APPENDIX E

LIFE HISTORIES OF SELECTED FISH SPECIES FOUND IN COMMENCEMENT BAY

CHINOOK SALMON (*Oncorhynchus tshawytscha*)

Life history information on the Chinook salmon is taken primarily from Hart (1973), Beauchomp et. al. (1983), and Smith personal communication (1994). Chinook salmon enter spawning rivers during most of the year and generally utilize relatively larger river systems. Chinook salmon utilizing the Puyallup River are generally categorized as two distinct races of salmon and include the spring and summer/fall Chinook, with the summer/fall Chinook population being considerably more abundant. These races exhibit distinct seasonal differences in their respective patterns of life history but share some similar behavioral attributes.

Spring Chinook

Spring Chinook salmon populations occur in large river systems where suitable flows exist over the summer to provide adequate habitat. Spring Chinook salmon in the Puyallup River basin consist of a native composite (i.e., a stock sustained by both wild and artificial production). The stock is significantly depleted with an estimated population size to be comprised of less than 100 individuals. Hatchery propagation efforts currently release spring Chinook fingerlings and yearlings into the system in an effort to revitalize the diminishing spring Chinook population.

Adult spring-run Chinook enter the Puyallup beginning in late-May with the run continuing through mid-September. Spring Chinook typically migrate relatively slowly to upstream habitats and remain for protracted periods in pools near spawning areas. Spawning activities typically extend from August to October with peak spawning occurring during the month of September. Adult spring Chinook principally utilize the high mountain streams of the upper White River system. Limited numbers of spring Chinook are likely to utilize the upper reaches of the mainstem Puyallup and the upper Carbon rivers. In addition, spring Chinook adults have been observed in the Bosie Creek, although these fish may be strays from the Muckleshoot White River hatchery.

Depending on the temperature and regime of the natal stream, eggs hatch in the late-fall or early-winter. Newly hatched salmonids, called alevins, remain in the gravel of the spawning beds for 4 to 6 weeks until the nutrient providing yolk sac is fully absorbed. After yolk absorption, young Chinook salmon commonly emerge from gravel as free-swimming fry. Although most juvenile spring Chinook characteristically remain in the freshwater system for more than a year and migrate seaward early in their second year of freshwater life, little is currently known about the emigration timing of the natural spring Chinook population in the Puyallup River basin to confirm such movements.

Fingerlings are typically hatched in the fall and subsequently released into the system the following year from May through June. Yearlings, also hatched in the fall, are commonly raised throughout the following year and released the next year during April. Rearing of natural and hatchery populations is considered to occur in spawning streams, as well as in the mainstem river and in the highly critical estaurine waters of Commencement Bay.

Summer/fall Chinook

Summer/fall Chinook salmon enter both large rivers and small coastal streams during the autumn months. Summer/fall Chinook spawning occurs throughout the Puyallup River system with concentrations noted in the mainstem Puyallup and the lower White and Carbon rivers.

Adult summer/fall Chinook enter the Puyallup as early as mid-July and move rapidly during high water periods to spawning areas. Spawning is usually completed throughout the Puyallup system by the first of November, with peak spawning occurring in the month of October. Spawning is generally completed within ten days after the initial breeding activity. Following incubation and subsequent fry emergence, juveniles generally rear in the system about three months prior to seaward migration which occurs mainly from late-February through early-August. Important rearing waters for the juvenile summer/fall Chinook are approximately the same as those of the spring Chinook. However, some Chinook emigrate throughout the year.

Juvenile Stages

Downstream fall migrants, including both fall and spring run juveniles, reach saltwater at an average length of 100 mm. During their juvenile life stage, Chinook are primarily characterized as opportunistic drift and benthic feeders primarily consuming insects in the stream-rearing phase of life. During the day the fish remain in a small home area, and at night settle to the bottom, usually after moving to areas adjacent to stream banks. In early-autumn, juvenile Chinook salmon emigrate downstream from the tributaries to overwinter in larger streams.

