Clear Lake TMDL for Mercury

Numeric Target Report

Preliminary Draft

August, 2000
DISCLAIMER

This publication is a technical report by staff of the California Regional Water Quality Control Board, Central Valley Region. No policy or regulation is either expressed or intended.
Clear Lake TMDL for Mercury

Numeric Target Report

Preliminary Draft

August, 2000

REPORT PREPARED BY:

JANIS COOKE
Environmental Specialist III

And

JOE KARKOSKI
Senior Land and Water Use Analyst

Sacramento River Watershed TMDL Unit
# Table of Contents

Executive Summary ......................................................................................................................1  

Introduction ..................................................................................................................................6  

Selection of Type of Target ..............................................................................................................11  
    Fish tissue ..................................................................................................................................12  
    Other biota ...............................................................................................................................12  
    Sediment .................................................................................................................................13  
    Water ....................................................................................................................................13  

Potential Human Health Targets ..................................................................................................15  
    Fish tissue target equation ......................................................................................................16  
    Acceptable Daily Intake Level.................................................................................................16  
    Body weight and portion size .................................................................................................20  
    Consumption Rates ................................................................................................................21  
    Fish Tissue Targets ................................................................................................................29  

Potential Wildlife Health Targets .................................................................................................30  
    Mammals ...............................................................................................................................31  
    Avian Species .........................................................................................................................32  
    Mercury in wildlife at Clear Lake ............................................................................................33  
    Comparison of human and wildlife potential targets ...............................................................34  
    Conclusions regarding wildlife targets ..................................................................................36  

References ......................................................................................................................................38
Executive Summary

Section 303(d) of the Federal Clean Water Act requires that States identify waterbodies that are not meeting water quality standards and to develop total maximum daily pollutant loads for those waterbodies. A Total Maximum Daily Load (TMDL) represents the total loading rate of a pollutant that can be discharged to a waterbody and still meet the applicable water quality standards. A TMDL can be part of a plan to fix existing water quality problems. The purpose of the mercury TMDL for Clear Lake is to identify the mercury control measures and additional information needed to meet water quality standards and to guide the implementation of control measures and monitoring programs.

This report, “Clear Lake Mercury TMDL Program: Identification of Numeric Water Quality Targets” presents the first major step in development of a TMDL for mercury in Clear Lake. Objectives of this report are to:

1. describe methodology that the Regional Board plans to use in determining water quality targets for mercury;
2. present options for targets and for factors, such as acceptable intake levels of mercury, that are incorporated into final target values.
3. recommend numeric targets for the Clear Lake mercury TMDL that are fully protective of beneficial uses of Clear Lake.

The numeric target recommendations result from review of the best available data and a scientifically-based evaluation of the risks posed by mercury in Clear Lake. Questions of economic or technical feasibility of reaching the target were not considered in determining the target recommendations. Feasibility and economic considerations will be addressed as a program of implementation is developed. The target suggested in this report may be modified based on consideration of economics, technical feasibility, as well as comments on the scientific merit of the methodologies described and the assumptions made.

This document is a draft, which will be revised following a public comment period and receipt of comments from peer and public reviewers. Reviewers are encouraged to examine the methodologies and data used in development of wildlife and human targets, as well as the final values. The final TMDL will also include: numeric water quality targets; quantification and location of all mercury sources; analysis of linkages between mercury entering Clear Lake and water quality endpoints; reductions in load from each source necessary to achieve targets, and margin of safety that considers seasonal variations and uncertainties.

A TMDL report will be completed by Regional Board staff and submitted to the US Environmental Protection Agency (EPA) in June 2001. The TMDL report will include those components of a TMDL required under the Clean Water Act. The TMDL described in the report to EPA may be modified as the Regional Board develops a program of implementation and goes through the public process of modifying its water quality control plan (Basin Plan). The Basin Plan Amendment, which will include the Clear Lake mercury TMDL and associated implementation plan, must be adopted by the Regional Board, approved by the State Water Resources Control Board, State Office of Administrative Law,
Mercury can be found in the environment in numerous chemical forms. One organic form, methylmercury, is the most hazardous form of mercury to mammals including humans, birds and aquatic animals. Within an organism, rates of intake of methylmercury tend to be greater than rates of elimination, such that it accumulates within tissues as an organism ages. Methylmercury also becomes increasingly concentrated in higher trophic levels of the food web.

Mercury adversely affects neurological, reproductive and immune systems. In humans, the nervous system during early development is the most sensitive organ system to toxic effects of mercury. In wildlife, sensitive endpoints that are measured in field or laboratory studies are various indicators of reproductive success, motor control and damage to the neural system detected microscopically after death. The primary route of exposure to mercury is through consumption of mercury-contaminated fish and other aquatic organisms.

Clear Lake in Lake County, California is considered impaired due to mercury. High levels of mercury in fish are of concern to humans and wildlife that eat fish from Clear Lake. A fish consumption advisory was issued by California Department of Health Services in 1987. Based upon high fish tissue concentrations of mercury and the fish consumption advisory, the Regional Board placed Clear Lake on the Clean Water Act 303(d) List of Impaired Waterbodies. Elevated levels of mercury have also been measured in lake sediment, water, birds and other organisms from Clear Lake. The objective of the TMDL is to lower mercury levels so that the beneficial uses of Clear Lake as wildlife habitat and sport and recreational fishery are fully supported. Sources of mercury in Clear Lake include the site of an inactive mercury mine on Oaks Arm, geothermal vents, erosion of mercury-enriched soil, urban and agricultural runoff and atmospheric deposition.

Types of Targets

Targets could be determined for mercury measurements in biota, water or sediment. Mercury measurements in the target media should assess fairly directly whether beneficial uses are being met. Because the major beneficial uses of Clear Lake that are not currently being met address fish consumption for humans and wildlife, a target of mercury in fish tissue would provide a direct measure of fishery conditions and improvement. Mercury data in fish from Clear Lake that has been collected since 1970 provides a good baseline from which to evaluate the success of future load reductions. A target of mercury in fish tissue, therefore, is proposed as the primary target type for the Clear Lake mercury TMDL.

Analyses of mercury in feathers and eggs are well-established methods for evaluating exposure of birds to mercury. However, information is lacking in order to develop avian targets for Clear Lake. Threshold effect levels of mercury are unknown for fish-eating birds at Clear Lake that could be used as indicator species, such as mergansers, grebes, herons or osprey. Human hair has been used extensively to estimate exposures of individual humans to mercury. Human exposure to mercury in the Clear Lake
region likely varies widely. It would be difficult to establish a baseline of human exposures, from which to make future comparisons.

Existing data from Clear Lake show that sediment concentrations of mercury or methylmercury correlate poorly with concentrations of methylmercury in the water column or biota. The California Toxics Rule (CTR) mercury criterion does apply to Clear Lake. This criterion of 50 ng/L total recoverable mercury in water is intended to protect human health from consuming contaminated organisms and drinking water. The CTR value is not considered to be sufficiently protective of humans consuming fish from Clear Lake. However, because the criterion is a definite goal which needs to be met in Clear Lake, it could be used as a secondary target for the TMDL.

**Potential Fish Tissue Targets for Human Health**

A fish tissue target can be calculated using the following basic equation:

\[
\text{Daily intake} \times \text{consumer’s body weight} = \text{acceptable level of mercury in fish tissue.} \\
\text{consumption rate}
\]

Units in this equation are: \(\mu g \, Hg/\, \text{kg bwt/day} \times \text{kg bwt} = \mu g \, Hg/\, \text{g fish (ppm)} \)

The acceptable daily intake is the quantity at or below which humans consuming methylmercury are expected to be protected from adverse effects. To people not exposed to mercury in a workplace, ingestion of seafood containing methylmercury is the most significant route of exposure. Mercury intake levels are based on studies of humans exposed to methylmercury in the diet. Retrospective studies have been made of effects of methylmercury poisoning incidents in Minamata Bay, Japan and in Iraq. These studies clearly showed that neonates and young children are most sensitive to toxic effects of methylmercury. More recently, long-term, cohort studies have been conducted within populations that regularly consume seafood contaminated with mercury. These newer studies evaluated exposure during pregnancy and measured relatively subtle effects on fine motor control, memory and audio-visual functions in children born to mothers who ate seafood.

The US EPA and the US Agency for Toxic Substances and Disease Registry have developed daily intake levels specifically designed to protect unborn children from mercury consumed by their mothers. The higher US Food and Drug Administration daily intake levels was designed only to protect adults. Since they protect the most sensitive lifestage, the USEPA reference dose (0.1 \(\mu g/\, \text{kg/bwt/day}\)) and the ATSDR minimal risk level (0.3 \(\mu g/\, \text{kg/bwt/day}\)) are both acceptable options for use in the TMDL. The Regional Board recommends using the USEPA reference dose. Although the US EPA acceptable daily intake value was originally based upon data from a mass poisoning incident in Iraq, a panel of the National Research Council recently concluded that more recent data supports the USEPA value.

An adult bodyweight of 65 kg is recommended for use in developing the target. This is USEPA’s standard bodyweight for pregnant females. To best ensure that a mercury target protects the unborn, it is logical that an average adult consumer be represented by a pregnant female. Conversion factors are
available to adjust the target for other bodyweights. Children would only be at risk of mercury toxicity if they consumed more than the average portion for their body size.

The most difficult of the variables to define is the consumption rate. One consumption study has been completed, with some neighbors of the Sulphur Bank Mercury Mine at Clear Lake (mainly members of the Elem Indian Colony). Participants reported eating an average 60 g/day of Clear Lake fish and, on average an additional amount of commercial fish. Species consumed in the greatest amounts were catfish and perch. Consumption rates of fish and other seafood determined in various national and regional studies vary widely. Consumption studies have been reviewed extensively in a report by the California Office of Environmental Health Hazard Assessment and in the Mercury Study Report to Congress. Mean consumption rates for consumers only range from 9 to 111 g/day, with several studies finding average consumption rates in the narrower range of 45-60 g/day. Consumption rates for consumers in the 90th to 95th percentiles range from 65 to more than 200 g/day. Consumers are exposed to mercury in sport as well as commercial fish. A person eating one eight ounce meal per month of commercial tuna would have a mercury exposure level of 0.02 µg/kg bwt/day. As a starting point for discussion of the human health target, Regional Board staff propose using a consumption rate of 60 g/day.

Using the above equation with the recommended values for acceptable daily intake, consumption rate and body weight, the resulting level of mercury in fish tissue that is safe for human consumption is 0.1 µg mercury/g fish tissue. This target is an overall value for mercury in trophic levels three and four fish. Acceptable levels of mercury could be higher in some species, depending upon the proportions of fish from each trophic level consumed. The target is recommended as a starting place for discussions of scientific merit. Technical and economic feasibilities of reaching the target, which are not addressed in this report, will be addressed in the final TMDL. Such considerations may result in final adoption of a different numeric target.

**Potential Fish Tissue Targets for Wildlife Health**

Wildlife species potentially at risk from toxic effects of mercury are those that eat fish or other aquatic organisms that contain mercury. Species of concern at Clear Lake include river otter, raccoon, mink, herons, grebes, bald eagles and osprey.

The same variables described above for humans can be used for wildlife to determine safe fish tissue concentrations. The above basic equation can also be rearranged to determine the average daily intake of mercury for different wildlife species consuming fish from Clear Lake with known levels of mercury. The average daily intake can then be compared with acceptable daily intake levels taken from scientific literature.

