US Fish & Wildlife Service

Methylmercury and Other Environmental Contaminants in Water and Fish Collected from Four Recreational Fishing Lakes on the Navajo Nation, 2004

US Fish and Wildlife Service
New Mexico Ecological Services Field Office
2105 Osuna Road NE
Albuquerque, New Mexico 87113
http://ifw2es.fws.gov/NewMexico/

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METHYLMERCURY AND OTHER ENVIRONMENTAL CONTAMINANTS IN WATER AND FISH COLLECTED FROM FOUR RECREATIONAL FISHING LAKES ON THE NAVAJO NATION, 2004

by

Joel D. Lusk[1], Eric Rich[2] and R. Sky Bristol[3]

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Window Rock Boulevard
Window Rock, Arizona

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http://ifw2es.fws.gov/NewMexico/
(505) 346-2525

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[1] U.S. Fish and Wildlife Service, 2105 Osuna Road NE, Albuquerque, NM
[2] Navajo Nation Environmental Protection Agency, P.O. Box 3780, Tuba City, AZ
[3] U.S. Geological Survey, P.O. Box 25046, Denver Federal Center, Denver, CO

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CONVERSION FACTORS AND EQUATIONS

Multiply	By	To obtain
inch (in)	25.40	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile	2.590	square kilometer (km^2)
acre	4.047	km^2
ounce (oz)	28.35	gram (g)
pound (lb)	453.59	g
short ton	907.18	kilogram (kg)
acre-feet	1233	cubic meter (m^3)

Celsius (C) and may be converted to degrees Fahrenheit (^oF) using the Equation 1:

$$^oF = (1.8 \times C) + 32 \qquad \text{Equation (1)}$$

Trace element data in fish tissues are reported in either dry weight (DW) or wet weight (WW) concentrations and are so indicated. Dry weight concentrations may be converted into wet weight concentrations using Equation 2:

$$WW = DW \times [1 - (\text{percent sample moisture}/100)] \qquad \text{Equation (2)}$$

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EXECUTIVE SUMMARY

In 2000, the U.S. Environmental Protection Agency (USEPA) stated that the Navajo Nation Water Quality Standards for mercury were likely to adversely affect the bald eagle. In 2002, the USEPA, the Navajo Nation Environmental Protection Agency (Navajo Nation EPA), and the U.S. Fish and Wildlife Service (USFWS) agreed to identify waterbodies on the Navajo Nation where elevated concentrations of mercury in fish could pose a health risk to people or to bald eagles that frequently ate fish from these lakes. In March and April 2004, the USFWS and the Navajo Nation EPA collected fish and water from four recreational fishing lakes on the Navajo Nation. The goal of the Navajo Nation Lake Fish and Water Quality Investigation was to provide data that could be used to evaluate mercury risks to bald eagles and people.

Based on the data collected, people can and should feel comfortable consuming fish on a recreational basis from Asaayi Lake, Wheatfields Lake, and Morgan Lake (that is, no more than 14 meals of fish per year). However, catfish from Red Lake may contain concentrations of methylmercury that may pose health risks to certain people who eat fish frequently (that is, more than two meals of fish per week) – especially women of childbearing age, nursing mothers, infants and young children. Additionally, selenium concentrations in fillets from Morgan Lake may also pose health risks to children who subsist on those fish (that is, eat more than 6 meals of fish per week).

An important technique to manage human health risks is to identify people whose diet contains a large portion of fish and communicate the risks posed by mercury or other contaminants to them while considering the nutritional role fish plays in their diet. The Navajo Nation has the primary responsibility for protecting their residents from the risks of eating contaminated fish. To reduce exposure to these contaminants, people may want to consult the Navajo Nation to help them make choices about which fish to eat and how often in order to reduce any health risks.

Bald eagles that consume catfish from Red Lake on a frequent basis (>30 days per year), also have the potential to experience mercury toxicity. Bald eagles attempting to establish nesting sites on the Navajo Nation may need to be monitored for their long-term mercury exposure and effects. To protect the bald eagle from consumption of mercury in fish, water quality criteria for wildlife were identified. Pollution prevention is also effective means of reducing fish contamination; therefore, it is important to identify the sources of mercury to Red Lake and their magnitude, so that they can be reduced. If necessary, lake oxygenation, increasing pH, riparian shading, excavation, sulfate reduction, flood peak minimization, vegetating uplands, riparian filter strips, increased upland filtration, and recreational fisheries management techniques can alter the forms and bioavailability of mercury and thereby reduce the mercury burden within fish eaten by bald eagles. Selenium contamination was also identified in fish from Morgan Lake at concentrations that may affect the reproductive success of resident fish and wildlife. Sources of selenium contamination should be identified and reduced. With the exception of aluminum, concentrations of contaminants in water samples collected did not exceed applicable Navajo Nation numeric water quality criteria.

INTRODUCTION

The Navajo Nation

The Navajo Nation is the largest North American Indian Tribe consisting of nearly 200,000 members (U.S. Census Bureau 2001). The Navajo Nation spans over 24,000 square mi (62,160 km^2) of land with its boundaries extending from northwestern New Mexico into northeastern Arizona and southeastern Utah (Figure 1). In 1995, the Navajo Nation Environmental Protection Agency ("Navajo Nation EPA") was established as a regulatory agency within the Navajo Nation government, in order to implement and enforce environmental laws for the protection of human health and the environment. The mission of Navajo Nation EPA is to protect, preserve, and enhance the environment for present and future generations, with respect to Diné values, by developing, implementing, and enforcing environmental laws; and to foster public awareness and cooperation through education.

Recreational fishing lakes are among the ultimate repositories of contaminants released from various natural and anthropogenic activities. Contaminants can come from point source discharges (*e.g.*, industrial and municipal facilities), accidental spills, and nonpoint sources (*e.g.*, atmospheric deposition from various combustion and incineration processes). Once contaminants reach these surface waters, they can undergo processes that affect the aquatic food chain and can bioaccumulate in fish. Thus, fish tissue monitoring can serve as an important indicator of water quality problems, and several Tribes routinely conduct chemical contaminant analyses of fish as part of their comprehensive water quality monitoring programs (Cunningham and Whitaker 1989). Tissue contaminant monitoring can also enable Tribes to detect levels of contamination in fish tissue or the water column that may be harmful to people or wildlife and enable them to take appropriate management actions.

The Navajo Nation has primary responsibility for protecting its members from the health risks of consuming contaminated fish and wildlife. Fish consumption advisories are one method to achieve this goal for the general population, including those who fish for recreation or those whose diet contains a large portion of fish, as well as for sensitive subpopulations (such as pregnant women, nursing mothers, and children). Fish consumption advisories are intended to inform people of concentrations of chemical contaminants found in local fish and can include recommendations to limit or avoid consumption of certain fish.

Sources, Fate and Transformations of Mercury

Mercury (Hg) is a natural element, a silver-colored, shiny metal found in a variety of forms in rocks, soil, water, air, plants, and animals (USEPA 1997; Wiener *et al.* 2003). Sometimes mercury occurs in its elemental liquid form, or gaseous, but more commonly mercury is found combined with other elements in various inorganic (*e.g.*, mercury chlorides, or mercury and sulfur cinnabar deposits) and organic (*e.g.*, methylmercury) compounds (Schierow 2004). Mercury has been used in dental fillings, thermometers, fluorescent lights, thermostats, and it is a constituent of mineral deposits such as coal.

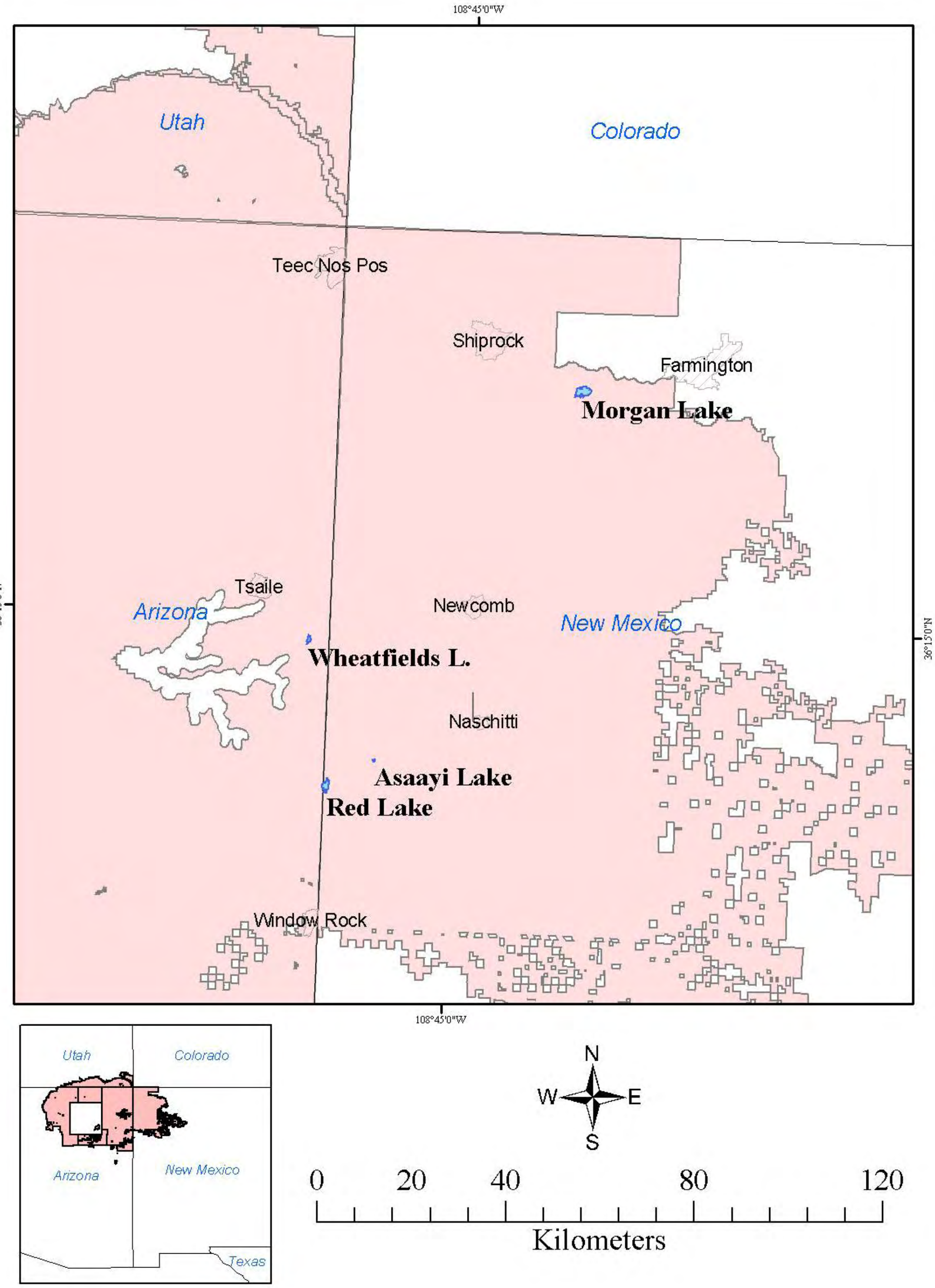

Figure 1. Location of the Lakes Sampled on the Navajo Nation and Nearby Towns. (Inset: Location of the Navajo Nation in the Arizona, New Mexico and Utah).

Mercury is found in the environment because of natural and human activities. Natural forces move mercury through the environment, from air to soil to water, and back again. Industrial activities have increased the portion of mercury in the atmosphere and oceans, and have contaminated some local environments. According to USEPA (1997), coal-fired electric utilities are the largest single unregulated source of mercury emissions in the United States, but other sources such as mines and incinerators are also important. Released mercury may enter the air, persist in the atmosphere and travel great distances or be deposited locally, dissolve in water droplets, settle back onto the land or water, re-enter the air (*i.e.*, be re-emitted), be buried in lake or ocean sediments, or be incorporated into plants and animals (Schierow 2004). These properties make mercury extremely mobile – a "grasshopper" pollutant -- that can enter various components of the environment.

During its movement among the atmosphere, land, and water, mercury undergoes a series of complex chemical transformations. Mercury deposited or delivered to surface water may be re-emitted to air, remain suspended or dissolved in the water column, be deposited in sediments, or absorbed or ingested by living organisms. For the oceans and large or isolated lakes such as the Great Lakes, atmospheric deposition (wet and dry) accounts for the largest portion of mercury contamination (Wiener *et al.* 2003). Rudd (2004) also reported that mercury that is newly deposited seems to be more readily converted into methylmercury than older deposited mercury.

The most biologically significant transformation of mercury occurs in watershed soils or in sediments of lakes or streams, where bacteria (primarily sulfate-reducing bacteria) are capable of converting inorganic mercury to methylmercury (Wiener *et al.* 2003). Methylmercury is easily absorbed by the digestive tract and accumulates in the bodies of fish and other animals, when it is ingested faster than it can be excreted. Because methylmercury tends to be stored in muscle tissue (*i.e.*, the edible meat of fish and other animals), animals higher on the food chain tend to have higher levels of exposure. For example, predatory fish (*e.g.*, walleye, largemouth bass, or tuna), fish-eating birds (*e.g.*, loons, ospreys, bald eagles), and fish-eating mammals (*e.g.*, raccoons, otters, mink) that top the longest food chains accumulate the greatest concentrations of methylmercury. [See Appendix A through F for lists of the common and scientific names of species used in this report]. The degree to which mercury is transformed into methylmercury and transferred up the food chain through bioaccumulation depends on many site-specific factors (such as water chemistry and the complexity of the food web) through processes that are not completely understood (Moore *et al.* 2003).

Generally, the more mercury that is introduced into an ecosystem, either through direct discharge to water, runoff from the surrounding watershed, or deposition from air, the higher the concentrations of methylmercury that will be found in fish (Schierow 2004). However, the rate of methylmercury formation and accumulation is highly variable, even within relatively small geographic areas, because it depends on many factors, in addition to the abundance of inorganic mercury. For example, ecosystems sensitive to mercury contamination are often warmer, oxygen-poor, acidic, contain more sulfate and dissolved humic matter (*i.e.*, characterized by an abundance of dissolved, decomposed, plant or bacterial matter), have more wetland areas or surface water tributaries connected to wetlands, or are subjected to flooding or drying and re-wetting (Moore *et al.* 2003; Wiener *et al.* 2003; Rudd 2004; Schierow 2004). Deposition of flooded vegetation and soils often stimulates methylation of mercury with an accompanying increase of mercury in fish (Rudd 2004).

Human Exposure and Toxicity of Methylmercury

People can be exposed to methylmercury by eating, drinking, inhaling, or absorbing it through their skin (USEPA 2001). The National Research Council (NRC 2000) reported that the nervous system is especially sensitive to methylmercury toxicity, particularly the developing fetus; as even small doses by a pregnant woman can lead to delays and deficits in learning ability in her children. The NRC (2000) reported that the brain is the most sensitive part of nervous system for which suitable data are available to quantify a dose-response relationship for methylmercury toxicity. However, research continues to find evidence of subtle impacts on human health through other types and routes of exposure. For example, Salonen *et al.* (1995) suggested that the adult sensitivity to cardiovascular toxicity due to mercury exposure might be as important as developmental neurotoxicity in children.

The observed effects of toxic levels of methylmercury exposure have generally been similar in laboratory animals, domestic pets, wildlife, and people (NRC 2000). Methylmercury that is absorbed is dispersed by blood throughout the body including the brain, where it may cause structural damage (NRC 2000). After exposure, physical lesions can develop that lead to tingling and numbness in fingers and toes, loss of coordination, difficulty in walking, generalized weakness, impairment of hearing and vision, tremors, as well as loss of consciousness and death (NRC 2000). Quite often, there is a lag time of weeks to months between exposure and the onset of health effects in people (Clarkson 2002). Injury to the brain may exist, however, in the absence of these observable symptoms of toxicity. Lower levels of exposure may have more subtle adverse impacts on coordination, ability to concentrate, and thought processes (Yokoo *et al.* 2003).

Methylmercury readily crosses the placenta of pregnant women to the fetus (USEPA 2001). The fetal brain has been demonstrated to be more sensitive to methylmercury than the adult brain (NRC 2000). Methylmercury exposure to the fetal brain can affect development, as evidenced during childhood by a child's ability to learn and function normally after birth. At low levels of exposure, the effects may be subtle and detectable only on a population basis— for example, by an increase in the proportion of an exposed population that falls below a level of function defined as impaired (NRC 2000). The NRC (2000) concluded that the sensitivity of the fetus to pre-natal methylmercury exposure, and that the risk to women who eat large amounts of fish and seafood during pregnancy is "likely to be sufficient to result in an increase in the number of children who have to struggle to keep up in school."

In the United States, most people are exposed to mercury primarily through eating the flesh (muscle) of fish (USEPA 1997). People who regularly eat predatory fish, such as largemouth bass, northern pike, tuna, shark, or swordfish, which are often contaminated with mercury, can increase the risk of adverse health effects for themselves or, in the case of women who become pregnant, for any unborn children (Hightower and Moore 2003).

The USEPA (1997) derived a "Reference Dose" (RfD) as a tool to estimate daily intake levels of methylmercury that are expected to be without an appreciable risk of deleterious health effects, even if exposure persists over a person's lifetime. The USEPA (2001) developed an RfD for methylmercury based largely on developmental toxicity to account for sensitive members of the exposed human population, such as pregnant women and infants, though it did not account for individuals with unusual sensitivity due to conditions such as genetic disorders or severe illness. To calculate the RfD, the USEPA generally uses a "no observed adverse effect level" (NOAEL), which is either observed or estimated using a mathematical model. The NOAEL estimates the threshold level of exposure below which adverse effects do not occur. The RfD is then derived by dividing the NOAEL value by uncertainty factors that account for the need to extrapolate from limited data sets to the general population. Therefore, even though the RfD was derived using developmental toxicity as an endpoint of concern, the USEPA (2001) recommends the use of the RfD to protect adults and children in the general population. The RfD for methylmercury is 0.1 micrograms per kilogram bodyweight of consumer per day (μg/kg-bw/day) (USEPA 2001).

Pursuant to section 304(a)(1) of the Clean Water Act, the USEPA (2001) established a water quality criterion for methylmercury of 0.3 milligrams of methylmercury per kilogram of fish tissue on a wet weight basis (mg/kg WW) based on the RfD. This was the first time the USEPA based a water quality criterion on a concentration of a pollutant in fish (and shellfish) rather than dissolved in the water column (Schierow 2004). The USEPA (2001) indicated that to protect consumers of fish and shellfish among the general population, the concentration of methylmercury in tissue should not be exceeded based on an average consumption of 17.5 grams of fish and shellfish consumed per person per day.

<u>Fish Exposure and Mercury Toxicity</u>

Adverse effects of methylmercury on fish, birds and mammals include death, reduced reproductive success, impaired growth and development, and behavioral abnormalities (USEPA 1997). Mercury is persistent and accumulates within the food chain of the environment, successively reaching higher concentrations in predators like eagles, mink, and fish such as tuna or largemouth bass. The USFDA (2003) reported that uncontaminated fish contain less than 0.01 mg/kg methylmercury (on a wet weight [WW] basis) in their muscle tissues, while contaminated shark can contain more than 4.5 mg/kg methylmercury.

The amount of mercury in fish has been found to vary with species, size, and age (Wiener *et al.* 2003). These factors are interrelated. For example, bioaccumulation in bass is greatly influenced by its degree of piscivory, which is a function of size – over time as bass increase in size; they feed almost exclusively on large-bodied fish (Harris *et al.* 2001). A strong relationship between species trophic classification and mercury is often observed at most sites sampled nationwide; however, variations in prey species populations and availability of mercury for bioaccumulation among some sites results in some disconnect between a strict trophic classification and expected mercury bioaccumulation (Brumbaugh *et al.* 2001).

Spatial variation in fish-mercury concentrations is also attributed to differences among surface waters and their watersheds, particularly in their tendency to convert inorganic mercury to methylmercury and in their tendency to accumulate mercury in the aquatic food web (Wiener *et al.* 2003). Verda (2000) reported over 38 water quality factors that may affect the methylmercury concentration in water and therefore, in fish. Generally, fish obtain methylmercury almost entirely through dietary uptake, which is influenced by their size, diet, and trophic structure, while site-specific water quality factors influence the chemistry and methylation potential of the water bodies in which the fish live.

After bioaccumulation, acute toxic effects and death are associated in adult fish ranging from 6 mg/kg WW (*e.g.*, for walleye) to 20 mg/kg WW (*e.g.*, for salmon) in muscle tissue (Wiener *et al.* 2003). Rarely, however, are these elevated concentrations encountered in the wild (Wiener *et al.* 2003). Recent evidence suggests that the reduced reproductive success and reduced survival are chronic toxic effects of dietary exposure of fish to methylmercury (Friedmann *et al.* 1996, 2002). However, the ecological effects of methylmercury exposure to fish populations remains largely unknown and understudied (Wiener *et al.* 2003).

Wildlife Exposure and Mercury Toxicity

Mercury is considered a serious risk to wildlife (Moore *et al.* 2003). Fish consumption is also the dominant pathway for wildlife exposure to methylmercury. Fish-eating predators generally have relatively high concentrations of mercury (Wiener and Spry 1996). Toxic mercury levels have been found in individual mink, otters, loons, and other piscivorous birds and wildlife (Heinz 1979, USEPA 1997, Wolfe *et al.* 1998, Russell 2003).

Methylmercury toxicity in wildlife is primarily manifested as central nervous system damage; including sensory and motor deficits and behavioral impairment (Wolfe *et al.* 1998). Exposed animals may experience weight loss, progressive weakness, liver damage, kidney damage, motor difficulties, reduced food consumption, reduced cardiovascular function, impaired immune response, reduced muscular coordination, impaired growth and development, altered blood and serum chemistry, and reproductive effects (Eisler 1987; Scheuhammer 1987, Scheuhammer and Blancher 1994). Many scientists suspect that the immune system is weakened because of methylmercury exposure. However, the most likely adverse impact on birds of methylmercury exposure is impaired ability to reproduce. For example, reduced egg laying by loons has been associated with concentrations greater than 0.4 mg/kg methylmercury in fish (Scheuhammer and Blancher 1994; Wiener *et al.* 2003).

The USEPA (1995c) also reviewed numerous subchronic and chronic mercury toxicity studies using birds. Data on methylmercury effects in wildlife suitable for dose-response assessment are limited to what are termed "individual effects" (USEPA 1997). The USEPA (1997) ultimately selected a study examining reproductive and behavioral effects in three generations of mallard ducks (Heinz 1979) to determine an appropriate test dose for its avian wildlife criteria calculations. In order to determine the RfD for a given taxonomic group, the test dose selected to represent that group may need to be adjusted by uncertainty factors to incorporate variability in toxicological sensitivity among species and to extrapolate for duration (subchronic-to-chronic) or dose spacing (LOAEL-to-NOAEL) issues. The RfD for wildlife is calculated using the following equation:

$$RfD = \frac{TD}{UF_A \times UF_S \times UF_L} \qquad \text{(Equation 3)}$$

Where:

- RfD = Reference Dose (mg/kg-bw/day)
- TD = Test Dose (mg/kg-bw/day)
- UF_A = Interspecies Uncertainty Factor (unitless) = 1 (USEPA 1997)
- UF_S = Subchronic-to-Chronic Uncertainty Factor (unitless) = 1 (USEPA 1997)
- UF_L = LOAEL-to-NOAEL Uncertainty Factor (unitless) = 3 (USEPA 1997)

Based on the avian test dose of 0.064 mg/kg-bw/day from the Heinz (1979) mallard duck study, and the uncertainty factor of 3 from USEPA (1997) and Russell (2003), an avian RfD of 0.021 mg/kg-bw/day was calculated and used in the evaluation of bald eagle risks below.

Objectives of the Lake Fish and Water Quality Investigation

The goal of the Navajo Nation Lake Fish and Water Quality Investigation was to provide data that may be used to estimate potential mercury risks to human health and to bald eagles that utilize fish from selected recreational lakes on the Navajo Nation. These data are also to be used to develop site-specific bioaccumulation factors and to evaluate the need for management actions to limit fish consumption, derive wildlife water quality criteria that would protect bald eagle, reduce the process of mercury methylation, or perhaps recommend reductions of local mercury and other contaminant emissions and discharges under various Navajo Nation authorities.

The specific objectives of the Navajo Nation Lake Fish and Water Quality Monitoring Project were:

1. To document the concentrations of mercury, methylmercury, and other trace elements in fish tissues consumed by people and wildlife; and,

2. To document the concentrations of selected trace elements dissolved in the water column and compare these concentrations to ambient Navajo Nation water quality criteria.

ENVIRONMENTAL SETTING

The Navajo Nation consists of over 24,000 mi^2 (62,160 km^2) of land and over 18 mi^2 (46.6 km^2) of surface water bodies (U.S. Census Bureau 2001). Surface-water and fish samples were collected from four Navajo Nation lakes that are used either for fishing (Figure 2) or by foraging bald eagles. These sites were selected through consultation with the Navajo Nation EPA and the Navajo Nation Natural Heritage Program's Department of Fish and Wildlife. The four lakes sampled (Figure 1 and Figure 2) for this study included:

1) Asaayi Lake, a coldwater lake;
2) Morgan Lake, a warmwater lake;
3) Red Lake, a warmwater lake; and,
4) Wheatfields Lake, a coldwater lake;

Asaayi Lake Setting

Asaayi Lake (Figure 3, Figure 4) is a 35.5-acre (0.1 km^2) lake located approximately 15 mi (24.1 km) southwest of Naschitti, New Mexico (Figure 1). This coldwater lake is found in the foothills of the Chuska Mountains at 7,562 ft (2.3 km) and has a maximum depth of approximately 25 ft (0.01 km). The area is characterized by mixed grasses, chaparral brush, oak-juniper woodland, piñon-juniper woodland and with occasional open forests of ponderosa pine. The shoreline is generally stable with some sloughing, but is mostly barren sand with only patchy grasses.