Chinook salmon migrations into estuaries are correlated with periods of high discharge and turbidity, and migration is normally heaviest at night. These migrations occur primarily during spring and early summer, but continue at lower levels throughout the fall. Smolts entering estuaries generally range from 35 mm to 160 mm. The larger juveniles tend to migrate earlier and growth increases in brackish/estuarine waters. Spatial distribution of juvenile Chinook salmon within a given estuary may be size dependent, while schooling in an estuary may be influenced by tidal cycles and wave action. Estuarine residence times may also be influenced by the occurrence of fall freshets, populations abundance, and various estuarine characteristics; duration and dates of estuarine residence vary geographically with seasonal differences. Yearling juveniles may have a shorter residence time than young of the year.

During their estuarine residence, juvenile Chinook utilize a wide range of invertebrate prey while retaining their insectivorous feeding habitats. Fry and subyearlings in salt marsh and other shallow habitats prey principally upon emergent insects and epibenthic crustaceans such as gammarid amphipods, mysids, and cumaceans. In neritic habitats, they feed upon small neckton (decapod larvae, larval and juvenile fishes, and euphausiids) and neustonic drift insects. Some studies have suggested that prey preference of fey and subyearlings may be related to size, time of year, temperature, salinity, and location in the river.

Some studies have found that some Chinook appear to demonstrate a preference for soft, packed substrate and suggest that the abundance of the epibenthic prey fauna in that type of habitat attract juvenile Chinook. Within estuaries and bays, juvenile Chinook utilize shoreline areas extensively. Juvenile Chinook have been found to reside for up to two months. In estuaries, juvenile Chinook salmon show a wide range of substrate associations with mud, sand, gravel, and eelgrass (*Zostera* spp.).

During estuarine rearing, Chinook exhibit significant growth. Some studies in the Duwamish River Estuary calculated a minimum growth estimate of 2.6 mm per week for juveniles. This spurt of growth before entering the marine environment may be vital to the subsequent early marine survival of juvenile Chinook salmon. Additional studies have also shown that juvenile Chinook occupy the waters near the surface during their initial marine stages and subsequently utilize waters down to 18 m (60 ft) (Stober et al., 1973).

As juvenile Chinook continue growing and move farther out into the marine environment, their diets include crab zoea, Pacific sand lance (*Ammodytes hexapoterus*), eulachon (*Thaleichthys pacificus*), copepods, euphausiids, cephalopods, isopods, and amphipods.

Marine Stages

Upon leaving the rivers of Oregon, Washington, and British Columbia, juvenile Chinook salmon move up the coast in a northwesterly direction. This migration is a relatively slow feeding and dispersal movement with distance from the natal stream and increasing age. Chinook remain in the marine environment between 1 and 6 years with the average being between 3 and 4 years. Certain races of Chinook, such as the Puget Sound blackmouth, tend to remain in local marine waters. This may not be a genetically distinct race but an artifact of some hatching practices and/or food availability.

Salmon spawning migrations are elicited by several environmental cues, such as temperature and salinity, olfaction, celestial navigation, and magnetic orientation. The timing of migration is innate, while the location or destination of the migration is learned through imprinting.

Literature Cited

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Stober, Q.J., S.J. Walden, and D.T. Griggs. 1973. Juvenile salmon migration through Skagit Bay. Pages 35–70 in Q.J. Stober and E. O. Salo, eds. Ecological studies of the proposed Kiket Island nuclear power site. Final Rep. FRI-UW-7304, University of Washington, Seattle.

PINK SALMON (*Oncorhynchus gorbuscha*)

Life history on the pink salmon was taken from Hart (1973) and Bonar et. al. (1989). Pink salmon demonstrate a highly invariable two-year life cycle. Populations occupying watersheds can be distinguished as odd-numbered-year and even-numbered-year races. Odd-numbered-year pink salmon are present within the Puyallup basin. Pink salmon are considered to possess the most simple and least varied life history of any of the Pacific salmonids. In some instances three-year specimens have been recorded, but are considered rare. Pink salmon return to their stream of origin to spawn in the fall when the water temperatures range from 8 to 14°C and usually enter the river on high water freshets. Some salmon spawn several miles upstream from saltwater in a few river systems, but spawning generally takes place either in freshwater close to marine habitats or in the intertidal zone. Most pink salmon spawning occurs almost exclusively in sections of the mainstem Puyallup, the lower Carbon, and the lower White rivers.