Many studies have been published that address mercury in wildlife, however there are relatively few studies that link known exposure levels to quantifiable effects. Authors of the 1997 Mercury Study Report to Congress (MRC) and the 1995 Great Lakes Water Quality Initiative Final Rule (GLWQI) selected one set of feeding studies in mink to determine acceptable daily intake levels for fish-eating
mammals. The single-generation investigations evaluated endpoints of survival, growth rates, motor control and histologic assessment of neuronal damage, but not reproduction. Final acceptable daily intake levels for mammalian wildlife were extremely close: 0.018 mg Hg/kg bwt/day from the MRC and 0.016 mg Hg/kg bwt/day from the GLWQI. Both the MRC and GLWQI based their acceptable daily intake levels for fish-eating birds on results of a three-generation study of mallard ducks by Heinz and colleagues. The daily intake value of 0.026 mg mercury/kg bwt per day determined in the MRC is used for calculations in this report.

Mammalian and avian acceptable daily intake values were compared with estimated actual daily intakes of wildlife at Clear Lake. These comparisons showed that wildlife consuming fish from Clear Lake are highly likely to exceed acceptable daily intake levels of mercury. Current mercury intake by river otters is estimated to be at least twice the acceptable daily intake level and by kingfishers to be about three times the acceptable level. For raptorial birds, intake may be at or slightly higher than acceptable daily levels.

In terms of absolute amounts of fish consumed, humans consume much less than most fish-eating wildlife species. A hypothetical human consumer eating 60 g/day of a combination of fish from trophic levels three and four, however, would be exposed to mercury at more than four times the acceptable daily intake level for humans. Reducing mercury concentrations in trophic level three and four fish such that human exposure is at a safe level would presumably reduce mercury exposure of wildlife to below safe levels. Therefore, Regional Board staff are not recommending a separate fish tissue target for the protection of wildlife at this time.
Clear Lake TMDL for Mercury

Numeric Target Report

Introduction

Mercury is a widespread environmental contaminant that adversely affects humans and wildlife. It is a potent neurotoxin that also affects reproductive, cardiovascular and immune systems. The purpose of this document is to describe the derivation of water quality targets for mercury that are designed to protect beneficial uses of the water and resources of Clear Lake, California by humans and wildlife. This draft report will be circulated to stakeholders and peer reviewers for comment. The final report, expected to be available in December 2000, will contain responses to all comments received. Final water quality targets will be derived based upon consideration of beneficial uses, economics and feasibility. The final water quality targets will be used for the mercury Total Maximum Daily Load (TMDL) program for Clear Lake.

The Regional Board will receive comments from the public on any portion of this document. Key topics about which the Regional Board would particularly like to receive opinions and any additional information are noted in bold type.

Toxicity of Mercury

Mercury is a potent neurotoxin. Developing fetuses and young children are at greatest risk of toxicity from mercury (White, 1995). Although the inhalation of elemental mercury fumes can cause harm, exposure to levels of concern most frequently occurs through the consumption of methylmercury in fish tissue. The aquatic food web provides more than 95% of humans’ intake of methylmercury (USEPA, 1997a). Toxicity of mercury to humans has been documented in populations consuming contaminated fish (Davidson et al., 1998; Grandjean et al., 1997; Kjellstrom et al., 1989; Tsubaki and Irukayama, 1977) and grains treated with methylmercury-containing fungicide (Bakir et al., 1973). Consumption of highly contaminated fish caused multiple effects, including tingling or loss of tactile sensation (paresthesia), loss of muscle control, blindness, paralysis, birth defects and death. Children whose mothers ate fish during pregnancy or who eat fish themselves, may be at risk for more subtle behavioral and developmental changes when fish contain lesser amounts of mercury. Effects in prenatally-exposed children appear at intakes five to ten times lower than intakes associated with toxicity in adults (NRC, 2000).

Effects of mercury are dependent upon the dose received. Levels of mercury in fish from Clear Lake are much lower (0.2 - 1.8 mg Hg/kg wet weight for top predator fish) (CVRWQCB, 1985) than levels in fish that poisoned consumers in Minamata Bay (fish levels up to 50 mg/kg). There is no current
evidence of acute or chronic mercury toxicity to humans due to consumption of fish from Clear Lake or Cache Creek. Extensive fish consumption and response studies, however, have not been conducted. Existing fish consumption advisories for Clear Lake, presented in terms of pounds of fish than can be safely consumed, are based upon the risk for average adult consumers of developing a non-fatal, neurologic impairment of paresthesia. Pregnant women, women who may soon become pregnant, nursing mothers and children under age 6 are advised not to eat fish from Clear Lake (Stratton et al., 1987).

Wildlife species also exhibit detrimental effects from mercury exposure. Behavioral effects including impaired learning, reduced social behavior and impaired physical abilities have been observed in mice and a primate species, crab-eating macaques exposed to methylmercury (Wolfe et al., 1998). Reproductive impairment following mercury exposure has been observed in several species, among them common loons and western grebe (Wolfe et al., 1998), walleye (Whitney, 1991 in: (Huber, 1997) and mink (Dansereau et al., 1999).

Mercury Chemistry and Accumulation by Biota

Mercury can exist in various chemical forms in the environment. Chemically, mercury can exist in three oxidation states: elemental (Hg⁰), mercurous ion (monovalent, Hg²⁺), or mercuric ion (divalent, Hg⁴⁺). Ionic mercury can react with other chemicals to form inorganic compounds (such as cinnabar, HgS) or organic compounds (such as methylmercury or dimethylmercury). Physically, mercury may be present in air as mercury vapor, dissolved in the water column, or may be associated with solid particles in air, water or soil.

Both inorganic mercury and organic mercury can be taken up from water, sediments and food by aquatic organisms. Because rates of uptake are generally much greater than rates of elimination, mercury concentrates within organisms. For low trophic level species such as phytoplankton, most mercury is obtained directly from the water. Bioconcentration describes the net accumulation of mercury directly from water. The bioconcentration factor (BCF) is the ratio of mercury concentration in an organism to mercury concentration in water. Most mercury in predatory species such as pisciverous fish and birds is obtained from mercury-containing prey rather than directly from the water (USEPA, 1997b). A bioaccumulation factor (BAF) describes the degree to which mercury accumulates from water and prey, relative to mercury concentration in the water. Compounds bioaccumulate when rates of uptake are greater than rates of elimination.¹

¹ The differences between BCF and BAF are not always clear. BCF are generally determined in the laboratory, by measuring concentration in an organism after being placed for a discrete period of time in water with a known concentration of mercury. A BCF calculated this way would measure mercury taken in by passive absorption and drinking, but not by eating. BAF are determined from field data as the ratio between organism concentration and water column concentration of mercury, which would include the mercury consumed by the organism in its prey. Human and wildlife criteria issued by USEPA in the Final Water Quality Guidance for the Great Lakes System were
Repeated consumption and accumulation of mercury from contaminated food sources results in tissue concentrations of mercury that are higher in each successive level of the food chain. This process is termed biomagnification. Methylmercury readily accumulates in fish due to efficient uptake from dietary sources and low rates of elimination. The proportion of total mercury that exists as the methylated form generally increases with level of the food chain, approaching greater than 90% in top trophic level fish (Nichols et al., 1999). This occurs because inorganic mercury is less well absorbed and/or more readily eliminated than methylmercury. Field studies indicate that diet is the primary route of mercury uptake by fish (Wiener and Spry, 1996). Methylmercury is the predominant form of organic mercury present in biological systems. Dimethylmercury is not considered to be a concern in freshwater systems. It is an unstable compound, which dissociates to methylmercury at neutral or acid pH (USEPA, 1997a).

Diet is also the primary route of methylmercury exposure for organisms that consume fish and aquatic invertebrates. Although a few studies have indicated that methylmercury impairs reproduction of some fish (Huber, 1997; Wiener and Spry, 1996), the greatest concern for mercury toxicity is in higher trophic-level organisms that consume seafood. Wildlife of potential concern in the Central Valley for which mercury TMDLs will be developed include herons, egrets, mergansers and other fish-eating waterfowl; bald eagles; osprey; mink; raccoon and otter.

Sources of Mercury
The Coast Range of California is a region naturally enriched in mercury. Active geothermal vents and hot springs deposit mercury, sulfur and other minerals at or near the earth’s surface. Extensive mining of mercury in the Coast Range began in the early 1800s. Much of the mercury produced in the Coast Range was used to recover gold in the Sierra Nevada mountains. Mercury mining exacerbated the amount of mercury entering some waterbodies, due to erosion, weathering and even mass dumping of mercury-containing ores. Unacceptably high levels of mercury are present in some streams and lakes in the Coast Range and Sierra Nevada, the Sacramento River and the Sacramento San Joaquin River Delta.

Clear Lake is one waterbody polluted by mercury. Water quality investigations in Clear Lake conducted by the Central Valley Regional Water Quality Control Board, Department of Health determined using BAFs USEPA, 1995. U.S. Environmental Protection Agency, Federal Register, Vol. 60, No. 56 (Thurs. 23 March, 1995). Final Water Quality Guidance for the Great Lakes System. In deriving criteria in the California Toxics Rule, the USEPA used what they term “practical bioconcentration factors” The practical BCFs have been used by USEPA since 1980 and were derived in a way to “take into account uptake from food as well as uptake from water” USEPA, 2000. US Environmental Protection Agency, Federal Register, Vol. 65, No. 97 (Thurs. 18 May, 2000). Water Quality Standards; Establishment of Numeric Criteria for Priority Toxic Pollutants for the State of California; Rule.
Services, Department of Fish and Game, and US Geological Survey at various times since 1970 have shown elevated levels of mercury in water, lake sediment and biota. One current and historical source of mercury entering the lake historically and extant is the Sulphur Bank Mercury Mine (SBMM) site. SBBM, located on the Oaks Arm of Clear Lake, was among the nation’s ten largest mercury mines in terms of total production. The mine is now inactive. Mercury extraction from shafts started at Sulphur Bank in 1872. Mining continued using open pit methods from 1927 until operations ceased in 1957. SBMM was declared a federal Superfund site in 1991. Two remediation projects have been completed: regrading and vegetation of mining waste piles along the shoreline that decreased mass erosion into the lake, and construction of a surface water runoff diversion system that diverts clean runoff from flowing over mercury-containing wastepiles. The federal Environmental Protection Agency (USEPA) is currently conducting a remedial investigation to fully characterize the SBMM site and propose a final remedy. Additional sources of mercury may include geothermal vents and hot springs, urban and agricultural runoff, erosion of naturally mercury-enriched soils, and atmospheric deposition. In the Upper Arm, wild rice fields that are irrigated with water from Clear Lake could be sites of production of methylmercury, which then drains back into the lake via Middle Creek and Rodman Slough. Quantitative loading estimates from these sources have not yet been made.

