol for Sport Fishing Sampling and Analysis. California Office of Environmental Health Hazard Assessment. California Environmental Protection Agency, Sacramento, CA.

Klasing, S. and R. Brodberg. 2008 (Updated ATL Table November 2017). Development of Fish Contaminant Goals and Advisory Tissue Levels for Common Contaminants in California Sport Fish: Chlordane, DDTs, Dieldrin, Methylmercury, PCBs, Selenium, and Toxaphene. California Office of Environmental Health Hazard Assessment. California Environmental Protection Agency, Sacramento, CA.

NCRWQCB. 2012. Final California 2012 Integrated Report (303(d) List/305(b) Report) Supporting Information, Regional Board 1 - North Coast Region. https://www.waterboards.ca.gov/water_issues/programs/tmdl/2012state_ir_reports/00001.shtml.

Silbernagel, S.M., D. O. Carpenter, S. G. Gilbert, M. Gochfeld, E. Groth III, J. M. Hightower, and F. M. Schiavone. 2011. Recognizing and Preventing Overexposure to Methylmercury from Fish and Seafood Consumption: Information for Physicians. Journal of Toxicology 2011: 1-7.

Smith, W., H.T. Pham, S. Klasing, M. Gassel, and S. Murphy. 2016. Statewide advisory for eating fish from California coastal locations without site-specific advice. Office of Environmental Health Hazard Assessment, Oakland, CA. 59 p.

Turtle Island Restoration Network Mercury Calculator: http://seaturtles.org/programs/mercury/

U.S. EPA. 2000. Guidance for assessing chemical contaminant data for use in fish advisories. Volume 1: Fish sampling and analysis, 3rd edition. Report #EPA 823-B-00-007.

Verbrugge, L.A. 2007. Fish Consumption Advice for Alaskans: A Risk Management Strategy to Optimize the Public's Health. Alaska Scientific Advisory Committee for Fish, Alaska Department of Public Health.

Weiss-Penzias, P. S., C. Ortiz Jr., R. P. Acosta, W. Heim, J. P. Ryan, D. Fernandez, J. L. Collett Jr., and A. R. Flegal. 2012. Total and monomethyl mercury in fog water from the central California coast. Geophysical Research Letters 39: 3804-3809.

Appendix A. Recommended equipment list for collecting tissue samples in the field for methylmercury testing. Developed for boat-based sampling in Humboldt Bay, California.

1. Field Log book.
2. Data sheets.
3. Sample ID labels.
4. Clip board.
5. Handheld GPS unit (or boat-based unit).
6. Depth finder on boat to measure depth(s) at collection location(s).
7. Indelible pens.
8. Collection equipment – rods, reels, bait, lures, landing net, club, etc.
9. Digital camera for taking specimen photos.
10. Measuring device – tape or board.
11. Scale for weighing fish.
12. Scale for weighing tissue samples.
13. Filet knives and sharpening stone.
14. Aluminum foil – extra-heavy duty.
15. Freezer tape.
16. Gallon zip-lock bags for tissue samples.
17. Folding table for processing fish and samples.
18. Plastic sheet or tarp to cover folding table.
19. Cleaning board.
20. Cooler with ice for temporary storage of tissue samples.
21. Liquid dish soap - for cleaning hands, knives and other processing equipment between samples.
22. Distilled water for rinsing hands, knives and other processing equipment between samples. Several gallons (at least).
23. Paper towels (two or three rolls).

APPENDIX B: PHOTOGRAPHS OF SAMPLED FISH FROM HUMBOLDT BAY

Figure B-1. Bat Ray #1 (weight = 48.0 pounds) caught on August 20, 2016.

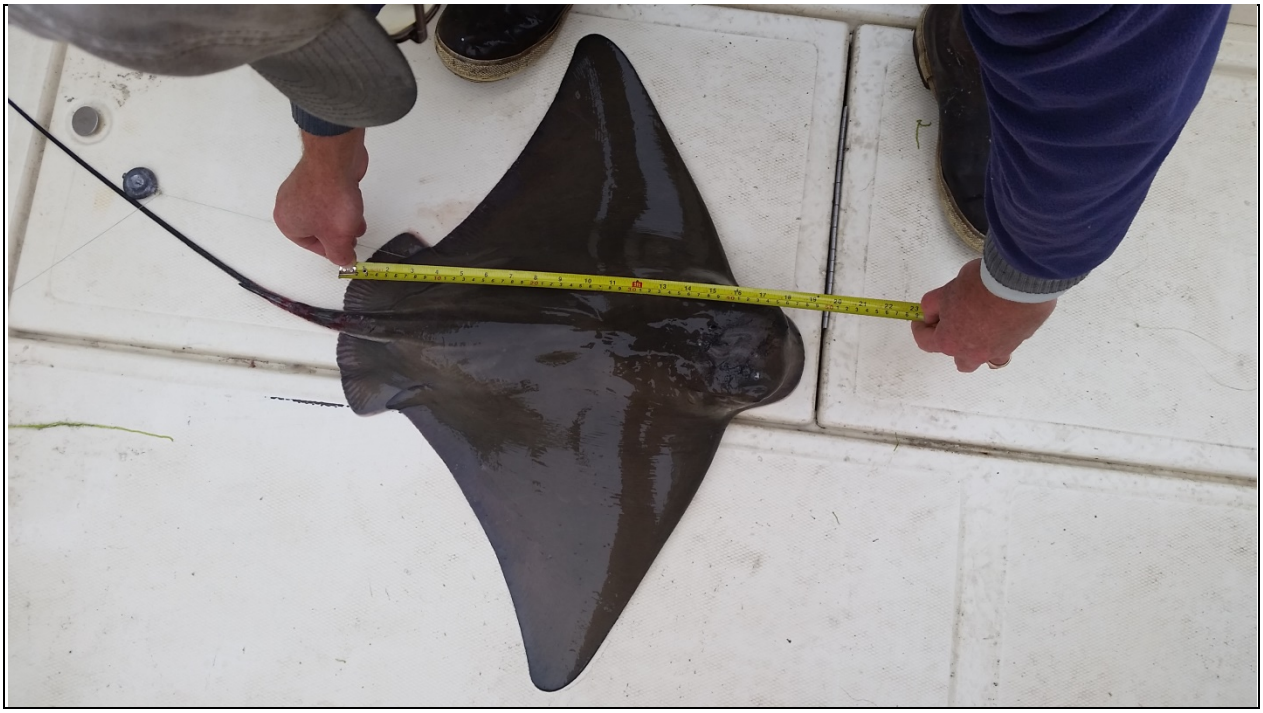


Figure B-2. Bat Ray #2 (weight = 24.4 pounds) caught on August 28, 2016.

Figure B-3. Black Rockfish #1 caught on July 29, 2017 along the south jetty of Humboldt Bay.

Figure B-4. Black Rockfish #2 caught on September 27, 2017 along the south jetty of Humboldt Bay.

Figure B-5. Lingcod #2 (weight = 9.8 pounds) caught on July 21, 2017 along the north jetty of Humboldt Bay.

Figure B-6. Lingcod #3 (weight = 6.8 pounds) caught on July 21, 2017 along the north jetty of Humboldt Bay.

Figure B-7. Walleye Surfperch caught on July 3, 2017.

Figure B-8. Walleye Surfperch #1-5 caught on July 3, 2017.

Figure B-9. Leopard Shark #1 (weight = 20.4 pounds) caught on August 20, 2016.

Figure B-10. California Halibut #3 (weight = 5.1 pounds) caught on August 24, 2016.