Pink salmon are considered to be the most specialized species within the genus *Oncorhynchus* because they are the least dependent of freshwater and have been regularly observed to spawn in intertidal areas. Males are typically larger than females. In general, larger fish, predominantly males, enter the streams first. Runs of pink salmon may be alternately large and small in consecutive years. Spawning usually occurs in late-August through early-October in much of the range of the species. In the Puyallup River, adult pink salmon have been recorded in mid-July with the run continuing into October. Spawning commonly commences in mid to late-September and is usually completed by early-November.

Fry and smolts

The length of the incubation period is directly dependent on water temperature. Under natural condition in the Puyallup River, eggs hatch from late-December to late-February. Once hatched, the alevins remain in the spawning gravel for several weeks while the yolk sac is absorbed and incorporated into the body. Swimming fry emerge from the gravel in Puyallup River streams as early as late-February, but peak emergence in most localities occurs during April or May.

Soon after the fry emerge from the gravel their seaward migration begins with this movement usually completed by the end of July. Fry have been found to occur in abundant numbers in marsh areas and tidal channels during the spring and early-summer. Pink salmon appear to be only transient residents of estuarine marsh areas as they make their rapid and active migrations downstream. Fry typically swim at the surface, creating ripples during their downstream migration. Downstream migrations are considered to usually begin at night. During their migration to saltwater, fry typically do not feed, but if the distance is great, they are known to feed on larval insects. Early hatchery fry migrate downstream about 35 days ahead of late hatchery fry and about 55 days ahead of wild fry in British Columbia. Later migrating fry have considerably higher marine survival than earlier migrating fry, potentially because low water temperatures encountered by early migrating fry may slow their growth in the estuary and make them more vulnerable to predators.

Marine Stages

When juvenile pink salmon enter the estuarine environment, they feed near the surface, primarily during daylight hours. Juvenile pink salmon quickly adapt to feeding on pelagic copepods and other epibenthic and planktonic organisms. Food of juveniles in protected water such as Puget Sound, include harpacticoid copepods, copepod nauplii, invertebrate eggs, tunicates, and barnacle larvae. The estuarine residence time of juvenile pink salmon varies from 4 to 18 weeks.

After leaving freshwater, the juvenile pink salmon tend to remain close inshore during their first summer. In intertidal regions, juvenile pinks prefer feeding in waters of relatively low salinity. Migrations in the sea are saltatory, with short periods of active migrations interspersed with longer periods when fry do not migrate. The fish begin moving offshore in late-summer, in a manner that appears to be gradual or irregular, and leave the young-of-the-year at a distance of 6 to 12 miles from the nearest land in the fall.

Upon entering marine environments the preferred food of pink salmon include amphipods, supplemented by fish, euphausiids, squid, and crustacean larvae. Pink salmon appear to select larger food items as they move farther offshore.

After spending about 18 months at sea, adults return to the spawning streams. Salmon spawning migrations are thought to be guided by environmental cues such as olfaction, currents, temperature, and salinity, as well as by celestial navigation or magnetic orientation, but the exact cause of the migrations is variable. The incidence of straying from natal spawning streams is much higher in pink salmon than other species of salmon. This occurrence could constitute a survival strategy that pink salmon have evolved to re-colonize streams which have lost a year class due to environmental catastrophe or to ensure that all fish headed for an uninhabitable stream are not eradicated from the gene pool. This straying mechanism may have evolved with the normal tendency of the species to spawn in small, environmentally unstable streams.

Literature Cited

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ENGLISH SOLE (*Parophrys vetulus*)

Life history information on the English sole was taken from Lassory (1989) and Emmett et. al. (1991).

Spawning and larvae

Although spawning activities of English sole have not been directly observed, spawning locations and times are inferred from the spatial and temporal distribution of either turgid or spent females or the presence of egg and larval stages within a given study area. Some studies suggest that spawning typically occurs over sand and sand-mud bottoms at depths of 60-110 meters (m). Spawning is thought to be most intense during winter (December - February), but is also known to occur throughout all seasons; peaks vary from September to April. Individual sole may spawn more than once in a given year, but probably do not spawn serially within a given season. Although English sole spawn demersally, their eggs are buoyant in full-strength seawater. Hatching time varied from 3.5 to 12 days and depends on both temperature and salinity.