High levels of mercury in fish are of concern to humans and wildlife that eat fish from Clear Lake. A fish consumption advisory was issued by California Department of Health Services (CDHS) in 1987 (Stratton et al., 1987). The Regional Board placed Clear Lake on the Clean Water Act 303(d) List of Impaired Waterbodies, based upon the fish consumption advisory. Elevated levels of mercury have also been measured in lake sediment, water, birds and other organisms from Clear Lake (CVRWQCB, 1985)

Mandated under Section 303(d) of the federal Clean Water Act, the Impaired Waterbody list for the Central Valley is prepared by the Central Valley Regional Water Quality Control Board (CVRWQCB) and approved by the State Water Resources Control Board (SWRCB) and the USEPA. Updates to the List are prepared every two years. Other waterbodies listed as impaired due to mercury are shown in Table 1.
Table 1. 1998 Clean Water Act Section 303(d) List of Waterbodies Impaired due to Mercury

<table>
<thead>
<tr>
<th>Waterbody</th>
<th>Total size</th>
<th>Impaired size</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>American River, downstream of Folsom Dam</td>
<td>30 miles</td>
<td>23 miles</td>
<td>medium</td>
</tr>
<tr>
<td>Cache Creek</td>
<td>60 miles</td>
<td>35 miles</td>
<td>high</td>
</tr>
<tr>
<td>Feather River, downstream of Oroville Dam</td>
<td>60 miles</td>
<td>60 miles</td>
<td>medium</td>
</tr>
<tr>
<td>Harley Gulch (flows to Cache Creek)</td>
<td>8 miles</td>
<td>8 miles</td>
<td>medium</td>
</tr>
<tr>
<td>James Creek (flows to Lake Berryessa)</td>
<td>6 miles</td>
<td>6 miles</td>
<td>low</td>
</tr>
<tr>
<td>Sacramento Slough</td>
<td>1 mile</td>
<td>1 mile</td>
<td>medium</td>
</tr>
<tr>
<td>Sacramento River, between City of Red Bluff &amp; the Delta</td>
<td>185 miles</td>
<td>30 miles</td>
<td>high</td>
</tr>
<tr>
<td>Sulfur Creek (flows to Bear Creek, then to Cache Creek)</td>
<td>7 miles</td>
<td>7 miles</td>
<td>high</td>
</tr>
<tr>
<td>Clear Lake</td>
<td>43,000 acres</td>
<td>43,000 acres</td>
<td>high</td>
</tr>
<tr>
<td>Davis Creek Reservoir</td>
<td>290 acres</td>
<td>290 acres</td>
<td>medium</td>
</tr>
<tr>
<td>Lake Berryessa</td>
<td>20,700 acres</td>
<td>20,700 acres</td>
<td>high</td>
</tr>
<tr>
<td>Waterways in the Sacramento-San Joaquin River Delta</td>
<td>48,000 acres</td>
<td>48,000 acres</td>
<td>high</td>
</tr>
</tbody>
</table>

By definition, an impaired waterbody does not support all of its designated beneficial uses. Water Quality Plans (Basin Plans) prepared by each RWQCB and approved by the SWRCB list the designated beneficial uses for each waterbody. Beneficial uses identified for Clear Lake are shown in Table 2.

Table 2. Existing and Potential Beneficial Uses of Clear Lake (Central Valley Region Basin Plan, 1998)

<table>
<thead>
<tr>
<th>Beneficial Use</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Municipal and domestic water supply</td>
<td>existing</td>
</tr>
<tr>
<td>Agriculture - irrigation</td>
<td>existing</td>
</tr>
<tr>
<td>Agriculture - stock watering</td>
<td>existing</td>
</tr>
<tr>
<td>Contact recreation (ex. swimming, skiing)</td>
<td>existing</td>
</tr>
<tr>
<td>Canoeing and rafting</td>
<td>existing</td>
</tr>
<tr>
<td>Other non-contact recreation (ex. boating, picnicking)</td>
<td>existing</td>
</tr>
<tr>
<td>Warm water fish habitat</td>
<td>existing **</td>
</tr>
<tr>
<td>Spawning area for warm water fish</td>
<td>existing **</td>
</tr>
<tr>
<td>Wildlife habitat</td>
<td>existing **</td>
</tr>
<tr>
<td>Sport/Recreational fishery</td>
<td>existing **</td>
</tr>
<tr>
<td>Cold water fish habitat</td>
<td>(potential use)</td>
</tr>
</tbody>
</table>

** Beneficial uses likely impaired by mercury in Clear Lake.

Waterbodies on the 303(d) List are not expected to meet water quality standards even if dischargers of point sources comply with their current discharge permit requirements. One tool to address ongoing
Preliminary Draft

issues of contamination from nonpoint and point sources is setting of TMDLs. The federal Clean Water Act mandates that TMDLs be developed for all waterbodies on the 303(d) List. A TMDL represents the maximum load (usually expressed as a rate, such as g/day) of a pollutant that can be discharged to a waterbody from all sources so that impairment is eliminated and beneficial uses are protected. In California, the RWQCB develops a TMDL and submits it to USEPA for approval. Elements that must be included in a TMDL are as follows:

• a numerical water quality target,
• identification of sources,
• the maximum load of the contaminant that will not adversely impact beneficial uses,
• a mathematical linkage between the water quality target and amount of contaminant (a linkage analysis is used to determine the amount by which current pollutant levels must be reduced in order to achieve the maximum load),
• allocation of portions of the necessary load reduction to the various sources, and
• margin of safety in the maximum load determination, that takes into account uncertainties and seasonal variations.

In addition to the federal TMDL requirements, the State of California is mandated under the Porter Cologne Water Quality Act to control pollution. As they are developed, water quality objectives and requirements are typically amended to regional Water Quality Plans (Basin Plans). Elements needed in the Basin Plan amendment process are like those needed for the TMDL, with the added requirement of an implementation plan. The CVRWQCB will submit the complete TMDL for mercury in Clear Lake to USEPA in June, 2001. Staff of the CVRWQCB anticipate bringing a Basin Plan amendment for mercury in Clear Lake before the citizen Board Members in 2002 or 2003.

SELECTION OF TYPE OF TARGET
Mercury is present in Clear Lake in sediment, water and biota. In theory, a target could be developed for any of these environmental compartments. In this section, environmental compartments will be evaluated for their applicability to the TMDL. Criteria for evaluating possible target media and evaluation results are also given in a target report prepared for the Sacramento River Watershed Program (LWA, 1999). Targets appropriate for the TMDL should evaluate as directly as possible whether beneficial uses are being attained. In the case of mercury, the beneficial uses unmet in Clear Lake are recreational and sport fishery and wildlife habitat. Other characteristics to be considered for the target:

• whether variability can be modeled and causes of variability are understood;
• whether ambient levels correlate with effects;
• Whether measurements of target level would reflect mass load reductions in a timely manner;
• the extent of remaining data gaps in the technical support of the target.
Fish Tissue
Fish tissue is proposed as the primary target type for this TMDL. Contaminated fish is the primary source of mercury for humans and wildlife species of concern. Adverse effects of mercury have been examined for at least some wildlife species and for humans (for reviews, see (USEPA, 1997a; USEPA, 1997b; Wolfe et al., 1998). Levels of mercury exposure in consumers can be estimated from these studies and known concentrations of mercury in fish. A fish tissue target, then, provides a direct measure of improvement in the capacity of Clear Lake to fully support its use as a fishery. Mercury data in fish from Clear Lake has been collected since 1970, providing a good baseline from which to evaluate the success of future load reductions [Stratton, 1987 #37; Suchanek, 1997 #42; (Suchanek et al., 2000). Clear Lake or region-specific values for bioaccumulation factors and consumption rates could be used to calculate fish tissue levels that are protective of wildlife and humans.

Other Biota
Tissues of mammals and birds that consume fish are also potential types of targets. Mercury concentrations have been reported in various internal organs, blood and in hair, fur and feathers. For mammals including humans, the most useful of these media are hair and blood. Human hair has been used extensively to estimate exposures of individuals to mercury (USEPA, 1997b). Targets based on human and other mammalian measurements have similar disadvantages. Sometimes wide variations are caused by differences in exposure, due to changing sizes, amounts and species of fish consumed, and in metabolism of mercury. For example, half-lives of mercury in adult humans can vary by a factor of two or more (MRC Vol. 7). Trapping fish-eating mammals is time consuming and, depending upon the study population, may not provide enough samples for statistical analysis (Wolfe and Norman, 1998). It would be difficult and likely expensive to establish a baseline representing all human consumers of Clear Lake fish, and to determine a subpopulation which could then tested periodically in the future.

Analyses in feathers or eggs are well established methods for evaluating exposure of birds to mercury (ETC review, Scheuhammer & Bond). Collection of feathers, particularly those that have been molted, is a non-invasive process. Because the embryo is the most sensitive life stage to mercury, analysis of eggs of nesting birds provides a valuable tool for evaluating effects of mercury on reproduction at the top of the food web. Although measurements have been made of mercury in eggs or feathers of birds at Clear Lake (Elbert, 1996; Suchanek et al., 1997; Suchanek et al., 1993), we are lacking information needed to develop avian targets for Clear Lake. Threshold effect levels in feathers or eggs are not known for potential indicator species at Clear Lake, such as mergansers, grebes, herons or osprey. The US Fish and Wildlife Service (USFWS) is currently conducting a CALFED-funded study on mercury dose and responses in avian species relevant to the San Francisco Bay and Delta, which may provide information applicable to Clear Lake.
Sediment

The Central Valley Regional Board is not seeking to develop a target for mercury or methylmercury in sediment. Existing data from Clear Lake shows poor correlations between concentration of mercury in sediment with levels of methylmercury in sediment or in the water column (McCalady et al., 2000; Suchanek et al., 1997). Sediment concentrations also do not correlate well with levels of mercury in fish or other aquatic organisms. Because of the lack of correlation between sediment levels and the amount of mercury found in biota and the lack of complete information about other sediment factors that regulate methylation, sediment is not recommended as a target compartment.

The draft mercury TMDL for San Francisco Bay proposes a target of total mercury in sediment for phase one of the San Francisco Estuary TMDL (Abu-Saba and Tang, 2000). Underlying the rationale of the proposed sediment target is the fact that for waterbodies in general, the concentration of total recoverable mercury in the water column is directly related to the amount of sediment suspended in the water. Concentrations and transport of suspended sediment in the Estuary are relatively well understood. The San Francisco Bay TMDL notes that if mercury concentrations in sediment were at pre-anthropogenic levels, there would be few, if any, instances for which concentrations of total recoverable mercury in the water column exceed the San Francisco Bay water quality objective (0.025 ng/L). The San Francisco Bay sediment target addresses the largest, ongoing external sources of inorganic mercury entering the Bay. Lacking complete information about factors controlling and sites of methylation, controlling mass loading of inorganic mercury is an appropriate place to start. The San Francisco Bay Regional Board proposes to develop targets for the second phase of TMDL that more directly assess beneficial uses, namely fish tissue and avian egg targets appropriate to San Francisco Bay. Studies are ongoing to obtain the data needed for these targets.

Water

Targets could be developed for four types of water measurements: total recoverable (unfiltered) or dissolved (filtered) levels, for mercury and/or methylmercury. There are established criteria for total recoverable mercury that apply to Clear Lake, that protect humans consuming aquatic organisms and drinking water. The California Toxics Rule (CTR) criterion of 50 ng/L total recoverable mercury is intended to protect human health from non-cancerous effects of consuming contaminated organisms and drinking water from the same source (USEPA, 2000). Mercury criteria for protection of aquatic life have not been promulgated in the CTR. The primary maximum contaminant level for mercury in drinking water, 2000 ng/L, is not exceeded in Clear Lake.

The CTR criterion for total recoverable mercury is exceeded in Clear Lake. Of water samples collected every six weeks to quarterly during May 1994 through August 1996, 25% (29/114) of deep water samples and 11% (13/114) of surface water samples contained mercury concentrations greater
than 50 ng/L. Most of the samples with levels above 50 ng/L were collected from Oaks Arm of Clear Lake. Mercury in water samples from Oaks Arm ranged up to 400 ng/L.

The CTR value is unlikely to be sufficiently protective of humans consuming fish from Clear Lake. The single study from Clear Lake and consumption studies from elsewhere in California suggest people catching fish from Clear Lake have a higher consumption rate than that used to derive the CTR value (Gassel et al., 1997; Harnly et al., 1997). The average consumption rate for a subpopulation at Clear Lake was 60 g/day of sport fish. An 18.7 g/day average consumption rate was used in calculation of the mercury CTR criterion (USEPA, 1997c). Bioaccumulation factors also appear to be higher for the Clear Lake ecosystem, than those used for the CTR criterion (Suchanek et al., 1993). EPA anticipates revising mercury criteria, based upon reevaluations of mercury human health information and additional bioaccumulation factor data. The CTR states that, “EPA supports the use of new information about bioaccumulation factors to develop site-specific criteria for mercury.” (USEPA, 2000).

