# APPENDIX G

## Screening-level Human Health Risk Assessment of Selenium Exposures from Consumption of Fish and Waterfowl from the Salton Sea

2006

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# APPENDIX G SCREENING-LEVEL HUMAN HEALTH RISK ASSESSMENT OF SELENIUM EXPOSURES FROM CONSUMPTION OF FISH AND WATERFOWL FROM THE SALTON SEA

This appendix evaluates human health risks associated with exposures to selenium from consumption of fish and waterfowl from the Salton Sea. This screening-level assessment considers selenium exposures to humans from fish and waterfowl consumption under Existing Conditions as well as future conditions associated with the No Action Alternative and other alternatives, as described in Chapter 3.

The purpose of this screening-level risk assessment is to determine whether the No Action Alternative or other alternatives would cause significant impacts to public health from exposures to selenium through consumption of fish and waterfowl from the Salton Sea. Selenium concentration data from analyses of fish (tilapia) muscle tissue samples collected during April 2005 and fish and duck tissue concentration values that were modeled using an ecological risk assessment were used to estimate maximum safe consumption rates (i.e., no significant increase in noncancer effects). The calculated consumption rates were compared to default rates used by regulatory agencies.

Selenium is known to be present in the Salton Sea, and a State health advisory has been issued for human consumption of fish from the Salton Sea. Alternatives considered for the Salton Sea may alter selenium exposures in fish and birds and, ultimately, humans who consume fish and birds from the Salton Sea. Thus, considerations of the potential human health risks associated with exposures to selenium from consumption of fish and waterfowl from the Salton Sea are important for evaluating the alternatives.

Selenium is a naturally occurring element found in rocks and soils. The environmental and human health risks associated with ambient exposure to selenium are discussed in the Selenium Summary report (DWR, 2005a). Selenium occurs in several forms, including multiple oxidation states, which vary depending on ambient conditions such as pH, Eh (oxidation/reduction potential), and microbial activity, as well as the environmental medium (such as water, sediment, or biological tissue). Biologically significant oxidation states include selenide ($Se^{2-}$), elemental selenium ($Se^{0}$), selenite ($Se^{4+}$), and selenate ($Se^{6+}$). Selenium is bioaccumulated in the aquatic food web. Selenite and selenate are the most common aqueous forms and are biotransformed into organic chemical species after uptake by primary producers (such as phytoplankton and other algae and rooted plants) (e.g., Ogle et al., 1988 as cited in DOI, 1998; Ohlendorf, 2003). Bioaccumulation is often a function of chemical species. Organic selenium is especially bioaccumulative, so that aquatic organisms exposed to organic selenium (such as selenomethionine) are likely to bioaccumulate much more selenium than those exposed to inorganic selenium in water (Ohlendorf, 2003).

Human exposure to excess selenium can result in acute or chronic toxic effects. Short-term oral exposure to high levels of selenium can cause nausea, vomiting, and diarrhea. Chronic oral exposure can result in a disease called selenosis; symptoms include hair loss, nail brittleness, and neurological abnormalities. However, selenium also is an essential nutrient, and selenium deficiency can be a greater threat to human health than selenium poisoning (Frost and Ingvold, 1975; Stadtman, 1977). Selenate or selenite supplements can prevent or reverse dietary deficiencies (Eisler, 2000). Minor increases in dietary exposure above dietary needs can exert toxic effects in some individuals but not others.

Table G-1 summarizes guidelines for dietary intake of selenium by humans. Chemical concentrations, including guidelines for daily selenium intake by humans, are expressed per standard convention in metric units, such as milligrams per kilogram (mg/kg). Typical selenium intake levels in humans are about 0.001 to 0.002 mg/kg/day for a 154-pound (70-kg) adult. The recommended daily allowance (RDA) for selenium is 0.055 mg/day or about 0.0008 mg/kg/day for an adult (ATSDR, 2003). A no observed adverse effect level (NOAEL) for selenium exposure of 0.015 mg/kg/day was proposed by Yang et al. (1989). Both the Agency for Toxic Substances and Disease Registry (ATSDR) and United States Environmental Protection Agency (USEPA) divided the NOAEL value by an uncertainty factor of three to allow for sensitive individuals, resulting in a maximum safe level for chronic oral ingestion of selenium of 0.005 mg/kg/day or 0.35 mg/day for a 154-pound (70-kg) adult.

**Table G-1**
**Guidelines for Selenium Intake by Humans**

| Value | Unit | Type of Guideline or Exposure | Receptor/Media | Tissue | Comment | Reference |
|---|---|---|---|---|---|---|
| 0.02 | mg/day | RDA | children (1-3 yrs) | NA | Recommended Dietary Allowance | ATSDR, 2003 |
| 0.03 | mg/day | RDA | children (4-8 yrs) | NA | Recommended Dietary Allowance | ATSDR, 2003 |
| 0.04 | mg/day | RDA | children (9-13 yrs) | NA | Recommended Dietary Allowance | NAS, 2000 |
| 0.015 | mg/day | RDA | infant (0-6 months) | NA | Recommended Dietary Allowance | ATSDR, 2003 |
| 0.02 | mg/day | RDA | infant (7-12 months) | NA | Recommended Dietary Allowance | ATSDR, 2003 |
| 0.07 | mg/day | RDA | lactating female | NA | Recommended Dietary Allowance | ATSDR, 2003 |
| 0.055 | mg/day | RDA | men and women | NA | Recommended Dietary Allowance | ATSDR, 2003 |
| 0.06 | mg/day | RDA | pregnant woman | NA | Recommended Dietary Allowance | ATSDR, 2003 |
| 0.005 | mg/kg/day | chronic oral MRL | human | NA | chronic oral reference dose | ATSDR, 2003 |
| 0.9 | µg/kg | drinking water intake | human | NA | recommended daily intake for adults | ATSDR, 2003 |
| 0.4 | mg/day | tolerable upper intake level | human | NA | maximum daily nutrient intake likely to pose no risk to individuals | ATSDR, 2003 |
| 0.015 | mg/kg/day | NOAEL | human | NA | disappearance of symptoms of selenosis* | ATSDR, 2003 |

Notes:
* Selenosis is the disease syndrome associated with excessive exposure to selenium.
NA = not applicable
NOAEL = no observed adverse effect level
RDA = Recommended Dietary Allowance
MRL = Minimum risk level

# OBJECTIVES

To evaluate contaminant exposure pathways and risks to humans and wildlife associated with the alternatives, existing information was reviewed and data gaps that could limit the ability to assess the impacts of the Alternatives were identified. Risks to human health from exposures to selenium via consumption of tilapia and other fish species targeted by recreational anglers were evaluated by Moreau et al. (2004, in press; 2005, draft manuscript). However, risks from selenium exposures calculated by Moreau et al. were based on fish collected and analyzed in 1998. Because the historic data may not be representative of current conditions, additional sampling and analyses of environmental media were recommended to address those data gaps (DWR, 2005b). Fish samples were collected and analyzed in spring 2005 to provide data for an ecological risk assessment and a screening-level human health risk assessment. Samples for the human health risk assessment were collected consistent with a protocol provided by the California Office of Environmental Health Hazard Assessment (OEHHA).

The spring 2005 sampling effort provided data to support a screening-level assessment of the potential risk to human health from exposures to selenium by consumption of fish from the Salton Sea. No current information is available on the frequency of recreational fishing or on fish consumption rates at the Salton Sea. While some recreational fishing occurs, recent catch levels have fluctuated and, in some cases, were relatively lower than in the past when the fisheries were more productive (J. Crayon, DFG, pers. comm.). In the absence of site-specific fish consumption rates for the Salton Sea, maximum safe consumption rates that correspond to specific levels of noncancer adverse health effects were estimated for this assessment.

Consumption of waterfowl by recreational hunters is another possible selenium exposure pathway with potential human health implications. The duck hunting season in southern California is 100 days (October 23 to January 30) (DFG, 2005). Current consumption rates for duck tissues are unknown, and no additional sampling was performed to characterize selenium concentrations in tissues of ducks at the Salton Sea. Consequently, this screening-level assessment estimated maximum safe consumption rates for humans on the basis of estimated tissue selenium concentrations for ducks from the Salton Sea related to modeled diet concentrations and diet-tissue relationships reported in the published literature.

# APPROACH

This screening-level human health risk assessment considers only exposures to selenium from consumption of fish and waterfowl because this was identified during scoping as an issue that needed to be addressed for this program. Exposure point concentrations (EPCs) of selenium in fish and waterfowl (duck) tissues used in this screening-level risk assessment were determined using the following three approaches: (1) fish samples were collected from the Salton Sea and analyzed for tissue concentrations of selenium; (2) fish tissue selenium concentrations were calculated based on modeled sediment selenium concentrations; and (3) duck muscle selenium concentrations were estimated based on relationships between concentrations in duck diets and duck muscle tissues as reported in the scientific literature. These approaches are summarized below.

## Fish Tissue Collection and Analyses

A Sampling and Analysis Plan (SAP) was prepared in April 2005 (DWR, 2005c). It described the proposed approach for collecting and analyzing fish tissue samples used to provide data for this risk assessment. The SAP also identified the data quality objectives (DQOs) and quality assurance procedures used to ensure that the data would meet accuracy, precision, representativeness, comparability, and completeness objectives.

