Appendix III. Impacts of Herbicides, Other Pesticides, and Fertilizers on Aquatic Species

Many pesticides (including herbicides, insecticides, and fungicides) and other chemicals commonly used for commercial forestry operations are likely to have significant if not substantial impact on amphibians and various fishes. Adverse effects can occur with even minute doses of some chemicals. (Colborn et al (1992), Colborn et al (1993), Colborn et al (1996), EPA (1997) in Hartwell et al (1999).) Fish and wildlife in the early stages of development are particularly vulnerable to chemicals; even brief exposures can affect the development of entire organ systems. (Guillette et al (1995) in Ewing (1999).)

Atrazine, malathion, and esfenvalerate have been linked to deformities in frogs, including (with atrazine and esfenvalerate) at very low dosages otherwise considered safe for drinking water (the chemicals render the frogs significantly more susceptible to deformity-causing parasites). (San Francisco Chronicle, July 9, 2002, and Science Daily Magazine, July 9, 2002.) Another study found that concentrations of atrazine as low as 20 ppb were sufficient to cause mortality in tadpoles. (See Cox (2001).) Other sources also indicate that the herbicides 2,4-D and atrazine have been linked to deformities or mortalities in birds, mammals, amphibians, reptiles, and fish. (Hall et al (1992), Colborn et al (1993), Berrill et al (1994), and Berrill et al (1997) in Hartwell et al (1998).). Another source also indicates that atrazine, captan, and benomyl are mutagens. (Radosevich et al (___), citing values from Kamrin (1997).)

Glyphosate based herbicides have also been shown to be lethal to frog tadpoles, including at concentrations of less than 1 ppm. (Smith (2001) in Cox (2003).) Esthers of triclopyr ("Garlon 3A," Garlon 4," "Pathfinder," "Remedy," "Turflon," "Release") have been found "highly toxic" to coho salmon, rainbow trout, and other fish, including at LC_{50} does of less than 0.5 ppm. (US EPA (1998) in Cox (2000).) Triclopyr has also been shown to harm the growth of rainbow trout at concentrations of 0.25 ppm. (US EPA (1998) in Cox (2000).)

Chlorinated hydrocarbons are often endocrine disrupters. Chlorinated hydrocarbons include: dicofol, methoxychlor, endosulfan, 2,4-D, chlorothalonil ("Daconil," "Bravo"), lindane, and mirex. Atrazine, 2,4-D, and methoxychor are known to be endocrine disrupters. (Radosevich et al (___), citing values from Kamrin (1997).) Atrazine has been found to affect Atlantic salmon sexual productivity at concentrations as low as 0.04 ppb. (See Cox (2001).) Lindane, chlordecone, alkylphenols, endosulfan, dieldrin, and toxaphene have all been shown to provoke estrogenic responses in fish and other wildlife. (Various sources in Ewing (1999).)

The insecticide fenithrothion and the herbicide triclopyr ("Garlon 3A," "Garlon 4," "Pathfinder," "Turflon," "Remedy," "Release") can also cause mortality, developmental, and/or behavioral problems in fish and amphibians, depending on the dosage, species, life stage, and water temperature. (Berrill et al (1993).)

One review of forest pesticides found that a host of forest chemicals have high aquatic toxicity ratings (i.e., LC_{50} < 50 mg/L at 48 hours for rainbow trout or other fish), including: sulfometuron ("Oust"), sethoxydim, picloram ("Grazon," "Tordan"), captan, 2,4-D, benomyl, oryzalin, oxyfluorfen, paraquat, lindane, permethrin ("Nix," "Pounce," "Ambush") methoxychlor, metolachlor, trifuralin, carbaryl ("Sevin"), mancozeb, diazinon, dicofol, and dimethoate. (Radosevich et al (___), citing values from Kamrin (1997).)

The herbicides 2,4,-D, atrazine, triclopyr, glyphosate ("Rodeo," "Roundup," "Accord," Vision"), and hexazinone are also among a suite of chemicals involved in a lawsuit that required the EPA to consult with NMFS and USFWS regarding the chemicals' effects on salmon and other imperiled species.

Even supposedly less toxic, newer generation synthetic pyrethroids (including fenvalerate and permethrin ("Nix," "Pounce," "Ambush")) can harm the behavior and growth of amphibians, and are likely to severely affect fish. (Berrill et al (1993), and Holdway et al (1998) and Haya (1989) in Berrill et al (1993).) Esfenvalerate was found to trigger trematode-caused deformities in frogs even at concentrations low enough to be considered safe for drinking water. (Science Daily Magazine, July 9, 2002.)