The most common large wild mammal in this area is mule deer. Mammalian predators include mountain lions, coyotes, and bobcats. Small mammals include deer mouse, porcupine, golden-mantled ground squirrel, Colorado chipmunk, wood rat, pocket gopher, Albert squirrel, and cottontail. Some of the more common birds are olive warbler, mountain bluebird, white-breasted nuthatch, Mexican junco, Steller's jay, red-shafted flicker and Rocky Mountain sapsucker.

Morgan Lake Setting

Morgan Lake (Figure 5) and the Four Corners Power Plant (Figure 6) are located on the Navajo Nation approximately 15 mi (24.1 km) southwest of Farmington, New Mexico (Figure 1). Morgan Lake encompasses approximately 1,287 surface acres (5.2 km^2) and has a maximum storage capacity of 39,000 acre-feet (4.8×10^7 m^3) of water. Water level is maintained by pumping from the San Juan River, a distance of 2 ½ mi (4.0 km). The maximum depth was about 100 feet (0.03 km) in 1966 (Sanchez 1972). The surrounding area is characterized by arid grasslands, but short grasses seldom cover the ground completely, leaving many areas bare with scattered shrubs. Xeric shrubs often grow in open stands among the grasses and sagebrush is dominant over extensive areas. Riparian shrubs and emergent wetland plants line and stabilize the edge of this lake.

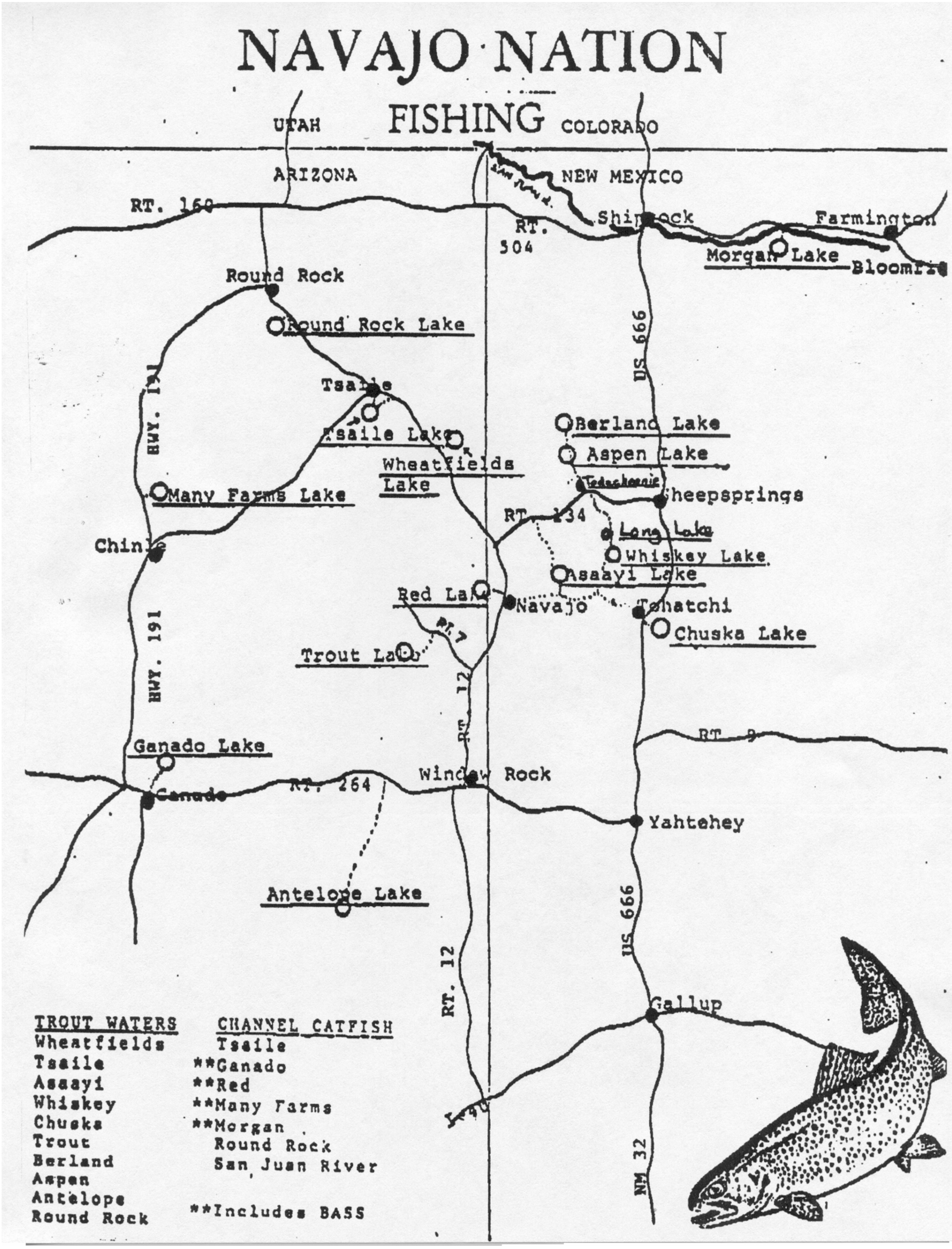

Figure 2. Location of Recreational Fishing Lakes on the Navajo Nation.
(Source: Navajo Nation Department of Fish and Wildlife)

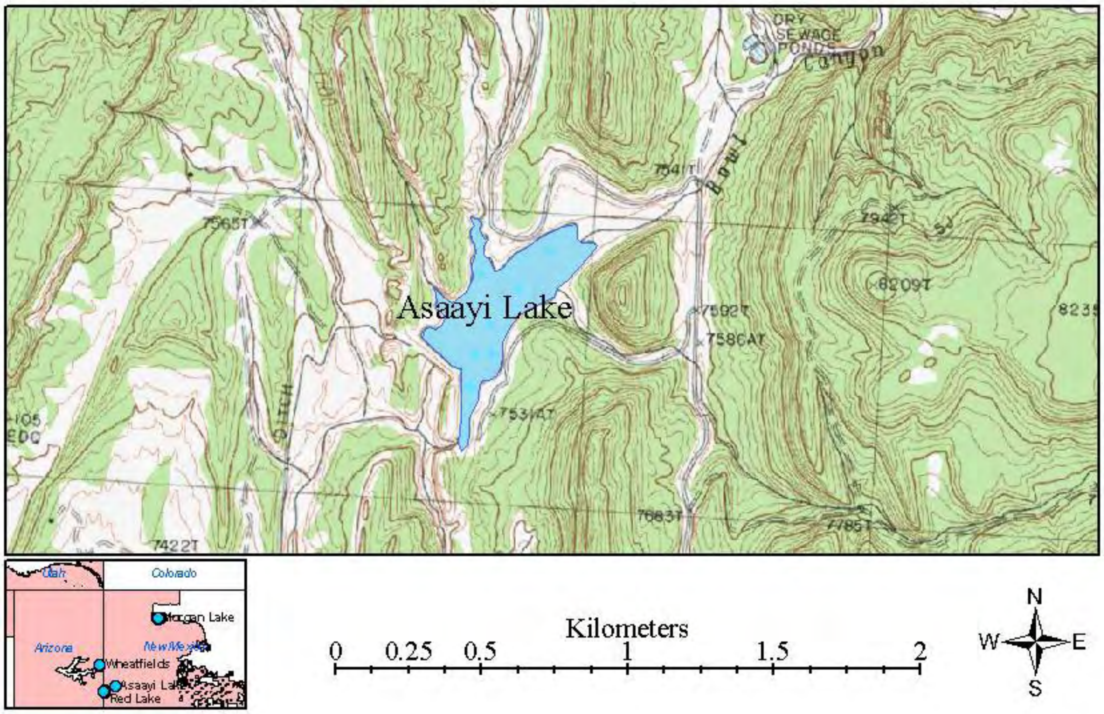

Figure 3. Location of Asaayi Lake on the Navajo Nation.

Figure 4. View of Asaayi Lake. Photo: Joel D. Lusk

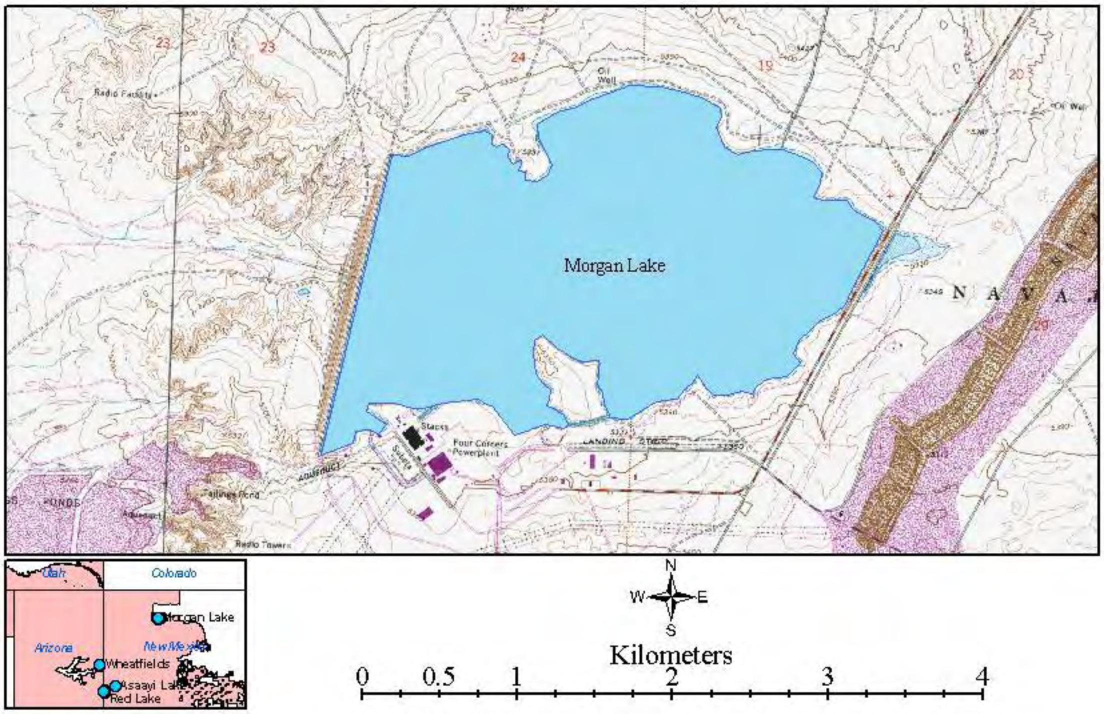

Figure 5. Location of Morgan Lake on the Navajo Nation.

Figure 6. View of Morgan Lake and the Four Corners Power Plant. Photo: Joel D. Lusk

Morgan Lake is near the Fruitland Formation coal reserves that are mined for power generation. Morgan Lake was built in 1961 by the Arizona Public Service Company. It serves the Four Corners Power Plant, which is the 10th largest power plant in the country (R. Clifford, Arizona Public Service Company, written communication, 1996). Electrical power is produced at the power plant by burning over 8 million tons (~7,260 kg) of coal per year to produce heat; this in turn is transformed into steam that turns the generators to produce electricity. This process requires an adequate supply of water as a cooling source for the power plant. In 1960, an agreement between the owners and the Navajo Nation established the use of Morgan Lake for recreation and various fish were stocked in 1962 (Sanchez 1972).

Previous Morgan Lake Studies

There have been several investigations into the quality of water or fish collected from Morgan Lake (Sanchez 1972, 1973; Blinn *et al.* 1976, Westinghouse Electric Corporation 1975; Geotz and Abeyta 1987; USFWS 1988; Esplain 1995, Bristol *et al.* 1997; and this study). Sanchez (1972) reported on the quality of water, sediment and invertebrates collected from 1966 to 1972. In 1973, a fish kill occurred during August 10 through 17, 1973. An estimated 33,674 fish ranging in total length from 5 to 24 inches (127 to 609 mm) were lost during the die-off (Sanchez 1973). A blue-green algal bloom and high surface water temperatures (32.2 to 40C) were thought to be contributing factors. In 1975, the Northern Arizona University was contracted to evaluate the probable causes of previous fish kills in the lake (Blinn *et al.* 1976). Blinn *et al.* (1976) identified the relationship between blue-green (Cyanophyta) algal blooms, elevated water temperatures, early summer warming, and anoxic conditions. Westinghouse Electric Corporation (1975) also reported on the quality of Morgan Lake fish collected during 1973 and 1975. Management of the lake was changed to reduce the potential for frequent fish kills.

The temporal and spatial water quality trends in Morgan Lake from 1973 through 1980 were described by Geotz and Abeyta (1987). Specific conductance, hydrogen potential (pH), orthophosphate, sodium, sulfate, iron, and manganese concentrations were reviewed for trends. During this period, specific conductance, sodium, and sulfate concentrations in Morgan Lake decreased significantly. The USFWS (1988) reported on the quality of fish collected in 1986. Concerns about onsite spills, including a spill of hydrazine in 1991, triggered additional monitoring of water and fish quality during a multi-agency investigation (Esplain 1995). Esplain (1995) reported on the quality of ground water, surface water, soils, and sediment from Morgan Lake and its surroundings. Clifford (1996) summarized water quality data for Morgan Lake collected from 1992 to 1996. Bristol *et al.* (1997) also reported on the quality of fish fillets and whole fish collected from Morgan Lake in 1993 as well as the potential acute health risks posed to both people and piscivorous birds.

Red Lake Setting

Red Lake (Figure 7, Figure 8) is a 611-acre (2.5 km^2) lake located approximately 22 mi (35.4 km) southwest of Naschitti, New Mexico (Figure 1). This warmwater lake is found at an elevation of 7,150 ft (2.2 km) within the Red Valley and has a maximum depth of approximately 5 ft (0.002 km). The area is characterized by mixed grasses, herbs, chaparral brush, sagebrush, with scattered two-needle, piñon pine and several species of juniper. The shoreline is generally stable with some sloughing, but two areas to the north and east have extensive cattail and willow stands.

Major mammals are mule deer, mountain lion, coyote, and bobcat. Smaller species include blacktail jackrabbit, Colorado chipmunk, rock squirrel, wood rat, white-footed mouse, cliff chipmunk, cottontail, porcupine, skunk, and gray fox. Resident birds include bushtit, piñon jay, plain titmouse, black-chinned hummingbird, Woodhouse's jay, red-tailed hawk, red-shafted flicker, and rock wren. Bald eagles have been observed feeding on catfish and waterfowl from this lake extensively (G. Tom, Navajo Nation Fish and Wildlife Department, written communication, 1999).

Wheatfields Lake Setting

Wheatfields Lake (Figure 9, Figure 10) is a 226-acre (0.91 km^2) lake located approximately 22 mi (35.4 km) southwest of Newcomb, New Mexico (Figure 1). This coldwater lake is found in the foothills of the Chuska Mountains at 7,304 ft (2.2 km) and has a maximum depth of approximately 18 ft (0.01 km). The area is characterized by mixed grasses, chaparral brush, oak-juniper woodland, piñon-juniper woodland and with occasional open forests of ponderosa pine. The shoreline is generally bare and stable with some sloughing.

The most common large mammal in this area is mule deer. Mammalian predators include mountain lions, coyotes, and bobcats. Small mammals include deer mouse, porcupine, golden-mantled ground squirrel, Colorado chipmunk, wood rat, pocket gopher, Albert squirrel, and cottontail. Some of the more common birds are olive warbler, mountain bluebird, white-breasted nuthatch, Mexican junco, Steller's jay, red-shafted flicker and the Rocky Mountain sapsucker.

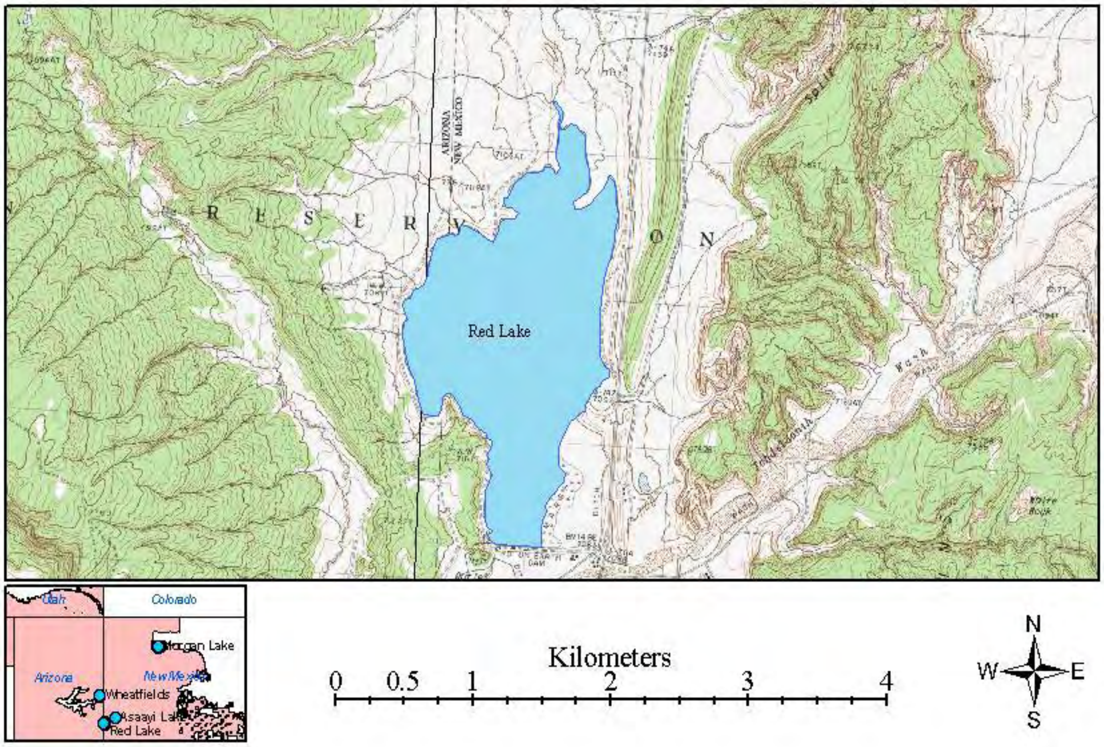

Figure 7. Location of Red Lake on the Navajo Nation.

Figure 8. View of Red Lake. Photo: Joel D. Lusk

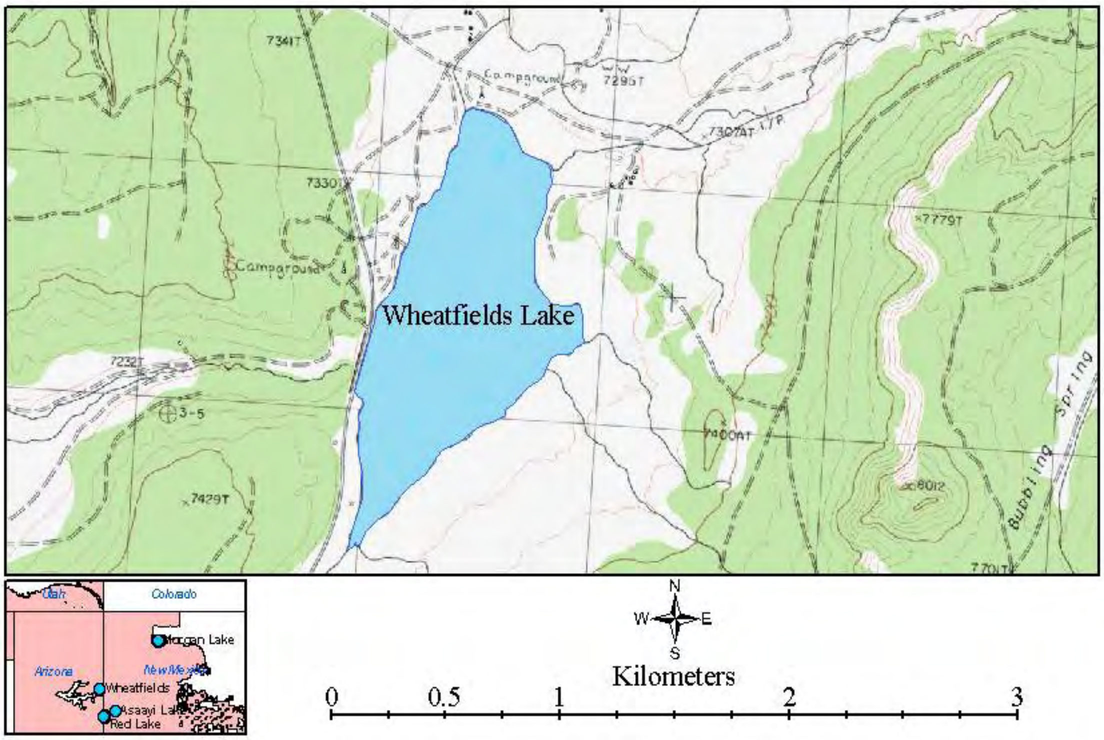

Figure 9. Location of Wheatfields Lake on the Navajo Nation.

Figure 10. View of Wheatfields Lake. Photo: Joel D. Lusk

METHODS

Sample Collection and Chemical Analyses

Methods of sample collection were detailed in the Sample and Analysis Plan (USFWS 2003; see Appendix G). All collections of water quality and fish were conducted between March 29 and April 2, 2004. In general, water samples were collected from the lake by way of motorized boat along two transects bisecting each lake. Fish samples were collected by electrofishing boat or trammel net. Chain-of-custody procedures were followed to ensure samples were collected, protected, stored, handled, chemically analyzed, and disposed of properly by authorized personnel. Each sample was labeled with a unique sample number, date and name of water body. Water and fish samples were placed on ice immediately after processing and kept on ice until delivery to the Texas A&M University laboratory the following day. All sampling equipment used to collect and process fish and water samples were decontaminated prior to use.

Collection of Water and Physical Measurements

Surface-water was sampled up to eight locations along two perpendicular cross-sections in each lake accessed by a boat. Surface water samples were collected from the epilimnion (*i.e.*, within 36 inches [762 mm] of the lake's surface) using a Teflon, DH-95 surface-water sampler, bottle, cap, and nozzle. Surface-water samples analyzed for trace elements were transferred into a polyurethane plastic bottle and then composited in a polyurethane plastic churn-splitter. The composite water was then transferred from the churn using a peristaltic pump, C-flex tubing, and a 0.45-micron in-line capsule filter into each sample bottle. Sample bottles for any particular analyses were filled and preserved immediately. However, whole-water samples to be analyzed for methylmercury were grab-sampled from the epilimnion at up to four locations from each lake using a gloved hand and a Teflon bottle.

A bottle blank was collected during the Red Lake sampling event using reagent water from the laboratory that prepared the methylmercury sample containers to insure the cleanliness of the bottles prior to use in the field. After decontamination of the churn and pump assembly, an equipment blank was collected into a clean container for each sampling event. In total, up to four grab samples of water for methylmercury analysis and two filtered composited samples of water for element analysis (plus 1 equipment field blank) were collected from each lake. While lake water quality is known to have spatial variability vertically, horizontally, and seasonally, the sampling design could not accommodate these factors within its budget.

At each sampling location along a depth profile every 2 to 5 ft (609 to 1,524 mm), the water column was measured for physical properties (*i.e.*, temperature, pH, electrical conductance, dissolved oxygen [DO], and turbidity as a measure of light scatter) using a Hydrolab multi-probe logger (Hydrolab Corporation 1998). The logger's sensors are designed to meet the criteria and specifications in section 2550 (temperature), section 2520-B (specific conductance), section 4500-O (DO), and section 4500-H+ (pH) in Standard Methods for the Examination of Water and Wastewater (American Public Health Association *et al.* 1995). Prior to use each day, the pH, DO, and conductivity probes were calibrated and maintained according to the manufacturer's instructions (Hydrolab Corporation 1998). Additionally, a simple measurement of light penetration was made with a secchi disk, which was lowered into the water to record the depth at which it appeared to disappear to the observer. These measurements and additional ecological observations were recorded on standardized field notes (field notes forms provided in Appendix H).

Collection and Processing of Fish Tissue

The USEPA (2000) guidelines were used for determining sample sizes of fish from each lake while also considering logistics, fish availability and budget. The minimum number of fish that we attempted to collect was determined using Table 6-1 in USEPA (2000). The use of 4 composite samples of 5 fish from each lake had the power between 50 to 90 percent to determine a statistically significant difference between the screening value (0.3 mg/kg), and the geometric mean concentration of each lake's fish samples, depending on the variability of mercury within each fish. Fish of the same species and the similar length (±10%) class were composited for each sample. Rainbow trout and channel catfish were the fishes targeted for sampling, as they are the primary fish permitted by the Navajo Nation Fish and Wildlife Department on coldwater and warmwater lakes, respectively. Additionally, these fish have been observed by biologists with the Navajo Nation Natural Heritage Program as being taken as food items by foraging bald eagles.

Fish tissues were collected to measure contaminant concentrations of selected elements and methylmercury. Fish were collected using an electrofishing boat with an adequate capacity to produce pulsed DC current in order to stun fish. The electrofishing boat has a positive foot-activated power control switch as well as other engineered safety features. All sampling personnel were familiar with safe electrofishing techniques including using net poles made of an insulating material such as fiberglass, wearing personal flotation devices, and wearing insulated lineman gloves. Members of the sampling crew were certified in CPR as well as First Aid. Boat electrofishing is a preferred technique to collect fish, as it is time-efficient and less destructive to the fish community. However, at Morgan Lake, the electrofishing boat generator failed and the remaining fish samples were collected with trammel nets. All fish collected were retained in a live well until sampling was completed and were iced after selection. Only live or freshly dead fish (red gills) were retained.