The April 2005 sampling at the Salton Sea addressed multiple objectives for filling data gaps that had been identified in a previous report (DWR, 2005b). The following sections address only the approach used to collect and analyze fish for the health risk evaluation (Table G-2). This portion of the sampling targeted large (i.e., 8 inches [20 cm] or larger) individuals of fish species that are representative of fish that have been caught and consumed by anglers at the Salton Sea in the past, such as tilapia, sargo, orangemouth corvina, and gulf croaker. However, it was recognized that only tilapia had been caught by Department of Fish and Game (DFG) staff during their fish surveys in the recent past, indicating it was unlikely that samples of other species would be available for analysis. The target fish size approximates the minimum fish length considered by OEHHA for edible tilapia (8 inches [20 cm]).

**Table G-2**
**Summary of Salton Sea Sampling for Fish (April 2005) to Support Health Risk Assessments**

| Media | Quantity | Analysis/Method |
|---|---|---|
| Large (> 8 inch [20 cm]) fish; individual fillet (muscle tissue, skin off) | < 50 | Total selenium /hydride generation atomic absorption spectroscopy (HGAA) |

Specific sampling sites were selected to characterize nearshore habitats (water depths less than about 6 feet [2 meters]) in each of the four quadrants of the Salton Sea (Figure G-1) corresponding to areas where public fishing has occurred in the past.

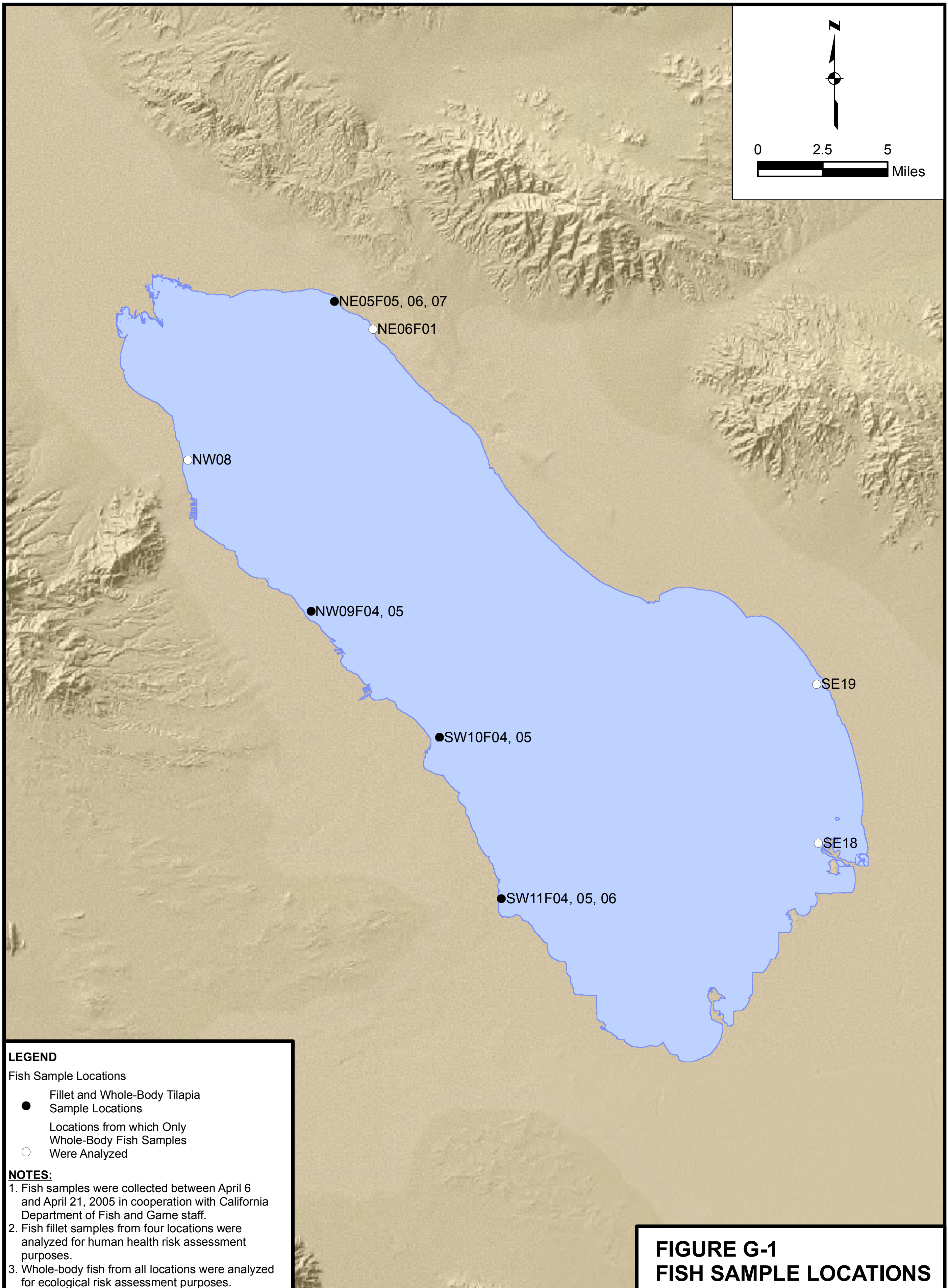
Fish were captured using gill nets and then placed in clean containers. Sample weights, lengths, and species identifications were recorded in the field. Fish were individually wrapped in clean aluminum foil and frozen for transport to the laboratory. Handling procedures are summarized in Table G-3.

**Table G-3**
**Summary of Sample Handling and Preservation Methods**

| Medium | Analysis | Sample Container | Preservatives | Analytical Holding Times |
|---|---|---|---|---|
| Fish | Total selenium | Resealable bags for fish individually wrapped in aluminum foil | Chill to 39°F (4°C) and freeze ASAP | Indefinite (frozen) |

The fish sampling effort collected 11 tilapia large enough to be considered representative of the fish caught and consumed by anglers. No other fish species were collected for this health risk evaluation. Also, fish large enough to use for fillet sampling were collected only in the southwest, northwest, and northeast quadrants; no large fish were obtained from the southeast quadrant, although smaller ones were collected there for ecological risk assessment purposes.

The total length and sample location for each fish are listed in Table G-4. The 11 samples were from four areas: Test Base and South Salton City locations in the southwest, The Dome in the northwest, and North Shore in the northeast. Sampling locations are shown in Figure G-1. Total length for individual fish ranged from 7.1 to 8.7 inches (18 to 22 cm). Only 4 of the 11 fish were larger than 8 inches (20 cm), which OEHHA considers the minimum size for edible tilapia. However, certain anglers may eat smaller fish, so all 11 fish were used for the risk assessment.




**NOTES:**
1. Fish samples were collected between April 6 and April 21, 2005 in cooperation with California Department of Fish and Game staff.
2. Fish fillet samples from four locations were analyzed for human health risk assessment purposes.
3. Whole-body fish from all locations were analyzed for ecological risk assessment purposes.

**FIGURE G-1**
**FISH SAMPLE LOCATIONS**

**Table G-4**
**Fish (Tilapia) Tissue Samples Collected for the Human Health Risk Assessment**

| Species | Sample No. | Location | Date | Sample Type | Total Length (cm/inches) |
|---|---|---|---|---|---|
| Tilapia | SW11F04 | Test Base | 4/21/2005 | Individual fish – muscle fillet | 19.5/7.7 |
| Tilapia | SW11F05 | Test Base | 4/21/2005 | Individual fish – muscle fillet | 20.5/8.1 |
| Tilapia | SW11F06 | Test Base | 4/21/2005 | Individual fish – muscle fillet | 22.0/8.7 |
| Tilapia | NW09F04 | The Dome | 4/7/2005 | Individual fish – muscle fillet | 18.0/7.1 |
| Tilapia | NW09F05 | The Dome | 4/7/2005 | Individual fish – muscle fillet | 18.4/7.2 |
| Tilapia | NE05F04 | N. Shore | 4/6/2005 | Individual fish – muscle fillet | 19.2/7.6 |
| Tilapia | NE05F05 | N. Shore | 4/6/2005 | Individual fish – muscle fillet | 21.0/8.3 |
| Tilapia | NE05F06 | N. Shore | 4/6/2005 | Individual fish – muscle fillet | 19.7/7.8 |
| Tilapia | NE05F07 | N. Shore | 4/6/2005 | Individual fish – muscle fillet | 18.8/7.4 |
| Tilapia | SW10F04 | S. Salton City | 4/8/2005 | Individual fish – muscle fillet | 20.6/8.1 |
| Tilapia | SW10F05 | S. Salton City | 4/8/2005 | Individual fish – muscle fillet | 19.5/7.7 |

Fish muscle tissues were dissected in the laboratory under clean (non-contaminating) conditions. Skin was removed from the muscle tissue samples.

Chemical analyses of tissue samples followed standard or laboratory-specific methods that are known to provide quality results. The target analyte, analytical methods, and reporting limits are listed in Table G-5. The analytical method is summarized briefly below.