Herbicides and other pesticides can also have significant indirect impacts on salmon and other fish (and perhaps also amphibians and other wildlife) that may not be evidenced in studies that focus on direct mortality or deformity. Pesticides can significantly impair fishes' swimming performance (impairing their ability to feed, avoid predators, etc.), sense of smell (resulting in increased predation), immune systems, and hormonal systems. (Lind (2002.)

Carbaryl ("Sevin"), chlordane, 2,4-D amine, methyl parathion, and pentachlorophenol have all been found to harm fishes' swimming ability. (Little et al (1990) in Lind (2002).) The fungicide TCMTB, which is used to prevent fungal staining of logs, harms salmonids' swimming abilities, and also damages their gill structure. (Nick et al (1993) in Ewing (1999).) Fenvalerate and permethrin ("Nix," "Pounce," "Ambush") have also been found to impact fishes' swimming ability, and perhaps also cause respiratory distress. (Holcombe et al (1982) in Ewing (1999).)

Even low concentrations of diazinon can impair fishes' sense of smell. (Scholtz et al (2002) in Lind (2002).) TCMTB has also been shown to impact coho salmon juveniles' ability to escape predators. (Kruzinski et al (1994) in Ewing (1999).) Fenitrothion, carbaryl ("Sevin"), and pentachlorophenol also can increase fishes' vulnerability to predation. (Hatfield et al (1972) and Little et al (1990) in Ewing (1999).) TCMTB, methoxyclor, kelthan, dursban, disulfoton, fenvalerate, and permethrin all can harm fishes' schooling behavior; TCMTB specifically has been shown to harm chinook salmon schooling behavior. (Kruzinskio et al (1994), Kruzinski (1972), and Holcombe (1982) in Ewing (1999).)

The herbicide diquat has also been shown to inhibit seaward migration of juvenile salmonids. (Lorz et al (1979).) TCMTB has also been shown to affect coho salmon's salinity preferences, and paraquat, diquat, Amitrole-T, and Tordon 101 (a combination of 2,4-D and picloram) can all cause coho salmon mortality in seawater tests, depending on the dosage and time of year. (Lorz et al (1979) in Ewing (1999).)

The behavioral patterns of amphibians can also be harmed by pesticides. Tadpoles of various frog species lose their avoidance response after being dosed with roughly 1 ppm of triclopyr, a concentration that was expected to occur in commercially managed forests. ("Garlon 3A," Garlon 4," "Pathfinder," "Remedy," "Turflon," "Release"). (Berrill et al (1994) in Cox (2000).)

"Vision" (a glyphosate herbicide) can also cause abnormal behavior in fish. (Morgan et al (1992).)

Pesticides can also reduce the availability of food sources for fishes. (Lind (2002).) For example, many insect larvae, crustaceans, algae, and diatoms are very sensitive to pesticides. (Various sources in Ewing (1999).) Atrazine was shown to reduce bluegill offspring by 90% in ponds treated at 20 ppb atrazine, due to having killed off the pond's aquatic plant life, and thus the insects which normally supported the bluegill. (See Cox (2001).)

Herbicides and other pesticides have also been documented in Washington watersheds at levels far exceeding standards established to protect aquatic life. These include 2,4-D, azinphos methyl, carbaryl ("Sevin") chlorpyrifos ("Dursban," "Lorsban"), diazinon, lindane, malathion, parathion, and traillate. However, it should be noted that water quality criteria have not been established for many pesticides, meaning other pesticides not identified in that study may also be present at harmful levels. (Lind (2002).) Lind (2002) also lists 34 pesticides for which the EPA has found that legal uses are likely to have a harmful effect on aquatic species, their habitats, and/or their food sources. Equally disturbing, 39% of pesticides commonly used or frequently detected in West Coast states do not have a completed EPA aquatic risk assessment, meaning that other pesticides may also be present in these watersheds at harmful, but undocumented, levels. (Lind (2002).) Another source also indicates that aquatic life protection standards have also not been established for most contemporary herbicides and other pesticides. (Ewing (1999.))

