Appendix E

PAH Impacts to Salmon
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Numerous scientific papers report that exposure to environmental contaminants compromises the health of anadromous and marine fish (Arkoosh et al. 1994, Moore and Waring 1996, Waring and Moore 1997, Ewing 1999, Scholz et al. 2000, Collier et al. 2002, Johnson et al. 2002, Arkoosh and Collier 2002 and Jacobson et al. 2003). These health impacts include many sublethal effects such as decreased immune function, DNA damage, liver dysfunction, reproductive impairment, growth impairment, decreased olfactory function and predator avoidance behavior dysfunction.

Polycyclic aromatic hydrocarbons (PAHs) are a group of chemicals that occur naturally in coal, crude oil gasoline, and products made from fossil fuels. PAHs are a sediment-associated contaminant frequently found in urban estuaries, urban or industrialized areas. Part of a broad class of chemicals referred to as polycyclic organic matter (POM); POMs have been listed by the U.S. EPA as pollutants of concern due to their persistence in the environment, potential to bioaccumulate and toxicity to humans and other organisms.

A known mutagenic, teratogenic, and carcinogenic set of compounds, PAHs are considered one of the most toxic compounds found in contaminated estuaries and watersheds (as reviewed by Arkoosh and Collier 2002). Anadromous fish are exposed to PAHs via direct sediment contact or food web dynamics. Laboratory and field studies have shown an increased risk of immunosuppression and disease resistance in juvenile chinook salmon migrating through polluted estuaries or through direct exposure to PAHs compounds (Arkoosh et al. 1994 and Arkoosh and Collier). Biological impacts to English sole taken from the Puget Sound have also been linked directly to sediment PAH concentrations (Johnson et al. 2002).

Arkoosh M.R., Clemons E., Myers M. and Casillas E. (1994). Suppression of B-Cell mediated immunity in juvenile chinook salmon (*Oncorhynchus tshawytscha*) after exposure to either a polycyclic aromatic hydrocarbon or to polycholinated biphenyls. *Immunopharmacology and Immunotoxicology*: Vol. 16, No. 2, 293-314.

Arkoosh M.R. and Collier T.K. (2002). Ecological risk assessment paradigm for salmon: Analyzing immune function to evaluate risk. *Human and Ecological Risk Assessment:* Vol. 8, No. 2, 265-276.

Collier T.K., Meador J.P. and Johnson L.L. (2002). Fish tissue and sediment effects thresholds for polychlorinated bihenyls, polycyclic aromatic hydrocarbons, and tributyltin. *Aquatic Conserv. Mar. Freshw. Ecosyst*. 12: 489-492.

Ewing R.D. (1999). Diminishing returns: Salmon decline and pesticides. Oregon Pesticide Education Network.

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Johnson L.L., Collier T.K., and Stein J.E. (2002). An analysis in support of sediment quality thresholds for polycyclic aromatic hydrocarbons (PAHs) to protect estuarine fish. *Aquatic Conserv.: Mar. and Freshw. Ecosyst.*12: 517-538.

Moore A.. and Waring C.P. (1996). Sublethal effects of the pesticide Diazinon on olfactory function in mature male Artlantic salmon parr. *Journal of Fish Biology* 48: 758-775.

Scholz N.L., Truelove K., French B.L., Berejikian B.A., Quinn T.P., Casillas E. and Collier T.K. (2000). Diazinon disrupts antipredator and homing behaviors in chinook salmon (*Oncorhynchus tshawytscha*). *Can. J. Fish. Aquat. Sci.* 57: 1911-1918.

Waring C.P. and Moore A. (1997). Sublethal effects of a carbamate pesticide on pheromonal mediated endocrine function in mature male Atlantic salmon (*Salmo salar* L.) parr. *Fish Physiology and Biochemistry* 17: 203-211.