**Table G-5**
**Chemical Analytes, Analytical Methods, and Target Reporting Limits for Fish Tissue Samples**

| Analyte | Method | Target Reporting Limits* (mg/kg) |
|---|---|---|
| Total Selenium | Hydride generation atomic absorption spectroscopy | 0.2 |

Notes:
Fish tissue samples also were analyzed for moisture content by weight difference before and after freeze-drying.
* Results and reporting limits for fish tissue samples were reported on a dry-weight basis.

_Total Selenium_. Total selenium in fish muscle tissues was analyzed using hydride generation atomic absorption spectroscopy (HGAA). This method requires a dry ash digestion of the sample together with magnesium nitrate in a muffle furnace heated to 932º F (500º C). The reporting limit was 0.2 mg/kg.

_Moisture Content_. Moisture was determined by measuring the sample weight before and after freeze-drying and then calculating the difference in those weights.

Based on preliminary analysis of the fish tissue data used in the ecological risk assessments for the Salton Sea, it was noted that selenium concentrations in ‘re-constructed’ whole-body fish using the analytical results from Applied Sciences Laboratory, Inc. (ASL) of Corvallis, Oregon were apparently lower than the co-located composite fish samples analyzed at a different laboratory (Laboratory and Environmental Testing [LET], Inc. in Columbia, Missouri). Because the difference could not be explained by the data validation or re-check of the calculations used to ‘re-construct’ the whole-body fish, it was decided in October 2005 to get a confirmatory laboratory comparison of the fillets and remainder samples. The fillet and remainder samples had been kept frozen at ASL for the period following the initial analyses in

May 2005. There was adequate sample material for re-analysis of all the remainders and all but three of the fillet samples. The available samples were shipped frozen under chain of custody to LET on October 13, 2005 for analysis.

A comparison of the data between ASL (original) and LET (re-run) analyses showed that the LET results were significantly higher for selenium (DWR, 2006). Based on this information and the fact that the LET analyses included analyses of a standard reference fish tissue material (where ASL did not), the decision was made to use the LET re-run analytical results for fish fillet concentrations. There was insufficient material from three of the fillet samples for an analytical re-run. Consequently, selenium values for these samples were estimated using the regression equations for the best linear fit of the paired data for the re-analyzed samples.

Third-party data validation services were provided by EcoChem, Inc. of Seattle, Washington. CH2M HILL was responsible for coordinating sample processing and analytical work and for ensuring that analyses and deliverables met the project milestones.

## Selenium Concentrations in Fish Muscle Tissues

Concentrations of selenium in the tilapia muscle tissue samples are listed in Table G-6. The moisture content of the individual muscle tissue samples is also listed to allow conversions to dry-weight concentrations.

Concentrations of selenium ranged from 1.5 to 3.0 mg/kg (wet weight), with a mean value of 2.0 mg/kg and 95 percent upper confidence limit (UCL95) of 2.36 mg/kg. The highest concentration was from Sample NE05F04 collected at North Shore (Figure G-1), and the lowest concentration was from Sample SW10F04 collected at South Salton City. Selenium concentrations were not strongly correlated with total length. For comparison, Moreau et al. (2004, in press) listed selenium concentrations in tilapia samples collected and analyzed during three previous studies (1980-2000 Toxic Substances Monitoring Program; 1998 San Diego State University Graduate School of Public Health; and 2000 Mississippi-Alabama Sea Grant Consortium). The geometric mean wet-weight selenium concentrations in tilapia muscle tissue samples from those studies ranged from 1.67 to 2.50 mg/kg.

**Table G-6**
**Concentrations of Selenium in Individual Fish (Tilapia) Muscle Tissue Samples Collected in April 2005**

| Sample No. | Location | Total Selenium (mg/kg ww) | Moisture Content (%) |
|---|---|---|---|
| SW11F04 | Test Base | 2.3[a] | 77.2[b] |
| SW11F05 | Test Base | 1.8[a] | 80.5[b] |
| SW11F06 | Test Base | 1.5 | 80.3 |
| NW09F04 | The Dome | 1.9 | 79.0 |
| NW09F05 | The Dome | 2.1[a] | 80.4[b] |
| NE05F04 | N. Shore | 3.0 | 77.2 |
| NE05F05 | N. Shore | 1.8 | 79.7 |
| NE05F06 | N. Shore | 1.6 | 78.5 |
| NE05F07 | N. Shore | 2.3 | 80.7 |
| SW10F04 | S. Salton City | 1.5 | 80.2 |
| SW10F05 | S. Salton City | 2.8 | 76.3 |

[a] Values calculated from regression fits using paired data from analyses of fish tissue samples performed by two separate laboratories; regression equation is: Selenium (ww) = 0.684 + 0.864 * original value.

[b] Original moisture content values.

ww = wet weight

# Modeled Fish Tissue Selenium Concentrations

Concentrations of selenium in whole-body fish were calculated using the sediment EPC for each habitat and the Salton Sea-specific biota-sediment accumulation factor (BSAF) of 4.6 for fish, as follows:

$$[Selenium_{whole\text{-}body\ fish}] = [Selenium_{sediment}] * 4.6$$

Where:

| | | |
|---|---|---|
| $Selenium_{whole\text{-}body\ fish}$ | = | $mg_{selenium}$/kg (dry wt. basis) |
| $Selenium_{sediment}$ | = | $mg_{selenium}$/kg (dry wt. basis) |

The procedures used to model sediment and whole-body fish EPCs for selenium at the Salton Sea are described in more detail in Appendix F.

Wet-weight selenium concentrations in fish muscle tissues were calculated from the modeled dry-weight whole-body fish values using relationships between fillet and whole-body tissue concentrations in the 11 tilapia samples collected and analyzed by LET from the April 2005 survey discussed above. For the 11 fish, the mean fillet-to-whole-body selenium ratio value is 1.11. That value (1.11) was applied to each of the dry-weight whole body EPC values (which are the UCL95 dry-weight concentrations) modeled for the various alternatives to obtain a dry-weight fillet concentration. The dry-weight fillet values then were converted to wet-weight concentrations by applying a dry-weight-to-wet-weight conversion factor (which corresponds to the average solids content of the 11 fish muscle samples) to obtain the UCL95 wet-weight selenium concentrations that are used to assess fish consumption risks. The conversion of the dry-weight whole body EPC to a wet-weight muscle tissue concentration can be represented as follows:

$Selenium_{muscle\ tissue}$ = $Selenium_{whole\text{-}body\ fish\ EPC}$ * fillet-to whole-body tissue concentration ratio * average tissue wet weight to dry weight conversion factor,

Where

| | | |
|---|---|---|
| $Selenium_{muscle\ tissue}$ | = | $mg_{selenium}$/kg (wet wt. basis) |
| $Selenium_{whole\text{-}body\ fish\ EPC}$ | = | $mg_{selenium}$/kg (dry wt. basis) |
| Fillet-to-whole-body tissue concentration ratio | = | 1.11 |
| average tissue wet-weight-to-dry-weight conversion factor | = | 0.2335 (i.e., [(100-average moisture content)/100]) |

For example, a whole body EPC value of 10 mg/kg dry weight is equivalent to a muscle tissue selenium concentration of 2.59 mg/kg wet weight, or

2.59 $mg_{selenium}$ /kg (muscle tissue wet-weight basis) = 10 $mg_{selenium}$ /kg (whole body dry-wt basis) * 1.11 * 0.2335.

Modeled selenium concentrations in whole-body fish, along with the calculated fillet concentrations, are listed in Table G-7. Note that the selenium concentration in the fish muscle for the Existing Conditions, Salton Sea Open Water habitat is based on the measured moisture content (79.1 percent) of the sample instead of the average moisture content value used to calculate selenium concentrations for all other alternative/habitat combinations.

# Modeled Duck Tissue Selenium Concentrations

Selenium concentrations in muscle tissues of waterfowl were estimated from selenium concentrations in the diet using relationships described by Heinz et al. (1987, 1990). Specifically, Heinz et al. (1987) reported that male and female mallards fed a diet containing 10 mg/kg (dry weight) selenium had wet-weight selenium concentrations of 3.1 mg/kg and 4.9 mg/kg, respectively, in breast muscle. Heinz et al. (1990) reported that the breast muscle tissue of mallards fed a diet containing 10 mg/kg selenium for six weeks had a selenium concentration of 6.1 mg/kg wet weight. For the purposes of this screening-level human health risk assessment, selenium concentrations in edible duck tissues (breast muscle) were estimated using the relationship between selenium concentrations in diet and duck tissue reported by Heinz et al. (1990). The dry-weight selenium concentrations in duck diets were modeled for different alternatives by the ecological risk assessment (Appendix F).