The larvae of English sole are pelagic and depend on favorable current patterns for transport to suitable nearshore nursery areas. The duration of this pelagic larval stage is generally cited as 6-10 weeks. As larvae reach 18 to 22 millimeters (mm) in total length they begin transforming to asymmetrical morphology and settle to a demersal existence.

Postlarvae and juveniles

The settling periods for English sole are considered to vary widely even within a confined study area. Earlier studies concluded that estuaries alone served as the nursery areas for juvenile English sole, but more recent evidence suggests that shallow, open coastal water may also provide juvenile rearing habitat. Postlarval settlement occurs both in estuaries and along sand bottomed open coastlines, primarily at depths of less than 16 m. Growth rates of post-settlement, 0-age English sole are comparable in estuaries and open coastal sites. The number of juveniles at open-coast sites, however, decrease sharply after settlement.

Juveniles move progressively to deeper waters with growth and leave nursery areas at 140 to 150 mm in total length. The emigration from estuarine areas generally occurs from August through November. Several alternative cues to induce emigrations have been proposed, such as temperature, niche shift, and competition avoidance.

Adults

Male English sole typically mature at 2 to 3 years of age and females at 3 to 4 years of age. Adult English sole are almost entirely absent from coastal bays and estuaries, and are generally restricted to offshore sand or sand-mud substrates. Depths at which they are most abundant vary from approximately 20 to 70 m in summer to 40 to 130 m during winter months. This distribution results from a seasonal bathymetric migration which is usually associated with a contranatant (against the current) movement to a movement with the current when returning from deep-water spawning grounds.

Mortality

As with most teleosts, mortality in English sole is greatest during early life-history stages. Temperature and salinity conditions, predation, adverse ocean advection, and absence of prey for larvae are considered to represent significant sources of mortality for eggs, larvae, and newly recruited juveniles. In adults, mortality rates vary widely with sex, age, and degree of fishing pressure. Investigations in Puget Sound demonstrated a greater mortality for females (36%) than males (33%) from the third to fifth years of life at one site, but the reverse was found for 8 to 10-year-old fish at a second study site.

Movement and stocks

Studies have found that movement is largely restricted to seasonal spawning migrations in geographically segregated stocks. Within specific stocks of English sole there may be a fraction of highly migratory individuals. Migrations rates have been as high as 4 mi/day and tag recovery distance have been as high as 700 miles.

Within the Pacific Northwest region, Puget Sound English sole is recognized as a major spawning population. Although still questionable, some studies suggest (on the basis of tagging and recapture data) that English sole in Puget Sound demonstrate a pronounced homing instinct and further suggest that individuals may exhibit territorial behavior.

Feeding behavior

Studies have found that the diet of larvae of English sole appear to be very specific. Appendicularians (*Oikopleura* spp.) represented a large component of the prey items consumed. Other food sources included tintinnids, invertebrate eggs, and nauplii. Early 0-age English sole are capable of expanding their prey selection to larger species. Harpacticoid copepods represent a major food component in their diet. Polychaete palps and juvenile bivalves also make up the prey assemblage of 0-age English sole.

Juvenile English sole are considered to be opportunistic and generalist benthic feeders, with selection only at the level of major taxonomic groups of prey. Within prey groups, the extent of dietary inclusion varies with local seasonal prey abundance. The most commonly found species predated by juvenile English sole include polychaetes, amphipods, cumaceans, and bivalve siphons. Studies have developed general patterns in the feeding behavior of juvenile English sole. These feeding strategies include a passive sit-and-wait behavior with occasional lunges at surface prey and an active disturbance of the upper few millimeters of sediment and subsequent feeding on fleeing prey. Studies have also suggested that juvenile English sole are primarily diurnal feeders.

The taxonomic composition of diets of adult English sole include shallow-burrowing and surface-active prey. Adult are also capable of digging into sediments to capture deeper-burrowing prey as well. Studies have found that the feeding habits of adult English sole are similar to those of juveniles. These studies found amphipods, polychaetes, and cumaceans to comprise the major dietary component of adults. Like juveniles, adult English sole were found to feed opportunistically on a wide variety of benthic invertebrates including shrimp, small molluscs and crabs, in addition to polychaetes.