Water column targets are not suggested as the primary target type for the Clear Lake TMDL. Total mercury in the water column is poorly correlated with levels of mercury in biota (Suchanek et al., 1992; Suchanek et al., 1997). The bulk of mercury measured as “total recoverable” is inorganic, particulate-bound mercury. It makes sense that measurements of mercury largely unavailable to organisms are not functionally related to mercury levels in fish. Criteria for total recoverable or dissolved mercury do not specifically address methylmercury, which is the form of mercury that bioaccumulates in organisms. If the linkage between loads of various forms of inorganic and organic mercury and total methylmercury concentrations in fish cannot be made sufficiently robust for the TMDL with existing Clear Lake data, the CTR value may be adopted as a first phase target for the Clear Lake TMDL. The correlation between dissolved mercury in the water column and mercury in biota of Clear Lake is slightly better than that for total recoverable mercury, but is still insufficient for the TMDL (Suchanek et al., 1997). Analysis of methylmercury in the water column, particularly of dissolved methylmercury, may provide a closer measure of mercury that actually accumulates within organisms and biomagnifies in the food web. The same concerns of lack of correlation between biota and water column measurements apply to methylmercury in Clear Lake.

Targets for mercury in water are one significant step removed from direct measurement of attainment of the beneficial use. In order to develop water column targets, a safe level of mercury in fish tissue is first determined, then the corresponding water column value calculated using the following equation:

\[
\text{concentration of mercury in water} = \frac{\text{concentration of mercury in fish}}{\text{bioaccumulation factor}}
\]

This method is used in the Mercury Study Report to Congress and the Great Lakes Water Quality Initiative – Final Rule to derive water column criteria for inorganic and methylmercury (USEPA, 1995;
USEPA, 1997a). This method is also used in the draft San Francisco Bay TMDL, which proposes a target for dissolved methylmercury. There is still considerable uncertainty in bioaccumulation factors, whether those that have been estimated using nationwide data (Mercury Study Report to Congress; used in the San Francisco Bay TMDL) or for Clear Lake (Suchanek et al., 1993). We propose calculating site-specific bioaccumulation factors for the Clear Lake TMDL to link the target with necessary load reductions.

**Key points – Selection of Type of Target**

- Fish tissue is proposed as the primary target type. Levels of mercury in fish tissue directly indicate whether beneficial uses are being met. Data on mercury in fish from Clear Lake has been collected since 1970.
- Other potential target types are mercury levels in hair and blood of mammals and in feathers and eggs of fish-eating birds, in sediment and in water.
- Data on baselines and causes of variations of mercury levels in biota other than fish are currently lacking.
- Levels of mercury and methylmercury in sediment do not correlate well with levels of methylmercury in the water column and biota.
- The California Toxics Rule criterion for total recoverable mercury in water, 50 ng/L, does apply to Clear Lake. This criterion is exceeded in 10-25% of water samples collected in Clear Lake.
- If linkages between loads of various forms of inorganic and organic mercury and total methylmercury concentrations in fish cannot be made sufficiently robust with existing Clear Lake data, the CTR value may be adopted as a first phase target for the Clear Lake TMDL.

**POTENTIAL HUMAN HEALTH TARGETS**

Note: The remainder of this document will discuss development of fish tissue targets for humans and wildlife. In fish consumed by humans and wildlife species of concern, more than 90 percent of mercury is in the form of methylmercury. Analyses of fish tissue typically measure total mercury, with the understanding that most of the mercury present is in the most toxic form. In the following discussions, “mercury” refers mainly to methylmercury.

The Clear Lake mercury TMDL process seeks to reduce the risks to humans and wildlife of consuming fish from Clear Lake. Setting a target for methylmercury in fish tissue to protect human health requires several decisions to be made on the way to determining a final fish tissue number. Key variables needed for the calculation of fish tissue targets are: an acceptable daily dose level, age and body weight of the consumer, fish consumption rate, and portion size. These variables will be discussed below.
Fish tissue target equation

The variables under consideration to develop a fish tissue target can be related using the following basic equation:

\[
\text{Daily intake} \times \text{consumer’s body weight} \times \text{consumption rate} = \text{acceptable level of mercury in fish tissue.}
\]

Units in this equation are: \(\mu g \, Hg / kg \, bwt/day \times kg \, bwt / g \, fish \, (ppm)\)

Here is one example using the following assumptions:

- Consumer adult body weight of 65 kg,
- Consumption rate of one 8 oz fish meal per month, equivalent to 7.5 g fish/day
- USEPA’s acceptable daily intake level of 0.1 \(\mu g / kg \, bwt / day\)

\[
0.1 \, \mu g / kg \, bwt / day \times 65 \, kg \, bwt \times 7.5 \, g \, fish / day = 0.86 \, \mu g \, mercury / g \, fish, \, wet \, weight = 0.86 \, ppm
\]

As shown by this equation, consumption rate can make a marked difference in the calculated fish tissue concentration. In the example above, for an adult eating one fish meal each month, the acceptable level of mercury in fish consumed is 0.86 ppm or less. For an adult eating four fish meals each month, the acceptable fish tissue level drops to 0.2 ppm.

Options - Acceptable Daily Intake Level

The first variable to be determined is an acceptable daily intake level of methylmercury. The acceptable daily intake is the quantity at or below which humans consuming methylmercury are expected to be protected from adverse effects. To people not exposed to mercury in a workplace, ingestion of seafood containing methylmercury is by far the most significant route of exposure (USEPA, 1997b). Intake levels generally describe the acceptable dose relative to the consumer’s body weight. Levels are expressed as a daily rate (\(\mu g\) of mercury per kg body weight per day) of mercury intake. Several national and international agencies have set acceptable intake levels that are potentially applicable to Clear Lake.

Mercury intake levels are based on studies of humans exposed to methylmercury in the diet. There were mass poisoning episodes resulting in many fatalities in Minamata and Niigata, Japan in the 1950s and 1960s due to consumption of fish taken from waters into which methylmercury was discharged from industrial sources (Tsubaki and Irukayama, 1977). Famines in 1971 and 1973 forced Iraqi people to eat seed grain that was treated with methylmercury fungicide, also resulting in fatalities and...
lesser effects (Bakir et al., 1973). Studies of these situations conclusively linked methylmercury exposure to neurological disease and death and demonstrated severe effects in infants born of mothers whom themselves had few symptoms of methylmercury poisoning. More recently, long-term, cohort studies have been conducted with inhabitants of the Faroe Islands (Grandjean et al., 1997) and Seychelles Islands (Davidson et al., 1998). Newer studies of mercury consumption are tracking relatively subtle effects on fine motor control, memory and audio-visual functions. Peoples of the Faroe and Seychelles Islands are chronically exposed to methylmercury through seafood in their diets. These studies evaluated exposure during pregnancy and are continuing to measure development throughout childhood.

The USEPA and the US Agency for Toxic Substances and Disease Registry (ATSDR) have developed consumption limits specifically designed to protect unborn children from mercury consumed by their mothers. The numerical limit of 0.1 µg/kg bwt/day that USEPA published in 1995 is slightly less than the 1999 value determined by ATSDR of 0.3 µg/kg bwt/day. In 1998, Health Canada released its daily intake level to protect fetuses of 0.2 µg/kg bwt/day. Values to protect the unborn were derived from studies that correlated methylmercury dose consumed by the mother with adverse neurological effects or delayed development in their young children. The USEPA evaluated studies of victims of the mass poisoning incidents in Iraq (Marsh et al., 1987). The USEPA issued a “reference dose” (RfD) for methylmercury, which EPA describes as an estimate of a daily exposure levels to humans that is likely to be without an appreciable risk of deleterious effect during a lifetime. The ATSDR developed its minimal risk level for mercury from a study of mother-child pairs in the Seychelles Islands (Davidson et al, 1998). Although the USEPA RfD and the ATSDR minimal risk level are presented as daily intakes for adults, the levels were calculated to prevent extra risk of neurological damage to infants during gestation. Details of the derivation of the USEPA and ATSDR values, including uncertainty factors, can be found in the appendix (Gassel et al., 1997). Uncertainty factors and specific parameters used to obtain exposure levels for acceptable daily intake levels are also discussed in the Sacramento River Watershed Program’s target report (Appendix; (LWA, 1999).

The National Research Council (NRC) of the National Academy of Sciences recently released its guidance to USEPA on development of a reference dose (NRC, 2000). The NRC committee determined that the Iraq study, because of uncertainties and difference in exposure routes, should no longer be considered the critical study for the derivation of the RfD. Methylmercury exposures in the Iraq poisoning episodes are not comparable to low-level chronic exposures from contaminated fish. The NRC compared design and results of studies in the Faroe Islands, Seychelles Islands and New Zealand, and concluded that the Faroe Islands study is the most appropriate for deriving an RfD. NRC identified a benchmark dose level of 58 ppb Hg in umbilical cord blood, which corresponds to a benchmark of 12 ppm Hg in maternal hair. On the basis of its evaluation of newer mercury exposure data, the NRC committee concluded that EPA’s existing RfD is a scientifically appropriate level for the protection of public health.
Other daily intake limits have been developed that protect from adverse effects of methylmercury exposure only in adults. USFDA and the World Health Organization (WHO) each set consumption limits that were designed to protect adults. Adults in the Iraq poisoning incidents were evaluated for development of paresthesia (an abnormal “prickling” sensation in the skin), which is an early clinical symptom of neurological damage. The physiological threshold for developing neurological deficits in adults is higher than for infants and children. As a result, consumption limits designed to protect only adults are higher than those created to protect the unborn. The FDA’s acceptable daily intake for methylmercury, set in the 1970s, is 0.4 µg/kg bwt/day. In 1990, WHO set a level to protect adults of 0.48 µg/kg bwt/day. Both FDA and WHO have acknowledged that fetuses may be more sensitive than adults to effects of mercury. FDA recommends that pregnant women and children limit their intake of fish species known to contain high levels of mercury (Toffleson and Cordle, 1986; WHO, 1990).

The daily intake levels described above were calculated to represent “safe” levels of mercury intake for the age range for which the level is intended. Mercury exposure at or below the USEPA reference dose, for example, is not expected to cause any increase in the background level of risk for adverse outcomes in fetuses, children or adults.

Recommendations - Acceptable Daily Intake Level

The USEPA reference dose and the ATSDR minimal risk level are acceptable options for use in the TMDL. Neural development of a fetus during pregnancy is the most sensitive human life stage to toxic effects of methylmercury. To be fully protective of human health, therefore, a mercury dose level should protect this most sensitive age. Of the mercury dose levels established by various United States entities, the USEPA reference dose and the ATSDR minimal risk level were clearly calculated to be safe levels for pregnant women and unborn children. OEHHA has adopted the USEPA reference dose for its risk assessments of methylmercury exposure via sport fish consumption (OEHHA, 2000).

The existing USEPA RfD appears to be the intake level most consistent with protecting the beneficial uses in Clear Lake. The USEPA reference dose was based on studies of the Iraqi poisoning episodes. One disadvantage of using the current USEPA RfD is that the Iraq situation of high concentrations of methylmercury in bread consumed over a short period of time is a different exposure pattern than chronic consumption of relatively low methylmercury levels that is expected for populations of concern for the TMDL. Mercury received in a low dose, consistent exposure regimen could result in effects less severe than the same amount of mercury taken in over a shorter time period. Another concern with the USEPA RfD is that measurements of effects were based largely on parental recall of developmental and behavioral milestones in their children. In deriving the RfD, the benchmark dose was lowered ten-fold to take into account individual variation and uncertainties in the data. Although concerns exist about the
Preliminary Draft

studies behind the EPA value, the National Research Council’s evaluation of newer mercury exposure studies supports a RfD of 0.1 \( \mu g/kg \text{ bwt/day} \).

Numeric targets for mercury TMDLs need to be reexamined, should the USEPA reference dose change. EPA indicated that it will reexamine mercury water quality objectives, taking into account the National Research Council’s findings and evaluations that are not yet available regarding fish consumption and bioaccumulation factors. Newer studies of mercury consumption are tracking relatively subtle effects on fine motor control, memory and audio-visual functions. An evaluation and possible adjustment of its reference dose is expected to be published by USEPA within the next two years. It seems unlikely, based upon ATSDR’s interpretation of the results of the Seychelles Island study and the National Research Council report, that USEPA will adjust its human health reference dose downward.