Concentrations of selenium in duck diet at the Salton Sea were calculated using the sediment EPC multiplied by the fraction of the total diet comprising aquatic plants, aquatic invertebrates, or benthic invertebrates. The selenium concentrations calculated for each food item were then summed to calculate the total dietary concentration as follows:

$$\textit{Total dietary Selenium} = \left[\left(EPC_{sed} \bullet P_{sed}\right) + \left(EPC_{sed} \bullet P_{AP}\right) + \left(EPC_{sed} \bullet P_{AI}\right) + \left(EPC_{sed} \bullet P_{BI}\right)\right]$$

Where:

| | | |
|---|---|---|
| Total dietary selenium | = | $mg_{selenium}/kg_{diet}$ (dry wt. basis) |
| $EPC_{sed}$ | = | Habitat-specific sediment exposure point concentration |
| $P_{sed}$ | = | Fraction of sediment in diet (0.033) |
| $P_{AP}$ | = | Fraction of diet composed of aquatic plants (0.30) |
| $P_{AI}$ | = | Fraction of diet composed of aquatic invertebrates (0.45) |
| $P_{BI}$ | = | Fraction of diet composed of benthic invertebrates (0.25) |

This modeling of selenium bioaccumulation into duck diets at the Salton Sea is described in more detail in Appendix F.

The wet-weight duck tissue selenium concentrations were calculated as 0.61 times the modeled dry-weight duck diet selenium concentrations based on the relationship described by Heinz et al. (1990). Modeled selenium concentrations in duck diets, along with the calculated duck muscle concentrations, are listed in Table G-8.

**Table G-7**
**Modeled Fish Whole Body Selenium Exposure Point Concentrations (EPC) and Corresponding Fish Muscle Selenium Concentrations Used for the Human Health Risk Assessment (HHRA)**

| Alternative/Habitat | Tissue | Selenium Exposure Point Concentrations[a] (mg/kg) | | | | HHRA Fish Muscle Selenium Concentration (mg/kg ww) |
|---|---|---|---|---|---|---|
| | | Sediment | | Whole Body Tissue EPC | | |
| | | EPC | Basis | dw | ww | |
| **Existing Conditions** | | | | | | |
| Salton Sea – Open Water | Fillet/muscle | na | na | 10.1 | 2.36 | 2.11 |
| Salton Sea – Shoreline and Shallow Water | Whole body | 1.67 | 95% Approximate Gamma UCL | 7.68 | 1.79 | 1.99 |
| Estuary – Alamo River | Whole body | na | na | 13.1 | 3.06 | 3.40 |
| Estuary – New River | Whole body | na | na | 11.2 | 2.62 | 2.91 |
| Estuary – Whitewater River | Whole body | na | na | 4.8 | 1.12 | 1.25 |
| Freshwater Marsh | Whole body | na | na | 5.3 | 1.24 | 1.38 |
| **No Action Alternative – CEQA Conditions** | | | | | | |
| Estuary – Alamo River | Whole body | 0.305 | 95% Student's-t UCL | 1.40 | 0.33 | 0.36 |
| Estuary – New River | Whole body | 0.604 | Maximum Result | 2.78 | 0.65 | 0.72 |
| Estuary – Whitewater River | Whole body | 2.57 | Maximum Result | 11.82 | 2.76 | 3.07 |
| **No Action Alternative – Variability Conditions** | | | | | | |
| Estuary – Alamo River | Whole body | 0.357 | 95% Student's-t UCL | 1.64 | 0.38 | 0.43 |
| Estuary – New River | Whole body | 0.853 | 95% Student's-t UCL | 3.92 | 0.92 | 1.02 |
| Estuary – Whitewater River | Whole body | 4.4 | 95% Student's-t UCL | 20.24 | 4.73 | 5.25 |
| **Alternative 1 – Saline Habitat Complex I** | | | | | | |
| Saline Habitat Complex – South | Whole body | 0.93 | 95% Chebyshev (Mean, Sd) UCL | 4.28 | 1.00 | 1.11 |
| Saline Habitat Complex – West | Whole body | 1.12 | 95% Student's-t UCL | 5.15 | 1.20 | 1.34 |
| **Alternative 2 – Saline Habitat Complex II** | | | | | | |
| Saline Habitat Complex – North | Whole body | 2.54 | 95% Student's-t UCL | 11.68 | 2.73 | 3.03 |
| Saline Habitat Complex – South | Whole body | 1 | 95% Chebyshev (Mean, Sd) UCL | 4.60 | 1.07 | 1.19 |
| Saline Habitat Complex – West | Whole body | 1.62 | 95% Student's-t UCL | 7.45 | 1.74 | 1.93 |
| **Alternative 3 – Concentric Rings** | | | | | | |
| First Ring | Whole body | 1.79 | 95% Chebyshev (Mean, Sd) UCL | 8.23 | 1.92 | 2.14 |
| Second Ring | Whole body | 1.66 | 95% Chebyshev (Mean, Sd) UCL | 7.64 | 1.78 | 1.98 |

**Table G-7**
**Modeled Fish Whole Body Selenium Exposure Point Concentrations (EPC) and Corresponding Fish Muscle Selenium Concentrations Used for the Human Health Risk Assessment (HHRA)**

| Alternative/Habitat | Tissue | Selenium Exposure Point Concentrations[a] (mg/kg) | | | | HHRA Fish Muscle Selenium Concentration (mg/kg ww) |
|---|---|---|---|---|---|---|
| | | Sediment | | Whole Body Tissue EPC | | |
| | | EPC | Basis | dw | ww | |
| **Alternative 4 – Concentric Lakes** | | | | | | |
| First Lake | Whole body | 1.67 | 95% Chebyshev (Mean, Sd) UCL | 7.68 | 1.79 | 1.99 |
| Second Lake | Whole body | 1.39 | 95% Chebyshev (Mean, Sd) UCL | 6.39 | 1.49 | 1.66 |
| Third Lake | Whole body | 2.15 | 95% Chebyshev (Mean, Sd) UCL | 9.89 | 2.31 | 2.57 |
| Fourth Lake | Whole body | 2.57 | 95% Chebyshev (Mean, Sd) UCL | 11.82 | 2.76 | 3.07 |
| **Alternative 5 – North Sea** | | | | | | |
| Marine Sea | Whole body | 3.93 | 95% Student's-t UCL | 18.08 | 4.22 | 4.69 |
| Saline Habitat Complex | Whole body | 1.03 | 95% Chebyshev (Mean, Sd) UCL | 4.74 | 1.11 | 1.23 |
| **Alternative 6 – North Sea Combined** | | | | | | |
| Marine Sea | Whole body | 3.1 | 95% Chebyshev (Mean, Sd) UCL | 14.26 | 3.33 | 3.70 |
| Saline Habitat Complex | Whole body | 0.945 | 95% Chebyshev (Mean, Sd) UCL | 4.35 | 1.02 | 1.13 |
| **Alternative 7 – Combined North and South Lakes[c]** | | | | | | |
| Marine Sea | Whole body | 3.23 | 95% Chebyshev (Mean, Sd) UCL | 14.86 | 3.47 | 3.85 |
| Saline Habitat Complex – East | Whole body | 0.587 | 95% Student's-t UCL | 2.70 | 0.63 | 0.70 |
| Saline Habitat Complex – North | Whole body | 2.01 | 95% Student's-t UCL | 9.25 | 2.16 | 2.40 |
| IID Freshwater Reservoir | Whole body | 0.575 | 95% Student's-t UCL | 2.65 | 0.62 | 0.69 |
| **Alternative 8 – South Sea Combined** | | | | | | |
| Marine Sea | Whole body | 1.41 | 95% Chebyshev (Mean, Sd) UCL | 6.49 | 1.51 | 1.68 |
| Saline Habitat Complex | Whole body | 1.83 | 95% Student's-t UCL | 8.42 | 1.97 | 2.18 |

Notes:
[a] All exposure point concentrations are for selenium
[b] Except for Existing Conditions, Salton Sea - Open Water, which are based on measured concentrations, exposure point concentrations are whole-body values modeled from sediment selenium concentration and fish biota-sediment accumulation factor (BSAF), as follows: [fish whole body Se EPC] = [sediment Se EPC] * 4.6. HHRA selenium concentrations in fish muscle tissue are based on the whole body EPCs multiplied by fillet-to-whole-body (1.11) and dry-to-wet-weight (0.2335) conversion factors.
[c] Note that the habitat designations are as described in Appendix F.
sd = standard deviation; UCL = upper confidence limit
EPC = exposure point concentration; HHRA = human health risk assessment
na = not applicable (measured tissue concentrations were available).
mg/kg dw = milligrams per kilogram dry weight; mg/kg ww = milligrams per kilogram wet weight