In disturbed areas, the polychaetes *Capitella* spp. are abundant in localized densities. In these areas, English sole have exhibited significant numerical and size selection of this food source. Benthic assemblages dominated by species such as *Capitella* spp. may have comparatively high productivity and hence represent an enhanced food source to English sole.

Literature Cited

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APPENDIX F

POTENTIAL INJURIES LINKED TO CONTAMINANTS OF CONCERN

In order to assess the potential injuries to the biological resources of Commencement Bay, data linking biological effects to the substances of concern were gathered. Priority was given to effects information for species found in Commencement Bay, but when that was lacking information for similar species was gathered. As an example, the winter flounder (*Pseudopleuronectes americanus*) is commonly used as a test species when determining the effects of chemicals on marine fish. When species-specific toxicity information was unavailable for flatfish found in Commencement Bay, toxicity data developed for the winter flounder (or other suitable flatfish species) was used.

Table F-1. Contaminants of concern in Commencement Bay and their impacts upon resources in Commencement Bay.

CHEMICAL/SPECIES	MEDIUM	ENDPOINT	CONC.	REFERENCE
PAH				
SALMONIDS				
Coho salmon (*Oncorhynchus kisutch*)	Water	96-hr LC50	3,200 µg/L	Neff, 1985 as cited in Eisler, 1987b
FLATFISH				
Flathead sole (*Hippoglossoides elassodon*)	Diet (5 hr. before spawning)	Reduced hatching success and increased developmental abnormalities	8,000 µg/kg live weight	Hose et al., 1981
Winter flounder (*Pseudopleuronectes americanus*)	Sediment (4 mon.)	Liver hypertrophy Fatty liver	224-1379 mg/kg	Payne et al., 1988
Sand sole eggs (*Psettichthys melanostichus*)	Water (6 days)	Reduced hatching success and increased developmental abnormalities	0.08-0.12 µg/L	Hose et al., 1982
Flathead sole	Water (6-9 days)	Morphological abnormalities	4.2 µg/L	Hose et al., 1982
CRAB				
Dungeness crab (*Cancer magister*)	Water (24-36 hrs.)	100 percent mortality	8-12 µg/L	Sanborn and Malins, 1977
Dungeness crab	Water	96-hr LC50	2,000 µg/L	Neff, 1985, as cited in Eisler, 1987b
BENTHIC INVERTEBRATES				
Molluscs	Sediment	Reduced recolonization	844 mg/kg	Tagatz et al., 1983
Polychaetes & Crustaceans	Sediment	Reduced recolonization	177 mg/kg	Tagatz et al., 1983
Benthic community composition	Sediment	Reduced abundance	13,000-69,000 µg/kg	PTI, 1988
Phoxocephalid amphipod (*Rhepoxynius abronius*)	Sediment	10-day LC 50	24,000-69,000 µg/kg	Long and Morgan, 1991

Table F-1. (Continued)

CHEMICAL/SPECIES	MEDIUM	ENDPOINT	CONC.	REFERENCE
PCBs				
FLATFISH				
Baltic flounder (*Platichthys flesus*)	Tissue	Population decline	>120 µg/kg	Von Westernhagen et al., 1981
Starry flounder (*Platichthys stellatus*)	Tissue	Reduced reproductive success	200 µg/kg WW	Spies et al., 1985
Winter flounder egg and larva	Tissue	Reduced growth	39,600 µg/kg DW	Black et al., 1988
BENTHIC INVERTEBRATES				
Benthic community composition	Sediment	Reduced abundance	1,000 µg/kg	PTI, 1988
Phoxocephalid amphipod (*Rhepoxynius abronius*)	Sediment	10-day LC 50	3,100 µg/kg	Long and Morgan, 1991
4,4′-DDE				
BENTHIC INVERTEBRATES				
Benthic community composition	Sediment	Reduced abundance	9 µg/kg	PTI, 1988
Phoxocephalid amphipod (*Rhepoxynius abronius*)	Sediment	10-day LC 50	15 µg/kg	Long and Morgan, 1991
4,4′-DDD				
BENTHIC INVERTEBRATES				
Benthic community composition	Sediment	Reduced abundance	16 µg/kg	PTI, 1988
Phoxocephalid amphipod (*Rhepoxynius abronius*)	Sediment	10-day LC 50	43 µg/kg	Long and Morgan, 1991
PENTACHLOROPHENOL				
FLATFISH				
Flounder eggs (*Pleuronectes platessa*)	Water (8 wks)	LC50	50 µg/L	Choudhury et al., 1987, in Eisler, 1989
Flounder larvae	Water	96-hr LC50	60-140 µg/L	
Flounder juveniles	Water	96-hr LC50	100-130 µg/L	