Fish sample preparation was completed in the field. All equipment used to prepare the samples was cleaned with soap and water, rinsed with a dilute nitric acid solution, and then rinsed with de-ionized water. Equipment was also cleaned between each site. Sample preparation included anesthetizing fish, weighing and measuring, removal and compositing of the fillet portions as well as compositing that portion which remained (the "offal"). Total length was measured to the nearest mm using a plastic measuring board. Total weight (using the spring balance) of fish, fillet composites and offal composites to the nearest gram was measured and recorded. Field data, including total lengths and mass of each fish, were recorded at the time of sample collection and processing onto the standardized field forms.

In total, from each lake, five similarly sized fish were composited into four fillet and four offal samples for chemical analyses. Four composite fillet samples for both methylmercury and element analyses as well as four composite offal samples for element analyses were collected. Fish were filleted using a stainless steel knife on a plastic resin cutting board. Each composite was placed in a new, clear, colorless plastic food-quality bag. Immediately after they were processed, packaged, and labeled, all samples of trout, catfish, and largemouth bass were placed on wet ice in a chest freezer. All samples were then packed with ice, shipped and received by the analytical laboratory on the following day.

Chemical Analyses

Methods of chemical analyses are detailed in Appendix I. Generally, fish samples were weighed and homogenized at the analytical laboratory. Water and fish samples were digested and analyzed either wet or after freeze-drying. Methylmercury was determined by cold vapor atomic absorption spectrophotometry with a Laboratory Data Control Model 1235 Mercury Monitor equipped with a 300 mm absorption cell (modified from Wagemann *et al.* 1997). Remaining elements in fish and water samples were analyzed by a combination of graphite furnace atomic absorption spectrophotometers, hydride generation atomic fluorescence analyzer, or inductively coupled plasma emitting mass spectroscopy. Normal calibration and quality assurance and quality control procedures were used to determine the concentration of elements and methylmercury. Quality control samples were processed in a manner identical to actual samples, and included reagent blanks, standard reference materials, spiked blanks, duplicates, and spiked samples.

<u>Data Analysis and Statistical Methods</u>

After conversion to wet weight concentrations, fish that had fillets removed were mathematically re-combined (as the sum of weighted concentrations of the parts of both the fillet and the offal) to yield an ‘re-integrated’ whole body fish concentration, thereby allowing comparisons of contaminant concentrations in whole fish with those mathematically re-integrated fish reported herein. A generalized equation was used to calculate re-integrated fish contaminant concentration (Equation 4).

$$\text{Re-integrated fish concentration} = [(fM/wM) \times cF] + [(oM/wM) \times cO] \qquad \text{Equation (4)}$$

Where:

fM	=	mass of a fillet (g WW)
wM	=	mass of fillet + mass of offal (g WW)
cF	=	contaminant concentration in a fillet (mg/kg WW)
oM	=	mass of offal (g WW)
cO	=	contaminant concentration in offal (mg/kg WW)

For statistical purposes as well as simplicity, all results, including integrated fish, which were below the laboratory’s instrument detection limit, were replaced with a value one-half the instrument detection limit (USEPA 1998). Where detectable concentrations were below the laboratory’s instrument detection limit in the offal, no descriptive statistics or comparisons were conducted. Several descriptive statistics (*e.g.*, the geometric mean), statistical analyses, and graphical representations were conducted on concentrations of selected contaminants in samples. For these analyses, the software program STATISTICA (version 6.0 by StatSoft Inc. 2001) was used. Unless otherwise noted, statistical significance in this report refers to a probability of less than or equal to 0.05. Geometric means were calculated in both dry and wet weight concentrations for selected environmental contaminants. The geometric mean provided a measurement of the central tendency of contaminant distributions and was calculated using data converted to their natural logarithms.

Environmental contaminant concentrations were evaluated using two techniques:

1. Concentrations in water or biota were compared to values reported in the literature as ambient or elevated and to Navajo Nation water quality standards (Navajo Nation 2004).
2. A human health and bald eagle risk assessment, as described below.

Risk assessments generally take the form of hazard identification (outlined above as methylmercury), dose-response (including the reference dose [RfD] identified above), exposure models (*e.g.*, amount and frequency of food ingestion, body weight), and risk characterization (identifying concerns and uncertainty).

<u>Human Health Risk Assessment Considerations</u>

Methylmercury is a developmental poison that can produce adverse effects following a comparatively brief exposure period (*i.e.*, a few months rather than decades) and therefore, short-term dietary patterns may be important (USEPA 2001). Consequently, estimation of recent patterns of methylmercury consumption from fish is the relevant exposure for the health endpoint of concern for people. Because it is not possible to identify the period of development during which mercury is likely to damage the nervous system of the developing fetus or growing child, exposure of women of childbearing age and to her children to mercury through consumption of fish is a cause for concern. Using the default characteristics provided by USEPA (2000), three hypothetical individual populations were modeled:

1. a woman (weighing 65 kg);
2. a child (less than 14 years old and weighing 14.5 kg); and,
3. a man (weighing 78 kg)

Estimates of health risks to human population consumers of fish were calculated and evaluated according to USEPA (2000) and other published data. The calculation of potential human daily intakes of methylmercury due to fish fillet ingestion was calculated according to the following formula:

$$\text{Intake} = \frac{C_f \times \text{SFIR} \times \text{EF}}{\text{BM} \times \text{AT}} \qquad \text{Equation (5)}$$

Where:

Intake = methylmercury intake rate (mg/kg-day)
C_f = geometric mean methylmercury concentration in fish fillet (mg/kg WW)
SFIR = subpopulation fish ingestion rate (kg/day)
EF = exposure frequency (days/year)
BM = body mass (kg)
AT = averaging time (days)

The importance of fish consumption patterns by the local population is critical when deriving protective criteria for local fish tissue concentrations as well as identifying risk or any epidemiological concerns (USEPA 2001). However, Navajo Nation-specific information on fish consumption was not available. In the absence of such information, the average nationwide fish consumption rate (17.5 g/day), and the average nationwide subsistence consumption rate (142.4 g/day) were used from the USEPA (2000) to model the exposure to the fish collected during this study. High-end exposure estimates are useful in estimating population risks and establishing exposure limits because they provided a plausible worst-case scenario at the upper end of the exposure distribution. Table 1 summarizes the assumptions of the human health risk assessment. However, selection of appropriate risk level, consumer body mass, exposure duration, and the average meal size are considered risk management decisions of the Navajo Nation.

Table 1. Selected Input Parameters for the Human Health Risk Assessment (modified from USEPA 2000).

Reference dose (RfD)	0.0001 mg methylmercury/kg-bw/day
Consumer body mass	78 kg (man) 65 kg (woman) 14.5 kg (child)
Fish consumption rate	17.5 g/day (nationwide average) 142.4 g/day (nationwide subsistence average)
Meal size	8 oz fish fillet per person per week
Exposure duration	14 days (recreational fishing) 156 days (subsistence fishing)
Geometric mean fish fillet methylmercury concentrations for various lake combinations	Asaayi Lake (0.06 mg/kg WW) Morgan Lake (0.01 mg/kg WW) Red Lake (0.39 mg/kg WW) Wheatfields Lake (0.08 mg/kg WW) Coldwater lakes (0.07 mg/kg WW) Warmwater lakes (0.06 mg/kg WW) All lakes combined (0.065 mg/kg WW)
Averaging Time	365 days per year for a lifetime

The number of days per month that an individual consumes methylmercury from the diet can be estimated from data on frequency of fish consumption. Accordingly, the simplifying assumption that the frequency of fish consumption was made for children is the same as for adults. Children's exposures, therefore, on a per kg body weight basis, are higher than those of adults. Since the methylmercury concentrations in the fish consumed are the same at a given site, exposure is the direct ratio of mass ingested per unit of body weight. Without additional information, successful recreational fishing occurred for 14 days per year and subsistence fishing occurred for 156 days per year was assumed. The assumption that the lakes studied were only source of fish in the diets of subsistence adults and children as well as the recreational angler was assumed. Contaminant concentrations used to estimate daily intakes were the geometric mean concentration for each lake individually, for either the coldwater or the warmwater lakes only, and for a combination of all four lakes. Only non-carcinogenic risks posed by methylmercury in fish fillets were modeled for people.

Bald Eagle Risk Assessment Considerations

An estimated 10,000 to 12,000 bald eagles inhabit the lower 48 United States (USFWS 1995). Bald eagles migrate into the lower forty-eight states only during the winter months; others are resident throughout the year. Bald eagles, like several other avian species, were adversely impacted by DDT and its metabolites during the 1950s, ‘60s, and ‘70s. Due to their status as a federally listed "threatened" species and as a national symbol, the potential threat of mercury exposure to bald eagle survival and recovery is a concern.

The Navajo Nation provides suitable migrating and wintering habitats, but has no current or historic nesting records of bald eagles (G. Tom, Navajo Nation Fish and Wildlife Department, written communication, 1999). Migrating bald eagles have been reported to use at least six interior lakes on the Navajo Nation. Except for Morgan Lake, these lakes can typically become frozen-over by November and remain frozen through February. The San Juan and Little Colorado Rivers are also known foraging and wintering sites for bald eagles.

Since information on body weights and food ingestion rates for bald eagles foraging on the Navajo Nation fishing lakes are not readily available, the bald eagle body weights (5.25 kg) used in calculations below were based on the mean of average female body weights reported nationwide by the USEPA (1993). As the avian reference dose for methylmercury is based on adverse reproductive effects manifested by laying females, it is more appropriate to use average female body weights (Russell 2003).

Information presented by the USEPA (1993) regarding metabolically available energy from various prey types and the ability of bald eagles to assimilate this energy allows for the use of methods to estimate daily food requirements. However, attempting to quantify a specific dietary composition for bald eagles is more difficult than for other species with a narrower range of prey types, and is further confounded by food preferences that may vary both geographically and temporally. An additional difficulty in calculating a general food ingestion rate (FIR) for bald eagles arises because of the composition of the diet can also vary substantially between seasons, locations, or individuals. Therefore, discussion of the energy content of diet items and prey composition that the bald eagle may choose are discussed below as they affect the uncertainties of the risk assessment calculations.

Uncertainty and variability described in predictions of human exposures that result from fish consumption are also applicable to the wildlife. It is interesting to note that on a per kilogram body weight basis, predicted exposures to wildlife are much greater than to humans. Estimates of risks to bald eagle foraging on the Navajo Nation were evaluated according to USEPA (1993). The following equation (Equation 6) was used to estimate daily food intake methylmercury:

$$\text{Intake} = \frac{C_f \times Ff_k I \times FIR \times EF \times ED}{BM \times AT} \qquad \text{(Equation 6)}$$

Where:

Intake	=	methylmercury intake rate (mg/kg WW per day)
C_f	=	geometric mean methylmercury concentration in whole fish (mg/kg WW)
Ff_kI	=	fraction of fish ingested compared to whole diet (*i.e.*, a unitless decimal)
ED	=	exposure duration (years)
EF	=	exposure frequency (days/year; assumption was 30 days for migrant, 180 days for wintering, and 365 days for nesting)
BM	=	body mass (kg)
AT	=	averaging time (days)

The bald eagle diet has been extensively studied throughout the country. Although generally known as a piscivorous species, bald eagles are opportunistic predators and carrion scavengers (Buehler 2000). Many bald eagles consume a mixture of both aquatic and terrestrially derived prey. A wide variety of various birds, mammals, reptiles, amphibians, and crustaceans may serve as additional bald eagle prey (Buehler 2000). Haywood and Ohmart (1986) reported the diet of nesting bald eagles in Arizona as 58% fish, 14% birds, and 28% mammals. Hunt *et al.* (1992) reported the diet of nesting bald eagles in Arizona as 71% fish, 10% birds, and 18% mammals. Hunt *et al.* (1992) further described the diets of bald eagles as varying with habitat setting. Furthermore, the distribution of prey types they consume may vary seasonally. While there is no definitive diet composition preferred by bald eagles in Arizona – they all show that fish are generally the predominant food item, and particularly, that catfish were the principal prey selected.

The diet composition reported by Hunt *et al.* (1992) of 71.4% fish, 10.3% birds, and 18.3% mammals was used for the generic bald eagle risk assessment calculations. Hunt *et al.* (1992) reported that of the fish, 34.5% were catfish, 25.7% were suckers, 24.3 % were carp, and 15.5% were bass, perch, bluegill, or other Centrarchids. Based on the diets of these fish (Sublette *et al.* 1990; Moyle 2002), suckers were classified as trophic level 2 herbivores, carp as trophic level 3 consumers, and catfish as trophic level 3.5 predators. While channel catfish are opportunistic omnivores, consuming whatever prey they can locate, as catfish increase in size, they become increasingly predatory (Moyle, 2002; USEPA 1995b). The fish lengths determined in this study for channel catfish, suggested that an intermediate trophic level of 3.5 be assigned to these fish when eaten by bald eagles. Using the intermediate trophic level breakdown for catfish, together with the other trophic level 4 fish (trout, largemouth bass), this suggests that about 17 percent of the overall estimated biomass would be comprised of trophic level 4 fish. Of the remainder of the overall fish component to the generic diet, 58 percent is classified as trophic level 3 and as 25 percent is trophic level 2.

While an overall dietary methylmercury concentration can be calculated, the amount of prey consumed from each trophic level is the driving factor influencing the amount of methylmercury ingested on a daily basis. The methylmercury concentration in the overall diet for bald eagle is dependent on both the trophic level composition of its diet and the methylmercury concentrations in each of the trophic levels from which the species feeds. In these situations, the bald eagle could obtain a higher mercury dose from eating other piscivorous birds than it would otherwise receive from a strictly fish-based diet.

Of the bird species consumed by bald eagles (10.3% of total biomass in the overall bald eagle diet as reported by Hunt *et al.* 1992), the most commonly seen in prey remains are coots and ducks, representing approximately 5 percent of the total estimated biomass. Several species were exclusively terrestrial (*e.g.*, mountain quail; <1%), and the remainder was primarily piscivorous: grebes, cormorants, and mergansers (5%). Based on the diets of these birds, coots, ducks, quail, and piscivorous birds were all classified as trophic level 3 consumers. Similarly, the mammal species consumed (18.3% of total biomass in overall bald eagle diet), were classified as 85% trophic level 2 and 15% trophic level 3 consumers.

The final bald eagle Food Ingestion Rate (FIR) was based on this generic bald eagle diet (71.4% fish, 10.3% birds, and 18.3% mammals; as described above) and was calculated using the methodology reported by the USEPA (1993, 1995b), wherein the animal's free-living metabolic rate (FMR, in kilocalories per day) is divided by the metabolizable energy from bald eagle prey. The FMR was determined by Nagy's (1987) allometric equation relating FMR for birds to body weight:

$$\text{FMR (kcal/day)} = 2.601 \times (\text{body weight [g]}^{0.640})$$
$$\text{FMR} = 2.601 \times ((5250)^{0.640})$$
$$\text{FMR} = 625 \text{ kcal/day}$$

According to the USEPA (1993), metabolizable energy (ME) equals gross energy (GE) of food in kcal/kg wet weight times the assimilation efficiency (AE) of the consumer. The USEPA (1993) gave a GE value of 1.2 kcal/kg for bony fishes, while bird tissue GE is 1.9, and the mammal GE is 1.7. The AEs for a bald eagle consuming birds/mammals and fish is given as 78 and 79 percent, respectively.

$$ME_{fish} = 1.2 \text{ kcal/g} \times 0.79 = 0.948 \text{ kcal/g fish}$$
$$ME_{birds} = 1.9 \text{ kcal/g} \times 0.78 = 1.482 \text{ kcal/g birds}$$
$$ME_{mammals} = 1.7 \text{ kcal/g} \times 0.78 = 1.326 \text{ kcal/g mammals}$$

If: Y = grams of birds consumed, and
6.93Y = grams of fish consumed (*i.e.*, 71.4% fish ÷ 10.3% birds = 6.93)
1.78Y = grams of mammals consumed (*i.e.*, 18.3% mammals ÷ 10.3% birds = 1.78)

Then the FIR for each food can be determined by the equation:

$$\text{FMR (625 kcal/day)} = [Y(g) \times 1.482 \text{ kcal/g birds}] + [6.93Y(g) \times 0.948 \text{ kcal/g fish}] + [1.78Y(g) \times 1.326 \text{ kcal/g mammals}]$$
$$625 \text{ kcal/day} = [1.482Y + 6.57Y + 2.36Y]$$
$$625 \text{ kcal/day} = 10.41Y$$

Since Y = 60.03 g birds consumed per day

Then 6.93Y = grams of fish consumed
= 416.1 g fish/day (*i.e.*, 6.93 x 60.03)

and 1.78Y = grams of mammals consumed
= 106.9 g mammals/day (*i.e.*, 1.78 x 60.03)
Therefore, the total FIR for a generic bald eagle becomes:
FIR = [60 g birds + 416 g fish + 107 g mammals]/day = 583 grams wet weight per day.

Exposure frequency represents how much time a bird will spend feeding at a particular lake each year. The bald eagle was assumed to over winter 182 days, stop to feed for as many as 30 days during migration, or would potentially nest and reside year round. A conservative assumption made for these assessments was that bald eagles would spend their entire exposure frequency and duration time feeding solely at each lake or at a combination of all lakes. Exposure duration represents the longevity of each bird species. Longevities were determined through banding data from a variety of sources. Generally, the age of the oldest banded wild bird was used for exposure duration. This provides a conservative estimate of actual longevities in the wild. Averaging time was calculated as 365 days per year multiplied by the exposure duration of the species. Table 2 summarizes the input parameters used in the bald eagle risk assessment.

Table 2. Selected Input Parameters for the Bald Eagle Risk Assessment.	
Reference dose (RfD)	0.021 mg mercury/kg-bw/day
Bald eagle body mass (BW)	5.25 kg (average mass of female)
Food ingestion rate (FIR)	60 g birds/day 107 g mammals/day 416 g fish/day
Exposure duration (ED)	30 days (migratory bald eagle stopover) 182 days (over wintering bald eagle) 365 days (hypothetical nesting bald eagle)
Geometric Mean Re-integrated fish mercury concentrations for various lake combinations	Asaayi Lake (0.07 mg/kg WW) Morgan Lake (0.01 mg/kg WW) Red Lake (0.23 mg/kg WW) Wheatfields Lake (0.06 mg/kg WW) Coldwater lakes (0.06 mg/kg WW) Warmwater lakes (0.05 mg/kg WW) All lakes combined (0.05 mg/kg WW)
Averaging Time	365 days per year for a 30 year lifetime

Using these parameters, the overall dietary concentration of mercury at or below the reference dose (*i.e.,* the Dietary Value [DV]) was calculated using the following equation:

$$DV = \frac{RfD \times BW}{\sum FIR_i} \quad \text{(Equation 7)}$$

Where:
DV = Dietary Value (mg/kg in the diet that is at or below the Reference Dose)
RfD = Reference Dose (0.021 mg/kg-bw/day, see above)
BW = Body Weight (in kg)
FIR_i = Food Ingestion Rate (kg food/day), from the i^{th} trophic level, for bald eagle

Bald Eagle Water Quality Criterion

Calculation of protective numeric water quality criteria to protect bald eagles through the consumption of fish is based upon a reference dose approach combined with the extent to which mercury becomes concentrated in the fish from specific water bodies (*i.e.*, "wildlife criteria" or WC). The methods used to calculate this criterion are based on those described in the Great Lakes Water Quality Initiative (USEPA 1995a, 1995b, 1995c). When originally implemented in support of the Great Lakes Water Quality Initiative, this approach yielded a single endpoint, which was the total mercury concentration in water protective of wildlife. In this report, an effort was made to update the WC for mercury by calculating its value using data for methylmercury. It should be noted that a methylmercury-based WC could still be related to total mercury residues in fish or water with appropriate conversion factors.

A WC value for mercury was estimated as the ratio of the RfD to an estimated mercury consumption rate in fish (only) referenced to water concentration using a bioaccumulation factor (BAF). A BAF is the ratio of the mercury concentration in fish to its concentration in water. The WC for bald eagles was calculated using the following equation and the BAF from methylmercury measured in water to the concentration of total mercury in re-integrated fish tissue (on a dry weight basis):

$$WC_{\text{bald eagle}} = \frac{(TD \times UF \times BW)}{D + (FF \times BAF)} \qquad \text{(Equation 8)}$$

Where:

WC	=	Wildlife Criteria for bald eagle (pg/L)
TD	=	Tested Dose (mg/kg-bw/day) (*i.e.*, 0.064 mg/kg-bw/day, from above)
UF	=	Uncertainty Factor (unitless) (*i.e.*, 0.33, from above)
BW	=	Body Weight (*i.e.*, 5.25 kg)
D	=	Drinking water intake (L/d)
FF	=	Fraction of diet that is fish (all other sources assumed to be negligible)
BAF	=	Bioaccumulation Factor (total mercury in fish/methylmercury in water)

RESULTS AND DISCUSSION

Limnological Characteristics of the Lakes

Only the average limnological and water quality characteristics of each lake were reviewed. Surface temperature and bottom temperature were strongly correlated (r^2=1.00). Of the lakes studied, there were significant correlations between lake size and water temperature (r^2=0.92), pH (r^2=0.86), specific conductivity (r^2=0.79), and including the dissolved Al (r^2=0.80), B (r^2=0.96), Ca (r^2=0.88), Fe (r^2=0.88), Mg (r^2=0.91), Na (r^2=0.98), Se (r^2=0.92), S (r^2=0.92), and Sr (r^2=0.93) in water. Asaayi Lake had the largest surface area-to-depth ratio (53 x 10^6 m for every meter of depth), Wheatfields and Morgan had a surface area-to-depth ratio of 6 x 10^6, while Red Lake had a surface area-to-depth ratio of 0.6 x 10^6. Surface area-to-depth ratio was correlated with dissolved oxygen (r^2=0.91) and low turbidity (r^2= -0.80) at the lake surface, with the pH (r^2=0.90) measured at the bottom, and with mercury dissolved in the water column (r^2= -0.81).

Environmental Contaminants other than Mercury in Water and Fish

The limits of detection for the analytical results reported in this investigation are found in Table 3. Several elements, such as silver, beryllium, cadmium, cobalt, chromium, copper, nickel, and zinc were not detected in any ambient dissolved water sample. Molybdenum was only detected in one dissolved water sample from Morgan Lake, and vanadium was only detected dissolved in two dissolved water samples from Red Lake. Beryllium, cadmium, boron, cobalt, and vanadium were only found in selected fish offal samples from Red Lake or Morgan Lake. These elements (Ag, Be, Cd, Co, Cr, Cu, Ni, and Zn) were not found above the limits of detection with sufficient frequency to further characterize or summarize in this report. All analytical results of lake water, fish tissues, and quality assurance samples, as well as the limnological characteristics of four recreational lakes studied in 2004 for the Navajo Nation Lake Fish and Water Quality Investigation are reported in Table 4. Trout collected from Wheatfields Lake were likely stocked within the previous month as indicated by their uniform condition and size and stock history (E. Benally, Navajo Nation Department of Game and Fish, oral communication, 2004).

Trace Elements Dissolved in Water

The average concentrations of elements found in ambient dissolved lake water samples are reported in Table 5. Several elements (B, Ca, K, Mg, Na, S, Se, and Sr) were found in dissolved Morgan Lake water at concentrations greater than those found at the other lakes. Several elements (Al, Fe, Hg, and P) were found dissolved in Morgan Lake water at concentrations less than found at the other lakes. Morgan Lake is filled with water from the San Juan River; however, concentrations of some elements (B, Ca, K, Na and Sr) were elevated compared to concentrations reported by Goetz and Abeyta (1987) and Ortiz *et al.* (2000) for the San Juan River. The average concentrations of elements dissolved in ambient lake water samples were compared with the numeric criteria of the Navajo Nation Surface Water Quality Standards (Navajo Nation 2004) in Table 5. Only aluminum was routinely detected at concentrations (up to 236 µg/L) greater than the chronic aquatic habitat criterion

Table 3. Element Name, Symbol, Method of Analysis, and Limit of Detection for the Navajo Nation Lake Fish and Water Quality Investigation, 2004.

Element Name	Symbol	Method	Limit of Detection[a] in Wet Weight	
			Water (mg/L)	Fish Tissue (mg/kg)
Aluminum	Al	ICP-AES[b]	0.05	1.11
Arsenic	As	ICP-MS[c]	0.0002	0.51
Barium	Ba	ICP-AES	0.001	0.02
Beryllium	Be	ICP-AES	0.005	0.01
Boron	B	ICP-AES	0.01	0.23
Cadmium	Cd	ICP-MS	0.00005	0.01
Calcium	Ca	ICP-AES	0.01	1.11
Chromium	Cr	ICP-AES	0.005	0.11
Cobalt	Co	ICP-AES	0.005	0.11
Copper	Cu	ICP-AES	0.005	0.11
Iron	Fe	ICP-AES	0.01	0.23
Lead	Pb	ICP-MS	0.00005	0.01
Magnesium	Mg	ICP-AES	0.01	0.23
Manganese	Mn	ICP-AES	0.002	0.05
Mercury	Hg	AFS[d]	0.0000005	---[e]
Mercury	Hg	CVAAS[f]	---[e]	0.002
Methylmercury	MeHg	AFS	0.000000011	0.002
Molybdenum	Mo	ICP-AES	0.01	0.25
Nickel	Ni	ICP-AES	0.005	0.11
Phosphorus	P	ICP-AES	0.05	1.11
Potassium	K	ICP-AES	0.10	0.01
Selenium	Se	AFS	0.0004	0.02
Silver	Ag	ICP-AES	0.010	---[e]
Sodium	Na	ICP-AES	2	44
Strontium	Sr	ICP-AES	0.0005	0.01
Sulfur	S	ICP-AES	0.1	2.5
Vanadium	V	ICP-AES	0.01	0.25
Zinc	Zn	ICP-AES	0.005	0.13

[a] = For tissue, limit of detection reported is the highest detection limit for the sample batch.
[b] = Analysis was by inductively coupled plasma - atomic emission spectroscopy.
[c] = Analysis was by inductively coupled plasma - mass spectroscopy.
[d] = Analysis was by atomic fluorescence.
[e] = Sample media was not analyzed using this method.
[f] = Analysis was by cold-vapor atomic absorption spectroscopy.