**Table G-8**
**Modeled Selenium Concentrations in Duck Diets and in Duck Muscle Tissue for the Human Health Risk Assessment**

| Alternative/Habitat | Duck Diet (mg Se/kg dw) | Duck Tissue (mg Se/kg ww) |
|---|---|---|
| **Existing Conditions** | | |
| Salton Sea – Shoreline and Shallow Water | 4.54 | 2.77 |
| Estuary – Alamo River | 4.58 | 2.79 |
| Estuary – New River | 1.69 | 1.03 |
| Estuary – Whitewater River | 3.65 | 2.22 |
| Freshwater Marsh | 2.52 | 1.54 |
| **No Action Alternative – CEQA Conditions** | | |
| Salton Sea – Shoreline and Shallow Water | 3.21 | 1.96 |
| Estuary – Alamo River | 0.93 | 0.57 |
| Estuary – New River | 1.48 | 0.90 |
| Estuary – Whitewater River | 4.64 | 2.83 |
| **No Action Alternative – Variability Conditions** | | |
| Salton Sea – Shoreline and Shallow Water | 3.85 | 2.35 |
| Estuary – Alamo River | 1.03 | 0.63 |
| Estuary – New River | 1.91 | 1.17 |
| Estuary – Whitewater River | 7.39 | 4.51 |
| **Alternative 1 – Saline Habitat Complex I** | | |
| Saline Habitat Complex – South | 2.04 | 1.25 |
| Saline Habitat Complex – West | 2.36 | 1.44 |
| **Alternative 2 – Saline Habitat Complex II** | | |
| Saline Habitat Complex – North | 4.59 | 2.80 |
| Saline Habitat Complex – South | 2.16 | 1.32 |
| Saline Habitat Complex – West | 3.17 | 1.93 |
| **Alternative 3 – Concentric Rings** | | |
| First Ring | 3.43 | 2.09 |
| Second Ring | 3.22 | 1.97 |
| **Alternative 4 – Concentric Lakes** | | |
| First Lake | 3.24 | 1.98 |
| Second Lake | 2.79 | 1.70 |
| Third Lake | 3.99 | 2.43 |
| Fourth Lake | 4.64 | 2.83 |
| **Alternative 5 – North Sea** | | |
| Marine Sea | 6.69 | 4.08 |
| Saline Habitat Complex | 2.21 | 1.35 |
| **Alternative 6 – North Sea Combined** | | |
| Marine Sea | 5.44 | 3.32 |
| Saline Habitat Complex | 2.07 | 1.26 |

**Table G-8**
**Modeled Selenium Concentrations in Duck Diets and in Duck Muscle Tissue for the Human Health Risk Assessment**

| Alternative/Habitat | Duck Diet (mg Se/kg dw) | Duck Tissue (mg Se/kg ww) |
|---|---|---|
| **Alternative 7 – Combined North and South Lakes*** | | |
| Marine Sea | 5.64 | 3.44 |
| Saline Habitat Complex – East | 1.45 | 0.89 |
| Saline Habitat Complex – North | 3.77 | 2.30 |
| IID Freshwater Reservoir | 1.43 | 0.87 |
| **Alternative 8 – South Sea Combined** | | |
| Marine Sea | 2.83 | 1.72 |
| Saline Habitat Complex | 3.49 | 2.13 |

Notes:
* The habitat designations are as described in Appendix F.
Selenium concentrations in duck diet modeled from sediment EPCs and the fractions of the diet from sediment, aquatic plants, aquatic invertebrates, and benthic invertebrates
Duck Tissue Se ww concentrations calculated as 0.61 times the diet concentrations based on relationships described by Heinz et al. (1990)
dw = dry weight; ww = wet weight

## Calculations of Maximum Safe Fish and Duck Tissue Consumption Rates

Health risks were estimated by calculating the maximum fish and duck consumption rates that are considered protective of human health. Because actual consumption rates are unknown, assessments and advisories determine a safe exposure or dose based on selenium concentrations in fish and duck tissues and numerical toxicity values specific to total selenium (i.e., all forms combined). For noncancer health effects of selenium, consumption rates were based on the following general relationship developed by USEPA (2000) for assessing chemical contaminant data for use in fish advisories:

$$CRlim = (RfD \times BW) \div Cm;$$

where:

CRlim is the maximum safe daily consumption rate (kg/day);
RfD is the reference dose (mg/kg/day) determined by USEPA;
BW is average human body weight (kg); and
Cm is the contaminant concentration (mg/kg) in the edible portions of fish.

Calculations for selenium were performed using the UCL95 of the mean for the April 2005 fish data (Existing Conditions only) and the predicted UCL95 values based on the modeled fish whole body EPC values. The UCL95 was calculated using Land's Method (USEPA, 2000), and a lognormal data distribution was confirmed using the Shapiro-Wilkes test. Risks for consumption of duck tissues were based on the concentrations calculated from the duck diet UCL95 EPC values.

In addition to daily consumption rates, the number of meals of fish per month was calculated assuming an adult meal size of 8 ounces (227 grams) and a child meal size of 6 ounces (172 grams) (USEPA, 2000). The USEPA does not have a waterfowl-specific default consumption rate. To calculate a safe number of meals per month, a meal size estimate was necessary. Meal size was estimated based on data on poultry consumption reported in Pao et al. (1982); the 50th percentile meal size for poultry (which includes chicken, turkey, Cornish game hen, duck, dove, squab, pigeon, quail, partridge, goose, and pheasant) of 4 ounces per meal (112 g/meal) was assumed to be a reasonable estimate of waterfowl meal size. This meal size is based on cooked meat; applying a cooking weight loss of 32 percent (from USEPA, 1997) results in an estimated uncooked meal size of 6 ounces per meal (165 g/meal). This is less than the estimated fish meal size of 8 ounces per meal (227 g/meal) size described above. However, Weston Solutions (2005) reports that a meal size of 6 ounces (165 g) (uncooked) is generally consistent with the average size of ducks collected in the Housatonic River study area, which found that a half breast with skin weighed approximately 3 ounces (90 g). Therefore, a meal consisting of an entire duck breast would weigh approximately 6 ounces (180 g).

To estimate waterfowl meal size for a child, poultry consumption rates for children and adults were used to calculate a ratio of the child to adult poultry consumption rates, as described by Weston Solutions (2005). Ratios range from 0.45 to 0.56; assuming a child meal size one-half the size of an adult meal size was therefore considered reasonable. Therefore, a child waterfowl meal size of 2.9 ounces per meal (82.5 g/meal) was used in this assessment.

Additional assumptions included the following:

- Samples of fish tissue (tilapia) are representative of the fish that are caught and eaten by recreational anglers, and fish are also brought home and consumed by their families, including children.
- Default exposure parameters from USEPA (2000) were used. For adults, a body weight of 154 pounds (70 kg) and exposure duration of 30 years were assumed. For children, a body weight of 33 pounds (15 kg) (default for children ages 0 to 6) and exposure duration of 6 years were assumed.
- The threshold for noncancer adverse effects, expressed as the ratio of the average daily intake to the reference dose for a specific contaminant (also known as the hazard quotient) was 1 (a unitless value). This implies that adverse effects would not occur at hazard quotient values less than 1.

# RESULTS

## Fish Consumption Rates

Estimates of safe consumption rates of fish under Existing Conditions and for each of the alternatives are summarized in Table G-9. Maximum consumption rates for adults and children are listed for individual habitat types under each of the Alternatives.

For the Existing Conditions, adult recreational anglers could consume from 13 to more than 30 meals per month of fish from different habitats within the Salton Sea without exceeding the maximum consumption rates based on selenium exposures. Children who consume more than about 4 meals per month may be exposed to health risks above target levels. For the No Action Alternative, maximum consumption rates range from about 9 to more than 100 meals per month for an adult and from 2 to more than 30 meals per month for a child. These large ranges in safe consumption rates are due to the high variability among the individual habitat types in the whole-body fish tissue EPCs, which are, in turn, proportional to the sediment EPCs that were determined based on projected selenium loadings and apportionment from the respective sources to a given habitat. For example, under the No Action Alternative – Variability Conditions, both the sediment and whole-body fish EPCs for the Alamo and Whitewater river estuaries vary by more than one order of magnitude (Table G-9), which accounts for the differences in the maximum consumption rates (109 versus 9, respectively) for these two habitats. Maximum fish consumption rates for the alternatives typically were greater than 15 meals per month for an adult, with the exception of the slightly lower rates associated with the Marine Sea habitats of Alternatives 5 and 6 (10 and 13 meals per month, respectively).