Uncertainty factors in the recommended reference dose provide a margin of safety for the final TMDL target. In calculation of its reference dose, USEPA incorporated a ten-fold uncertainty factor to account for individual variation. The National Research Council committee supported the 10-fold uncertainty factor. Incorporation of the uncertainty factor lowers the acceptable daily intake level ten times below the benchmark level at which adverse effects are expected. Also, the EPA RfD is intended to protect the most sensitive human portion of the population, unborn children. According to the FDA and WHO, acceptable daily intakes for men, and women not intending to have children, are 3-5 times higher than EPA RfD.

**Seeking Public Comment.** In this draft report, the Regional Board is seeking public comment on the optimum daily intake level to be used in the final TMDL numeric target. Any option considered for the TMDL must be fully protective of humans exposed to methylmercury through consumption of Clear Lake fish.
Key points – Selection of Human Health Reference Dose

- A fish tissue target must be calculated to protect human health. Children during gestation and in their earliest years are most sensitive to the toxic effects of mercury.
- Key variables needed for the calculation of fish tissue targets are: an acceptable daily dose level, age and body weight of the consumer, fish consumption rate, and portion size. These variables are related in the following equation:

\[
\text{Daily intake} \times \text{consumer's body weight} = \text{acceptable level of mercury in fish tissue.}
\]

- The acceptable daily intake is the quantity at or below which humans consuming methylmercury are expected to be protected from adverse effects. Daily intakes are reported as the amount of mercury safely consumed relative to the consumer’s body weight.
- Of the various acceptable daily intake values determined by different agencies, only those released by US EPA (0.1 µg/kg bwt/day) and the Agency for Toxic Substances Disease Registry (0.3 µg/kg bwt/day) are calculated to fully protect unborn children.
- Although the US EPA acceptable daily intake value was originally based upon data from a mass poisoning incident in Iraq, a panel of the National Research Council recently concluded that more recent data supports the EPA value. The more recent data is from populations that regularly consume mercury-containing fish.
- The USEPA acceptable daily intake value of 0.1 µg/kg bwt/day appears to be the intake level most consistent with protecting the beneficial uses in Clear Lake.

Options - Body weight and portion size

The previous section described selection of an acceptable daily intake of methylmercury to protect human health. In setting a fish tissue target that will not cause consumers to exceed the reference dose, variables pertaining to the consumer must be incorporated into the target value. Three necessary values are fish portion size, consumption rate and consumer body size.

USEPA has stated, based on review of fish consumption studies, that the most commonly reported seafood portion size was 8 oz (227 g; Gassel et al., 1997). A review by the California Office of Environmental Health Hazard Assessment of consumption studies found that single serving sizes of seafood consumed by adults usually ranged from four to eight ounces; one study found an average portion size of 11 oz eaten by coastal fishers in New Jersey (Gassel et al., 1997).

USEPA uses standard bodyweights of 60 kg for an average adult female and 72 kg for an average adult man. A bodyweight of 65 kg has been used as an average measure of a pregnant adult. The standard portion size of fish fillet eaten by an adult is 8 oz. Children’s bodyweights and smaller portion sizes can
also be fitted into the equation above. OEHHA has published a table of sizes of typical fish meals that correspond to smaller bodyweights (OEHHA, 1999).

**Recommendation - Body weight and portion size**
CVRWQCB staff suggest using the standard portion size of eight ounces for the TMDL numeric target. There is limited data on serving sizes for consumers of freshwater or marine sport fish in California. Any new studies of sport fish consumption from a Central Valley region or specific waterbody should collect information about portion size.

CVRWQCB staff also recommends that a TMDL target use USEPA’s standard pregnant female bodyweight (65 kg). To best ensure that a mercury target protects fetuses, it is logical that an “average adult consumer” be a woman of childbearing age. A table, such as that created by OEHHA, could be used to adjust the target for smaller bodyweight or portion size of children. Many fish consumption advisories provide a numeric limit on consumption for adults, then recommend pregnant women and children eat less or no fish at all from a particular waterbody. Using USEPA’s RfD for the TMDL target would protect unborn and all children, even though the RfD is expressed as acceptable daily exposure for adults. Children would only be at risk of mercury toxicity if they consumed more than the average portion for their body size.

**Seeking Public Comment.** In this draft report, the Regional Board is seeking public comment on the average body weights and portion sizes to be used in the final TMDL numeric target.

**Options - Consumption Rate**
The fourth variable needed to determine a fish tissue target is the consumption patterns for people eating fish from Clear Lake. Consumption rate is the most difficult of the fish tissue target variables to define. The amount of methylmercury ingested is highly dependent on the amount of fish and species consumed. Ideally, a fish tissue target for Clear Lake would be based upon actual patterns of consumption of fish from Clear Lake. One consumption study has been completed for residents of the Elem Rancheria (Harnly et al., 1997), but data for others eating Clear Lake fish has not been collected. It is necessary then, to examine national and other localized seafood consumption studies. A number of these have been conducted regionally and nationwide. OEHHA has published a comprehensive review and evaluation of these studies (Gassel et al., 1997). Results of fish consumption surveys are also compiled in the Mercury Report to Congress (USEPA, 1997b). The following summary of fish consumption studies is derived primarily from the OEHHA report. A variety of consumption rates, including those recommended for consideration in preparing a fish tissue target, is presented in Table 3.
The definition of “sport fish” includes any seafood not obtained at a commercial market, caught by self or family member by recreational means. With respect to consumption rates in the following text, “fish” is used interchangeably with “seafood” to include any bony fish, shark, or shellfish eaten.

Fish consumption data is generally reported two ways. “Per capita” values indicate fish consumption by an entire study population, including those that do not eat seafood. “Consumer-only” rates indicate consumption patterns for portions of the general population that consume sport and/or commercial seafood. Per capita rates are available from nationwide diet surveys conducted by USDA. Mean consumption rates expressed per capita from these studies for all men, women and children range from 6.5 to 18 g fish consumed per day (Gassel et al., 1997). Per capita rates are useful for market trend analyses but are not as relevant for deriving water quality criteria. Water quality criteria are designed to protect users of aquatic resources. Consumption rates used for developing criteria, therefore, should describe intake only for those that consume seafood.

**Sport Fish Consumption Surveys**

One method of collecting sport fish consumption data is through surveys sent to licensed sport anglers. The 1988 Michigan Statewide Survey is one of the most comprehensive mail surveys of sport fish license holders and their families. Surveys sent between January and June, 1988 asked respondents to report consumption during a seven-day recall period. From the 1988 Michigan survey data, West and colleagues reported an overall mean rate of fish consumption by all ages of 18.3 g/day. In their calculations, West et al. included all ages and respondents, including those who did not consume fish during the study period. The same raw data was analyzed by Murray and Burmaster (1994), who calculated a mean rate for adults who consumed fish during the study period of 45.3 g/d. Both rates represent consumption of commercial and sport fish. Other mail surveys of anglers have reported the following consumption rates for commercial plus sport fish:

- Michigan 1991-92 survey - 45 g/day average consumption
- New York 1988 survey - 28 g/day average consumption
- Wisconsin 1985 survey - 28 g/day average consumption, 64 g/day for the 95th percentile.

Mail surveys have the advantage of being able to reach large numbers of people with relatively little expense. This method, however, collects no information from fishers without licenses or from survey recipients who do not return the survey (such as recipients with limited language ability to understand the survey).

The average quantity of commercial fish eaten in addition to catches of sport fish was 10 g/day, as reported in an analysis of the Michigan Statewide Survey (Murray and Burmaster, 1994). Other studies showed consumers ate a range of 8 - 20 g/day of commercial fish in addition to sport fish (Gassel et al., 1997).
Table 3. Representative Seafood Consumption Rates

<table>
<thead>
<tr>
<th>Site and dates collected</th>
<th>Data type</th>
<th>Fish consumption (g/day)</th>
<th>Reference</th>
<th>Comment</th>
<th>Equiv. meals per month (a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Santa Monica Bay</td>
<td>median</td>
<td>21</td>
<td>SCCWRP and MCB Appl. Env. Sci, 1994; Allen et al, 1996</td>
<td>comprehensive study, interviewed fishers on site.</td>
<td>2.8</td>
</tr>
<tr>
<td></td>
<td>mean</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>90th percentile</td>
<td>107</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>95th percentile</td>
<td>161</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elem Indian Rancheria, 1992</td>
<td>mean Clear L. fish only mean commercial fish only</td>
<td>60</td>
<td>Harnly et al., 1997</td>
<td>Study didn’t report sport + commercial consumption rates</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nationwide mean rate for adult consumers only</td>
<td>mean</td>
<td>48</td>
<td>Pao et al., 1982</td>
<td>Data from USDA 1977-78 Nationwide Food Consumption Survey</td>
<td>6.4</td>
</tr>
<tr>
<td>US women ages 19-50 for consumers only, 1977-78</td>
<td>mean</td>
<td>111</td>
<td>Popkin et al., 1989</td>
<td>Data from USDA 1977-78 Nationwide Food Consumption Survey, includes mixed dishes</td>
<td>15</td>
</tr>
<tr>
<td>US women ages 19-64 for consumers only, 1977-78</td>
<td>mean</td>
<td>44-49</td>
<td>Pao et al., 1982</td>
<td>Data from USDA 1977-78 Nationwide Food Consumpt. Survey, doesn’t include mixed dishes</td>
<td>6</td>
</tr>
<tr>
<td>US Women ages 19-44, consumers only, mid 1990s</td>
<td>50th percentile</td>
<td>9</td>
<td>USEPA, 1997a</td>
<td>Data from National Health and Nutrition Examination Survey, month-long recall</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>90th percentile</td>
<td>46</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Michigan Statewide Survey, Jan. - June 1988</td>
<td>mean</td>
<td>45</td>
<td>Murray and Burmaster, 1994</td>
<td>Rate for adults that ate fish during study period</td>
<td>6</td>
</tr>
<tr>
<td>Michigan Statewide Survey, Jan. - June 1988</td>
<td>mean</td>
<td>18</td>
<td>West et al., 1992</td>
<td>included all ages and respondents, including non-consumers during study period</td>
<td>2.4</td>
</tr>
<tr>
<td>USEPA, for general US population</td>
<td>“default” rate</td>
<td>6.5</td>
<td>USEPA, in Gassel et al, 97.</td>
<td>per capita rate for nonmarine species only, using early 1970s consumption data</td>
<td>0.87</td>
</tr>
<tr>
<td>State of California Ocean Plan, 1990</td>
<td>Average</td>
<td>23</td>
<td>Based on estimate by Calif. Dpt Health Serv.</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Minamata Bay</td>
<td>mean</td>
<td>300</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(a) - Equivalent meals per month calculated for a 65 kg person eating 8 oz seafood portions.
The USEPA determined a consumption rate of 6.5 g/day, that has become the “default” rate nationwide and has been adopted by other agencies. This rate was derived from data on non-marine fish and shellfish consumption collected in the early 1970s. More recently, USEPA selected 15 g/day as the consumption rate for the Final Great Lakes Water Quality Guidance (USEPA, 1995). The rate used in the Great Lakes Final Guidance was derived using the West et al. analysis of the Michigan Statewide Survey and several other studies and intended to be specific to the Great Lakes. Both of these rates issued by USEPA included non-consumers in the data analysis, resulting in lower average rate of consumption. Neither value would be appropriate for application in a TMDL target aimed a protecting consumers of sport fish.