Table 4. Sample Information, Analytical Results, and Liminological Characteristics of Four Navajo Nation Lakes.
[See Table 3 for abbreviations; all water values are mg/L; all fish values are mg/kg dry weight].

Sample Number	Lake Name	Sample Type	Collection Date	Latitude (decimal degrees)	Longitude (decimal degrees)	Average Fish Length (mm)	Average Fish Weight (grams)	Average Surface Water Temperature (Celsius)
T304-2001	Asaayi Lake	unfiltered grab water	31-Mar-2004	35.980917	-108.930194			9.73
T304-2002	Asaayi Lake	unfiltered grab water	31-Mar-2004	35.980917	-108.930194			9.73
T304-2003	Asaayi Lake	unfiltered grab water	31-Mar-2004	35.980917	-108.930194			9.73
T304-2004	Asaayi Lake	unfiltered grab water	31-Mar-2004	35.980917	-108.930194			9.73
T304-2005	Wheatfields Lake	unfiltered grab water	30-Mar-2004	36.206806	-109.097583			9.93
T304-2006	Wheatfields Lake	unfiltered grab water	30-Mar-2004	36.206806	-109.097583			9.93
T304-2007	Wheatfields Lake	unfiltered grab water	30-Mar-2004	36.206806	-109.097583			9.93
T304-2008	Wheatfields Lake	unfiltered grab water	30-Mar-2004	36.206806	-109.097583			9.93
T304-2009	Red Lake	unfiltered grab water	29-Mar-2004	35.919417	-109.040661			10.39
T304-2010	Red Lake	unfiltered grab water	29-Mar-2004	35.919417	-109.040661			10.39
T304-2011	Red Lake	unfiltered grab water	29-Mar-2004	35.919417	-109.040661			10.39
T304-2012		unfiltered Blank meHg water	29-Mar-2004	35.919417	-109.040661			
T304-2013	Morgan Lake	unfiltered grab water	1-Apr-2004	36.702417	-108.474167			23.77
T304-2014	Morgan Lake	unfiltered grab water	1-Apr-2004	36.702417	-108.474167			23.77
T304-2015	Morgan Lake	unfiltered grab water	1-Apr-2004	36.702417	-108.474167			23.77
T304-2016	Morgan Lake	unfiltered grab water	1-Apr-2004	36.702417	-108.474167			23.77
T304-2017	Asaayi Lake	filtered, composited water	31-Mar-2004	35.980917	-108.930194			9.73
T304-2018	Asaayi Lake	filtered, composited water	31-Mar-2004	35.980917	-108.930194			9.73
T304-2019	Asaayi Lake	filtered, Blank Deionized water	31-Mar-2004	35.980917	-108.930194			
T304-2020	Wheatfields Lake	filtered, composited water	30-Mar-2004	36.206806	-109.097583			9.93
T304-2021	Wheatfields Lake	filtered, composited water	30-Mar-2004	36.206806	-109.097583			9.93
T304-2022	Wheatfields Lake	filtered, Blank Deionized water	30-Mar-2004	36.206806	-109.097583			
T304-2023	Red Lake	filtered, composited water	29-Mar-2004	35.919417	-109.040661			10.39
T304-2024	Red Lake	filtered, composited water	29-Mar-2004	35.919417	-109.040661			10.39
T304-2025	Red Lake	filtered, Blank Deionized water	29-Mar-2004	35.919417	-109.040661			
T304-2026	Morgan Lake	filtered, composited water	1-Apr-2004	36.702417	-108.474167			23.77
T304-2027	Morgan Lake	filtered, composited water	1-Apr-2004	36.702417	-108.474167			23.77
T304-2028	Morgan Lake	filtered, Blank Deionized water	1-Apr-2004	36.702417	-108.474167			

Table 4. Sample Information, Analytical Results, and Liminological Characteristics of Four Navajo Nation Lakes.
[See Table 3 for abbreviations; all water values are mg/L; all fish values are mg/kg dry weight].

Sample Number	Lake Name	Sample Type	Collection Date	Latitude (decimal degrees)	Longitude (decimal degrees)	Average Fish Length (mm)	Average Fish Weight (grams)	Average Surface Water Temperature (Celsius)
T304-2029	Asaayi Lake	composited skinless trout fillet	31-Mar-2004	35.980917	-108.930194	365.4	588.2	9.73
T304-2030	Asaayi Lake	composited skinless trout fillet	31-Mar-2004	35.980917	-108.930194	309.2	359.8	9.73
T304-2031	Asaayi Lake	composited skinless trout fillet	31-Mar-2004	35.980917	-108.930194	368.8	597.0	9.73
T304-2032	Asaayi Lake	composited skinless trout fillet	31-Mar-2004	35.980917	-108.930194	277.6	255.4	9.73
T304-2033	Wheatfields Lake	composited skinless trout fillet	30-Mar-2004	36.206806	-109.097583	247.4	163.9	9.93
T304-2034	Wheatfields Lake	composited skinless trout fillet	30-Mar-2004	36.206806	-109.097583	231.6	170.2	9.93
T304-2035	Wheatfields Lake	composited skinless trout fillet	30-Mar-2004	36.206806	-109.097583	188.8	83.0	9.93
T304-2036	Wheatfields Lake	composited skinless trout fillet	30-Mar-2004	36.206806	-109.097583	186.6	69.7	9.93
T304-2037	Red Lake	composited skinless catfish fillet	29-Mar-2004	35.919417	-109.040661	452.2	836.2	10.39
T304-2038	Red Lake	composited skinless catfish fillet	29-Mar-2004	35.919417	-109.040661	450.6	790.0	10.39
T304-2039	Red Lake	composited skinless catfish fillet	29-Mar-2004	35.919417	-109.040661	468.0	969.8	10.39
T304-2040	Red Lake	composited skinless catfish fillet	29-Mar-2004	35.919417	-109.040661	454.2	836.2	10.39
T304-2041	Morgan Lake	composited skinless catfish fillet	2-Apr-2004	36.702417	-108.474167	418.4	697.4	23.77
T304-2042	Morgan Lake	composited skinless catfish fillet	2-Apr-2004	36.702417	-108.474167	365.4	405.2	23.77
T304-2043	Morgan Lake	composited skinless bass fillet	1-Apr-2004	36.702417	-108.474167	349.0	734.2	23.77
T304-2044	Morgan Lake	composited skinless catfish fillet	2-Apr-2004	36.702417	-108.474167	407.6	504.8	23.77
T304-2045	Asaayi Lake	composited trout offal	31-Mar-2004	35.980917	-108.930194	365.4	588.2	9.73
T304-2046	Asaayi Lake	composited trout offal	31-Mar-2004	35.980917	-108.930194	309.2	359.8	9.73
T304-2047	Asaayi Lake	composited trout offal	31-Mar-2004	35.980917	-108.930194	368.8	597.0	9.73
T304-2048	Asaayi Lake	composited trout offal	31-Mar-2004	35.980917	-108.930194	277.6	255.4	9.73
T304-2049	Wheatfields Lake	composited trout offal	30-Mar-2004	36.206806	-109.097583	247.4	163.9	9.93
T304-2050	Wheatfields Lake	composited trout offal	30-Mar-2004	36.206806	-109.097583	231.6	170.2	9.93
T304-2051	Wheatfields Lake	composited trout offal	30-Mar-2004	36.206806	-109.097583	188.8	83.0	9.93
T304-2052	Wheatfields Lake	composited trout offal	30-Mar-2004	36.206806	-109.097583	186.6	69.7	9.93
T304-2053	Red Lake	composited catfish offal	29-Mar-2004	35.919417	-109.040661	452.2	836.2	10.39
T304-2054	Red Lake	composited catfish offal	29-Mar-2004	35.919417	-109.040661	450.6	790.0	10.39
T304-2055	Red Lake	composited catfish offal	29-Mar-2004	35.919417	-109.040661	468.0	969.8	10.39
T304-2056	Red Lake	composited catfish offal	29-Mar-2004	35.919417	-109.040661	454.2	836.2	10.39
T304-2057	Morgan Lake	composited catfish offal	2-Apr-2004	36.702417	-108.474167	418.4	697.4	23.77
T304-2058	Morgan Lake	composited catfish offal	2-Apr-2004	36.702417	-108.474167	365.4	405.2	23.77
T304-2059	Morgan Lake	composited bass offal	1-Apr-2004	36.702417	-108.474167	349.0	734.2	23.77
T304-2060	Morgan Lake	composited catfish offal	2-Apr-2004	36.702417	-108.474167	407.6	504.8	23.77

Table 4. Sample Information, Analytical Results, and Liminological Characteristics of Four Navajo Nation Lakes.
[See Table 3 for abbreviations; all water values are mg/L; all fish values are mg/kg dry weight].

Sample Number	Lake Name	Sample Type	Collection Date	Latitude (decimal degrees)	Longitude (decimal degrees)	Average Fish Length (mm)	Average Fish Weight (grams)	Average Surface Water Temperature (Celsius)
2945	Asaayi Lake	Re-integrated whole fish composite	31-Mar-2004	35.980917	-108.930194	365.4	588.2	9.73
3046	Asaayi Lake	Re-integrated whole fish composite	31-Mar-2004	35.980917	-108.930194	309.2	359.8	9.73
3147	Asaayi Lake	Re-integrated whole fish composite	31-Mar-2004	35.980917	-108.930194	368.8	597.0	9.73
3248	Asaayi Lake	Re-integrated whole fish composite	31-Mar-2004	35.980917	-108.930194	277.6	255.4	9.73
3349	Wheatfields Lake	Re-integrated whole fish composite	30-Mar-2004	36.206806	-109.097583	247.4	163.9	9.93
3450	Wheatfields Lake	Re-integrated whole fish composite	30-Mar-2004	36.206806	-109.097583	231.6	170.2	9.93
3551	Wheatfields Lake	Re-integrated whole fish composite	30-Mar-2004	36.206806	-109.097583	188.8	83.0	9.93
3652	Wheatfields Lake	Re-integrated whole fish composite	30-Mar-2004	36.206806	-109.097583	186.6	69.7	9.93
3753	Red Lake	Re-integrated whole fish composite	29-Mar-2004	35.919417	-109.040661	452.2	836.2	10.39
3854	Red Lake	Re-integrated whole fish composite	29-Mar-2004	35.919417	-109.040661	450.6	790.0	10.39
3955	Red Lake	Re-integrated whole fish composite	29-Mar-2004	35.919417	-109.040661	468.0	969.8	10.39
4056	Red Lake	Re-integrated whole fish composite	29-Mar-2004	35.919417	-109.040661	454.2	836.2	10.39
4157	Morgan Lake	Re-integrated whole fish composite	2-Apr-2004	36.702417	-108.474167	418.4	697.4	23.77
4258	Morgan Lake	Re-integrated whole fish composite	2-Apr-2004	36.702417	-108.474167	365.4	405.2	23.77
4359	Morgan Lake	Re-integrated whole fish composite	1-Apr-2004	36.702417	-108.474167	349.0	734.2	23.77
4460	Morgan Lake	Re-integrated whole fish composite	2-Apr-2004	36.702417	-108.474167	407.6	504.8	23.77

Table 4. Sample Information, Analytical Results, and Liminological Characteristics of Four Navajo Nation Lakes.
[See Table 3 for abbreviations; all water values are mg/L; all fish values are mg/kg dry weight].

Sample Number	Lake Name	Sample Type	Average Surface pH (Standard units)	Average Surface Dissolved Oxygen (mg/L)	Average Surface Specific Conductivity (uS/cm)	Secchi Depth (inches)	Average Surface Turbidity (NTU)	Average Bottom Temperature (Celsius)
T304-2001	Asaayi Lake	unfiltered grab water	8.48	8.58	108.5	34.4	9.6	8.00
T304-2002	Asaayi Lake	unfiltered grab water	8.48	8.58	108.5	34.4	9.6	8.00
T304-2003	Asaayi Lake	unfiltered grab water	8.48	8.58	108.5	34.4	9.6	8.00
T304-2004	Asaayi Lake	unfiltered grab water	8.48	8.58	108.5	34.4	9.6	8.00
T304-2005	Wheatfields Lake	unfiltered grab water	8.37	7.73	282.3	6.4	83.8	9.06
T304-2006	Wheatfields Lake	unfiltered grab water	8.37	7.73	282.3	6.4	83.8	9.06
T304-2007	Wheatfields Lake	unfiltered grab water	8.37	7.73	282.3	6.4	83.8	9.06
T304-2008	Wheatfields Lake	unfiltered grab water	8.37	7.73	282.3	6.4	83.8	9.06
T304-2009	Red Lake	unfiltered grab water	8.76	6.76	3.6	2.1	120.7	9.08
T304-2010	Red Lake	unfiltered grab water	8.76	6.76	3.6	2.1	120.7	9.08
T304-2011	Red Lake	unfiltered grab water	8.76	6.76	3.6	2.1	120.7	9.08
T304-2012		unfiltered Blank meHg water						
T304-2013	Morgan Lake	unfiltered grab water	8.83	7.85	854.8	34.4	5.5	21.19
T304-2014	Morgan Lake	unfiltered grab water	8.83	7.85	854.8	34.4	5.5	21.19
T304-2015	Morgan Lake	unfiltered grab water	8.83	7.85	854.8	34.4	5.5	21.19
T304-2016	Morgan Lake	unfiltered grab water	8.83	7.85	854.8	34.4	5.5	21.19
T304-2017	Asaayi Lake	filtered, composited water	8.48	8.58	108.5	34.4	9.6	8.00
T304-2018	Asaayi Lake	filtered, composited water	8.48	8.58	108.5	34.4	9.6	8.00
T304-2019	Asaayi Lake	filtered, Blank Deionized water						
T304-2020	Wheatfields Lake	filtered, composited water	8.37	7.73	282.3	6.4	83.8	9.06
T304-2021	Wheatfields Lake	filtered, composited water	8.37	7.73	282.3	6.4	83.8	9.06
T304-2022	Wheatfields Lake	filtered, Blank Deionized water						
T304-2023	Red Lake	filtered, composited water	8.76	6.76	3.6	2.1	120.7	9.08
T304-2024	Red Lake	filtered, composited water	8.76	6.76	3.6	2.1	120.7	9.08
T304-2025	Red Lake	filtered, Blank Deionized water						
T304-2026	Morgan Lake	filtered, composited water	8.83	7.85	854.8	34.4	5.5	21.19
T304-2027	Morgan Lake	filtered, composited water	8.83	7.85	854.8	34.4	5.5	21.19
T304-2028	Morgan Lake	filtered, Blank Deionized water						

Table 4. Sample Information, Analytical Results, and Liminological Characteristics of Four Navajo Nation Lakes.
[See Table 3 for abbreviations; all water values are mg/L; all fish values are mg/kg dry weight].

Sample Number	Lake Name	Sample Type	Average Surface pH (Standard units)	Average Surface Dissolved Oxygen (mg/L)	Average Surface Specific Conductivity (uS/cm)	Secchi Depth (inches)	Average Surface Turbidity (NTU)	Average Bottom Temperature (Celsius)
T304-2029	Asaayi Lake	composited skinless trout fillet	8.48	8.58	108.5	34.4	9.6	8.00
T304-2030	Asaayi Lake	composited skinless trout fillet	8.48	8.58	108.5	34.4	9.6	8.00
T304-2031	Asaayi Lake	composited skinless trout fillet	8.48	8.58	108.5	34.4	9.6	8.00
T304-2032	Asaayi Lake	composited skinless trout fillet	8.48	8.58	108.5	34.4	9.6	8.00
T304-2033	Wheatfields Lake	composited skinless trout fillet	8.37	7.73	282.3	6.4	83.8	9.06
T304-2034	Wheatfields Lake	composited skinless trout fillet	8.37	7.73	282.3	6.4	83.8	9.06
T304-2035	Wheatfields Lake	composited skinless trout fillet	8.37	7.73	282.3	6.4	83.8	9.06
T304-2036	Wheatfields Lake	composited skinless trout fillet	8.37	7.73	282.3	6.4	83.8	9.06
T304-2037	Red Lake	composited skinless catfish fillet	8.76	6.76	3.6	2.1	120.7	9.08
T304-2038	Red Lake	composited skinless catfish fillet	8.76	6.76	3.6	2.1	120.7	9.08
T304-2039	Red Lake	composited skinless catfish fillet	8.76	6.76	3.6	2.1	120.7	9.08
T304-2040	Red Lake	composited skinless catfish fillet	8.76	6.76	3.6	2.1	120.7	9.08
T304-2041	Morgan Lake	composited skinless catfish fillet	8.83	7.85	854.8	34.4	5.5	21.19
T304-2042	Morgan Lake	composited skinless catfish fillet	8.83	7.85	854.8	34.4	5.5	21.19
T304-2043	Morgan Lake	composited skinless bass fillet	8.83	7.85	854.8	34.4	5.5	21.19
T304-2044	Morgan Lake	composited skinless catfish fillet	8.83	7.85	854.8	34.4	5.5	21.19
T304-2045	Asaayi Lake	composited trout offal	8.48	8.58	108.5	34.4	9.6	8.00
T304-2046	Asaayi Lake	composited trout offal	8.48	8.58	108.5	34.4	9.6	8.00
T304-2047	Asaayi Lake	composited trout offal	8.48	8.58	108.5	34.4	9.6	8.00
T304-2048	Asaayi Lake	composited trout offal	8.48	8.58	108.5	34.4	9.6	8.00
T304-2049	Wheatfields Lake	composited trout offal	8.37	7.73	282.3	6.4	83.8	9.06
T304-2050	Wheatfields Lake	composited trout offal	8.37	7.73	282.3	6.4	83.8	9.06
T304-2051	Wheatfields Lake	composited trout offal	8.37	7.73	282.3	6.4	83.8	9.06
T304-2052	Wheatfields Lake	composited trout offal	8.37	7.73	282.3	6.4	83.8	9.06
T304-2053	Red Lake	composited catfish offal	8.76	6.76	3.6	2.1	120.7	9.08
T304-2054	Red Lake	composited catfish offal	8.76	6.76	3.6	2.1	120.7	9.08
T304-2055	Red Lake	composited catfish offal	8.76	6.76	3.6	2.1	120.7	9.08
T304-2056	Red Lake	composited catfish offal	8.76	6.76	3.6	2.1	120.7	9.08
T304-2057	Morgan Lake	composited catfish offal	8.83	7.85	854.8	34.4	5.5	21.19
T304-2058	Morgan Lake	composited catfish offal	8.83	7.85	854.8	34.4	5.5	21.19
T304-2059	Morgan Lake	composited bass offal	8.83	7.85	854.8	34.4	5.5	21.19
T304-2060	Morgan Lake	composited catfish offal	8.83	7.85	854.8	34.4	5.5	21.19

Table 4. Sample Information, Analytical Results, and Liminological Characteristics of Four Navajo Nation Lakes.
[See Table 3 for abbreviations; all water values are mg/L; all fish values are mg/kg dry weight].

Sample Number	Lake Name	Sample Type	Average Surface pH (Standard units)	Average Surface Dissolved Oxygen (mg/L)	Average Surface Specific Conductivity (uS/cm)	Secchi Depth (inches)	Average Surface Turbidity (NTU)	Average Bottom Temperature (Celsius)
2945	Asaayi Lake	Re-integrated whole fish composite	8.48	8.58	108.5	34.4	9.6	8.00
3046	Asaayi Lake	Re-integrated whole fish composite	8.48	8.58	108.5	34.4	9.6	8.00
3147	Asaayi Lake	Re-integrated whole fish composite	8.48	8.58	108.5	34.4	9.6	8.00
3248	Asaayi Lake	Re-integrated whole fish composite	8.48	8.58	108.5	34.4	9.6	8.00
3349	Wheatfields Lake	Re-integrated whole fish composite	8.37	7.73	282.3	6.4	83.8	9.06
3450	Wheatfields Lake	Re-integrated whole fish composite	8.37	7.73	282.3	6.4	83.8	9.06
3551	Wheatfields Lake	Re-integrated whole fish composite	8.37	7.73	282.3	6.4	83.8	9.06
3652	Wheatfields Lake	Re-integrated whole fish composite	8.37	7.73	282.3	6.4	83.8	9.06
3753	Red Lake	Re-integrated whole fish composite	8.76	6.76	3.6	2.1	120.7	9.08
3854	Red Lake	Re-integrated whole fish composite	8.76	6.76	3.6	2.1	120.7	9.08
3955	Red Lake	Re-integrated whole fish composite	8.76	6.76	3.6	2.1	120.7	9.08
4056	Red Lake	Re-integrated whole fish composite	8.76	6.76	3.6	2.1	120.7	9.08
4157	Morgan Lake	Re-integrated whole fish composite	8.83	7.85	854.8	34.4	5.5	21.19
4258	Morgan Lake	Re-integrated whole fish composite	8.83	7.85	854.8	34.4	5.5	21.19
4359	Morgan Lake	Re-integrated whole fish composite	8.83	7.85	854.8	34.4	5.5	21.19
4460	Morgan Lake	Re-integrated whole fish composite	8.83	7.85	854.8	34.4	5.5	21.19

Table 4. Sample Information, Analytical Results, and Liminological Characteristics of Four Navajo Nation Lakes.
[See Table 3 for abbreviations; all water values are mg/L; all fish values are mg/kg dry weight].

Sample Number	Lake Name	Sample Type	Average Bottom pH (Standard Units)	Average Bottom Dissolved Oxygen (mg/L)	Sample Weight (grams)	Moisture Content (%)	Ag	Al	As	B	Ba
T304-2001	Asaayi Lake	unfiltered grab water	8.21	8.15	500	100					
T304-2002	Asaayi Lake	unfiltered grab water	8.21	8.15	500	100					
T304-2003	Asaayi Lake	unfiltered grab water	8.21	8.15	500	100					
T304-2004	Asaayi Lake	unfiltered grab water	8.21	8.15	500	100					
T304-2005	Wheatfields Lake	unfiltered grab water	8.37	7.39	500	100					
T304-2006	Wheatfields Lake	unfiltered grab water	8.37	7.39	500	100					
T304-2007	Wheatfields Lake	unfiltered grab water	8.37	7.39	500	100					
T304-2008	Wheatfields Lake	unfiltered grab water	8.37	7.39	500	100					
T304-2009	Red Lake	unfiltered grab water	8.79	6.68	500	100					
T304-2010	Red Lake	unfiltered grab water	8.79	6.68	500	100					
T304-2011	Red Lake	unfiltered grab water	8.79	6.68	500	100					
T304-2012		unfiltered Blank meHg water			500	100					
T304-2013	Morgan Lake	unfiltered grab water	8.51	5.83	500	100					
T304-2014	Morgan Lake	unfiltered grab water	8.51	5.83	500	100					
T304-2015	Morgan Lake	unfiltered grab water	8.51	5.83	500	100					
T304-2016	Morgan Lake	unfiltered grab water	8.51	5.83	500	100					
T304-2017	Asaayi Lake	filtered, composited water	8.21	8.15	500	100	<0.01	0.143	0.0021	0.01	0.049
T304-2018	Asaayi Lake	filtered, composited water	8.21	8.15	500	100	<0.01	0.153	0.0031	0.01	0.05
T304-2019	Asaayi Lake	filtered, Blank Deionized water			500	100	<0.01	<0.05	<0.0002	<0.01	<0.001
T304-2020	Wheatfields Lake	filtered, composited water	8.37	7.39	500	100	<0.01	0.127	0.0056	0.08	0.16
T304-2021	Wheatfields Lake	filtered, composited water	8.37	7.39	500	100	<0.01	0.236	0.0056	0.08	0.168
T304-2022	Wheatfields Lake	filtered, Blank Deionized water			500	100	<0.01	<0.05	<0.0002	<0.01	<0.001
T304-2023	Red Lake	filtered, composited water	8.79	6.68	500	100	<0.01	0.08	0.0082	0.13	0.09
T304-2024	Red Lake	filtered, composited water	8.79	6.68	500	100	<0.01	0.166	0.0083	0.134	0.093
T304-2025	Red Lake	filtered, Blank Deionized water			500	100	<0.01	<0.05	<0.0002	<0.01	<0.001
T304-2026	Morgan Lake	filtered, composited water	8.51	5.83	500	100	<0.01	<0.05	0.0063	0.634	0.132
T304-2027	Morgan Lake	filtered, composited water	8.51	5.83	500	100	<0.01	<0.05	0.0059	0.652	0.136
T304-2028	Morgan Lake	filtered, Blank Deionized water			500	100	<0.01	<0.05	<0.0002	<0.01	<0.001

Table 4. Sample Information, Analytical Results, and Liminological Characteristics of Four Navajo Nation Lakes.
[See Table 3 for abbreviations; all water values are mg/L; all fish values are mg/kg dry weight].