**Table G-9**
**Maximum Safe Fish Consumption Rates Based on Selenium Exposure Point Concentrations (EPC) For Salton Sea Restoration Alternatives and Habitats**

| Alternative/Habitat | Fillet Tissue Concentration – Selenium (mg/kg ww) | Maximum Fish Consumption Rate – Adult (g/week) | Maximum Fish Consumption Rate – Child (g/week) | Maximum Meals per Month – Adult | Maximum Meals per Month – Child |
|---|---|---|---|---|---|
| **Existing Conditions** | | | | | |
| Salton Sea – Open Water | 2.11 | 1,161 | 249 | 22.2 | 6.3 |
| Salton Sea – Shoreline and Shallow Water | 1.99 | 1,231 | 264 | 23.6 | 6.7 |
| Estuary – Alamo River | 3.4 | 721 | 154 | 13.8 | 3.9 |
| Estuary – New River | 2.91 | 842 | 180 | 16.1 | 4.6 |
| Estuary – Whitewater River | 1.25 | 1,960 | 420 | 37.5 | 10.6 |
| Freshwater Marsh | 1.38 | 1,775 | 380 | 34.0 | 9.6 |
| **No Action Alternative – CEQA Conditions** | | | | | |
| Estuary – Alamo River | 0.36 | 6,806 | 1,458 | 130.3 | 36.8 |
| Estuary – New River | 0.72 | 3,403 | 729 | 65.1 | 18.4 |
| Estuary – Whitewater River | 3.07 | 798 | 171 | 15.3 | 4.3 |
| **No Action Alternative – Variability Conditions** | | | | | |
| Estuary – Alamo River | 0.43 | 5,698 | 1,221 | 109.1 | 30.8 |
| Estuary – New River | 1.02 | 2,402 | 515 | 46.0 | 13.0 |
| Estuary – Whitewater River | 5.25 | 467 | 100 | 8.9 | 2.5 |
| **Alternative 1 – Saline Habitat Complex I** | | | | | |
| Saline Habitat Complex-South | 1.11 | 2,207 | 473 | 42.3 | 11.9 |
| Saline Habitat Complex-West | 1.34 | 1,828 | 392 | 35.0 | 9.9 |
| **Alternative 2 – Saline Habitat Complex II** | | | | | |
| Saline Habitat Complex-North | 3.03 | 809 | 173 | 15.5 | 4.4 |
| Saline Habitat Complex-South | 1.19 | 2,059 | 441 | 39.4 | 11.1 |
| Saline Habitat Complex-West | 1.93 | 1,269 | 272 | 24.3 | 6.9 |
| **Alternative 3 – Concentric Rings** | | | | | |
| First Ring | 2.14 | 1,145 | 245 | 35.0 | 6.2 |
| Second Ring | 1.98 | 1,238 | 265 | 37.9 | 6.7 |

**Table G-9**
**Maximum Safe Fish Consumption Rates Based on Selenium Exposure Point Concentrations (EPC) For Salton Sea Restoration Alternatives and Habitats**

| Alternative/Habitat | Fillet Tissue Concentration – Selenium (mg/kg ww) | Maximum Fish Consumption Rate – Adult (g/week) | Maximum Fish Consumption Rate – Child (g/week) | Maximum Meals per Month – Adult | Maximum Meals per Month – Child |
|---|---|---|---|---|---|
| **Alternative 4 – Concentric Lakes** | | | | | |
| First Lake | 1.99 | 1,231 | 264 | 37.7 | 6.7 |
| Second Lake | 1.66 | 1,476 | 316 | 45.2 | 8.0 |
| Third Lake | 2.57 | 953 | 204 | 29.2 | 5.2 |
| Fourth Lake | 3.07 | 798 | 171 | 24.4 | 4.3 |
| **Alternative 5 – North Sea** | | | | | |
| Marine Sea | 4.69 | 522 | 112 | 10.0 | 2.8 |
| Saline Habitat Complex | 1.23 | 1,992 | 427 | 38.1 | 10.8 |
| **Alternative 6 – North Sea Combined** | | | | | |
| Marine Sea | 3.70 | 662 | 142 | 12.7 | 3.6 |
| Saline Habitat Complex | 1.13 | 2,168 | 465 | 41.5 | 11.7 |
| **Alternative 7 – Combined North and South Lakes*** | | | | | |
| Marine Sea | 3.85 | 636.3 | 137 | 19.5 | 3.4 |
| Saline Habitat Complex – East | 0.70 | 3,500 | 750 | 107.1 | 18.9 |
| Saline Habitat Complex – North | 2.40 | 1,021 | 219 | 31.3 | 5.5 |
| IID Freshwater Reservoir | 0.69 | 3,550 | 761 | 108.7 | 19.2 |
| **Alternative 8 – South Sea Combined** | | | | | |
| Marine Sea | 1.68 | 1,458 | 312 | 27.9 | 7.9 |
| Saline Habitat Complex | 2.18 | 1,124 | 241 | 21.5 | 6.1 |

Notes:
* The habitat designations are as described in Appendix F.
Rates are based on an oral RfD of 0.005 mg/kg-day and body weights of 70 kg and 15 kg for adults and children, respectively.
Maximum meals per month based on meal sizes of 227 grams (8 ounces) for an adult and 172 grams (6 ounces) for a child.
mg/kg ww = milligrams per kilogram wet weight; g/week = grams per week

For comparison, Table G-10 lists default fish consumption rates cited by federal and State regulatory agencies. If those default values are lower than those calculated as safe consumption rates for Salton Sea fish, it indicates risks are lower than the guidelines. Under all habitat and alternative combinations, the maximum safe consumption rates of fish from the Salton Sea are higher than the recreational fishing consumption rate of 0.6 ounces per day (17.5 g/day or 122 g/week) used by USEPA's Fish Advisory Guidance. The maximum safe consumption rates for adults also are higher than USEPA's default adult fish ingestion rate of 2 ounces per day (54 g/day or 378 g/week). The consumption rates for children are higher than USEPA's Exposure Factors Handbook (USEPA, 1989) mean fish consumption rate of 0.4 ounces per day (11.4 g/day or 80 g/week) for children between the ages of 1 and 5 who eat fish and reside in households with recreational fish consumption. Thus, anglers and their families could safely consume tilapia or other fish species from Salton Sea at higher rates than USEPA's default fish consumption rates.

**Table G-10**
**Default Fish Consumption Rates**

| Receptor | Source | Fish Consumption Rate (g/day) | Basis |
|---|---|---|---|
| Recreational anglers (adult) | EPA Fish Advisory Guidance (USEPA, 2000) | 17.5 | Average consumption of uncooked fish and shellfish from estuarine and fresh waters |
| Subsistence anglers (adult) | EPA Fish Advisory Guidance (USEPA, 2000) | 142.4 | Average consumption of uncooked fish and shellfish from estuarine and fresh waters |
| Recreational anglers (adult) | EPA Standard Default Exposure Factors (USEPA, 1991) | 54 | Based on 3-day dietary study of people who ate finfish, other than canned, dried or raw |
| Children, age 1 to 5 | EPA Exposure Factors Handbook | 11.4 | Mean fish consumption rate for children age 1 to 5 who eat fish and who reside in households with recreational fish consumption |
| Recreational anglers in California (adult) | OEHHA | 30.5 | Adjusted mean recreational fish consumption rate, based on Santa Monica Bay Seafood Consumption Study |
| Recreational anglers (adult) | OEHHA | 85.2 | Adjusted 95th percentile recreational fish consumption rate, based on Santa Monica Bay Seafood Consumption Study |

OEHHA (2001) determined that default fish consumption rates obtained from the Santa Monica Bay Seafood Consumption Study can reasonably be applied to anglers for any productive water body in the State. That study defined the median, mean, 90th percentile, and 95th percentile fish consumption rates as follows: 0.7 ounces per day (21 g/day), 1.8 ounces per day (50 g/day), 3.8 ounces per day (107 g/day), and 5.7 ounces per day (161 g/day), respectively. OEHHA also noted that for cases where the target population is the general fishing population and fish consumption is not the major exposure pathway, the adjusted mean and 95th percentile consumption rates of 1.1 ounces per day (30.5 g/day) and 1.8 ounces per day (85.2 g/day), respectively, can be used as default consumption rates. Given the low yield of target fish species encountered during the April 2005 sampling at the Salton Sea, the latter adjusted rates may be more appropriate as default consumption rates for Salton Sea anglers, although current angling success, and resultant levels of fish consumption, may not be less than they were historically. The maximum fish consumption rates estimated for all but the Whitewater River estuary habitat under the No Action Alternative – Variability Conditions and for the Marine Sea habitat under Alternative 5 are greater than the OEHHA default 95th percentile rate (i.e., 3 ounces per day or 85.2 g/day), suggesting a low potential for adverse health effects.

## Waterfowl Consumption Rates

Selenium concentrations reported previously for muscle and liver tissues of ruddy ducks and northern shovelers from the area of the Salton Sea are listed in Table G-11. These samples may have been collected from areas different than those where most of the waterfowl are taken by hunters, and which are supplied by Colorado River water (e.g., Wister and private duck clubs). Thus, they may not be entirely representative of potential exposure by hunters and their families, but they constitute the only available data for waterfowl. Mean selenium concentrations for muscle and liver tissues ranged from 4.8 to 5.2 mg/kg (dry weight) and from 11.7 to 19.3 mg/kg (dry weight), respectively. Assuming moisture content of 70 percent (Ohlendorf et al., 1990; SWRCB, 1991), these dry-weight concentrations correspond to mean wet-weight selenium concentrations from 1.4 to 1.6 mg/kg and from 3.5 to 5.6 mg/kg, respectively.