Table F-1. (Continued)

CHEMICAL/SPECIES	MEDIUM	ENDPOINT	CONC.	REFERENCE
PENTACHLOROPHENOL (CONTINUED)				
BENTHIC INVERTEBRATES				
Benthic community composition	Water	Significantly reduced number of individuals	76 µg/L	Tagatz et al., 1977, in EPA, 1980c
Benthic community composition	Water	Significantly reduced molluscs	9 µg/L	
Benthic community composition	Sediment	Reduced abundance	690 µg/kg	PTI, 1988
Phoxocephalid amphipod (*Rhepoxynius abronius*)	Sediment	10-day LC 50	360 µg/kg	Long and Morgan, 1991
PHENOL				
Benthic Invertebrates				
Benthic community composition	Sediment	Reduced abundance	1,200 µg/kg	PTI, 1988
Phoxocephalid amphipod (*Rhepoxynius abronius*)	Sediment	10-day LC 50	1,200 µg/kg	Long and Morgan, 1991
2,4-DIMETHYLPHENOL				
BENTHIC INVERTEBRATES				
Benthic community composition	Sediment	Reduced abundance	210 µg/kg	PTI, 1988
Phoxocephalid amphipod (*Rhepoxynius abronius*)	Sediment	10-day LC 50	72 µg/kg	Long and Morgan, 1991
2-METHYLPHENOL				
BENTHIC INVERTEBRATES				
Benthic community composition	Sediment	Reduced abundance	72 µg/kg	PTI, 1988
Phoxocephalid amphipod (*Rhepoxynius abronius*)	Sediment	10-day LC 50	63 µg/kg	Long and Morgan, 1991

Table F-1. (Continued)

CHEMICAL/SPECIES	MEDIUM	ENDPOINT	CONC.	REFERENCE
4-METHYLPHENOL				
BENTHIC INVERTEBRATES				
Benthic community composition	Sediment	Reduced abundance	1,800 µg/kg	PTI, 1988
Phoxocephalid amphipod (*Rhepoxynius abronius*)	Sediment	10-day LC 50	3,600 µg/kg	Long and Morgan, 1991
1,3-DICHLOROBENZENE				
BENTHIC INVERTEBRATES				
Benthic community composition	Sediment	Reduced abundance	>170 µg/kg	PTI, 1988
Phoxocephalid amphipod (*Rhepoxynius abronius*)	Sediment	10-day LC 50	>170 µg/kg	Long and Morgan, 1991
1,2-DICHLOROBENZENE				
BENTHIC INVERTEBRATES				
Benthic community composition	Sediment	Reduced abundance	50 µg/kg	PTI, 1988
Phoxocephalid amphipod (*Rhepoxynius abronius*)	Sediment	10-day LC 50	>110 µg/kg	Long and Morgan, 1991
1,4-DICHLOROBENZENE				
BENTHIC INVERTEBRATES				
Benthic community composition	Sediment	Reduced abundance	110 µg/kg	PTI, 1988
Phoxocephalid amphipod (*Rhepoxynius abronius*)	Sediment	10-day LC 50	120 µg/kg	Long and Morgan, 1991
HEXACHLOROBENZENE				
BENTHIC INVERTEBRATES				
Benthic community composition	Sediment	Reduced abundance	22 µg/kg	PTI, 1988
Phoxocephalid amphipod (*Rhepoxynius abronius*)	Sediment	10-day LC 50	130 µg/kg	Long and Morgan, 1991

Table F-1. (Continued)