Sample Number	Lake Name	Sample Type	Average Bottom pH (Standard Units)	Average Bottom Dissolved Oxygen (mg/L)	Sample Weight (grams)	Moisture Content (%)	Ag	Al	As	B	Ba
T304-2029	Asaayi Lake	composited skinless trout fillet	8.21	8.15	310	77.3		<4.71	0.363	<0.942	<0.094
T304-2030	Asaayi Lake	composited skinless trout fillet	8.21	8.15	206	77.6		<4.97	0.483	<0.994	<0.099
T304-2031	Asaayi Lake	composited skinless trout fillet	8.21	8.15	276	77.9		<4.56	0.301	<0.912	<0.091
T304-2032	Asaayi Lake	composited skinless trout fillet	8.21	8.15	158	78.1		56.7	0.667	<0.978	0.176
T304-2033	Wheatfields Lake	composited skinless trout fillet	8.37	7.39	118	79.5		<4.85	1.01	<0.969	0.301
T304-2034	Wheatfields Lake	composited skinless trout fillet	8.37	7.39	134	78.4		<4.68	0.83	<0.937	0.806
T304-2035	Wheatfields Lake	composited skinless trout fillet	8.37	7.39	60	77.3		10.5	1.03	<0.959	0.269
T304-2036	Wheatfields Lake	composited skinless trout fillet	8.37	7.39	57	77.2		<4.80	0.511	<0.959	0.115
T304-2037	Red Lake	composited skinless catfish fillet	8.79	6.68	214	82.5		<4.68	0.295	<0.937	0.487
T304-2038	Red Lake	composited skinless catfish fillet	8.79	6.68	220	81.6		5.68	0.335	<0.947	0.275
T304-2039	Red Lake	composited skinless catfish fillet	8.79	6.68	314	81.3		21.7	0.279	<0.965	0.193
T304-2040	Red Lake	composited skinless catfish fillet	8.79	6.68	306	81.2		12.9	0.255	<0.955	0.344
T304-2041	Morgan Lake	composited skinless catfish fillet	8.51	5.83	308	81.4		7.9	<0.194	<0.968	0.135
T304-2042	Morgan Lake	composited skinless catfish fillet	8.51	5.83	202	82.9		5.62	0.216	1.01	0.112
T304-2043	Morgan Lake	composited skinless bass fillet	8.51	5.83	422	80.0		<4.83	0.408	<0.967	<0.097
T304-2044	Morgan Lake	composited skinless catfish fillet	8.51	5.83	238	83.3		19.7	0.246	<0.942	0.697
T304-2045	Asaayi Lake	composited trout offal	8.21	8.15	2652	73.5		26.8	<1.85	<0.924	9.24
T304-2046	Asaayi Lake	composited trout offal	8.21	8.15	1634	72.1		30.3	<1.82	<0.912	4.4
T304-2047	Asaayi Lake	composited trout offal	8.21	8.15	2793	74.7		33.4	<1.87	<0.935	14.2
T304-2048	Asaayi Lake	composited trout offal	8.21	8.15	1166	76.0		22.4	<1.89	<0.945	4.07
T304-2049	Wheatfields Lake	composited trout offal	8.37	7.39	726	77.7		22.5	<1.85	<0.924	6.92
T304-2050	Wheatfields Lake	composited trout offal	8.37	7.39	764	75.6		18.5	<1.85	<0.923	10.3
T304-2051	Wheatfields Lake	composited trout offal	8.37	7.39	382	73.9		24	1.49	<0.726	6.19
T304-2052	Wheatfields Lake	composited trout offal	8.37	7.39	320	74.2		12.5	<1.86	<0.929	4.49
T304-2053	Red Lake	composited catfish offal	8.79	6.68	4100	80.0		153	<1.81	3.770	129
T304-2054	Red Lake	composited catfish offal	8.79	6.68	4280	72.9		510	1.33	5.760	46.9
T304-2055	Red Lake	composited catfish offal	8.79	6.68	4860	77.5		65.1	<1.63	1.300	52.1
T304-2056	Red Lake	composited catfish offal	8.79	6.68	3996	76.0		70.1	<1.83	0.946	27.1
T304-2057	Morgan Lake	composited catfish offal	8.51	5.83	2904	70.7		17.4	<1.24	0.971	4.01
T304-2058	Morgan Lake	composited catfish offal	8.51	5.83	1632	76.8		49.7	<1.65	1.950	6.13
T304-2059	Morgan Lake	composited bass offal	8.51	5.83	3044	71.6		31	<1.34	<0.67	3.24
T304-2060	Morgan Lake	composited catfish offal	8.51	5.83	2114	75.1		49.7	<1.51	1.470	2.64

Table 4. Sample Information, Analytical Results, and Liminological Characteristics of Four Navajo Nation Lakes.
[See Table 3 for abbreviations; all water values are mg/L; all fish values are mg/kg dry weight].

Sample Number	Lake Name	Sample Type	Average Bottom pH (Standard Units)	Average Bottom Dissolved Oxygen (mg/L)	Sample Weight (grams)	Moisture Content (%)	Ag	Al	As	B	Ba
2945	Asaayi Lake	Re-integrated whole fish composite	8.21	8.15	2962	73.9		24.2	0.866	<0.46	8.278
3046	Asaayi Lake	Re-integrated whole fish composite	8.21	8.15	1840	72.7		27.2	0.862	<0.46	3.913
3147	Asaayi Lake	Re-integrated whole fish composite	8.21	8.15	3069	75.0		30.6	0.878	<0.46	12.927
3248	Asaayi Lake	Re-integrated whole fish composite	8.21	8.15	1324	76.3		26.5	0.912	<0.47	3.605
3349	Wheatfields Lake	Re-integrated whole fish composite	8.37	7.39	844	78.0		19.7	0.937	<0.47	5.995
3450	Wheatfields Lake	Re-integrated whole fish composite	8.37	7.39	898	76.0		16.1	0.911	<0.46	8.883
3551	Wheatfields Lake	Re-integrated whole fish composite	8.37	7.39	441.8	74.4		22.2	1.428	<0.38	5.389
3652	Wheatfields Lake	Re-integrated whole fish composite	8.37	7.39	377.0	74.7		11.0	0.867	<0.47	3.828
3753	Red Lake	Re-integrated whole fish composite	8.79	6.68	4314	80.1		145.5	0.875	3.606	122.625
3854	Red Lake	Re-integrated whole fish composite	8.79	6.68	4500	73.3		485.3	1.281	5.502	44.621
3955	Red Lake	Re-integrated whole fish composite	8.79	6.68	5174	77.7		62.5	0.782	1.250	48.950
4056	Red Lake	Re-integrated whole fish composite	8.79	6.68	4302	76.4		66.0	0.868	0.913	25.197
4157	Morgan Lake	Re-integrated whole fish composite	8.51	5.83	3212	71.7		16.5	0.570	0.920	3.638
4258	Morgan Lake	Re-integrated whole fish composite	8.51	5.83	1834	77.5		44.8	0.758	1.850	5.467
4359	Morgan Lake	Re-integrated whole fish composite	8.51	5.83	3466	72.6		27.5	0.638	<0.35	2.851
4460	Morgan Lake	Re-integrated whole fish composite	8.51	5.83	2352	75.9		46.7	0.703	1.370	2.443

Table 4. Sample Information, Analytical Results, and Liminological Characteristics of Four Navajo Nation Lakes.
[See Table 3 for abbreviations; all water values are mg/L; all fish values are mg/kg dry weight].

Sample Number	Lake Name	Sample Type	Be	Ca	Cd	Co	Cr	Cu	Fe	Hg	K	MeHg
T304-2001	Asaayi Lake	unfiltered grab water										0.000000058
T304-2002	Asaayi Lake	unfiltered grab water										0.000000071
T304-2003	Asaayi Lake	unfiltered grab water										0.000000077
T304-2004	Asaayi Lake	unfiltered grab water										0.000000088
T304-2005	Wheatfields Lake	unfiltered grab water										0.000000134
T304-2006	Wheatfields Lake	unfiltered grab water										0.000000143
T304-2007	Wheatfields Lake	unfiltered grab water										0.000000159
T304-2008	Wheatfields Lake	unfiltered grab water										0.000000159
T304-2009	Red Lake	unfiltered grab water										0.000000418
T304-2010	Red Lake	unfiltered grab water										0.000000152
T304-2011	Red Lake	unfiltered grab water										0.000000068
T304-2012		unfiltered Blank meHg water										<0.000000011
T304-2013	Morgan Lake	unfiltered grab water										0.000000037
T304-2014	Morgan Lake	unfiltered grab water										0.000000017
T304-2015	Morgan Lake	unfiltered grab water										0.000000023
T304-2016	Morgan Lake	unfiltered grab water										0.000000020
T304-2017	Asaayi Lake	filtered, composited water	<0.0005	23.8	<0.00005	<0.005	<0.005	<0.005	0.08	0.00000190	1.46	
T304-2018	Asaayi Lake	filtered, composited water	<0.0005	24.3	<0.00005	<0.005	<0.005	<0.005	0.08	0.00000189	1.48	
T304-2019	Asaayi Lake	filtered, Blank Deionized water	<0.0005	0.04	<0.00005	<0.005	<0.005	<0.005	<0.01	<0.00000050	<0.10	
T304-2020	Wheatfields Lake	filtered, composited water	<0.0005	29.6	<0.00005	<0.005	<0.005	<0.005	0.05	0.00000178	2.68	
T304-2021	Wheatfields Lake	filtered, composited water	<0.0005	30.9	<0.00005	<0.005	<0.005	<0.005	0.09	0.00000178	2.8	
T304-2022	Wheatfields Lake	filtered, Blank Deionized water	<0.0005	0.08	<0.00005	<0.005	<0.005	<0.005	<0.01	0.00000114	<0.10	
T304-2023	Red Lake	filtered, composited water	<0.0005	22.7	<0.00005	<0.005	<0.005	<0.005	0.04	0.00000366	4.51	
T304-2024	Red Lake	filtered, composited water	<0.0005	23	<0.00005	<0.005	<0.005	<0.005	0.08	0.00000359	4.57	
T304-2025	Red Lake	filtered, Blank Deionized water	<0.0005	0.03	<0.00005	<0.005	<0.005	<0.005	0.01	<0.00000050	<0.10	
T304-2026	Morgan Lake	filtered, composited water	<0.0005	98.4	<0.00005	<0.005	<0.005	<0.005	<0.01	<0.00000050	7.28	
T304-2027	Morgan Lake	filtered, composited water	<0.0005	101	<0.00005	<0.005	<0.005	<0.005	<0.01	<0.00000050	7.49	
T304-2028	Morgan Lake	filtered, Blank Deionized water	<0.0005	0.07	<0.00005	<0.005	<0.005	<0.005	<0.01	<0.00000050	<0.10	

Table 4. Sample Information, Analytical Results, and Liminological Characteristics of Four Navajo Nation Lakes.
[See Table 3 for abbreviations; all water values are mg/L; all fish values are mg/kg dry weight].

Sample Number	Lake Name	Sample Type	Be	Ca	Cd	Co	Cr	Cu	Fe	Hg	K	MeHg
T304-2029	Asaayi Lake	composited skinless trout fillet	<0.0471	679	<0.0471	<0.471	<0.471	1.5	14.6	0.489	15200	0.482000000
T304-2030	Asaayi Lake	composited skinless trout fillet	<0.0497	828	<0.0497	<0.497	<0.497	1.22	18.7	0.327	15900	0.293000000
T304-2031	Asaayi Lake	composited skinless trout fillet	<0.0456	588	<0.0456	<0.456	<0.456	1.56	17.2	0.593	15300	0.311000000
T304-2032	Asaayi Lake	composited skinless trout fillet	<0.0489	1450	<0.0489	<0.489	<0.489	1.57	16.7	0.184	15900	0.137000000
T304-2033	Wheatfields Lake	composited skinless trout fillet	<0.0485	1820	<0.0485	<0.485	<0.485	1.52	29.4	0.277	17400	0.292000000
T304-2034	Wheatfields Lake	composited skinless trout fillet	<0.0468	3090	<0.0468	<0.468	<0.468	1.72	15.1	0.297	16200	0.343000000
T304-2035	Wheatfields Lake	composited skinless trout fillet	<0.0480	1940	<0.0480	<0.480	<0.480	1.82	12.4	0.332	15600	0.380000000
T304-2036	Wheatfields Lake	composited skinless trout fillet	<0.0480	818	<0.0480	<0.480	<0.480	1.3	11.6	0.392	15600	0.417000000
T304-2037	Red Lake	composited skinless catfish fillet	<0.0468	373	<0.0468	<0.468	<0.468	1.1	20.8	2.53	16300	2.690000000
T304-2038	Red Lake	composited skinless catfish fillet	<0.0474	409	<0.0474	<0.474	<0.474	1.05	22.4	1.74	15100	1.640000000
T304-2039	Red Lake	composited skinless catfish fillet	<0.0483	358	<0.0483	<0.483	<0.483	1.17	16	2.12	15800	2.440000000
T304-2040	Red Lake	composited skinless catfish fillet	<0.0477	481	<0.0477	<0.477	<0.477	1.18	27.4	1.96	15800	1.870000000
T304-2041	Morgan Lake	composited skinless catfish fillet	<0.0484	559	<0.0484	<0.484	<0.484	1.25	16.5	0.0571	14900	0.059100000
T304-2042	Morgan Lake	composited skinless catfish fillet	<0.0467	467	<0.0467	<0.467	<0.467	1.33	15.4	0.0437	15900	0.034900000
T304-2043	Morgan Lake	composited skinless bass fillet	<0.0483	1210	<0.0483	<0.483	<0.483	1.08	8.49	0.0774	14700	0.081600000
T304-2044	Morgan Lake	composited skinless catfish fillet	<0.0471	844	<0.0471	<0.471	<0.471	1.34	37.6	0.0488	16900	0.044100000
T304-2045	Asaayi Lake	composited trout offal	<0.0462	22200	<0.0462	<0.462	0.709	2.87	117	0.343	10000	
T304-2046	Asaayi Lake	composited trout offal	<0.0456	22800	<0.0456	<0.456	0.819	3.86	93.9	0.243	9600	
T304-2047	Asaayi Lake	composited trout offal	<0.0467	28900	<0.0467	<0.467	<0.467	4.14	147	0.414	10300	
T304-2048	Asaayi Lake	composited trout offal	<0.0472	24500	<0.0472	<0.472	0.584	2.71	95.5	0.137	11200	
T304-2049	Wheatfields Lake	composited trout offal	<0.0462	31200	<0.0462	<0.462	<0.462	2.66	67.5	0.201	12100	
T304-2050	Wheatfields Lake	composited trout offal	<0.0461	25300	<0.0461	<0.461	0.48	3.6	62.9	0.213	11100	
T304-2051	Wheatfields Lake	composited trout offal	<0.0363	28300	<0.0363	<0.363	0.857	2.94	55.9	0.252	10100	
T304-2052	Wheatfields Lake	composited trout offal	<0.0465	22200	<0.0465	<0.465	1.16	2.28	46.7	0.262	10400	
T304-2053	Red Lake	composited catfish offal	<0.0453	51800	0.597	0.701	2.66	2.17	243	1.08	9440	
T304-2054	Red Lake	composited catfish offal	0.0387	47700	0.092	<0.327	2.18	2.92	466	0.783	7550	
T304-2055	Red Lake	composited catfish offal	0.0409	89500	0.048	<0.409	2.25	1.45	141	1.16	10000	
T304-2056	Red Lake	composited catfish offal	<0.0457	65500	0.054	<0.457	2.31	2.04	184	0.773	8030	
T304-2057	Morgan Lake	composited catfish offal	<0.0310	55700	<0.0310	<0.310	2.68	1.3	74	0.0241	7320	
T304-2058	Morgan Lake	composited catfish offal	<0.0413	65300	<0.0413	<0.413	1.77	2.14	139	0.0215	9830	
T304-2059	Morgan Lake	composited bass offal	0.0339	83800	0.037	<0.336	4.70	1.32	78.3	0.0358	8820	
T304-2060	Morgan Lake	composited catfish offal	<0.0377	34400	<0.0377	<0.377	1.54	1.8	113	0.0195	7500	

Table 4. Sample Information, Analytical Results, and Liminological Characteristics of Four Navajo Nation Lakes.
[See Table 3 for abbreviations; all water values are mg/L; all fish values are mg/kg dry weight].

Sample Number	Lake Name	Sample Type	Be	Ca	Cd	Co	Cr	Cu	Fe	Hg	K	MeHg
2945	Asaayi Lake	Re-integrated whole fish composite	<0.023	19948	<0.023	<0.23	0.659	2.7	106.3	0.358	10544	
3046	Asaayi Lake	Re-integrated whole fish composite	<0.023	20340	<0.023	<0.23	0.755	3.6	85.5	0.252	10305	
3147	Asaayi Lake	Re-integrated whole fish composite	<0.023	26354	<0.023	<0.23	<0.233	3.9	135.3	0.430	10750	
3248	Asaayi Lake	Re-integrated whole fish composite	<0.024	21749	<0.024	<0.23	0.543	2.6	86.1	0.143	11761	
3349	Wheatfields Lake	Re-integrated whole fish composite	<0.023	27092	<0.023	<0.23	<0.233	2.5	62.2	0.212	12841	
3450	Wheatfields Lake	Re-integrated whole fish composite	<0.023	21986	<0.023	<0.23	0.443	3.3	55.8	0.226	11861	
3551	Wheatfields Lake	Re-integrated whole fish composite	<0.019	24735	0.019	<0.19	0.774	2.8	50.0	0.263	10844	
3652	Wheatfields Lake	Re-integrated whole fish composite	<0.023	18965	<0.023	<0.23	1.021	2.1	41.4	0.282	11187	
3753	Red Lake	Re-integrated whole fish composite	<0.023	49249	0.569	0.678	2.540	2.1	232.0	1.152	9780	
3854	Red Lake	Re-integrated whole fish composite	0.038	45388	0.089	<0.17	2.085	2.8	444.3	0.830	7919	
3955	Red Lake	Re-integrated whole fish composite	0.040	84090	0.047	<0.21	2.128	1.4	133.4	1.218	10352	
4056	Red Lake	Re-integrated whole fish composite	<0.023	60875	0.052	<0.23	2.163	2.0	172.9	0.857	8583	
4157	Morgan Lake	Re-integrated whole fish composite	<0.016	50413	<0.016	<0.17	2.446	1.3	68.5	0.027	8047	
4258	Morgan Lake	Re-integrated whole fish composite	<0.021	58159	<0.021	<0.21	1.601	2.1	125.4	0.024	10499	
4359	Morgan Lake	Re-integrated whole fish composite	0.033	73744	<0.035	<0.19	4.157	1.3	69.8	0.041	9536	
4460	Morgan Lake	Re-integrated whole fish composite	<0.019	31004	<0.019	<0.19	1.408	1.8	105.4	0.022	8451	

Table 4. Sample Information, Analytical Results, and Liminological Characteristics of Four Navajo Nation Lakes.
[See Table 3 for abbreviations; all water values are mg/L; all fish values are mg/kg dry weight].

Sample Number	Lake Name	Sample Type	Mg	Mn	Mo	Na	Ni	P	Pb	S	Se	Sr	V	Zn
T304-2001	Asaayi Lake	unfiltered grab water												
T304-2002	Asaayi Lake	unfiltered grab water												
T304-2003	Asaayi Lake	unfiltered grab water												
T304-2004	Asaayi Lake	unfiltered grab water												
T304-2005	Wheatfields Lake	unfiltered grab water												
T304-2006	Wheatfields Lake	unfiltered grab water												
T304-2007	Wheatfields Lake	unfiltered grab water												
T304-2008	Wheatfields Lake	unfiltered grab water												
T304-2009	Red Lake	unfiltered grab water												
T304-2010	Red Lake	unfiltered grab water												
T304-2011	Red Lake	unfiltered grab water												
T304-2012		unfiltered Blank meHg water												
T304-2013	Morgan Lake	unfiltered grab water												
T304-2014	Morgan Lake	unfiltered grab water												
T304-2015	Morgan Lake	unfiltered grab water												
T304-2016	Morgan Lake	unfiltered grab water												
T304-2017	Asaayi Lake	filtered, composited water	2.87	0.011	<0.01	3	<0.005	0.08	0.00018	1.5	0.00048	0.12	<0.01	<0.005
T304-2018	Asaayi Lake	filtered, composited water	2.88	0.012	<0.01	4	<0.005	0.08	0.00014	1.6	0.00046	0.125	<0.01	<0.005
T304-2019	Asaayi Lake	filtered, Blank Deionized water	<0.01	<0.002	<0.01	<2	<0.005	<0.05	0.00007	<0.1	<0.00040	<0.0005	<0.01	0.026
T304-2020	Wheatfields Lake	filtered, composited water	13.6	0.003	<0.01	31.4	<0.005	0.125	0.00009	6.2	0.00045	0.414	<0.01	<0.005
T304-2021	Wheatfields Lake	filtered, composited water	14.1	0.004	<0.01	33.6	<0.005	0.151	0.00010	6.5	0.00047	0.438	<0.01	<0.005
T304-2022	Wheatfields Lake	filtered, Blank Deionized water	0.01	<0.002	<0.01	<2	<0.005	<0.05	0.00005	<0.1	<0.00040	<0.0005	<0.01	0.031
T304-2023	Red Lake	filtered, composited water	9.29	<0.002	<0.01	65	<0.005	0.103	0.00007	10.7	0.00052	0.339	0.01	<0.005
T304-2024	Red Lake	filtered, composited water	9.39	0.002	<0.01	66	<0.005	0.112	0.00009	11	0.00052	0.343	0.01	<0.005
T304-2025	Red Lake	filtered, Blank Deionized water	<0.01	<0.002	<0.01	<2	<0.005	<0.05	<0.00005	<0.1	<0.00040	<0.0005	<0.01	0.008
T304-2026	Morgan Lake	filtered, composited water	35.8	<0.002	<0.01	99.9	<0.005	<0.05	0.00015	138	0.00128	1.66	<0.01	<0.005
T304-2027	Morgan Lake	filtered, composited water	36.7	<0.002	0.01	106	<0.005	<0.05	0.00015	141	0.0013	1.76	<0.01	<0.005
T304-2028	Morgan Lake	filtered, Blank Deionized water	0.02	<0.002	<0.01	<2	<0.005	<0.05	<0.00005	<0.1	0.00042	0.0008	<0.01	0.021

Table 4. Sample Information, Analytical Results, and Liminological Characteristics of Four Navajo Nation Lakes.
[See Table 3 for abbreviations; all water values are mg/L; all fish values are mg/kg dry weight].

Sample Number	Lake Name	Sample Type	Mg	Mn	Mo	Na	Ni	P	Pb	S	Se	Sr	V	Zn
T304-2029	Asaayi Lake	composited skinless trout fillet	1160	0.556	<0.942	925	<0.471	11000	0.234	8340	1.25	0.603	<0.942	13.3
T304-2030	Asaayi Lake	composited skinless trout fillet	1220	0.616	<0.994	1130	<0.497	11500	0.215	8430	1.14	0.945	<0.994	16.6
T304-2031	Asaayi Lake	composited skinless trout fillet	1130	0.511	<0.912	1070	<0.456	10900	0.182	8270	1.16	0.511	<0.912	14.8
T304-2032	Asaayi Lake	composited skinless trout fillet	1230	0.841	<0.978	1210	<0.489	11700	0.223	8160	1.23	1.56	<0.978	19.7
T304-2033	Wheatfields Lake	composited skinless trout fillet	1270	0.717	<0.969	1310	<0.485	12300	0.201	8350	1.22	3.57	<0.969	16.3
T304-2034	Wheatfields Lake	composited skinless trout fillet	1270	0.768	<0.937	1240	<0.468	12400	0.183	8400	1.09	7.64	<0.937	16
T304-2035	Wheatfields Lake	composited skinless trout fillet	1290	0.844	<0.959	1190	<0.480	11800	0.188	8220	1.06	3.04	<0.959	15.8
T304-2036	Wheatfields Lake	composited skinless trout fillet	1280	0.652	<0.959	1150	<0.480	11400	0.172	8470	1.17	1.06	<0.959	17.7
T304-2037	Red Lake	composited skinless catfish fillet	1050	0.778	<0.937	2110	<0.468	10500	0.152	9690	0.886	1.74	<0.937	21.9
T304-2038	Red Lake	composited skinless catfish fillet	1040	0.625	<0.947	1810	<0.474	9840	0.159	9320	0.849	1.74	<0.947	21.1
T304-2039	Red Lake	composited skinless catfish fillet	1060	0.531	<0.965	1790	<0.483	10400	0.153	9850	0.881	1.37	<0.965	20.2
T304-2040	Red Lake	composited skinless catfish fillet	1070	0.725	<0.955	1890	<0.477	10400	0.159	9530	0.848	1.82	<0.955	20.7
T304-2041	Morgan Lake	composited skinless catfish fillet	1090	0.735	<0.968	1720	<0.484	9980	0.144	10800	15.1	2.6	<0.968	22.5
T304-2042	Morgan Lake	composited skinless catfish fillet	1110	0.672	<0.933	2060	<0.467	10600	0.121	11600	21	2.38	<0.933	24.2
T304-2043	Morgan Lake	composited skinless bass fillet	1290	0.3	<0.967	1450	<0.483	9980	0.128	10800	17.2	5.63	<0.967	18.8
T304-2044	Morgan Lake	composited skinless catfish fillet	1210	1.47	<0.942	1950	<0.471	11200	0.234	12200	23.1	3.92	<0.942	24.9
T304-2045	Asaayi Lake	composited trout offal	1010	36.4	<0.924	3520	<0.462	17500	0.124	7320	1.39	29.4	<0.924	83
T304-2046	Asaayi Lake	composited trout offal	950	10	<0.912	3310	0.661	17800	0.138	6860	1.38	28.4	<0.912	86.6
T304-2047	Asaayi Lake	composited trout offal	1190	55.4	<0.935	3830	<0.467	20500	0.157	7500	1.28	41.1	<0.935	102
T304-2048	Asaayi Lake	composited trout offal	1110	10.2	<0.945	4060	<0.472	19700	0.11	7470	1.39	31.1	<0.945	102
T304-2049	Wheatfields Lake	composited trout offal	1220	5.47	<0.924	5040	<0.462	22900	0.113	8200	1.42	66.6	<0.924	131
T304-2050	Wheatfields Lake	composited trout offal	1150	5.01	<0.923	4290	<0.461	19700	0.113	7840	1.24	67.6	<0.923	103
T304-2051	Wheatfields Lake	composited trout offal	1240	5.24	<0.726	3520	0.497	22000	0.0841	7660	1.48	53.7	<0.726	87.8
T304-2052	Wheatfields Lake	composited trout offal	1040	3.79	<0.929	3420	0.737	18500	0.0767	7090	1.54	43.7	<0.929	74.9
T304-2053	Red Lake	composited catfish offal	1420	76.9	<0.905	7690	1.84	29500	0.388	6870	1.69	190	1.82	84.4
T304-2054	Red Lake	composited catfish offal	1430	46.7	<0.654	4930	1.37	26100	0.569	6280	1.63	185	2.34	66.7
T304-2055	Red Lake	composited catfish offal	1980	44.7	<0.817	6210	1.08	49100	0.315	6980	1.39	293	1.58	103
T304-2056	Red Lake	composited catfish offal	1510	30.2	<0.915	6300	1.36	36400	0.296	5680	1.6	231	1.48	90.1
T304-2057	Morgan Lake	composited catfish offal	1510	11.6	<0.620	4660	1.3	31900	0.306	6010	8.95	280	1.04	82.5
T304-2058	Morgan Lake	composited catfish offal	1910	26.4	<0.826	6020	1.15	38000	0.331	7880	12.5	338	0.90	127
T304-2059	Morgan Lake	composited bass offal	2270	6.93	<0.672	4820	2.33	45300	0.121	8080	12.1	488	<0.672	64
T304-2060	Morgan Lake	composited catfish offal	1180	5.77	<0.754	5120	0.97	21200	0.208	6780	12	179	<0.754	70.7

Table 4. Sample Information, Analytical Results, and Liminological Characteristics of Four Navajo Nation Lakes.
[See Table 3 for abbreviations; all water values are mg/L; all fish values are mg/kg dry weight].