**Table G-11**
**Selenium Concentrations Reported in Birds from the Salton Sea and Associated Areas**

| Description/Location | Selenium Concentration (mg/kg dw) | Parameter | Reference |
|---|---|---|---|
| Bird muscle/Salton Sea area | 2.7 to 7.2 | Range | Skorupa (1998) |
| Bird kidney or liver/Salton Sea area | 2.7 to 42 | Range | Skorupa (1998) |
| Northern shoveler liver/New and Alamo Rivers and irrigation drains | 19.1<br>9.1 to 47.0 | Geometric mean<br>Range (n=19) | Setmire et al. (1993) |
| Northern shoveler muscle/New and Alamo Rivers and irrigation drains | 5.2<br>3.8 to 12.0 | Geometric mean<br>Range (n=6) | Setmire et al. (1993) |
| Northern shoveler livers/Imperial Valley (1986-90) | 19.3<br>9.1 to 47.0 | Geometric mean<br>Range (n=31) | Setmire et al. (1993) |
| Ruddy duck liver/Salton Sea | 11.7<br>5.2 to 41.5 | Geometric mean<br>Range (n=57) | Setmire et al. (1993) |
| Ruddy duck liver/Salton Sea (1992) | 12<br>9.2 to 24 | Geometric mean<br>Range (n=10) | Audet et al. (undated) |
| Ruddy duck muscle/Salton Sea | 4.8<br>2.7 to 7.2 | Geometric mean<br>Range (n=17) | Setmire et al. (1993) |

Notes: All concentrations are on a dry-weight (dw) basis.

Estimates of safe consumption rates of duck tissues under Existing Conditions and the alternatives are summarized in Table G-12. Maximum consumption rates for adults and children are listed for individual habitat types under each of the alternatives.

For the Existing Conditions, adults could consume from 23 to more than 60 meals per month of duck muscle from different habitats within the Salton Sea without exceeding the maximum consumption rates based on selenium exposures. Children who consume more than about 10 meals per month may be exposed to health risks above target levels. For the No Action Alternative, maximum consumption rates range from about 14 to more than 100 meals per month for an adult and from 6 to more than 40 meals per month for a child. Similar to safe consumption rates estimated for fish, these large ranges in safe consumption rates for ducks are due to the high variability among the individual habitat types in the duck diet EPCs, which are, in turn, proportional to the sediment EPCs. Maximum duck meal consumption rates for the alternatives typically were greater than 20 meals per month for an adult, with the exception of the slightly lower rates associated with the Marine Sea habitats of Alternatives 5 and 6 (16 and 19 meals per month, respectively). Maximum safe consumption rates for children ranged from about 6 to more than 30 meals per month for various alternative and habitat combinations.

**Table G-12**
**Maximum Safe Duck Consumption Rates Based on Selenium Exposure Point Concentrations (EPC) For Salton Sea Restoration Alternatives and Habitats**

| Alternative/Habitat | Duck Tissue Concentration – Selenium (mg/kg ww) | Maximum Duck Consumption Rate – Adult (g/week) | Maximum Duck Consumption Rate – Child (g/week) | Maximum Meals per Month – Adult | Maximum Meals per Month – Child |
|---|---|---|---|---|---|
| **Existing Conditions** | | | | | |
| Salton Sea – Shoreline and Shallow Water | 2.77 | 884 | 190 | 23.3 | 10.0 |
| Estuary – Alamo River | 2.79 | 878 | 188 | 23.1 | 9.9 |
| Estuary – New River | 1.03 | 2,379 | 510 | 62.6 | 26.8 |
| Estuary – Whitewater River | 2.22 | 1,104 | 236 | 29.1 | 12.5 |
| Freshwater Marsh | 1.54 | 1,591 | 341 | 41.9 | 18.0 |
| **No Action Alternative – CEQA Conditions** | | | | | |
| Salton Sea – Shoreline and Shallow Water | 1.96 | 1,250 | 268 | 32.9 | 14.1 |
| Estuary – Alamo River | 0.57 | 4,298 | 921 | 113.2 | 48.5 |
| Estuary – New River | 0.90 | 2,722 | 583 | 71.7 | 30.7 |
| Estuary – Whitewater River | 2.83 | 886 | 186 | 22.8 | 9.8 |
| **No Action Alternative – Variability Conditions** | | | | | |
| Salton Sea – Shoreline and Shallow Water | 2.35 | 1,043 | 223 | 27.5 | 11.8 |
| Estuary – Alamo River | 0.63 | 3,889 | 833 | 102.4 | 43.9 |
| Estuary – New River | 1.17 | 2,094 | 449 | 55.1 | 23.6 |
| Estuary – Whitewater River | 4.51 | 543 | 116 | 14.3 | 6.1 |
| **Alternative 1 – Saline Habitat Complex I** | | | | | |
| Saline Habitat Complex – South | 1.25 | 1,960 | 420 | 51.6 | 22.1 |
| Saline Habitat Complex – West | 1.44 | 1,701 | 365 | 44.8 | 19.2 |
| **Alternative 2 – Saline Habitat Complex II** | | | | | |
| Saline Habitat Complex – North | 2.80 | 875 | 188 | 23.0 | 9.9 |
| Saline Habitat Complex – South | 1.32 | 1,856 | 398 | 48.9 | 20.9 |
| Saline Habitat Complex – West | 1.93 | 1,269 | 272 | 33.4 | 14.3 |
| **Alternative 3 – Concentric Rings** | | | | | |
| First Ring | 2.09 | 1,173 | 251 | 35.9 | 13.2 |
| Second Ring | 1.97 | 1,244 | 267 | 38.1 | 14.0 |

**Table G-12**
**Maximum Safe Duck Consumption Rates Based on Selenium Exposure Point Concentrations (EPC) For Salton Sea Restoration Alternatives and Habitats**

| Alternative/Habitat | Duck Tissue Concentration – Selenium (mg/kg ww) | Maximum Duck Consumption Rate – Adult (g/week) | Maximum Duck Consumption Rate – Child (g/week) | Maximum Meals per Month – Adult | Maximum Meals per Month – Child |
|---|---|---|---|---|---|
| **Alternative 4 – Concentric Lakes** | | | | | |
| First Lake | 1.98 | 1,238 | 265 | 37.9 | 14.0 |
| Second Lake | 1.70 | 1,441 | 309 | 44.1 | 16.3 |
| Third Lake | 2.43 | 1,008 | 216 | 30.9 | 11.4 |
| Fourth Lake | 2.83 | 866 | 186 | 26.5 | 9.8 |
| **Alternative 5 – North Sea** | | | | | |
| Marine Sea | 4.08 | 600 | 129 | 15.8 | 6.8 |
| Saline Habitat Complex | 1.35 | 1,815 | 389 | 47.8 | 20.5 |
| **Alternative 6 – North Sea Combined** | | | | | |
| Marine Sea | 3.32 | 738 | 158 | 19.4 | 8.3 |
| Saline Habitat Complex | 1.26 | 1,944 | 417 | 51.2 | 21.9 |
| **Alternative 7 – Combined North and South Lakes**[b] | | | | | |
| Marine Sea | 3.44 | 712 | 153 | 21.8 | 8.0 |
| Saline Habitat Complex – East | 0.89 | 2,753 | 590 | 84.3 | 31.1 |
| Saline Habitat Complex – North | 2.30 | 1,065 | 228 | 32.6 | 12.0 |
| IID Freshwater Reservoir | 0.87 | 2,816 | 603 | 86.2 | 31.8 |
| **Alternative 8 – South Sea Combined** | | | | | |
| Marine Sea | 1.72 | 1,424 | 305 | 37.5 | 16.1 |
| Saline Habitat Complex | 2.13 | 1,150 | 246 | 30.3 | 13.0 |

Notes:
[a] All exposure point concentrations are for selenium.
[b] The habitat designations are as described in Appendix F.
Rates are based on an oral RfD of+ 0.005 mg/kg-day and body weights of 70 kg and 15 kg for adults and children, respectively.
Maximum meals per month based on meal sizes of 180 grams (6 ounces) for an adult and 82.5 grams (2.9 ounces) for a child.
mg/kg ww = milligrams per kilogram wet weight; g/week = grams per week

For comparison, a recent human health risk assessment for the GE/Housatonic River Project estimated a reasonable maximum exposure (RME) waterfowl consumption rate of 0.18 ounces per day (5 g/day) for adults and 0.09 ounces per day (2.5 g/day) for children (Weston Solutions, 2005). All of the maximum consumption rates for waterfowl estimated for this screening level risk assessment are substantially higher than the 0.18 ounces per day (5 g/day) RME consumption rate used in the Housatonic River risk assessment.

Current site-specific rates for human consumption of waterfowl from the Salton Sea are not available. However, the present hunting season for waterfowl is from October 23 to January 30, and the bag limit is 7 ducks, with a possession limit of 14 (DFG, 2004). Thus, it is possible for a recreational hunter to consume waterfowl tissue on a daily basis throughout the waterfowl hunting season. Further, assuming that some ducks can be preserved for later consumption (e.g., freezing), it would be possible for a hunter to consume waterfowl tissues throughout the year. For comparison, a human health risk assessment prepared for the Housatonic River site in Massachusetts and Connecticut estimated waterfowl consumption rates indirectly from hunting frequency, frequency of waterfowl consumption, and portion size. That assessment determined that the average and 95$^{th}$ percentile consumption rates for waterfowl at that location were 5.4 meals per year and 44 meals per year, respectively (Weston Solutions, 2005). Individual consumption rates for waterfowl tissues from the Salton Sea may be higher or lower than those values.

## Uncertainty of Risk Estimates

Estimates of human health risks associated with consumption of fish and waterfowl from the Salton Sea are based on a number of assumptions and simplifications that affect the accuracy of the consumption rates. Major sources of uncertainty are described below.