The other main method of gathering sport fish consumption information is through personal interviews, either at a central location (used for recording fish-eating habits of some Native American tribes) or “creel surveys”, conducted at fishing locations, including shoreline, piers and boat docks. Patterns of consumption of locally-caught sport fish were studied for a wide demographic of fishers in Santa Monica Bay (S. Calif. Coastal Water Research Project et al., 1994; Allen et al., 1996). Fishers were asked about their consumption of eight commonly caught species plus fish in hand. Interviews were conducted in five languages, twelve times per month during the summer and six times per month otherwise, for one year, 1991-1992. Reported fish consumption rates for Santa Monica Bay fishers are shown in Table 3. Only anglers who had eaten a species during four weeks prior to the interview were included as “consumers”. The Santa Monica Bay Study is the largest and best available dataset for estimating sport fish consumption rates among California fishers (Gassel et al., 1997).

Several other, less extensive creel surveys have been conducted in California. Sport fishers in the Los Angeles metropolitan area (encompasses Santa Monica Bay) were asked about consumption of their catch by themselves and their families during interviews conducted throughout 1980. Interviews were conducted only in English. The LA Metropolitan Survey reported the median amount of sport fish and/or shellfish consumed was 37 g/day and the 90th percentile was 225 g/day (Puffer et. al. 1982, in Gassel et al., 1997). The San Diego County Dept. of Health Services conducted interviews at popular fishing locations in San Diego Bay An average consumption rate of 31 g/day was reported for the small number of anglers (N = 59) for whom year-round consumption data was available (SDCDHS, 1990 in Gassel et al., 1997). The only consumption data that has been published for San Francisco Bay is from a small creel survey conducted in 1993 by the The Save San Francisco Bay Association (Wong, 1997), which reported a median consumption rate of sport fish and/or shellfish was 32 g/day. The OEHHA review noted that sample sizes were small (N = 62) and survey sites were not randomly selected for the San Francisco Bay study.

To date, only one study of mercury exposure including consumption of Clear Lake sport fish has been completed (Harnly et al., 1997). In November 1992, Harnly and coworkers interviewed 63 members
of the Elem Indian Rancheria and seven non-tribal neighbors of the Rancheria. Study participants recalled the frequency, species and sources of seafood they had eaten in the previous six months. Twenty-three consumers of Clear Lake fish had an average consumption rate of 60 g fish/day. Thirty two persons reported eating an average of 24 g/day of commercial seafood. Total consumption rates for study participants eating both commercial and sport fish, and portion sizes were not reported.

Several rates for consumers-only nationwide, for all consumers and for women of child-bearing age, are shown in the table above. There are no national surveys aimed at sport fishers or that separate sport and commercial fish consumption. Some consumer-only nationwide rates have been derived through reanalysis of national food consumption surveys. Evaluations of nationwide consumption information can produce widely varying results, depending upon study population, types of fish meal (fish only or including “mixed” dishes like tuna casserole and chowder), and the survey methodology (single-day recall data or month-long recall). Incorporation of mixed dishes results in a higher consumption rate, but reliability of the results depends upon how accurately the portions of fish in mixed dishes were estimated. Consumption rates based upon recall periods of a month or more tend to be lower than rates based on intake over periods over less than one week.

Long recall periods provide better estimates of the dose of mercury obtained over lifetime consumption. In terms of potential developmental problems caused by maternal exposure to methylmercury, however, short-term peak exposures could have significant adverse effects on the developing infant (Mahaffey, 1999). During implementation period of the TMDL, it seems clear that efforts should be substantially increased to educate female consumers on the potential risks during pregnancy.

Consumption Risks and Additional Consumption Factors
The above paragraphs provide a range of consumption rates that could be used to derive a TMDL fish tissue target. For evaluating consumption rate options, one helpful piece of information is at what consumption levels people may be exceeding a safe mercury dosage.

Table 4 shows sport fish consumption by species reported by Harnly and coworkers, fish tissue mercury concentrations measured by California Department of Health services (Stratton et al., 1987) and the predicted methylmercury intake of adults due to the reported consumption. Fish tissue concentrations were unavailable for two of the species reported eaten by study participants, carp and perch. The last row in the table shows a hypothetical consumer eating 60 g/day of top trophic level, predatory fish from Clear Lake (e.g., largemouth bass having 0.40- 0.8 ppm mercury; level depends on size and location caught). A person eating only largemouth bass or fish with similar mercury concentration could have a daily intake of methylmercury that was nearly four to seven times greater than the RfD. Although the fish tissue measurements used in this table were collected in the early 1980s,
analysis of more recent samples indicates that fish tissue concentrations have not declined (Suchanek et al., 2000).

Table 4. Potential daily intake of methylmercury, using consumption rates of Clear Lake residents and Clear Lake sport fish and commercial fish consumption levels.

<table>
<thead>
<tr>
<th>Fish Species</th>
<th>Avg. consumption among consumers (# of consumers) g/day (^a)</th>
<th>methylmercury in fish tissue (\mu g/g) wet wt. (^b)</th>
<th>Calculated daily intake of methylmercury (\mu g/kg/day) (^c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clear Lake fish</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>catfish</td>
<td>53 (19)</td>
<td>0.42</td>
<td>0.34</td>
</tr>
<tr>
<td>hitch</td>
<td>12 (4)</td>
<td>0.15</td>
<td>0.03</td>
</tr>
<tr>
<td>largemouth bass near Rancheria</td>
<td>5 (2)</td>
<td>0.8</td>
<td>0.06</td>
</tr>
<tr>
<td>carp</td>
<td>1(1)</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>perch</td>
<td>74 (4)</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Average consumption, all Clear Lake fish</td>
<td>60 (23)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypothetical consumer of Clear Lake largemouth bass only</td>
<td>60</td>
<td>0.4 - 0.8</td>
<td>0.4 - 0.7</td>
</tr>
</tbody>
</table>

\(a\) - Harnly et al., 1997  
\(b\) – Stratton et al., 1987; USFDA 1995  
\(c\) - Assuming 65 kg adult body weight.  
\(d\) - Concentration of mercury in largemouth bass varies, depending on size, age and location of capture in Clear Lake.  
\(e\) – compare to USEPA reference dose of 0.1 \(\mu g/kg/day\)

As is seen in Table 4, species and size of fish as well as consumption rate affects methylmercury intake. It is difficult to estimate amounts of various species of sport fish that might be consumed from Clear Lake. The principal fish species eaten from Clear Lake, as listed in the Clear Lake consumption advisory and in the Harnly study arranged by trophic level\(^2\) of the adult fish are:

- Trophic level 4
  - largemouth bass, channel catfish, white crappie, black crappie
- Trophic level 3
  - Sacramento blackfish, hitch, sunfishes*

\(^2\) In this report, trophic levels are identified as: level 1 – phytoplankton; level 2 – zooplankton; level 3 – organisms that consume zooplankton, benthic invertebrates and phytoplankton; level 4 - organisms that consume trophic level 3 fish. These definitions of trophic levels are also used in the Mercury Report to Congress.
Trophic level 3 and 4 white catfish, brown bullhead
* “Perch” reportedly consumed in the study by Hamly et al. were most likely bluegills and other sunfishes, rather than Sacramento perch (Moyle, 1976).

The Mercury Report to Congress describes an average, adult high-end consumer as eating only trophic level 4 fish (USEPA, 1997b). Limited data from Clear Lake suggests that fish from trophic levels 3 and 4 are consumed, although averages and range for individuals of proportions of fish consumed from each trophic level are unknown (Hamly et al., 1997). In the Final Water Quality Guidance for the Great Lakes, USEPA represented human consumption of sport fish as being one quarter from trophic level 3 and the remainder from trophic level 4 (USEPA, 1995). For the TMDL, it seems reasonable to assume a mixture of trophic levels 3 and 4 fish consumed from Clear Lake.

Consumption studies indicate that many people who eat sport fish also eat fish purchased commercially. Because methylmercury is present in commercial fish, potential exposure to mercury by ingestion should be assessed in sport and commercial fish (Gassel et al., 1997). Unfortunately, no consumption study has reported complete details on the amounts and species of sport and commercial fish consumed. National food surveys have reported total consumption, without separating sport from commercial fish. Regional studies in Santa Monica Bay and Clear Lake obtained species and rates of sport fish consumed, but not totals of sport and commercial fish.

For purposes of the TMDL, one way to estimate average commercial fish supplementing sport fish consumption is to use a value of 15 g/day of commercial fish tissue (2 meals/month). This value is within the 8-20 g/day range compiled in the OEHHA review. It is less than the 24 g/day of commercial consumption reported by Hamly and coworkers for Clear Lake, which was reported separately from sport fish consumption and was not a supplemental rate. The daily intake of methylmercury depends upon the level in the fish. In the ten most popular types of fish and seafood sold in the United States that comprise 80% of the market, average methylmercury concentrations are less than 0.2 µg/g wet wt. On the 10 most popular list, catfish, clam, pollock, salmon, shrimp and salmon have levels of methylmercury less than the detection limit of 0.1 µg/g. Average mercury concentrations of other popular types are 0.2 µg/g in canned tuna, 0.13 µg/g in cod, 0.13 µg/g in crab and less than 0.1 to 0.24 µg/g for flatfishes (USFDA, 1995). Elem Rancheria residents reported eating commercial products, including tuna, salmon, crab, snapper and shrimp (Hamly et al., 1997). Tuna was eaten by almost half of those reporting. If we assume sport fishers also consume 15 g/day methylmercury from commercial fish, we could also suppose that one meal/month was tuna and the other was salmon or similar species with little methylmercury. Daily intake of methylmercury in 7.5 g/day tuna and 7.5 g/day salmon would be 0.02 to 0.03 µg/kg bwt/day for consumption of commercial fish.

Recommendations - Consumption Rate
A main objective of a mercury TMDL for Clear Lake is to identify the conditions that would have to exist in Clear Lake in order for the lake to fully support its beneficial uses. Restoring the beneficial use of sport fishing requires that the Regional Board identify the desired amount of fish that could be caught from Clear Lake and safely consumed, per person. Phrased differently, the TMDL seeks to determine a functional definition of what it means for Clear Lake to be “fishable”. The desired level of fishing and consuming from Clear Lake lies somewhere between the limited amount recommended in the existing fish advisory and a probable upper bound of a very high consumer (i.e., the 99th percentile in US consumption studies).

The TMDL mercury target should protect consumers of sport fish in Clear Lake and should not be based on averages which include non-consumers. Local information, along with existing nationwide and regional consumption studies, can be used to estimate a consumption rate for adults.

As a starting point for the numeric target, Regional Board staff propose using a consumption rate of 60 g/day. One study showed that one group of consumers consumes this much of sport fish from Clear Lake on average. Several consumption studies conducted in California and nationwide have shown higher consumption rates, at least in some portions of the population. There are quite likely consumers at Clear Lake that also eat greater than 60 g/day. These people are still expected to be protected, by uncertainty factors included in the reference dose.

Seeking Public Comment: A goal of this draft Numeric Target Report is to obtain public comment on options for a consumption rate to be used in the TMDL that restores the beneficial use. The final TMDL target must protect the expected range of consumers of Clear Lake sport fish.

<table>
<thead>
<tr>
<th>Key points from the Human Health - Body Weights, Portion Size and Consumption Rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>• The human adult bodyweight recommended for use in the TMDL is 65 kg, the average weight of a pregnant woman.</td>
</tr>
<tr>
<td>• Eight ounces is recommended as the average portion size of fish meal consumed by an adult.</td>
</tr>
<tr>
<td>• Consumption rates of fish and other seafood determined in various national and regional studies vary widely. Mean consumption rates for consumers only range from 9 to 111 g/day, with several studies finding average consumption rates in the narrower range of 45-60 g/day. Consumption rates for consumers in the 90th to 95th percentiles range from 65 to more than 200 g/day.</td>
</tr>
<tr>
<td>• One small study of consumers at Clear Lake has been conducted. Members of the Elem Indian Colony and a few neighbors reported eating an average of 60 g/day of fish from Clear Lake. Species consumed in the greatest amounts were catfish and perch.</td>
</tr>
<tr>
<td>• It seems likely that consumers at Clear Lake typically eat a combination of fish from trophic levels</td>
</tr>
</tbody>
</table>
three and four. Average amounts of each species consumed are unknown.