Sample Number	Lake Name	Sample Type	Mg	Mn	Mo	Na	Ni	P	Pb	S	Se	Sr	V	Zn
2945	Asaayi Lake	Re-integrated whole fish composite	1026	32.65	<0.47	3248	<0.23	16820	0.14	7427	1.38	26.39	<0.46	75.71
3046	Asaayi Lake	Re-integrated whole fish composite	980	8.95	<0.47	3066	0.61	17095	0.15	7036	1.35	25.33	<0.46	78.76
3147	Asaayi Lake	Re-integrated whole fish composite	1185	50.46	<0.47	3582	<0.23	19637	0.16	7569	1.27	37.45	<0.47	94.16
3248	Asaayi Lake	Re-integrated whole fish composite	1124	9.08	<0.47	3720	<0.24	18745	0.12	7552	1.37	27.57	<0.47	92.18
3349	Wheatfields Lake	Re-integrated whole fish composite	1227	4.81	<0.47	4519	<0.23	21418	0.13	8221	1.39	57.79	<0.47	114.96
3450	Wheatfields Lake	Re-integrated whole fish composite	1168	4.38	<0.47	3835	<0.23	18611	0.12	7924	1.22	58.65	<0.46	90.02
3551	Wheatfields Lake	Re-integrated whole fish composite	1247	4.65	<0.38	3205	0.46	20620	0.10	7736	1.42	46.85	<0.38	78.06
3652	Wheatfields Lake	Re-integrated whole fish composite	1076	3.32	<0.47	3077	0.66	17426	0.09	7299	1.48	37.25	<0.47	66.25
3753	Red Lake	Re-integrated whole fish composite	1402	73.12	<0.47	7413	1.76	28557	0.38	7010	1.65	180.66	1.75	81.30
3854	Red Lake	Re-integrated whole fish composite	1411	44.45	<0.33	4777	1.31	25305	0.55	6429	1.59	176.04	2.25	64.47
3955	Red Lake	Re-integrated whole fish composite	1924	42.02	<0.41	5942	1.03	46751	0.31	7154	1.36	275.30	1.51	97.98
4056	Red Lake	Re-integrated whole fish composite	1479	28.10	<0.47	5986	1.28	34551	0.29	5954	1.55	214.70	1.41	85.16
4157	Morgan Lake	Re-integrated whole fish composite	1470	10.56	<0.33	4378	1.20	29798	0.29	6469	9.54	253.40	0.99	76.75
4258	Morgan Lake	Re-integrated whole fish composite	1822	23.57	<0.42	5584	1.05	34982	0.31	8290	13.44	301.03	0.85	115.68
4359	Morgan Lake	Re-integrated whole fish composite	2151	6.12	<0.35	4410	2.08	41000	0.12	8411	12.72	429.27	<0.35	58.50
4460	Morgan Lake	Re-integrated whole fish composite	1183	5.33	<0.39	4799	0.90	20188	0.21	7328	13.12	161.28	<0.39	66.07

Table 5. Average Concentration of Elements Dissolved in Lake Water Composites (N=2 from each lake) Compared with Selected Numeric Navajo Nation (2004) Water Quality Criteria for Various Designated Uses.

[Note: for the lead criteria that are dependent on hardness in the calculation, a value of 100 mg/L was used; all values are mg/L unless specified otherwise; **bolded** values may exceed water quality criteria within the same row as identified by *italics*; NNCNS = No Numeric Criteria, Narrative Standard applies.]

Dissolved Element (mg/L)[a]	Asaayi Lake	Wheat-fields Lake	Red Lake	Morgan Lake	Aquatic Habitat Acute	Aquatic Habitat Chronic	Agricultural Water Supply	Domestic Water Supply	Fish Consumption	Livestock & Wildlife Watering	Secondary Contact
Al	**0.15**	**0.18**	**0.12**	0.03	0.75	*0.087*	5.0	NNCNS	NNCNS	5.0	NNCNS
As	0.003	0.006	0.008	0.006	0.340	0.150	0.100	0.050	1.450	0.020	0.420
B	0.01	0.08	0.13	**0.64**	NNCNS	NNCNS	0.750	*0.630*	NNCNS	10.000	126.000
Ba	0.05	0.09	0.09	0.11	NNCNS	NNCNS	NNCNS	1.000	NNCNS	NNCNS	98.000
Ca	24.1	30.3	22.9	99.7	NNCNS	NNCNS	NNCNS	NNCNS	NNCNS	NNCNS	NNCNS
Fe	0.08	0.07	0.06	< 0.01	NNCNS	1.000	NNCNS	NNCNS	NNCNS	NNCNS	NNCNS
K	1.5	2.7	4.5	7.4	NNCNS	NNCNS	NNCNS	NNCNS	NNCNS	NNCNS	NNCNS
Total Hg (µg/L)	0.00190	0.00178	0.00363	0.00025	2.4	0.012	NNCNS	2.0	0.15	10.0	420.0
MeHg (µg/L)	0.00007	0.00015	0.00016	0.00002	NNCNS	NNCNS	NNCNS	NNCNS	NNCNS	NNCNS	NNCNS
Mg	2.9	13.9	9.3	36.3	NNCNS	NNCNS	NNCNS	NNCNS	NNCNS	NNCNS	NNCNS
Mn	0.012	0.004	<0.002	<0.002	NNCNS	NNCNS	NNCNS	NNCNS	NNCNS	NNCNS	NNCNS
Na	3.5	32.5	65.5	102.9	NNCNS	NNCNS	NNCNS	NNCNS	NNCNS	NNCNS	NNCNS
P	0.08	0.14	0.11	0.03	NNCNS	NNCNS	NNCNS	NNCNS	NNCNS	NNCNS	NNCNS
Pb (µg/L)	0.16	0.09	0.08	0.15	64.58	2.52	5000.0	15.0	NNCNS	100.0	15.0
S	1.6	6.4	10.9	139.5	NNCNS	NNCNS	NNCNS	NNCNS	NNCNS	NNCNS	NNCNS
Se	<0.001	<0.001	<0.001	0.001	0.020	0.002	0.130	0.050	9.000	0.050	7.000
Sr	0.12	0.43	0.34	1.71	NNCNS	NNCNS	NNCNS	NNCNS	NNCNS	NNCNS	NNCNS

[a] = See Table 3 for element abbreviations, method of analysis, and limits of detection.

of 87µg/L at Asaayi, Red, and Wheatfield Lakes. Hem (1985) reported that in most natural waters aluminum is rarely above a few tenths of a milligram per liter. However, water samples with dissolved aluminum concentrations frequently exceeding the chronic and even acute (750g/L) water quality criteria for aquatic life are frequently reported in the Rio Grande basin (NMWQCC 2000; Buhl 2002; Lusk *et al.* 2002). Hem (1985) reported that some water-borne colloids that are rich in aluminum have small size (<0.10 micrometers in diameter) and can pass through the 0.45 micrometer filter media (as used in this study). In development of the aquatic life criteria for aluminum, research was focused primarily on aquatic systems with low pH (USEPA 1988). However, there may have been an information gap regarding the chemical and biological effects of elevated aluminum to aquatic life similar to those alkaline waters found on the Navajo Nation in the USEPA (1988) criteria document.

Boron was found dissolved in ambient water samples from Morgan Lake (0.64 mg/L) above the boron criteria for a domestic water supply (0.63 mg/L). However, Morgan Lake is not designated as a domestic water supply by the Navajo Nation. Furthermore, the USEPA (1991) reported that boron as low as 1.52 mg/L is not likely to affect aquatic life. Because boron concentrations dissolved in Morgan Lake water are less than this value, boron toxicity would not be expected to pose a significant risk to aquatic life. However, elevated boron in Morgan Lake water may limit its value as a domestic water supply (Table 5).

Trace Elements in Fish Fillet Tissues

The geometric mean concentrations of trace elements found in fish fillets from lakes sampled are reported in Table 6. Several elements (As, Ca, Cu, P, Mg, K, and P) were found at higher geometric mean concentrations in trout from coldwater lakes than in warmwater fish from Morgan and Red Lakes. In addition, the elements Ba and Na were found at higher concentrations in catfish and bass from warmwater lakes than in coldwater trout from Asaayi and Wheatfields Lakes.

The geometric mean concentrations in fish fillets collected from the Navajo Nation lakes was compared to the geometric mean concentrations in fish fillets collected from the San Juan River by Blanchard *et al.* (1993), Wilson *et al.* (1995), as well as unreported data from Bristol *et al.* (1997) and Simpson and Lusk (2000). Navajo Nation fish fillets had higher geometric mean concentrations of aluminum, arsenic, and strontium than in fillets from the San Juan River but lower geometric mean concentrations of barium and iron.

Concentrations of selenium in fish fillets were elevated in Morgan Lake (3.4 mg/kg WW), and they were greater than the concentration (>1.5 mg/kg WW) associated with human health advisories for adults (USEPA 2000). Therefore, for children whose diet contains a large portion of fish, consuming more than 6, 2-lb catfish per month would likely exceed the USEPA (2000) health effects threshold for selenium. Typically, selenium concentrations in fish fillets are < 0.6 mg/kg WW. Reproductive failure in fisheries has been identified in some species with fillet concentrations as low as 1.7 mg/kg WW (Lemly 1996a, 1996b; USDOI 1998). Selenium in fish fillets may pose a risk to human health and may be reducing the reproductive success of some Morgan Lake fishes as well as to piscivorous wildlife that resides there and consume a diet consisting mainly of whole fish.

Trace Elements in Re-Integrated Fish

The geometric mean concentrations of trace elements found in re-integrated fish from lakes sampled are reported in Table 7. Several trace elements (Al, Ba, Be, Ca, Cd, Fe, Mn, Pb, and V) were found at higher geometric mean concentrations in catfish from Red Lake than fish from any other lake. Sediment chemistry may play a part in the accumulation of these elements in Red Lake catfish, as it is a shallower, more turbid lake. Simpson and Lusk (2000) reported that an organisms association with sediment, such as benthic algae, aquatic worms, and fish explain over 80% of the accumulation of these elements than found in less turbid river reaches with pelagic organisms. These elements are often associated with soil and sediment and therefore, concentrations in benthic biota may likely reflect the ambient geochemical environment.

The geometric mean concentrations in re-integrated fish collected from the Navajo Nation lakes were compared to the those reported in whole fish collected from the San Juan River (Simpson and Lusk 2000), and to the 85th percentile concentration in whole fish collected nationwide (Schmitt and Brumbaugh 1990). Only mercury and selenium in re-integrated fish from the study lakes were above concentrations of concern or were above concentrations typical in fish collected from the San Juan River or collected nationwide.

Catfish collected from Morgan Lake had elevated selenium concentrations (> 12 mg/kg DW). While selenium concentrations in whole fish collected from the San Juan River have ranged from 0.1 to 15.1 mg/kg DW, the composite sample of catfish from Morgan Lake had the highest selenium concentrations (13.4 mg/kg DW) ever reported in the San Juan River Basin. Occasionally, wild catfish captured from the San Juan River are stocked into Morgan Lake (J. Brooks, USFWS, written communication, 2005), so there may be multiple sources of selenium in the tissues of these catfish. However, largemouth bass that were collected were not recently stocked (largemouth bass were stocked in 2002; C. Kitcheyan, USFWS, oral communication, 2005) and these fish contained selenium concentrations as high as 12.7 mg/kg DW.

Nationally, selenium concentrations in whole fish are typically < 2 mg/kg DW (USDOI 1998). Bluegill that contained selenium concentrations from 4 to 6 mg/kg DW have been reported to have a 10 percent reproductive impairment (Lemly 1996a, 1996b; USDOI 1998). As selenium concentrations in fish from Morgan Lake fish are much greater than this threshold, Morgan Lake fish may experience periodic reproductive failures that may affect the fishery. Selenium concentrations in whole body fish above 4 mg/kg DW have also been associated reduced growth and higher mortality rates (Lemly 1996a, 1996b; USDOI 1998). Lemly (1996a, 1996b) and the USDOI (1998) also reported selenium concentrations greater than 3 mg/kg DW in the diets of predatory species pose reproductive risks to migratory and resident birds such as those that may feed extensively on fish from Morgan Lake. Selenium contamination in Morgan Lake fish may be at a level where it could affect the fishery, as well as pose a health risk to people and wildlife that consume a large amount of fish from Morgan Lake. Sources of selenium to Morgan Lake fish should be identified and reduced if population effects are identified in fish, people or wildlife or if health impacts are observed in people or wildlife that regularly eat fish from this lake.

Table 6. Comparison of the Geometric Mean Concentrations of Trace Elements in Fish Fillets collected from Four Recreational Lakes on the Navajo Nation to Fish Fillets collected from the San Juan River, Human Health Endpoints and General Dietary Concentrations of Concern for Wildlife.

Element (ug/g Wet Weight)[a]	Asaayi Lake Trout Fillets	Wheat-fields Lake Trout Fillets	Red Lake Catfish Fillets	Morgan Lake Catfish & Bass Fillets	All Lake Fish Fillets Combined	San Juan River Fillets[b]	No Fish Consumption Recommended (Non-Cancer Enpoint)[c]	No Fish Consumption Recommended (Cancer Endpoint)[c]	General Dietary Level of Concern for Wildlife [d]
Al	1.2	0.8	1.4	1.2	1.1	0.50	---[e]	---[e]	>200
As	0.10	**0.18**	0.05	0.04	0.08	0.06	> 5.6 [f]	*> 0.13* [f]	> 10
B	<0.2	<0.2	<0.2	<0.2	<0.2	< 0.20	---[e]	---[e]	> 30
Ba	0.01	0.01	0.06	0.03	0.03	0.07	---[e]	---[e]	> 20
Be	<0.01	<0.01	<0.01	<0.01	<0.01	< 0.20	---[e]	---[e]	>0.8
Ca	185.3	378.2	73.6	126.7	161.0	---[e]	---[e]	---[e]	---[e]
Cd	<0.01	<0.01	<0.01	<0.01	<0.01	< 0.01	> 0.09	---[e]	>0.1
Cr	<0.05	<0.05	<0.05	<0.05	<0.05	0.08	---[e]	---[e]	>5.1
Cu	0.3	0.4	0.2	0.2	0.3	0.37	---[e]	---[e]	> 40
Fe	3.7	3.4	3.9	3.0	3.5	6.42	---[e]	---[e]	>500
Total Hg	0.08	0.07	**0.40**	0.01	0.07	0.08	---[e]	---[e]	*>0.10*
MeHg	0.06	0.08	**0.39**	0.01	0.06	---[e]	*> 0.3*	---[e]	---[e]
K	3,468	3,541	2,888	2,811	3,160	---[e]	---[e]	---[e]	---[e]
Mg	264	280	194	212	234	287	---[e]	---[e]	>3,000
Mn	<0.2	<0.2	<0.2	<0.2	<0.2	<0.25	---[e]	---[e]	>400
Mo	<0.1	<0.1	<0.1	<0.1	<0.1	0.08	---[e]	---[e]	> 10
Na	240	267	348	321	291	---[e]	---[e]	---[e]	---[e]
Ni	<0.1	<0.1	<0.1	<0.1	<0.1	0.03	---[e]	---[e]	> 50
P	2,510	2,618	1,886	1,883	2,198	---[e]	---[e]	---[e]	---[e]
Pb	<0.1	<0.1	<0.1	<0.1	<0.1	<0.04	---[e]	---[e]	> 40
S	1,849	1,829	1,760	2,046	1,868	---[e]	---[e]	---[e]	---[e]
Se	0.27	0.25	0.16	**3.4**	0.43	0.60	*>1.5*	---[e]	*> 0.8*
Sr	0.2	0.7	0.3	0.6	0.4	2.0	---[e]	---[e]	>2,000
V	<0.2	<0.2	<0.2	<0.2	<0.2	<0.1	---[e]	---[e]	> 10
Zn	3.6	3.6	3.9	4.1	3.8	7.4	---[e]	---[e]	> 45

[a] = See Table 3 for element abbreviations, methods of analysis, and limits of detection.
[b] = Based on Blanchard *et al.* 1993; Wilson *et al.* 1995; Thomas *et al.* 1997, 1998; Simpson and Lusk 2000; and on unreported data from Bristol *et al.*(1997).
[c] = Based on USEPA 2000; fish consumption not recommended based cancer or chronic systemic effects using 8 oz meal size and other assumptions.
[d] = Based on NRC 1980; Eisler 1985; Eisler 1986; Eisler 1987; Eisler 1993; Eisler 1994; Eisler 1997; and USDOI 1998.
[e] = Data not available.

Table 7. Comparison of the Geometric Mean Concentrations of Trace Elements in Re-integrated Fish collected from Four Navajo Nation Recreational Lakes to Whole Fish Collected from the San Juan River Basin, Collected Nationwide and General Dietary Concentrations of Concern for Wildlife.

Element (ug/g Dry Weight)[a]	Asaayi Lake Trout	Morgan Lake Catfish and Bass	Red Lake Catfish	Wheat-fields Lake Trout	All Catfish	All Trout	Fish From All Lakes	San Juan River Fish[b]	Fish Sampled Nationwide (85th Percentile)[c]	General Dietary Level of Concern for Wildlife[d]
Al	27.0	31.2	130.6	16.7	72.0	21.2	36.8	171.8	---[e]	>1,000
As	0.9	0.7	0.9	1.0	0.8	0.9	0.9	0.3	1.2	> 30
B	0.5	1.0	2.1	0.4	1.8	0.5	0.8	1.1	---[e]	> 30
Ba	6.2	3.4	51.0	5.8	16.5	6.0	8.9	7.4	---[e]	---[e]
Be	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.05	---[e]	> 3
Ca	21,960	50,884	58,161	22,991	52,087	22,470	34,962	---[e]	---[e]	---[e]
Cd	0.02	0.02	0.11	0.02	0.2	0.2	0.03	0.06	0.28	>0.5
Cr	0.5	2.2	2.2	0.5	2.0	0.5	1.1	0.7	---[e]	> 10
Cu	3.1	1.6	2.0	2.7	1.9	2.9	2.3	3.6	5.1	> 120
Fe	101	89	221	52	155	73	101	210	---[e]	>1,000
Hg	0.27	0.03	**1.00**	0.24	0.20	0.26	0.21	0.19	*0.81*	*>0.3*
K	10,826	9,084	9,108	11,659	9,035	11,235	10,109	---[e]	---[e]	---[e]
Mg	1,076	1,616	1,540	1,178	1,509	1,126	1,332	1038	---[e]	>10,000
Mn	19.1	9.5	44.3	4.2	24.4	9.0	13.6	16.4	---[e]	>1,000
Mo	0.5	0.4	0.4	0.4	0.4	0.5	0.4	0.4	---	> 30
Na	3,394	4,769	5,958	3,615	5,477	3,503	4,321	---[e]	---[e]	---[e]
Ni	0.3	1.2	1.3	0.4	1.2	0.3	0.6	0.5	---[e]	>300
P	18,037	30,471	32,870	19,454	30,502	18,732	24,349	---[e]	---[e]	---[e]
Pb	0.1	0.2	0.4	0.1	0.3	0.1	0.2	0.4	---[e]	> 120
S	7,393	7,583	6,619	7,788	6,913	7,588	7,332	---[e]	---[e]	---[e]
Se	1.3	**12.1**	1.5	1.4	**3.7**	1.4	2.4	2.6	*3.1*	> 3
Sr	28.8	269.6	208.2	49.3	217.6	27.7	94.5	53.0	---[e]	>5,000
V	0.5	0.6	1.7	0.4	1.2	0.5	0.7	0.6	---[e]	> 30
Zn	84.8	76.5	81.3	85.5	82.3	85.2	82.0	82.5	258	>180

[a] = See Table 3 for element abbreviations, methods of analysis, and limits of detection.
[b] = Based on Simpson and Lusk (2000).
[c] = Based on Schmitt and Brumbaugh (1990); 85th percentile concentration converted to dry weight using 76.6 % moisture.
[d] = Based on NRC 1980; Eisler 1985; Eisler 1986; Eisler 1987; Eisler 1993; Eisler 1994; Eisler 1997; and USDOI 1998.
[e] = Data not available.

Mercury and Methylmercury in Water and Fish

Mercury and Methylmercury Dissolved in Water

The average concentrations of mercury dissolved in ambient lake water samples are reported in Tables 4 and 5. The highest dissolved mercury concentrations were found at Red Lake (~3.63 ng/L) and was below our detection limit at Morgan Lake (<0.5 ng/L). Dissolved mercury concentrations were significantly correlated with water temperature (r^2= -0.77), specific conductivity (r^2= -0.91), secchi disk visibility (r^2= -0.73), turbidity (r^2= 0.82), maximum lake depth (r^2= -0.88) and surface-to-depth ratio (r^2= -0.81). That is, in the four lakes studied, more dissolved mercury was found in those lakes that were warmer, more turbid, and shallow (*e.g.*, Red Lake) and less in those lakes that were cold, clear and deep (*e.g.* Asaayi Lake).

The average concentrations of total methylmercury in ambient lake water samples are reported in Table 5. As a percentage of dissolved mercury, methylmercury was approximately 4% in Asaayi Lake, 8% in Wheatfields Lake, and 6 % in Red Lake. The highest average methylmercury concentrations were found at Red Lake (0.21 ng/L; higher at the south end and decreasing northward) and the lowest were found at Morgan Lake (0.02 ng/L). Average methylmercury concentrations were 0.07 ng/L at Asaayi Lake and 0.15 ng/L at Wheatfields Lake. Harris and Snodgrass (1993) reported that ambient background methylmercury concentrations are approximately 0.05 ng/L. They cautioned however, that due to the long-range atmospheric transport of mercury and other atmospheric emissions, the current “background” mercury concentrations in water probably reflect an anthropogenic influence even in “pristine” lakes. Total methylmercury concentrations in water were significantly correlated with maximum lake depth (r^2= -0.60), specific conductivity (r^2= -0.53), secchi disk visibility (r^2= -0.68), turbidity (r^2= 0.70), maximum lake depth (r^2= -0.88) and surface-to-depth ratio (r^2= -0.54). That is, similar to dissolved mercury, more methylmercury was found in those lakes that were warmer, more turbid, and shallow (*e.g.*, Red Lake) and less in those lakes that were cold, clear and deep (*e.g.* Asaayi Lake) though these correlations were not as robust.

Mercury concentrations in water were below the Navajo Nation numeric criteria for mercury for all designated uses. However, methylmercury is generally more toxic than inorganic mercury to aquatic organisms. Methylmercury in these lakes would not be expected to exert aquatic plant toxicity (*i.e.*, > 800 ng/L; USEPA 1997). Concentrations of methylmercury that induce toxic effects in aquatic invertebrates are greater than 40 ng/L. Wiener and Spry (1996) suggested that histological changes and effects to fish behavior, reproduction, and development could occur at water concentrations as low as 100 ng/L. During the period sampled, the range of methylmercury concentrations (0.017 to 0.418 ng/L) measured in the lake water did not exceed these levels of concern for toxicity to aquatic life.

Bald Eagle Water Quality Criteria

Calculation of protective numeric criteria to protect wildlife (WC) such as the bald eagle through the consumption of fish was based upon a reference dose approach, combined with the extent to which mercury becomes concentrated in the fish from the four lakes sampled (per Russell 2003). The BAFs were 4.2×10^{-6} for Asaayi, 1.6×10^{-6} for Wheatfields Lake,

7.5×10^{-6} for Red Lake, and 1.3×10^{-6} for Morgan Lake. Using these BAFs, the methylmercury wildlife criteria (WC) would be 0.11 ng/L for Asaayi Lake, 0.27 ng/L for Wheatfields Lake, 0.06 ng/L for Red Lake, and 0.35 ng/L for Morgan Lake. The WC for mercury was calculated using the estimate of methylmercury as a proportion of dissolved mercury in water for Asaayi, Wheatfields, and Red Lakes (as 0.039, 0.084, and 0.059, respectively; mercury was not found above the detection limit at Morgan Lake). Using these values, a methylmercury WC of 0.11 ng/L, 0.27 ng/L, and 0.35 ng/L corresponds to a mercury WC of 2.7 ng/L at Asaayi Lake, 3.2 ng/L at Wheatfields Lake, and 1.0 ng/L at Red Lake. Therefore, the current water quality standard to protect aquatic life (12 ng/L) may not be protective of bald eagles through the consumption of fish from these waters. The WC for mercury is the concentration in surface water that, if not exceeded, protects both bald eagles that use the water for drinking or as a foraging source. Thus, the WC is the highest aqueous concentration of mercury that causes no significant reduction in growth, reproduction, or viability of a population of animals exposed over multiple generations and may be an appropriate goal to protect bald eagles that forage on fish from these lakes (*i.e.*, 1.0 ng/L).