Exposure Assumptions - It was assumed that recreational fishing and duck hunting occurs in the area, and that some area residents fish and hunt regularly in the Salton Sea for a period of time. Abundances of fish and ducks were assumed to be adequate to support this activity. If the abundances of fish and duck are not adequate to support long-term exposures, this assumption will result in overestimation of potential human health effects.

EPA default exposure parameters were used for body weight, exposure duration, and averaging time. These assumptions are conservative and may result in overestimation of potential human health effects.

Noncancer Toxicity Values - Numerous assumptions are required to develop toxicity values from dose-response data. The oral reference dose for selenium used by ATSDR and USEPA is based on the NOAEL for clinical selenosis in a human epidemiological study (Yang et al., 1989), with an uncertainty factor of 3 applied to the oral reference dose. Confidence in the reference dose is listed as “high.” Assumptions used to develop toxicity values may result in over- or underestimation of human health effects.

Additional factors that contribute to the uncertainty of the risk estimates include the following: (1) risks were estimated only from exposures to selenium, and other possible contaminants were not included; (2) contributions from other possible sources (e.g., drinking water, inhalation) were not considered; and (3) risks assume complete absorption and lifetime exposure. These and other factors could contribute to over- or underestimating risks.

## Comparisons to Previous Studies

Several human health risk assessments and health advisories related to selenium exposure from the consumption of sportfish have been developed for the Salton Sea. The results of these previous risk assessments are compared with those from the present assessment in Table G-13. Recent studies by Moreau et al. (2004, in press; 2005, draft manuscript) evaluated health risks from selenium concentrations in tilapia fillets and from other fish species obtained from the Salton Sea. Moreau et al. (2004, in press) used a mean selenium concentration of 1.67 mg/kg wet weight, based on measured concentrations in 24 tilapia samples collected in 1998 at three locations in the Salton Sea Basin (Red Hill Marina, Bombay Beach, and the Salton Sea State Recreational Area Headquarters), combined with a background daily selenium intake from other sources of 0.0016 mg/kg per unit body weight. The risk-based analysis indicated that a 154-pound (70-kg) adult could consume as much as 19 8-ounce meals per month (or 1,000 grams per week), and a 66-pound (30-kg) child could consume as much as16 4-ounce meals per month (or 430 grams per week) with no expected adverse health effects. If the daily selenium intake from other sources was considered zero, adults and children could safely consume 28 and 24 meals per month of tilapia fillets, respectively. Using the maximum measured selenium concentration (2.06 mg/kg) in tilapia fillets, the safe consumption rate was estimated at 15 meals per month (810 grams per week) for an adult or 13 meals per month (350 grams) for a child. A companion study by Moreau et al. (2005, draft manuscript) reported average selenium concentrations of 2.9, 2.8, and 2.2 mg/kg wet weight in gulf croaker (bairdiella), orangemouth corvina, and sargo, respectively, from the Salton Sea. Safe consumptions rates for these species were estimated at 20 ounces per week (571 g/week), 21 ounces per week (602 g/week), and 26 ounces per week (754 g/week), respectively, or 9 to 12 meals per month, even when selenium intake from other sources was included. A similar study by Costa-Pierce et al. (2000) indicated that selenium exposure through the consumption of Salton Sea fish should be limited to 17 to 25 8-ounce meals per month for a 154-pound (70-kg) adult (or 910 to 1,330 grams per week).

**Table G-13**
**Comparisons of Estimated Safe Fish Consumption Rates and Advisories for the Salton Sea Based on Selenium Concentrations in Fish Tissues**

| Description | Maximum Safe Consumption Rate | | Reference |
|---|---|---|---|
| | g/week | Meals/month | |
| Adult consumption of tilapia muscle tissue | 810 to 1,190 | 15 to 23 | Moreau et al. (2004, in press) |
| Adult consumption of gulf croaker (bairdiella), orangemouth corvina, and sargo muscle tissue | 571 to 754 | 11 to 14 | Moreau et al. (2005, draft manuscript) |
| Adult consumption of tilapia muscle tissue | 910 to 1,330 | 17 to 25 | Costa Pierce et al. (2000) |
| Adult consumption of Salton Sea fish (tilapia, gulf croaker, sargo, orangemouth corvina) muscle tissue | 57 | 1* | CalEPA (2004) |
| Adult consumption of tilapia muscle tissue – Existing Conditions | 721 to 1,960 | 13 to 37 | This evaluation |
| Adult consumption of fish muscle tissue – No Action Alternatives | 467 to 6,806 | 9 to 130 | This evaluation |
| Adult consumption of fish muscle tissue – Project Alternatives #1 – 8 (see Table G-9) | 522 to 3,550 | 10 to 108 | This evaluation |

* Advisory limits stated as no more than 4 ounces (114 g) per two-week period, which is equivalent to one meal (8 ounces) per month.

Health risks estimated for the present evaluation generally are comparable to those determined by Moreau et al. (2004, in press; 2005, draft manuscript) and by Costa-Pierce et al. (2000). Current USEPA (2000) guidelines for selenium exposure via fish consumption allow 16 8-ounce (227-gram) meals per month for an average 154-pound (70-kg) adult consuming fish with an average wet-weight concentration from greater than 1.5 to 2.9 mg/kg. These guidelines are comparable to the safe consumption rates estimated by this evaluation and by the studies of Moreau et al. and Costa-Pierce et al. Nevertheless, these maximum safe consumption rates are about one order of magnitude higher (i.e., less restrictive) than the present advisory limits issued by OEHHA.

The OEHHA web site (http://www.oehha.ca.gov/fish/so_cal/saltonsea.html) was updated on September 19, 2004 with the following advisory:

> "Because of elevated selenium levels, no one should eat more than four ounces [114 g] of croaker, orangemouth corvina, sargo, or tilapia taken from the Salton Sea in any two-week period."

An additional warning for the New River has been published and posted by the Imperial County Health Department for people to avoid physical contact with the waters of the New River and to avoid eating fish of any variety taken from the river. This advisory may be due to exposures from multiple contaminants, including elevated concentrations of organochlorine compounds, such as dichlorodiphenyldichloroethene (DDE) and polychlorinated biphenyls (PCBs) (Riedel et al., 2002; Sapozhinkova et al., 2004), and not just selenium.

It is recognized that regulating authorities would need to agree on which consumption levels are adequately protective of human health. Regardless, Moreau et al. (2004, in press) stated

> "The assumptions used in the original state advisory recommendation were based on scientific knowledge of human Se dietary requirements, acceptable daily intake and toxicity threshold available 20 years ago. Selection of additional variables used in the advisory, such as risk values, additional sources of exposure, if considered, average consumer body weight and meal size, was also contingent upon decisions made by the U.S. EPA and state agencies. The sampling and analysis protocols used, along with the number of fish analyzed, were also important factors in the determination of the advisory.
>
> However, assumptions in the risk assessment of the original advisory have changed since the mid 1980s, and, in light of new information, a revision should be considered. The informal advice we offer here can hopefully prompt the California Office of Environmental Health Hazard Assessment to carry out further sampling and assessments, bringing about the development of a more accurate advisory based on As, Se, tDDT (total dichlorodiphenyltrichloroethane [DDT]), and PCB values, for all sport fish species present in the Salton Sea."

## HEALTH RISKS FROM FUTURE CONSUMPTION OF FISH AND WATERFOWL

As mentioned under "Uncertainty of Risk Estimates," this screening-level human health risk assessment assumes that the abundances of fish and waterfowl at the Salton Sea will be adequate to sustain fishing and hunting activities for a period of time under the No Action Alternative. The present abundances of fish species targeted by anglers appear to be very low and are likely to decline in the future in response to increasing salinity under the No Action Alternative. As the salinity of the Salton Sea increases beyond the tolerances of remaining sportfish species, fish targeted by anglers may disappear from the Salton Sea within the next 5 to 10 years. During this time, fish capture and consumption are expected to decline to a point where realistic consumption rates are appreciably lower than the maximum exposures considered protective of human health rates, as estimated by this and other risk assessments. At that time, the risks associated with fish consumption would be negligible because few if any fish from the Salton Sea would be consumed on a regular basis. Risks to humans from consumption of fish collected under the alternatives will vary in proportion to the water and sediment quality conditions associated with the individual habitats. Habitats with relatively higher selenium loads will result in proportionally higher fish tissue concentrations and, in turn, higher exposure rates for humans consuming these fish.

Compared with the future risks associated with fish consumption, future health risks from selenium exposures due to waterfowl consumption are expected to be generally comparable to current risks. Although habitat conditions (including specific food web organisms that are available) will change under the No Action Alternative, waterfowl are expected to continue to feed at the Salton Sea, especially in near-shore areas and in the estuarine habitats at the mouths of rivers where elevated selenium concentrations are found. Similar to risks for fish consumption, the possible health risks from consumption of waterfowl tissues may vary in proportion to the water and sediment quality conditions associated with the individual habitats and alternatives. Habitats with relatively higher selenium loads will result in proportionally higher waterfowl tissue concentrations and, in turn, higher exposure rates for humans consuming these waterfowl.

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