- Consumers are also exposed to methylmercury in commercial fish. A hypothetical consumer eating 1 meal per month of commercial tuna would take in 0.02 µg/kg bwt/day of mercury.
- As a starting point for the numeric target, Regional Board staff propose using a consumption rate of 60 g/day, the average reported in the one Clear Lake study.

### Fish Tissue Targets

Table 5 shows fish tissue guidance or regulatory levels that are already in use by various agencies. Most of the information in this table was compiled by Larry Walker Associates for the SRWP’s Target Report (Appendix). The table shows assumptions made in setting each level and the purpose for which it was meant to be used. All potential target levels discussed below are micrograms of mercury per gram of wet weight tissue (µg/g, equivalent to ppm). USFDA issued its Action Level of 1 ppm to regulate seafood sold commercially in the United States. The FDA action level was based in part on a nationwide Total Diet Study and levels of mercury in commercial seafood. Screening levels set by USEPA, OEHHA and the San Francisco Bay RWQCB were designed as “flags” for evaluating fish tissue data from pilot studies; bodies of water with fish mercury levels above the screening value would be candidates for further investigation.

**Table 5. Existing fish tissue screening and regulatory levels**

<table>
<thead>
<tr>
<th>Organization</th>
<th>Hg in fish tissue (µg/g wet wt)</th>
<th>Assumptions</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>FDA Action Level</td>
<td>1</td>
<td>0.4 µg/kg/day FDA acceptable daily intake; assumes consumers eat variety of species. Protects consumers of fish bought on commercial market.</td>
<td>FDA (vm.cfsan.fda.gov/~dms/)</td>
</tr>
<tr>
<td>USEPA</td>
<td>0.6</td>
<td>Screening value</td>
<td>EPA (1995)</td>
</tr>
<tr>
<td>San Francisco Estuary Institute</td>
<td>0.23</td>
<td>Screening value calculated by San Francisco Estuary Institute (SFEI). Assumed 30 g/day consumption rate</td>
<td>SFEI (1999a)</td>
</tr>
<tr>
<td>SFRWQCB</td>
<td>0.14</td>
<td>Screening value calculated by San Francisco Bay Regional Water Quality Control Board</td>
<td>SFRWQCB (1995)</td>
</tr>
<tr>
<td>USEPA</td>
<td>0.36</td>
<td>corresponds to EPA RfD assuming a 65 kg individual and 18 g/day consumption rate.</td>
<td>MRC Vol. VII, 1997</td>
</tr>
</tbody>
</table>

Table adapted from LWA, 1999.
Based on the recommendations for each component of the fish tissue target calculations made in previous sections, the fish tissue target recommended by CVRWQCB to protect human health would be:

\[
\frac{0.1 \mu g \text{ Hg/kg bwt day} \times 65 \text{ kg bwt}}{60 \text{ g fish/day}} = 0.1 \mu g/g \text{ mercury in fish}
\]

Note that the above equation does not include a determination as to whether the target is technically feasible. Prior to finalizing the target, the Regional Board will need to consider economics and whether the desired water quality condition could reasonably be achieved. It should also be recognized that since actual consumption patterns include consumption of different species of fish, the desired fish tissue target should be applied as a weighted average based on actual consumption patterns. If single species of fish or certain sizes of fish have mercury levels above the final target adopted by the Regional Board, it may be acceptable, as long as other species consumed are below the target.

**Key points from Human Health - Fish Tissue Target Section**

- The target for mercury in fish tissue recommended by CVRWQCB to protect human health is 0.1 µg/g.
- This target is an overall value for the average of mercury in trophic level three and four fish that are consumed. Acceptable levels of mercury could be higher in some species, depending upon the proportions of fish from each trophic level and species that are consumed.
- This target is recommended as a starting place for discussions of scientific merit. Technical and economic feasibilities of reaching the target, which are not addressed in this report, will be addressed in the final TMDL.

**POTENTIAL WILDLIFE HEALTH TARGETS**

Fish-eating birds and mammals are potentially at risk for impairments caused by consumption of mercury-contaminated fish. Mercury studies conducted in the laboratory and field are used to evaluate fish tissue targets that would protect health of wildlife at Clear Lake and to compare those with fish tissue levels recommended to protect humans. Wildlife studies have been reviewed in a report prepared for the Sacramento River Watershed Program on the status of information needed for a numeric target (LWA, 2000).

Both human and wildlife consumers of fish from Clear Lake should be protected from adverse effects of mercury. The aim of “protection”, however, differs with species. Human health criteria are developed to ensure the safety of individuals. Wildlife criteria, in general, are developed to protect reproduction...
and population survival. Except in the case of endangered species, wildlife protection efforts tend not to be concerned with survival or health of individuals. This distinction is important, in terms of the data that has been collected to assess effects of mercury.

Mammals
Many studies have been published addressing aspects of mercury in wildlife. There are relatively few studies that link known exposure levels to quantifiable effects (Wolfe et al., 1998). Exposure methods and subsequent effects for studies in mink are shown in Table 6. Authors of the Mercury Study Report to Congress (MRC; USEPA 1997a and b) and the Great Lakes Water Quality Initiative Final Rule (GLWQI; USEPA, 1995) selected one set of feeding studies in mink as the basis of water quality criteria recommended in those documents to protect fish-eating mammals. The single-generation investigations conducted by Wobeser and colleagues evaluated endpoints of survival, growth rates, motor control and histologic assessment of neuronal damage following a range of doses (Wobeser et al., 1976a; Wobeser et al., 1976b). No behavioral or reproductive endpoints were evaluated.

The Sacramento River Watershed Program Candidate Targets Report describes in detail the derivation of the mammalian criteria in the MRC and the GLWQI (LWA, 1999; See also appendix). The MRC identified 0.33 mg mercury/kg diet (ppm) as the no-observable adverse effect level (NOAEL) in mink. For the Great Lakes Criteria, USEPA identified 1.1 mg/kg mercury in the diet as the NOAEL. The combination of different NOAELs and uncertainty factors selected by authors of the MRC and the GLWQI, resulted in final acceptable daily intake levels that were extremely close: 0.018 mg Hg/kg bwt/day in the MRC and 0.016 mg Hg/kg bwt/day in the GLWQI.

Data from one study completed since the Mercury Report to Congress measured reproductive success in mink (Dansereau et al., 1999). Dansereau and coworkers found that a diet containing 0.5 µg/g mercury caused a statistically significant decrease in the number of mated females that actually gave birth. This effect was not seen at the 0.1 µg/g dose level. These results indicate that a NOAEL for reproductive success of mink could be less than the 0.3 µg/g NOAEL for neurologic impairment in adult mink. Uncertainty factors were incorporated into derivation of the acceptable daily intake levels in the MRC and GLWQI, in part to account for lack of information about effects on the next generation. Without a rigorous analysis of the study methodology and reproduction data by Dansereau et al. and comparison with the Wobeser studies, it would be difficult to incorporate the reproduction information into calculation of a revised acceptable daily intake level. This data does suggest that mink could be experiencing decreased reproductive success from consuming trophic level 3 fish from Clear Lake (mercury in TL3 fish ranges up to 0.4 µg /g; CVRWQCB, 1985; Suchanek et al., 1997).
### Table 6. Mercury Effects in Mink

<table>
<thead>
<tr>
<th>Level of mercury in the diet</th>
<th>Exposure type</th>
<th>Effect</th>
<th>Comment</th>
<th>reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.33 (0.44 ppm as 75% of diet)</td>
<td>Subchronic exposure to adults</td>
<td>No clinical or pathological effect</td>
<td>0.055mg/kg/d NOAEL for MRC, added UF of 3 for subchronic to chronic</td>
<td>Wobeser 76</td>
</tr>
<tr>
<td>1 ppm</td>
<td>2 mo</td>
<td>Death of females</td>
<td></td>
<td>Kirk 71</td>
</tr>
<tr>
<td>0.5 ppm</td>
<td>3 mo</td>
<td>No deaths</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 ppm</td>
<td>6 mo</td>
<td>Neurologic lesions, death</td>
<td>Concludes 1.0 ppm as LOAEL for adult survival</td>
<td>Wren 87</td>
</tr>
<tr>
<td>0.9 ppm</td>
<td>75 – 100 d</td>
<td>Death of 30/50 females</td>
<td></td>
<td>Dansereau 99</td>
</tr>
<tr>
<td>0.56 ppm</td>
<td>704 d</td>
<td>No deaths</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1 ppm</td>
<td>93 d</td>
<td>Neurologic lesions (authors expected mink deaths had exposure been longer)</td>
<td>MRC LOAEL, GLWQI used this as NOAEL with UF of 10</td>
<td>Wobeser 76</td>
</tr>
<tr>
<td>0.5 ppm</td>
<td>430 d</td>
<td>Statistically significant decrease in number of mated females that gave birth; (No effect on litter size, kit growth rate through day 35 or on overall kit mortality)</td>
<td></td>
<td>Dansereau 99</td>
</tr>
<tr>
<td>0.1 ppm</td>
<td>430 d</td>
<td>Number of mated females giving birth equivalent to untreated females as reported in literature.</td>
<td>Data suggests NOAEL of 0.1 ppm for gestational success</td>
<td>Dansereau 99</td>
</tr>
<tr>
<td>0.22 ppm</td>
<td>7 mo (212 d)</td>
<td>Statistically significant decrease in maternal bwt, male kit weight, and litter size.</td>
<td></td>
<td>Halbrook 97</td>
</tr>
<tr>
<td>0.15 ppm</td>
<td>7 mo (212 d)</td>
<td>No significant effects on maternal bwt, male kit weight, or litter size.</td>
<td></td>
<td>Halbrook 97</td>
</tr>
</tbody>
</table>

**Avian Species**

Acceptable daily intake levels for avian species were determined in a manner similar to that used for mink. Both the MRC and GLWQI based their avian RfD on the lowest-observable adverse effect level (LOAEL) determined in a three-generation study of mallard ducks by Heinz and colleagues. (Heinz, 1974; Heinz, 1976a; Heinz, 1976b; Heinz, 1979). MRC and GLWQI authors selected the same
Preliminary Draft

LOAEL for reproductive and behavioral effects of 0.5 µg/g. Authors of the two reports applied different consumption rates and uncertainty factors, resulting in slightly different RfDs. The MRC reported a RfD of 0.026 mg mercury/kg bwt per day and the GLWQI reported a RfD of 0.032 mg/kg bwt/day. Derivation of the avian reference doses is explained more fully in the Sacramento River Watershed Program’s draft report on candidate targets (LWA, 1999).

A number of field studies of birds have been conducted that provide some information about levels of mercury in fish associated with adverse effects. Fish with mercury concentrations in the range of 0.3 to 0.4 ppm wet weight were associated with reduced egg-laying and decreased territorial fidelity by the common loon breeding on mercury-contaminated lakes in northeastern Ontario (Barr, 1986). In a report prepared for the US Fish and Wildlife Service, Eisler proposed a minimum criterion level for protection of adult birds from toxic effects of mercury as measured in feathers is 5.0 ppm. Adverse effects in various species occur in range of 5-40 ppm dw (Eisler, 1987). In a separate review, Scheuhammer and Bond concluded that birds with feather mercury concentrations above 20 ppm are at risk for toxic effects of mercury (Scheuhammer and Bond, 1991a). These authors estimated that the normal background of mercury in feathers of raptorial birds (including bald eagle and osprey) is 1-5 ppm (Scheuhammer, 1991b Environ Pollution Vol. 71)

Mercury in wildlife at Clear Lake
Mercury levels and nesting success of western grebes at Clear Lake have been studied (Elbert, 1996; Elbert and Anderson, 1998). Nests were surveyed monthly in summers 1992-1994. For all three years, productivity (recorded as young/adult ratio) at Clear Lake was well below productivity level recorded as normal for grebes at other western lakes (Table 7). Concentrations of total mercury in breast muscle, brain and kidney were twice as high (p < 0.05) in adult birds from Clear Lake than in birds from Tule and Eagle Lakes. Mercury likely adversely impacts grebe reproduction at Clear Lake, however, other factors such as disturbance from boat traffic may also impact the western grebe populations. Mercury levels in the brains of Clear Lake western grebes are below levels expected to result in adverse effects in wild birds (Elbert, 1996).