Mercury and Methylmercury in Fish Tissues

The average concentrations of methylmercury and mercury in fish fillets or in re-integrated fish samples are reported in Tables 4 and 6. Mercury concentrations in trout ranged from 0.03-0.11 mg/kg WW and from 0.01-0.27 mg/kg WW in catfish. Stafford and Haines (1997) and Walter *et al.* (1973) reported ambient concentrations of mercury in trout (0.1-0.4 mg/kg WW) and channel catfish (0.1-0.3 mg/kg WW). Simpson and Lusk (2000) reported that concentration of mercury in whole body fish collected from the San Juan River were <0.05 to 0.32 mg/kg WW. The USDOI (1998) reported that warmwater fish (bluegill) experienced toxic effects above 0.11 mg/kg WW. All catfish samples from Red Lake had mercury concentrations above this threshold of concern, depending on species sensitivity.

By excluding Morgan Lake data (which were below the detection limit), dissolved mercury concentrations in water were significantly correlated with mercury concentrations in fish fillets (r^2= 0.96) and in re-integrated fish (r^2= 0.96). By including Morgan lake data, methylmercury concentrations in water were more weakly correlated with methylmercury concentrations in fish fillets (r^2= 0.56) and in re-integrated fish (r^2= 0.39). By excluding Morgan Lake data, methylmercury concentrations in fish fillets were significantly correlated (r^2= 0.96) with mercury concentrations in re-integrated fish.

Methylmercury concentrations in catfish fillets were significantly correlated with average length (r^2= 0.87) and average weight (r^2= 0.88). There was no significant correlation found for the trout size and methylmercury in their fillets. For consideration of a consumption advisory that is based on the catfish, the relationship between methylmercury concentrations in catfish fillets and average catfish weight (in grams) can be described by the equation:

$$\text{MeHg in Fillets} = -0.4512 + 0.0095 \times \text{Average Total Weight (g)} \qquad \text{(Equation 9)}$$

Similar to water, mercury concentrations in re-integrated fish were significantly correlated with the specific conductivity (r^2= -0.75), secchi disc visibility (r^2= -0.67), and turbidity (r^2= 0.78) of the lake surface, as well as the maximum depth (r^2= 0.71) and surface-to-depth ratio (r^2= -0.90) of the lakes. That is, more mercury was found in fish from lakes that had lower oxygen content, less salinity, and were more turbid and shallow in relation to their size. Mercury concentrations in whole fish also positively correlated with concentrations of Ba (r^2= 0.81), Mn (r^2= 0.76), S (r^2= 0.70), and V (r^2= 0.72) in the tissue.

Human Health Risks

The goal of the Navajo Nation Lake Fish and Water Quality Investigation was to provide data that may be used to *estimate* mercury risks to human health (and to bald eagles) from the consumption of fish obtained from selected recreational lakes on the Navajo Nation. These data can be also used to develop site-specific bioaccumulation factors and to evaluate the need for management actions to limit fish consumption, reduce the process of methylation, or perhaps recommend reductions of local mercury emissions and discharges under various authorities of the Navajo Nation. This study was not designed to determine the sources of mercury found in water or fish. This study also did not determine the fish consumption patterns of the local community, which is the most critical factor in estimating human health exposures and therefore for the estimation of potential health risks.

Without these local estimates of fish consumption, national default consumption values were assumed for this study. However, although large-scale surveys of mercury contents of fish and fish consumption patterns have been conducted (USEPA 2000), these surveys have limitations for applications to a human health risk assessment on the Navajo Nation. Estimates of dietary intakes of mercury in food based on national or regional data cannot accurately reflect the intake of mercury from locally harvested foods, including vegetables, fish, and game. This can be a particularly important limitation when the people of concern are those whose diet contains a large portion of locally caught fish. National estimates do not address how many anglers are in an area, when and how often they catch fish, and to whom they may distribute fish to within a community, or any cultural practices that augment or limit fish consumption. To reduce these uncertainties, the contributions of mercury in local fish can be assessed by conducting consumption surveys for the local population of concern.

Every local population in the United States is exposed to a wide variety of metals in air, food, drinking water, and soils derived from both natural and anthropogenic sources. The distinction between natural and anthropogenic sources can sometimes be further blurred when a previously deposited metal is recycled by natural processes, thereby becoming an important source in some ecosystems. For many metals, present-day exposures are expected to be above the natural background doses and the biological implications of any increase in levels of historical human exposures are unknown. One collateral effect of background contribution to human metal intake would be to push the total exposure over the toxicity threshold depending on a person's relative amount of fish consumption. This is likely the case for mercury.

Using default assumptions for fish consumption, body weight, days of exposure, and the geometric mean of methylmercury concentrations in fish fillets from the four lakes sampled, those men, women, and children that consume fish on a *recreational* basis are not at significant health risks (Table 9). However, children that eat fish on a frequent basis (>150 days per year), or any adult whose diet contains a large portion of catfish from Red Lake may be at risk of mercury toxicity. Using consumption scenarios and Red Lake fish fillet data, consumption of more than 2 fish per month would not be recommended (Table 10). In the context of consumption of contaminated fish, risk managers may need to consider the fish consumption patterns around Red Lake and, if necessary, seek ways to minimize the health risk to people that eat lots of fish, depending on local conditions including social and cultural factors and the benefits of eating fish. However, a long-term goal may be to reduce the mercury contamination of the water body or reduce the rate of mercury accumulation in the fish tissue through a variety of means, including source control and management.

Bald Eagle Health Risks

Using default assumptions for fish consumption, body weight, days of exposure, and averaging time, and using the geometric mean of methylmercury concentrations in re-integrated fish from the four lakes sampled, bald eagles that migrate through the Navajo Nation and consume fish equally from the all four lakes sampled are not at significant health risks (Table 10). However, bald eagles that consume catfish from Red Lake on a frequent basis (>30 days per year), have the potential to experience mercury toxicity. Bald eagles that may feed on catfish from Red Lake for over 60 days are at a significant health risk to mercury. Bald eagles that forage exclusively from Morgan Lake have the lowest exposure to mercury but the highest exposure to selenium. Bald eagles that attempt to establish nesting on the Navajo Nation may need to be monitored for their long-term mercury exposure and effects. There are few management options to affect bald eagle consumption patterns around Red Lake, and therefore additional information would be needed to identify if extensive use is occurring and to determine if there are additional sources of mercury to Red Lake. However, a long-term goal to reduce the mercury contamination of the water body or reduce the rate of mercury accumulation in the fish tissue through a variety of means would be recommended for bald eagles that feed at Red Lake.

Table 8. Human Health Risk Quotients for Children, Women, and Men Using Various Fish Exposure Scenarios for Each Lake and for All Lakes Combined. [Note: exposure duration of 365 days and body mass data not shown]

Lake Scenario	*Consumer Scenario*	*MeHg in Fillets (mg/kg WW)*	*Fish Consumption (kg/day)*	*Exposure to Fish (days/yr)*	*MeHg Dose (mg/kg-day)*	*USEPA Reference Dose (RfD)*	*Risk Quotient > 1 ?*
Asaayi Lake	***Child - Recreation***	0.06	0.0175	14	2.78E-06	0.0001	0.03
Asaayi Lake	***Child - Subsistence***	0.06	0.1424	156	2.52E-04	0.0001	**2.52**
Wheatfields Lake	***Child - Recreation***	0.08	0.0175	14	3.70E-06	0.0001	0.04
Wheatfields Lake	***Child - Subsistence***	0.08	0.1424	156	3.36E-04	0.0001	**3.36**
Morgan Lake	***Child - Recreation***	0.01	0.0175	14	4.63E-07	0.0001	0.00
Morgan Lake	***Child - Subsistence***	0.01	0.1424	156	4.20E-05	0.0001	0.42
Red Lake	***Child - Recreation***	0.39	0.0175	14	1.81E-05	0.0001	0.18
Red Lake	***Child - Subsistence***	0.39	0.1424	156	1.64E-03	0.0001	**16.37**
All lakes combined	***Child - Recreation***	0.07	0.0175	14	3.01E-06	0.0001	0.03
All lakes combined	***Child - Subsistence***	0.07	0.1424	156	2.73E-04	0.0001	**2.73**
Asaayi Lake	***Woman - Recreation***	0.06	0.0175	14	6.20E-07	0.0001	0.01
Asaayi Lake	***Woman - Subsistence***	0.06	0.1424	156	5.62E-05	0.0001	0.56
Wheatfields Lake	***Woman - Recreation***	0.08	0.0175	14	8.26E-07	0.0001	0.01
Wheatfields Lake	***Woman - Subsistence***	0.08	0.1424	156	7.49E-05	0.0001	0.75
Morgan Lake	***Woman - Recreation***	0.01	0.0175	14	1.03E-07	0.0001	0.00
Morgan Lake	***Woman - Subsistence***	0.01	0.1424	156	9.36E-06	0.0001	0.09
Red Lake	***Woman - Recreation***	0.39	0.0175	14	4.03E-06	0.0001	0.04
Red Lake	***Woman - Subsistence***	0.39	0.1424	156	3.65E-04	0.0001	**3.65**
All lakes combined	***Woman - Recreation***	0.07	0.0175	14	6.71E-07	0.0001	0.01
All lakes combined	***Woman - Subsistence***	0.07	0.1424	156	6.09E-05	0.0001	0.61
Red Lake	***Man - Recreation***	0.39	0.0175	14	3.36E-06	0.0001	0.03
Red Lake	***Man - Subsistence***	0.39	0.1424	156	3.04E-04	0.0001	**3.04**
All lakes combined	***Man - Recreation***	0.07	0.0175	14	5.59E-07	0.0001	0.01
All lakes combined	***Man - Subsistence***	0.07	0.1424	156	5.07E-05	0.0001	0.51

Table 9. Estimation of the Maximum Allowable Fillet Consumption Rate and the Maximum Allowable Fish Consumption Rates for each Lake Scenario that has a Risk Quotient > 1. [Note: RfD of 0.0001 mg/kg-bw/day not shown]

Consumer Scenario	**Lake Scenario**	**Consumer Body mass (kg)**	**Geometric Mean Fillet MeHg (mg/kg WW)**	**Maximum Allowable Daily Fillet Consumption (ounces/day)**	**Maximum Allowable Weekly Fillet Consumption (8-oz. fillets)**	**Maximum Allowable Number of Fish per Week (1-lb. fish)**	**Maximum Allowable Number of Fish per Month (1-lb. fish)**
Children - Subsistence	All lakes	14.5	0.07	0.8	6.3	3	13
Children - Subsistence	Asaayi Lake	14.5	0.06	0.9	6.8	3	14
Children - Subsistence	Red Lake	14.5	0.39	0.1	1.0	0.5	2
Children - Subsistence	Wheatfields Lake	14.5	0.08	0.6	5.1	3	10
Women - Subsistence	Red Lake	65.0	0.39	0.6	4.7	2	9
Men - Subsistence	Red Lake	78.0	0.39	0.7	5.6	3	11

Table 10. Bald Eagle Health Risk Quotients for Various Exposure Scenarios for Each Lake, for various Types of Lakes, and for All Lakes Combined. [Note: averaging time of 10950 days not shown]

Bald Eagle Exposure Scenario	Geometric Mean Mercury Concentration in Whole Fish (mg/kg WW)	Fraction of Fish in the Total Diet	Food Ingestion Rate (kg/day)	Exposure Frequency (days an bald eagle spends in an area)	Exposure Duration (estimated bald eagle lifetime - years)	Bald Eagle Body Mass (kg)	Mercury Ingestion Rate (mg/kg/day)	Risk Quotient > 1 ?
Migrant ~ All lakes combined	0.05	0.71	0.583	30	30	0.525	0.0073	0.3
Migrant ~ Asaayi Lake	0.07	0.71	0.583	30	30	0.525	0.0067	0.3
Migrant ~ Coldwater lakes	0.06	0.71	0.583	30	30	0.525	0.0078	0.4
Migrant ~ Morgan Lake	0.01	0.71	0.583	30	30	0.525	0.0011	0.1
Migrant ~ Red Lake	0.23	0.71	0.583	30	30	0.525	0.0436	**2.1**
Migrant ~ Warmwater lakes	0.05	0.71	0.583	30	30	0.525	0.0067	0.3
Migrant ~ Wheatfields Lake	0.06	0.71	0.583	30	30	0.525	0.0089	0.4
Wintering ~ All lakes combined	0.05	0.71	0.583	182	30	0.525	0.0441	**2.1**
Wintering ~ Asaayi Lake	0.07	0.71	0.583	182	30	0.525	0.0407	**1.9**
Wintering ~ Coldwater lakes	0.06	0.71	0.583	182	30	0.525	0.0474	**2.3**
Wintering ~ Morgan Lake	0.01	0.71	0.583	182	30	0.525	0.0068	0.3
Wintering ~ Red Lake	0.23	0.71	0.583	182	30	0.525	0.2643	**12.6**
Wintering ~ Warmwater lakes	0.05	0.71	0.583	182	30	0.525	0.0407	**1.9**
Wintering ~ Wheatfields Lake	0.06	0.71	0.583	182	30	0.525	0.0542	**2.6**
Nesting ~ All lakes combined	0.05	0.71	0.583	365	30	0.525	0.0883	**4.2**
Nesting ~ Asaayi Lake	0.07	0.71	0.583	365	30	0.525	0.0815	**3.9**
Nesting ~ Coldwater lakes	0.06	0.71	0.583	365	30	0.525	0.0951	**4.5**
Nesting ~ Morgan Lake	0.01	0.71	0.583	365	30	0.525	0.0136	0.6
Nesting ~ Red Lake	0.23	0.71	0.583	365	30	0.525	0.5301	**25.2**
Nesting ~ Warmwater lakes	0.05	0.71	0.583	365	30	0.525	0.0815	**3.9**
Nesting ~ Wheatfields Lake	0.06	0.71	0.583	365	30	0.525	0.1087	**5.2**

CONCLUSIONS AND RECOMMENDATIONS

Are fish safe to eat at the four lakes sampled on the Navajo Nation?

Based on the data available, the Navajo people can and should feel comfortable consuming fish on a recreational basis from Asaayi, Wheatfields, and Morgan Lakes (that is, at no more than 14 meals of fish per year). However, some fish in Red Lake may contain mercury at levels that may pose health risks to certain people who eat fish frequently – especially women of childbearing age, nursing mothers, infants and young children. Additionally, selenium concentrations in fish from Morgan Lake may also pose health risks to certain people who eat those fish frequently. To reduce exposure to these contaminants, individuals may want to consult the Navajo Nation and seek advice from doctors to help make choices about which fish to eat and how often to reduce any health risks.

Individual people and communities, as well as ecological systems, are subjected to many stressors. Most risk assessment calculations, including those used in this study, take a single-source–single-effect approach, thereby ignoring this complexity. In the final analysis, it will be important to consider not only the potential adverse effects of mercury, but also the potential nutritional benefits of fish consumption. There could be critical need by the local population for food security and traditional diet containing fish that warrant consideration. Any anticipated dietary composition changes by fish consumption advisories must be considered in light of the public health challenges faced by the Navajo community.

How can the human health risks be reduced?

The Navajo Nation has the primary responsibility for protecting their residents from the risks of eating contaminated fish. After reviewing the relative health risks and benefits of fish consumption, the Navajo Nation can issue fish consumption advisories for the general population (including for recreation or those that eat a lot of fish) or for sensitive subpopulations (such as pregnant women, nursing mothers, and children), or take no action. Fish consumption advisories are meant to inform people about unacceptable concentrations of chemical contaminants that have been found in local fish. They also can recommend limiting or avoiding consumption of certain fish species from specific waterbodies or, in some cases, identify those lakes where fish consumption would be considered beneficial.

One of the most important techniques to manage human health risks is to identify those whose diets contain a large portion of fish and communicate any risks posed by mercury or other contaminants to them while considering the nutritional role fish plays in their diet.

What about mercury in the air?

Although most of the largest and most direct sources of mercury releases to water and air have been regulated in the U.S., the levels of mercury in fish continue to be a concern. The Navajo Nation may want to monitor atmospheric depositions of mercury onto the Navajo Nation's land and water. Over time, the Navajo Nation, along with others, may need to establish effective source control and management programs to reduce the widespread mercury contamination of their aquatic environments. Such actions could eventually reduce mercury contamination so that fish consumption advisories can be removed, but this process could take decades, and would need to be an effort coordinated with others.

How can bioaccumulation of mercury in lakes and wetlands be reduced?

Pollution prevention is one of the most effective means of reducing fish contamination, therefore it is important to identify any sources and their magnitudes, so that they can be better managed or reduced. For instance, methylmercury concentrations were highest in the southern portion of the Red Lake and further reconnaissance of this portion of the lake may be warranted. If necessary, oxygenation, increasing the pH, riparian shading, excavation, sulfate reduction, flood peak minimization, vegetative uplands, riparian filter strips, increased filtration, species management, and recreational fisheries management may alter the forms and bioavailability of mercury and thereby reduce the mercury burden within fish.

What about other contaminants of concern and protective water quality criteria?

Water quality criteria for aluminum developed for waters of the Navajo Nation may need to consider exposure to aluminum particles in the development of a site-specific standard for aluminum in certain recreational lakes. Selenium contamination within Morgan Lake may be reducing the reproductive success of fish and wildlife. The sources of this selenium contamination should be identified and if necessary, protective water quality criteria could be designed in order to reduce the potential population impacts to fish and wildlife residing at Morgan Lake. Current Navajo Nation water quality criteria do not consider the pathway of consumption of mercury in fish to predatory wildlife, and therefore the aquatic life criteria for mercury may not be fully protective of wildlife. Criteria to protect piscivorous birds and mammals from mercury toxicity through fish consumption are warranted. It is also important to note that other environmental contaminants, such as polychlorinated biphenyl compounds and organochlorine pesticides, were not quantified in the fish collected, and these contaminants could present additional hazards to people and wildlife. An additional fish tissue quality-monitoring program that includes these contaminants is recommended.

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Appendices for the Navajo Nation Lake Fish and Water Quality Investigation

Appendix A. Common and Scientific Names of Fish That May Occur on the Navajo Nation.

Common Name	Scientific Name
White sucker	*Catostomus commersoni*
Bluehead sucker	*Catostomus discobolus discobolus*
Zuni bluehead sucker	*Catostomus discobolus yarrowi*
Flannelmouth sucker	*Catostomus latipinnis*
Mottled sculpin	*Cottus bairdi*
Red shiner	*Cyprinella lutrensis*
Common carp	*Cyprinus carpio*
Threadfin shad	*Dorosoma petenense*
Plains killifish	*Fundulus zebrinus*
Western mosquitofish	*Gambusia affinis*
Bonytail chub	*Gila elegans*
Roundtail chub	*Gila robusta robusta*
Black bullhead	*Ictalurus melas*
Channel catfish	*Ictalurus punctatus*
Green sunfish	*Lepomis cyanellus*
Bluegill	*Lepomis macrochirus*
Longear sunfish	*Lepomis megalotis*
Largemouth bass	*Micropterus salmoides*
Striped bass	*Morone saxatilis*
Rainbow trout	*Oncorhynchus gairdneri*
Yellow perch	*Perca flavescens*
Fathead minnow	*Pimephales promelas*
White crappie	*Pomoxis annularis*
Colorado pikeminnow	*Ptychocheilus lucius*
Speckled dace	*Rhinichthys osculus*
Brown trout	*Salmo trutta*
Walleye	*Stizostedion vitreum*
Razorback sucker	*Xyrauchen texanus*

Appendix B. Common and Scientific Names of Plants That May Occur on the Navajo Nation.

Common Name	Scientific Name
Box elder	*Acer interius*
Streambank wheatgrass	*Agropyron riparium*
Western wheatgrass	*Agropyron smithii*
Wheatgrass	*Agropyron sp.*
Slender wheat grass	*Agropyron trachycaulum*
Redtop	*Agrostis alba*
Creeping bentgrass	*Agrostis palustris*
Water foxtail	*Alopecurus aegaulilis sobol*
Tumbleweed	*Amaranthus graecizans*
Flatspine burr ragweed	*Ambrosia acanthicarpa*
Serviceberry	*Amelanchier alnifolia*
Western service berry	*Amelanchier utahensis*
Rockcress	*Arabis perennans*
Three-awns	*Aristida sp.*
Indian root	*Aristolochia watsoni*
Tarragon	*Artemisia dracunculoides*
Fringed sage	*Artemisia frigida*
White sagebrush	*Artemisia ludoviciana*
Black sagebrush	*Artemisia nova*
Basin big sagebrush	*Artemisia tridentata*
Milkweed	*Asclepias fascicularis*
Four-wing saltbush	*Atriplex canescens*
Shadescale	*Atriplex confertifolia*
Annual atriplex	*Atriplex hastate*
Redscale	*Atriplex rosea*
Wild oat	*Avena fatua*
American slough grass	*Beckmannia syzigachne*
Water birch	*Betula occidentalis*
Blue gramma	*Bouteloua gracilis*
Meadow brome	*Bromus commutatus*
Cheatgrass	*Bromus tectorum*
Emory’s Sedge	*Carex emoryi*
Stalkgrain sedge	*Carex stipata*
Fox sedge	*Carex vulpinoidea*
Indian paintbrush	*Castilleja linariaefolia*
Netleaf hackberry	*Celtis reticulata*
Mountain-mahogany	*Cercocarpus montanus*
Lambsquarters	*Chenopodium album*
Rubber rabbitbrush	*Chrysothamnus nauseosus*
Chicory	*Cichorium intybus*
Water hemlock	*Cicuta douglasii*

Appendix B continued. Common and Scientific Names of Plants That May Occur on the Navajo Nation.

Common Name	Scientific Name
Parry's thistle	*Circium parryi*
Virgin's bower	*Clematis lingustifolia*
Rocky mountain beeplant	*Cleome serrulata*
Field bindweed	*Convolvulus arvensis*
Redosier dogwood	*Cornus stolonifera*
Cliffrose	*Cowania mexicana*
River hawthorn	*Crataegus rivularis*
Missoure gourd	*Cucurbita foetidissima*
Cymopterus	*Cymopterus newberryi*
Cymopterus	*Cympoterus fendleri*
Orchard grass	*Dactylis glomerata*
Western tansymustard	*Descurainia pinnata*
Hairy crabgrass	*Digitaria sanguinalis*
Salt grass	*Distichlis stricta*
Barnyard grass	*Echinochloa crusgalli*
Russian olive	*Elaeagnus angustifolia*
Spike rush	*Eleocharis macrostachya*
Creeping spike rush	*Eleocharis palustris*
Canada wildrye	*Elymus canadensis*
Mormon tea	*Ephedra torreyana*
Green joint-fir	*Ephedra viridis*
American willowherb	*Epilobium adenocaulon*
Common horsetail	*Equisetum arvense*
Dwarf horsetail	*Equisetum kansanum*
Smooth scouring rush	*Equisetum laevigatum*
Green rabbitbrush	*Ericameria viscidiflora*
Bisti fleabane	*Erigeron bistiensis*
Canadian fleabane	*Erigeron canadensis*
Buckwheat	*Eriogonum sp.*
Red-stemmed filaree	*Erodium cicutarium*
Blister cress	*Erysium rapandum*
Ridgeseed spurge	*Euphorbia glyptosperma*
Thyme leaved spurge	*Euphorbia serpyllifolia*
Barrel cactus	*Ferocactus wislizenii*
Meadow fescue	*Festuca elatior*
New Mexico olive	*Forestiera neomexicana*
Reed manna grass	*Glyceria grandis*
American licorice	*Glycyrrhiza lepidota*
Spiny hopsage	*Grayia spinosa*
Broom snakeweed	*Gutierrezia sarothrae*
Common sunflower	*Helianthus annuus*

Appendix B continued. Common and Scientific Names of Plants That May Occur on the Navajo Nation.

Common Name	Scientific Name
Golden aster	*Heterotheca villosa*
Galleta	*Hilaria jamesii*
Foxtail barley	*Hordeum jubatum caespitosum*
Wall barley	*Hordeum murinum*
Cultivated barley	*Hordeum vulgare*
Wiregrass	*Juncus balticus*
Torrey's rush	*Juncus torreyi*
Juniper	*Juniperus spp.*
Mexican-fireweed	*Kochia scoparia*
Little leaf ratany	*Krameria sp.*
Blue lettuce	*Lactuca pulchella*
Aspen pea	*Lathyrus laetivirens*
Hoary cress	*Lepidium drapa*
Desert pepperweed	*Lepidium fremonti*i
Clasping pepperweed	*Lepidium perfoliatum*
Blue flax	*Linum lewisi*i
Spurred lupine	*Lupinus laxiflorus*
Small lupine	*Lupinus pusillus*
Pale wolfberry	*Lycium pallidum*
Nees	*Machaeranthera tanacetifolia*
Cheeseweed mallow	*Malva parviflora*
Horehound	*Marrubium vulgare*
Black medick	*Medicago lupulina*
Alfalfa	*Medicago sativa*
White sweetclover	*Melilotus albus*
Yellow sweetclover	*Melilotus officinalis*
Mint	*Mentha penardi*
Adonis blazingstar	*Mentzelia multiflora*
Common monkeyflower	*Mimulus guttatus*
Colorado four-o'clock	*Mirabilis multiflora*
Pony beebalm	*Monarda pectinata*
Scratchgrass	*Muhlenbergia asperifolia*
Sandhill muhly	*Muhlenbergia pungens*
Muhly	*Muhlenbergia torreyi*
European watercress	*Nasturtium Officinale*
Evening primrose	*Oenothera marginata*
Cholla	*Opuntia sp.*
Pricklybear cactus	*Opuntia sp.*
Indian ricegrass	*Oryzopsis hymenoides*
Witchgrass	*Panicum capillare*
Virginia creeper	*Parthenocissus inserta*

Appendix B continued. Common and Scientific Names of Plants That May Occur on the Navajo Nation.