Fertilizers may also potentially impact amphibians and other aquatic species. A study by Andrew Blaustein, of Oregon State University's Zoology Department, in

2000, reportedly found that some tadpoles and young frogs raised in water with very low levels of nitrates developed abnormalities, suffered paralysis, and eventually died.

There are also reports that some fertilizers used in commercial forestry have been laced with heavy metals and other contaminants that are toxic to humans, fish, and other species, including chromium, strontium, nickel, and zinc. The contents may not be disclosed by the Material Safety Data sheets.

While most pesticides breakdown some time after application, this can take considerable time for some chemicals. Glyphosate ("Roundup," "Rodeo," "Accord," "Vision") has been shown to persist for as long as 3 years. (Torstensson et al (1989) in Ewing (1999).) Other studies have shown glyphosate to persist for as long as 55 days and 1 year, in Oregon and British Columbian forestry sites respectively. (See Cox (2003).) Triclopyr ("Garlon 3A," Garlon 4," "Pathfinder," "Remedy," "Turflon," "Release") has been shown to persist for as long as a year in some conditions. (Various sources in Cox (2000).) The breakdown of pesticides generally takes longer in colder and cloudier, northern latitudes. (Ewing (1999).) Equally important, the resulting chemicals are sometimes more toxic and/or persistent, not less, than the original chemical. (Ewing (1999).) One of the breakdown products of triclopyr, 3,5,6-trchloro-2-pyridinol (or TCP), is both persistent and mobile in soils, and is considered hazardous to children, with concentrations of only 0.2 ppm being sufficient to disrupt growth. (US EPA (1998) and Das et al (1999) in Cox (2000).) In many cases, the effects of breakdown chemical products are not well studied. (Ewing (1999).)

Chemicals applied in and around non-fish bearing stream segments and riparian areas may be retained in water and sediments and transported downstream, where they can affect sensitive fish and other aquatic species. Pesticides commonly reach water after becoming bound to soil particles which are transported into aquatic systems. (Barbash et al (1996) in Ewing (1999).) Glyphosate is also likely to reach water as a result of de-binding from soil particles, rendering it even more mobile. (See Cox (2003).) Indeed, glyphosate has been found in forest streams in both Washington and Oregon. (Rashin et al (1993) and Oregon Dept. Forestry (1992) in Cox (2003).) Triclopyr is also considered "very mobile" in soils, and has been found in streams as a result of forestry applications. (Various sources in Cox (2000).) Chemicals are also less likely to breakdown in the oxygen-poor muds of estuaries. (Barbash et al (1996) in Ewing (1999).)

Chemicals may bioaccumulate in plant and animal food sources for the covered species, thereby potentially impacting aquatic species higher-up the food chain, as well as exposing wildlife species to higher concentrations of pesticides than might be found in streams and other waterways. Ewing (1999) lists a number of pesticides and related compounds known to bioaccumulate at different levels.

Even modern water soluble chemicals, which are less likely to accumulate in fatty tissues, can still bioaccumulate. (Ewing (1999).)

Some pesticides can also disrupt basic ecosystem processes. Triclopyr ("Garlon 3A," Garlon 4," "Pathfinder," "Remedy," "Turflon," "Release") can inhibit the growth of mycorrhrizal fungi, which are important to nutrient uptake by many forest trees, and can also directly interfere with the transformation of ammonia to nitrogren by microorganisms. (Various sources in Cox (2000).)

Some forestry chemicals can also become more toxic in the field than in the laboratory, due to their application in conjunction with surfactants, dispersants, or solvents. Indeed, surfactants and other compounds used in the application of pesticides can be highly toxic, both individually and in combination with the pesticide. The surfactant used with glyphosate herbicides ("Roundup," "Accord," etc.) is 20 to 70 times more toxic to fish than the glyphosate itself, and the combination of two, yet more toxic. (Folmar et al (1979) in Cox (2003).)

Some of the chemicals discussed above may not be currently used in the US for forestry applications. However, research findings for these chemicals are still important, as they show the types of impacts that can result from forestry chemicals, including newer chemicals which have not been adequately studied yet. The lack of studies showing impacts from specific chemicals on specific fish and wildlife species does not necessarily indicate that the chemicals are safe for fish and wildlife; rather, it may simply indicate a lack of research. Given the likelihood that herbicides, other pesticides, and even some fertilizers may harm fish and wildlife species, it makes sense to adopt a precautionary approach, and assume a chemical may be toxic until proven otherwise.