Table 7. Nesting Success of Western Grebes at Clear Lake and other Western Lakes

<table>
<thead>
<tr>
<th>Site</th>
<th>Productivity</th>
<th>Years</th>
<th>Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clear Lake, CA</td>
<td>0.001 – 0.16</td>
<td>1992 – 1994</td>
<td>Eagle Lake, CA 1970s</td>
</tr>
<tr>
<td>Tule Lake &amp; Eagle Lake, CA</td>
<td>0.16 – 0.74</td>
<td>1992 – 1994</td>
<td>Bear River Migratory Bird Refuge, Utah 1980s</td>
</tr>
<tr>
<td>Normal productivity, recorded at other western lakes</td>
<td>0.25 – 0.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Feathers were collected from nesting, fish-eating birds at Clear Lake in the early 1990s (Suchanek et al., 1997). Adult osprey showed the highest mercury values with an average of 20 µg/g dry weight. Adult western grebes and great blue herons had average mercury levels in feathers of 9.74 and 7.4 µg/g, respectively. Mercury concentrations averaged 5.25 in juvenile osprey and 6.5 in juvenile double-crested cormorant. Osprey at Clear Lake had elevated concentrations of mercury when compared to control sites near St. Joe and Coeur d’Alene Idaho and in Baja, California.

In a separate study involving birds at Clear Lake, Wolfe and Norman (1998) found no significant difference between growth rates of great blue heron nestlings raised at Clear Lake relative to young in colonies in relatively pristine sites in Washington and Nova Scotia. The number of young per active great blue heron nest was comparable to reproductive success rates in heron colonies from sites not contaminated with mercury. Concentrations of mercury in great blue heron and double crested cormorant nestlings were below tissue mercury concentrations associated with toxicity in young birds.

Mercury has been measured in a few mammals caught near the shores of Clear Lake (Wolfe and Norman, 1998). Levels of mercury in the brain and fur of raccoons were below no observable effect levels reported in the literature for wild mammals. Seven out of eight mink examined also had mercury levels below those associated with adverse effects; the 7.1 ppm mercury in the brain of one adult mink is near the low end of the range of brain mercury concentrations associated with toxic effects (8-30 ppm).

Comparison of human and wildlife potential targets

One way to compare potential risks to humans and wildlife is to compare estimated mercury exposures to acceptable daily intake levels. As in the MRC and GLWQI, we will use acceptable daily intakes for mammalian wildlife and birds based on the studies in mink and mallards, respectively. Using the mink feeding studies by Wobeser, MRC authors determined a reference dose for mammalian wildlife of 0.018 mg/kg bwt/day. Similarly, mallard reproduction studies by Heinz et al. (Heinz, 1974; Heinz, 1976a; Heinz, 1976b; Heinz, 1979) were used to determine an avian reference dose of 0.026 mg/kg bwt/day. Species-specific factors of consumption rate and body weight can be used with reference doses to estimate amounts of mercury consumed. In the Mercury Report to Congress ecological assessment, risk was examined for two mammalian and four bird species. Consumption of contaminated fish is thought to be the main exposure pathway of these species to mercury. In the MRC report, daily exposure rates for these species were estimated as the product of methylmercury levels in fish eaten and the daily amount of fish eaten. Since all of these species occur at Clear Lake, a similar estimation can be done using average mercury concentrations in fish from Clear Lake.
Table 8 shows data needed to estimate daily mercury exposure to wildlife and humans. Body weights and quantities of fish ingested were obtained from MRC Volume 6 (USEPA, 1997a). Average mercury concentrations in trophic level 3 (TL3) and 4 (TL4) fish were estimated as 0.15 and 0.6 µg/g, respectively, and were determined from Clear Lake fish tissue data (CVRWQCB, 1985; Suchanek et al., 1997). The human consumption rate and body weights are those recommended in the previous section of this report on potential human health targets. Human consumption rate is estimated as a total 60 g/day, three quarters of which is trophic level 4 fish and the remainder from trophic level 3. These proportions of TL3 and TL4 fish eaten by humans were used in derivation of human health criteria in the Great Lakes Water Quality Initiative Final Rule and supported by fish consumption studies in the Great Lakes region and Clear Lake (Gassel et al., 1997; Harnly et al., 1997; USEPA, 1995).

Table 8. Exposure parameters for fish-eating wildlife and humans

<table>
<thead>
<tr>
<th>Animal</th>
<th>Trophic Level 3 Fish Ingestion Rate (g fish/day, wet wt)</th>
<th>Trophic Level 4 Fish Ingestion Rate (g fish/day, wet wt)</th>
<th>Body weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>river otter</td>
<td>976</td>
<td>244</td>
<td>7.4</td>
</tr>
<tr>
<td>mink</td>
<td>160.2</td>
<td>0</td>
<td>0.8</td>
</tr>
<tr>
<td>osprey</td>
<td>300</td>
<td>0</td>
<td>1.5</td>
</tr>
<tr>
<td>bald eagle</td>
<td>370</td>
<td>90</td>
<td>4.6</td>
</tr>
<tr>
<td>kingfisher</td>
<td>75</td>
<td>0</td>
<td>0.15</td>
</tr>
<tr>
<td>loon</td>
<td>800</td>
<td>0</td>
<td>4.0</td>
</tr>
<tr>
<td>human</td>
<td>15</td>
<td>45</td>
<td>65</td>
</tr>
</tbody>
</table>

Adapted from Mercury Study Report to Congress, Volume 7 pg. 6-7 (USEPA, 1997b)

Daily mercury exposure rates are calculated using the following equation:

\[
\text{Mercury in TL3 fish} \times \text{TL3 ingestion rate} + \text{mercury in TL4 fish} \times \text{TL4 ingestion rate} / \text{Body weight}
\]

A sample calculation using the parameters for river otter is given below. Estimates of daily exposure rates calculated for the representative wildlife species are presented in Table 9.

For river otter:

\[
(0.15 \mu g \text{ Hg/g fish})(976 \text{ g fish/day}) + (0.6 \mu g \text{ Hg/g fish})(244 \text{ g fish/day}) = 39 \mu g \text{ Hg/kg bwt/day}
\]

\[
7.4 \text{ kg bwt}
\]
Table 9. Comparison of acceptable daily intake and estimated daily exposure for humans and wildlife ingesting fish from Clear Lake

<table>
<thead>
<tr>
<th>Species</th>
<th>Acceptable daily intake level µg/kg bwt/day</th>
<th>Estimated exposure to mercury in Clear Lake fish (c) µg/kg bwt/day</th>
<th>Ratio of exposure to acceptable daily intake</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mammalian wildlife</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>river otter</td>
<td>18 (a)</td>
<td>39</td>
<td>2.2</td>
</tr>
<tr>
<td>mink</td>
<td></td>
<td>30</td>
<td>1.7</td>
</tr>
<tr>
<td>Avian wildlife</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>osprey</td>
<td>26 (a)</td>
<td>30</td>
<td>1.2</td>
</tr>
<tr>
<td>bald eagle</td>
<td></td>
<td>23</td>
<td>1</td>
</tr>
<tr>
<td>kingfisher</td>
<td></td>
<td>75</td>
<td>2.9</td>
</tr>
<tr>
<td>loon</td>
<td></td>
<td>30</td>
<td>1.2</td>
</tr>
<tr>
<td>Human</td>
<td>0.1 (b)</td>
<td>0.45</td>
<td>4.5</td>
</tr>
</tbody>
</table>

a - (USEPA, 1997a)  
b - (USEPA, 1999)  
c – assumes mercury concentrations of 0.15 µg/g in trophic level 3 fish and 0.6 µg/g in trophic level 4 fish. Averages based on Clear Lake fish tissue levels (CVRWQCB, 1985; Suchanek et al., 1997)

Two important points can be drawn from information in Table 9. The first is that wildlife eating fish from Clear Lake likely take in mercury in excess of safe levels. The last column in Table 9 shows the ratio of estimated exposure to the acceptable daily intake level. Exposure rates are anticipated to be at or above the corresponding acceptable daily intake levels for all species evaluated. Mercury intake by river otters is estimated to be at least twice the acceptable daily intake level, and intake by kingfishers to be nearly three times a safe intake level.

As shown in column three of Table 9, the estimated exposure rate of humans to mercury in fish from Clear Lake is much lower than that of piscivorous wildlife. This is logical, given that a large portion of the diet of humans is not fish. The second point is that although daily intake of mercury by humans is less than the wildlife species, human exposure is estimated to be more than four times an acceptable daily intake level. Reducing mercury concentrations in TL3 and TL4 fish enough to lower human daily exposure to a safe amount would presumably reduce intake by wildlife species to at or below safe levels.
Conclusions regarding wildlife targets

1. In general, studies are lacking in wildlife that relate quantified mercury exposure to sublethal or reproductive endpoints. Field studies of effects of mercury are especially lacking. In cases in which adverse effects of mercury on wildlife are hypothesized, such as impaired nesting success of western grebes at Clear Lake, follow-up studies have not been conducted to separate effects of mercury from confounding environmental factors.

2. Limited data available has been used to develop acceptable daily intake levels for mammalian and avian wildlife that consume fish. These levels should be refined or validated using multi-generational studies that address effects on reproduction and neurological development.

3. Wildlife consuming aquatic organisms from Clear Lake may be at risk for adverse effects from mercury.

4. Humans regularly consuming fish from Clear Lake are estimated to be at risk for adverse effects from mercury. Based upon comparisons of daily intake levels, reductions in fish tissue levels intended to meet safe human exposure levels would likely meet needs for wildlife protection as well.

Seeking public comment. The Regional Board is seeking input on its analysis of potential wildlife targets and its conclusions regarding comparisons of human and wildlife mercury exposure assessments.

Key Points from Wildlife Target Section

- Wildlife consuming fish from Clear Lake are highly likely to exceed acceptable daily intake levels of mercury. Mercury intake by river otters is estimated to be at least twice the acceptable daily intake level, and intake by kingfishers to be nearly three times a safe intake level.

- Poor nesting success of western grebes at Clear Lake may be due, in part to mercury. Reproduction of double crested cormorant, great blue heron and osprey at Clear Lake do not appear to be impaired by mercury.

- More data on effects of mercury on wildlife is needed, at Clear Lake and for wildlife species in general.

- If fish tissue levels of mercury were reduced to levels safe for human consumption, it is expected that wildlife would be protected as well.
References


Preliminary Draft


OEHHA, 1999. California Sport Fish Consumption Advisories 1999, Office of Environmental Health Hazard Assessment, California Environmental Protection Agency.


Suchanek, T.H. et al., 1997. The Role of the Sulphur Bank Mercury Mine Site in the Dynamics of Mercury Transport and Bioaccumulation within the Clear Lake Aquatic Ecosystem. Interim Final Report, Prepared for the USEPA Region 9 Superfund Program.

Suchanek, T.H. et al., 1993. Preliminary Lake Study Report. A Survey and Evaluation of Mercury in: sediment, water, plankton, periphyton, benthic invertebrates and fishes within the aquatic...
ecosystem of Clear Lake, California, University of California, Davis. Report prepared for EPA Region 9, Ecological Assessment: Sulphur Bank Mercury Mine Superfund Site, Clear Lake, Davis, CA.


USEPA, 1999. Integrated Risk Information System (IRIS). Available from:


Preliminary Draft