Common Name	Scientific Name
Timothy	*Phleum pratense*
Common reed	*Phragmites communis*
Pinyon pine	*Pinus edulis*
Narrowleaf plantain	*Plantago lanceolata*
Common plantain	*Plantago major*
Kentucky bluegrass	*Poa pratensis*
Knotgrass	*Polygonum aviculare*
Annual rabbitsfoot grass	*Polypogon monospeliensis*
Narrow-leaf cottonwood	*Populus angustifolia*
Rio Grande cottonwood	*Populus wislizenii*
Little hogweed	*Portulaca oleracea*
Silverweed	*Potentilla anserina*
Alkali grass	*Puccinellia pauciflora*
Antelope bitterbrush	*Purshia tridentata*
Oak	*Quercus sp.*
Alkali buttercup	*Ranunculus cymbalaria*
Poison ivy	*Rhus radicans*
Squawbush	*Rhus trilobata*
Wax currant	*Ribes cereum*
Watercress	*Rorippa nasturtium-aquaticum*
Spreading yellowcress	*Rorippa sinuata*
Wildrose	*Rosa fendleri*
Cutleaf coneflower	*Rudbeckia laciniata*
Curly dock	*Rumex crispus*
Peach-leaf willow	*Salix amygdaloides*
Coyote willow	*Salix exigua*
Pacific willow	*Salix lasiandra*
Russian thistle	*Salsola kali tenuifolia*
Greasewood	*Sarcobatus vermiculatus*
Hardstem bulrush	*Scirpus acutus*
Olney bulrush	*Scirpus americanus*
Cloaked bulrush	*Scirpus pallidus*
Bulrush	*Scirpus paludosus*
Giant bulrush	*Scirpus validus*
Brack’s fishhook cactus	*Sclerocactus cloveriae var. brackii*
Mesa Verde cactus	*Sclerocactus mesae-verdae*
Skullcap	*Scutellaria galericulata*
Rye	*Secale cereale*
Senecio	*Senecio cymbalarioides*
Threadleaf groundsel	*Senecio longilobus*
Green foxtail	*Setaria viridis*

Appendix B concluded. Common and Scientific Names of Plants That May Occur on the Navajo Nation.

Common Name	Scientific Name
Tumbling mustard	*Sisymbrium altissimum*
Bottlebrush squirreltail	*Sitanion hystrix*
False soloman's seal	*Smilacina stellata*
Cutleaf nightshade	*Solanum triflorum*
Goldenrod	*Solidago sparsiflora*
Emory's globe mallow	*Sphaeralcea emoryi*
Globemallow	*Sphaeralcea sp.*
Alkaki sacaton	*Sporobolus airoides*
Spike dropseed	*Sporobolus contractus*
Sand dropseed	*Sporobolus cryptandrus*
Salt cedar	*Tamarix chinensis*
Common dandelion	*Taraxacum officinale*
Mountain meadow rue	*Thalictrum fendleri*
Puncturevine	*Tribulus terrestris*
Rancheria clover	*Trifolium albopurpureum*
White clover	*Trifolium repens*
Wheat	*Triticum aestivum*
Common cattail	*Typha latifolia*
Brewer nettle	*Urtica breweri*
Common mullein	*Verbascum thapsus*
Golden crownbeard	*Verbesina encelioides*
Water speedwell	*Veronica anagallis-aquatica*
Rough cockleburr	*Xanthium strumarium*
Yucca	*Yucca spp.*
Cultivated corn	*Zea maes*

Appendix C. Common and Scientific Names of Birds That May Occur on the Navajo Nation.

Common Name	Scientific Name
Cooper's hawk	*Accipiter cooperii*
Sharp-shinned hawk	*Accipiter striatus*
Northern goshawk	*Accipter gentilis*
Spotted sandpiper	*Actitis macularia*
Western grebe	*Aechmorphorus occidentalis*
Northern sah-whet owl	*Aeogolius acadicus*
White-throated swift	*Aeronautes saxatalis*
Red-winged blackbird	*Agelaius phoeniceus*
Cassin's sparrow	*Aimophila cassinii*
Wood duck	*Aix sponsa*
Chukar	*Alectoris chukar*
Baird's sparrow	*Ammodramus bairdii*
Sage sparrow	*Amphispiza belli*
Black-throated sparrow	*Amphispiza bilineata*
Northern pintail	*Anas acuta*
American wigeon	*Anas americana*
Northern shoveler	*Anas clypeata*
Green-winged teal	*Anas crecca*
Cinnamon teal	*Anas cyanoptera*
Blue-winged teal	*Anas discors*
Mallard	*Anas platyrhynchos*
Gadwall	*Anas strepera*
White-fronted goose	*Anser albifrons*
Water pipit	*Anthus rebescens*
Western scrub jay	*Aphelocoma californica*
Golden eagle	*Aquila chrysaetos*
Black-chinned hummingbird	*Archilochus alexandri*
Great egret	*Ardea alba*
Great blue heron	*Ardea herodias*
Short-eared owl	*Asio flammeus*
Long-eared owl	*Asio otus*
Lesser scaup	*Aythya affinis*
Redhead	*Aythya americana*
Ring-necked duck	*Aythya collaris*
Canvasback	*Aythya valisineria*
Upland plover	*Bartramia longicauda*
Upland sandpiper	*Bartramia longicauda*
Cedar waxwing	*Bombycilla cedrorum*
Bohemian waxwing	*Bombycilla garrulus*
American bittern	*Botarus lentiginosus*

Appendix C continued. Common and Scientific Names of Birds That May Occur on the Navajo Nation.

Common Name	Scientific Name
Canada goose	*Branta canadensis*
Great-horned owl	*Bubo virginiansus*
Bufflehead	*Bucephala albeola*
Common goldeneye	*Bucephala clangula*
Barrow's goldeneye	*Bucephala islandica*
Red-tailed hawk	*Buteo jamaicensis*
Rough-legged hawk	*Buteo lagopus*
Ferruginous hawk	*Buteo regalis*
Swainson's hawk	*Buteo swainsoni*
Green heron	*Butorides virescens*
Lark bunting	*Calamospiza melanocorys*
Sanderling	*Calidris alba*
Baird's sandpiper	*Calidris bairdii*
Western sandpiper	*Calidris mauri*
Pectoral sandpiper	*Calidris melanotos*
Least sandpiper	*Calidris minutilla*
Gambel's quail	*Callipepla gambelii*
Scaled quail	*Callipepla squamata*
Lawrence's goldfinch	*Carduelis lawrencei*
Pine siskin	*Carduelis pinus*
Lesser goldfinch	*Carduelis psaltria*
American goldfinch	*Carduelis tristis*
Cassin's finch	*Carpodacus cassinii*
House finch	*Carpodacus mexicanus*
Turkey vulture	*Cathartes aura*
Hermit thrush	*Catharus guttatus*
Swainson's thrush	*Catharus ustulatus*
Canon wren	*Catherpes mexicanus*
Willet	*Catoptrophorus semipalmatus*
Greater Sage grouse	*Centrocercus urophasianus*
Brown creeper	*Certhia americana*
Belted kingfisher	*Ceryle alcyon*
Snowy plover	*Charadrius alexandrinus*
Mountain plover	*Charadrius montanus*
Semi-palmated plover	*Charadrius semipalmatus*
Killdeer	*Charadrius vociferus*
Snow goose	*Chen caerulescens*
Black tern	*Chlidonias niger*
Lark sparrow	*Chondestes grammacus*
Common nighthawk	*Chordeiles minor*
American Dipper	*Cinclus mexicanus*

Appendix C continued. Common and Scientific Names of Birds That May Occur on the Navajo Nation.

Common Name	Scientific Name
Norther harrier hawk	*Circus cyaneus*
Evening grosbeak	*Coccothraustes vespertinus*
Yellow-billed cuckoo	*Coccyzus americanus*
Northern flicker	*Colaptes auratus*
Band-tailed pigeon	*Columba fasciata*
Rock dove	*Columba livia*
Inca dove	*Columbina inca*
Olive-sided flycatcher	*Contopus cooperi*
Greater pewee	*Contopus pertinax*
Western wood-pewee	*Contopus sordidulus*
American crow	*Corvus brachyrhynchos*
Common raven	*Corvus corax*
Blue jay	*Cyanocitta crystata*
Steller’s jay	*Cyanocitta stelleri*
Black swift	*Cypseloides niger*
Blue grouse	*Dendragapus obscurus*
Black-throated blue warbler	*Dendroica caerulescens*
Yellow-rumped warbler	*Dendroica coronata*
Grace’s warbler	*Dendroica graciae*
Black-throated gray warbler	*Dendroica nigrescens*
Hermit warbler	*Dendroica occidentalis*
Palm warbler	*Dendroica palmarum*
Yellow warbler	*Dendroica petechia*
Townsend’s warbler	*Dendroica townsendi*
Black-throated green warbler	*Dendroica virens*
Gray catbird	*Dumetella carolinensis*
Snowy egret	*Egretta thula*
White pelican	*Elecanus erythorhynchos*
Western flycatcher	*Empidonax difficilis*
Hammond’s flycatcher	*Empidonax hammondii*
Dusky flycatcher	*Empidonax oberholseri*
Southwestern willow flycatcher	*Empidonax traillii extimus*
Gray flycatcher	*Empidonax wrightii*
Horned lark	*Eremophila alpestris*
Brewer’s blackbird	*Euphagus cyanocephalus*
Merlin	*Falco columbarius*
Prairie falcon	*Falco mexicanus*
American peregrine falcon	*Falco peregrinus anatum*
Arctic peregrine falcon	*Falco peregrinus tundrius*
American kestrel	*Falco sparverius*
American coot	*Fulica americana*

Appendix C continued. Common and Scientific Names of Birds That May Occur on the Navajo Nation.

Common Name	Scientific Name
Common snipe	*Gallinago gallinago*
Common gallinule	*Gallinula chloropus*
Greater roadrunner	*Geococcyx californianus*
Common yellowthroat	*Geothlypis trichas*
Pygmy owl	*Glaucidium californicum*
Blue grosbeak	*Guiraca caerulea*
PiZon jay	*Gymnorhinus cyanocephalus*
Bald eagle	*Haliaeetus leucocephalus*
Black-necked stilt	*Himantopus mexicanus*
Barn swallow	*Hirundo rustica*
Yellow-brested chat	*Icteria virens*
Northern oriole	*Icterus galbula*
Scott's oriole	*Icterus parisorum*
Mississippi kite	*Ictinia mississippiensis*
Least bittern	*Ixobrychus exilis*
Gray-headed junco	*Junco caniceps*
Dark-eyed junco	*Junco hyemalis*
Northern shrike	*Lanius exubitor*
Loggerhead shrike	*Lanius ludovicianus*
Herring gull	*Larus argentatus*
Laughing gull	*Larus atricilla*
California gull	*Larus californicus*
Ring-billed gull	*Larus delawarensis*
Bonaparte's gull	*Larus philidelphia*
Franklin's gull	*Larus pipixcan*
Black rosy finch	*Leucosticte atrata*
Brown-capped rosy finch	*Leucosticte australis*
Gray-crowned rosy finch	*Leucosticte tephrocotis*
Long-billed dowithcher	*Limnodromus scolopaceus*
Marbled godwit	*Limosa fedoa*
Hooded merganser	*Lophodytes cucullatus*
Red crossbill	*Loxia curvirostra*
Red-headed woodpecker	*Melanerpes erythrocephalus*
Acorn woodpecker	*Melanerpes formicivorus*
Lewis woodpecker	*Melanerpes lewis*
Surf scoter	*Melanitta perspicillata*
Turkey	*Meleagris gallopavo*
Lincoln's sparrow	*Melospiza lincolnii*
Song sparrow	*Melospiza melodia*
Common merganser	*Mergus merganser*
Red-breasted merganser	*Mergus serrator*

Appendix C continued. Common and Scientific Names of Birds That May Occur on the Navajo Nation.

Common Name	**Scientific Name**
Northern mockingbird	*Mimus polyglottos*
Black and white warbler	*Mniotilta varia*
Brown-headed cowbird	*Molothrus ater*
Townsend's solitaire	*Myadestes townsendi*
Ash-throated flycatcher	*Myiarchus cinerascens*
Clark's nutcracker	*Nucifraga columbiana*
Long-billed curlew	*Numenius americanus*
Black-crowned night heron	*Nycticorax nycticorax*
Whistling swan	*Olor columbianus*
MacGillivray's warbler	*Oporornsis tolmiei*
Sage thrasher	*Oreoscoptes montanus*
Screech owl	*Otus asio*
Flammulated owl	*Otus flammeolus*
Ruddy duck	*Oxyura jamaicensis*
Osprey	*Pandoin haliaetus*
Plain titmouse	*Parus inornatus*
House sparrow	*Passer domesticus*
Savannah sparrow	*Passerculus sandwichensis*
Fox sparrow	*Passerella iliaca*
Lazuli bunting	*Passerina amoena*
Indigo bunting	*Passerina cyanea*
Brown pelican	*Pelecanus occidentalis*
Gray jay	*Perisoreus canadensis*
Double-crested cormorant	*Phalacrocorax auritus*
Common poorwill	*Phalaenoptilus nuttallii*
Red-necked phalarope	*Phalaropus lobatus*
Wilson's phalarope	*Phalaropus tricolor*
Ring-necked pheasant	*Phasianus colchicus*
Rose-breasted grosbeak	*Pheuticus ludovicianus*
Black-headed grosbeak	*Pheuticus melanocephalus*
Black-billed magpie	*Pica hudsonia*
Downy woodpecker	*Picoides pubescens*
Northern three-toed woodpecker	*Picoides tridactylus*
Hairy woodpecker	*Picoides villosus*
Green-tailed towhee	*Pipilo chlorurus*
Rufous-sided towhee	*Pipilo erythrophthalmus*
Brown towhee	*Pipilo fuscus*
Hepatic tanager	*Piranga flava*
Western tanager	*Piranga ludoviciana*
Scarlet tanager	*Piranga olivacea*
White-faced ibis	*Plegadis chihi*

Appendix C continued. Common and Scientific Names of Birds That May Occur on the Navajo Nation.

Common Name	**Scientific Name**
Black-bellied plover	*Pluvialis squatarola*
Horned grebe	*Podiceps auritus*
Eared grebe	*Podiceps nigricollis*
Pied-billed grebe	*Podilymbus podiceps*
Black-capped chickadee	*Poecile atricapilla*
Mountain chickadee	*Poecile gambeli*
Blue-gray gnatcatcher	*Polioptila caerulea*
Vesper sparrow	*Pooecetes gramineus*
Sora	*Porzana carolina*
Purple martin	*Progne subis*
Common bushtit	*Psaltriparus minimus*
Great-tailed grackle	*Quiscalus mexicanus*
Common grackle	*Quiscalus quiscula*
Virginia rail	*Rallus limicola*
American avocet	*Recurvirostra americana*
Ruby-crowned kinglet	*Regulus calendula*
Golden-crowned kinglet	*Regulus satrapa*
Bank swallow	*Riparia riparia*
Rock wren	*Salpinctes obsoletus*
Black phoebe	*Sayornis nigricans*
Eastern phoebe	*Sayornis phoebe*
Say's phoebe	*Sayornis saya*
Ovenbird	*Seiurus aurocapillus*
Northern waterthrush	*Seiurus noveboracensis*
Broad-tailed hummingbird	*Selasphorus platycercus*
Rufous hummingbird	*Selasphorus rufus*
American redstart	*Setophaga ruticilla*
Mountain bluebird	*Sialia currucoides*
Western bluebird	*Sialia mexicana*
Eastern bluebird	*Sialia sialis*
Red-breasted nuthatch	*Sitta canadensis*
White-breasted nuthatch	*Sitta carolinensis*
Pygmy nuthatch	*Sitta pygmaea*
Western burrowing owl	*Speotyto cunicularia hypugea*
Williamson's sapsucker	*Sphyrapicus thyroideus*
Yellow-billed sapsucker	*Sphyrapicus varius*
Dickcissel	*Spiza americana*
American tree sparrow	*Spizella arborea*
Brewer's sparrow	*Spizella breweri*
Chipping sparrow	*Spizella passerina*
Northern rough-winged swallow	*Stelgidopteryx serripennis*

Appendix C concluded. Common and Scientific Names of Birds That May Occur on the Navajo Nation.

Common Name	Scientific Name
Calliope hummingbird	*Stellula calliope*
Caspian tern	*Sterna caspia*
Forster’s tern	*Sterna forsteri*
Common tern	*Sterna hirundo*
Mexican spotted owl	*Strix occidentalis lucida*
Eastern meadowlark	*Sturnella magna*
Western meadowlark	*Sturnella neglecta*
European starling	*Sturnus vulgaris*
Tree swallow	*Tachycineta bicolor*
Long-billed marsh wren	*Telmatodytes palustris*
Bewick’s wren	*Thryomanes bewickii*
Bendire’s thrasher	*Toxostoma bendirei*
Brown thrasher	*Toxostoma rufum*
Violet-green swallow	*Trachycineta thalassina*
Lesser yellowlegs	*Tringa flavipes*
Greater yellowlegs	*Tringa melanoleuca*
Solitary sandpiper	*Tringa solitaria*
House wren	*Troglodytes aedon*
American robin	*Turdus migratorius*
Eastern kingbird	*Tyrannus tyrannus*
Western kingbird	*Tyrannus verticalis*
Cassin’s kingbird	*Tyrannus vociferans*
Common barn-owl	*Tyto alba*
Orange-crowned warbler	*Vermivora celata*
Lucy’s warbler	*Vermivora luciae*
Nashville warbler	*Vermivora ruficapilla*
Virginia’s warbler	*Vermivora virginiae*
Warbling vireo	*Vireo gilvus*
Red-eyed vireo	*Vireo olivaceus*
Solitary vireo	*Vireo solitarius*
Gray vireo	*Vireo vicinior*
Wilson’s warbler	*Wilsonia pusilla*
Yellow-headed blackbird	*Xanthocephalus xanthocephalus*
Sabine’s gull	*Xema sabini*
Mourning dove	*Zenaida macroura*
White-crowned sparrow	*Zonotrichia leucophrys*
Harris’ sparrow	*Zonotrichia querula*

Appendix D. Common and Scientific Names of Mammals That May Occur on the Navajo Nation.

Common Name	Scientific Name
White-tailed antelope ground squirrel	*Ammospermophilus leucurus*
Pronghorn antelope	*Antilocapra americana*
Pallid bat	*Antrozous pallidus*
Ring-tailed cat	*Bassariscus astutus*
Coyote	*Canis latrans*
Beaver	*Castor canadensis*
Elk	*Cervus canadensis*
Gunnison's prairie dog	*Cynomys gunnisoni*
Ord's kangaroo rat	*Dipodomys ordi*
Banner-tailed kangaroo rat	*Dipodomys spectabilis*
Big brown bat	*Eptesicus fuscus*
Porcupine	*Erethizon dorsatum*
Spotted bat	*Euderma maculata*
Mountain lion	*Felis concolor*
Silver-haired bat	*Lasionycteris noctivagans*
Red bat	*Lasiurus borealis*
Hoary bat	*Lasiurus cinereus*
Blacktail jackrabbit	*Lepus californicus*
River otter	*Lutra canadensis*
Bobcat	*Lynx rufus*
Marten	*Martes americana*
Striped skunk	*Mephitis mephitis*
Long-tailed vole	*Microtus longicaudus*
Mexican vole	*Microtus mexicanus*
Montane vole	*Microtus montanus*
Meadow vole	*Microtus pennsylvanicus*
House mouse	*Mus musculus*
Long-tailed weasel	*Mustela frenata*
Black-footed ferret	*Mustela nigripes*
Mink	*Mustela vison*
California myotis	*Myotis californicus*
Western small-footed myotis	*Myotis ciliolabrum*
Long-eared myotis	*Myotis evotis*
Little brown myotis	*Myotis lucifugus*
Fringed myotis	*Myotis thysanodes*
Cave myotis	*Myotis velifer*
Long-legged myotis	*Myotis volans*
Yuma myotis	*Myotis yumanensis*
White-throated woodrat	*Neotoma albigula*
Bushy-tailed woodrat	*Neotoma cinerea*

Appendix D concluded. Common and Scientific Names of Mammals That May Occur on the Navajo Nation.

Common Name	Scientific Name
Mexican woodrat	*Neotoma mexicana*
Stephen's woodrat	*Neotoma stephensi*
Desert shrew	*Notiosorex crawfordi*
Big free-tailed bat	*Nyctinimops macrotis*
Mule deer	*Odocoileus hemionus*
Muskrat	*Ondatra zibethica*
Northern grasshopper mouse	*Onychomys leucogaster*
Plains pocket mouse	*Perognathus flavescens*
Silky pocket mouse	*Perognathus flavus*
Brush mouse	*Peromyscus boylii*
Canyon mouse	*Peromyscus crinitus*
Rock mouse	*Peromyscus difficilis*
White-footed mouse	*Peromyscus leucopus*
Deer mouse	*Peromyscus maniculatus*
Piñon mouse	*Peromyscus truei*
Western pipistrel	*Pipistrellus hesperus*
Townsend's big-eared bat	*Plecotus tounsendii*
Raccoon	*Procyon lotor*
Western harvest mouse	*Reithrodontomys megalotis*
Abert's squirrel	*Sciurus aberti*
Merriam shrew	*Sorex merriami*
Dwarf shrew	*Sorex nanus*
Vagrant shrew	*Sorex vagrans*
Spotted ground squirrel	*Spermophilus spilosoma*
Rock squirrel	*Spermophilus variegatus*
Western spotted skunk	*Spilogale gracilis*
Desert cottontail rabbit	*Sylvilagus audoboni*i
Eastern cottontail rabbit	*Sylvilagus floridanus*
Mexican free-tailed bat	*Tadarida brasiliensis*
Cliff chipmunk	*Tamias dorsalis*
Least chipmunk	*Tamias minimus*
Colorado chipmunk	*Tamias quadrivittatus*
American red squirrel	*Tamiasciurus hudsonicus*
Badger	*Taxidea taxus*
Botta's pocket gopher	*Thomomys bottae*
Gray fox	*Urocyon cinereoargenteus*
Black bear	*Ursus americanus*
Kit fox	*Vulpes macrotis*
Swift fox	*Vulpes velox*
Red fox	*Vulpes vulpes*
Northern pocket gopher	*Thomomys talpoides*

Appendix E. Common and Scientific Names of Amphibians and Reptiles That May Occur on the Navajo Nation.

Common Name	**Scientific Name**
Amphibians	
Tiger salamander	*Ambystoma tigrinum*
Great Plains toad	*Bufo cognatus*
Red-spotted toad	*Bufo punctatus*
Woodhouse's toad	*Bufo woodhousii*
Canyon treefrog	*Hyla arenicolor*
Western chorus frog	*Pseudacris triseriata*
Bullfrog	*Rana catesbeiana*
Northern leopard frog	*Rana pipiens*
Plains spadefoot	*Scaphiopus bombifrons*
Western spadefoot	*Spea hammondii*
Reptiles	
Chuckwalla	*Sauromalus obesus*
Collard lizard	*Crotophytus collaris*
Longnose leopard lizard	*Crotophytus wislezenii*
Lesser earless lizard	*Holbrookia maculata*
Eastern fence lizard	*Sceloporus undulatus*
Desert spiny lizard	*Sceloporus magister*
Common sagebrush lizard	*Sceloporus graciosus*
Ornate tree lizard	*Urosaurus ornatus*
Common side-blotched lizard	*Uta stansburiana*
Short-horned lizard	*Phrynosoma douglassi*
Little striped whiptail	*Cnemidophorus inornatus*
Western whiptail	*Cnemidophorus tigris*
Plateau striped whiptail	*Cnemidophorus velox*
Desert night lizard	*Xantusia vigilis*
Many-lined skink	*Eumeces multivirgatus*
Smooth green snake	*Ophedrys vernalis*
Ring-neck snake	*Diadophis punctatus*
Striped whipsnake	*Masticophis taeniatus*
Coachwhip	*Masticophis flagellum*
Racer	*Coluber constrictor*
Corn snake	*Elaphe guttata*
Gopher snake	*Pituophis melanoleucus*
Milk snake	*Lampropeltis triangulum*
Common king snake	*Lampropeltis getulus*
Longnose snake	*Rhinocheilus lecontei*
Western terrestrial garter snake	*Thamnophis elegans*
Common garter snake	*Thamnophis sirtalis*
Blackneck garter snake	*Thamnophis cyrtopsis*

Appendix E concluded. Common and Scientific Names of Amphibians and Reptiles That May Occur on the Navajo Nation.

Common Name	Scientific Name
Western blackhead snake	*Tantilla planiceps*
Night snake	*Hypsiglena torquata*
Glossy snake	*Arizona elegans*
Western rattlesnake	*Crotalus viridis*
Western diamondback rattlesnake	*Crotalus atrox*
Mountain patch-nosed snake	*Salvadora grahamiae*

Appendix F. Common and Scientific Names of Other Animals Mentioned in this Report.

Common Name	Scientific Name
“tuna”	*Auxis, Euthynnus, Katsuwonus, Thunnus sp.*
“loon”	*Gavia spp.*
“pike”	*Esox spp.*
“shark”	members of the Family *Lamnidae*
“swordfish”	*Xiphias gladius*

Appendix G, Appendix H and Appendix I are on compact disk (in pocket)

or on the website: http://ifw2es.fws.gov/NewMexico/