CHEMICAL/SPECIES	MEDIUM	ENDPOINT	CONC.	REFERENCE
HEXACHLOROBUTADIENE				
BENTHIC INVERTEBRATES				
Benthic community composition	Sediment	Reduced abundance	22 µg/kg	PTI, 1988
Phoxocephalid amphipod (*Rhepoxynius abronius*)	Sediment	10-day LC 50	180 µg/kg	Long and Morgan, 1991
PHTHALATE ESTERS				
FISH				
Shiner perch (*Cymatogaster aggregata*)	Water (96 hrs)	Changes in schooling behavior (butybenzyl phthalate -BBP)	80 µg/L	Ozretich et al., 1983
Shiner perch	Water (96 hrs)	Changes in color	240 µg/L	Ozretich et al., 1983
		LC 50	510 µg/L	
English sole (*Parophrys vetulus*)	Water (96 hrs)	Loss of equilibrium (BBP)	100 µg/L	Randall et al., 1983
		LC 50	550-610 µg/L	
BENTHIC INVERTEBRATES				
Benthic community composition Bis (2-ethylhexyl) phthalate Di-n-butyl phthalate Butylbenzyl phthalate Di-methyl phthalate	Sediment	Reduced abundance	 1,300 µg/kg >5,100 µg/kg 900 µg/kg >1,400 µg/kg	PTI, 1988
Phoxocephalid amphipod (*Rhepoxynius abronius*) Bis (2-ethylhexyl) phthalate Di-n-butyl phthalate Butylbenzyl phthalate Di-methyl phthalate	Sediment	10-day LC 50	 >3,100 µg/kg 1,400 µg/kg 900 µg/kg >1,400 µg/kg	Long and Morgan, 1991

Table F-1. (Continued)

CHEMICAL/SPECIES	MEDIUM	ENDPOINT	CONC.	REFERENCE
BENZYL ALCOHOL				
BENTHIC INVERTEBRATES				
Benthic community composition	Sediment	Reduced abundance	870 µg/kg	PTI, 1988
Phoxocephalid amphipod (*Rhepoxynius abronius*)	Sediment	10-day LC 50	870 µg/kg	Long and Morgan, 1991
BENZOIC ACID				
BENTHIC INVERTEBRATES				
Benthic community composition	Sediment	Reduced abundance	650 µg/kg	PTI, 1988
Phoxocephalid amphipod (*Rhepoxynius abronius*)	Sediment	10-day LC 50	760 µg/kg	Long and Morgan, 1991
TETRACHLOROETHANE				
No data				
		TRACE ELEMENTS		
ANTIMONY				
BENTHIC INVERTEBRATES				
Benthic community composition	Sediment	Reduced abundance	150 mg/kg	PTI, 1988
Phoxocephalid amphipod (*Rhepoxynius abronius*)	Sediment	10-day LC 50	200 µg/kg	Long and Morgan, 1991
ARSENIC				
SALMONIDS				
Pink salmon (*Oncorhynchus gorbuscha*)	Water (10 days)	LC 54	3,800 µg/L	EPA, 1985, as cited in Eisler, 1988a
CRAB				
Dungeness crab zoea	Water	96-hr LC 50	230 µg/L	EPA, 1985, as cited in Eisler, 1988a
BIVALVE MOLLUSC				
Blue mussel embryo (*Mytilus edulis*)	Water (3 to 16 days)	Lethality	16,000 µg/L	NAS, 1977, as cited in Eisler, 1988a

Table F-1. (Continued)

Chemical/Species	Medium	Endpoint	Conc.	Reference
Arsenic (Continued)				
Benthic Invertebrates				
Benthic community composition	Sediment	Reduced abundance	57 mg/kg	PTI, 1988
Phoxocephalid amphipod (*Rhepoxynius abronius*)	Sediment	10-day LC 50	93 mg/kg	Long and Morgan, 1991
Beryllium				
No data				
Cadmium				
Flatfish				
Winter flounder	Water (8 days)	60 % mortality	1,066 µg/L	Mance, 1987
Crab				
Dungeness crab zoea	Water	96-hr LC 50	247 µg/L	Mance, 1987
Bivalve mollusc				
Blue mussel larvae	Water	48-hr EC 50 Abnormal development	1,200 µg/L	Mance, 1987
Benthic Invertebrates				
Benthic community composition	Sediment	Reduced abundance	5.1 mg/kg	PTI, 1988
Phoxocephalid amphipod (*Rhepoxynius abronius*)	Sediment	10-day LC 50	6.9-11.5 mg/kg	Long and Morgan, 1991
Chromium				
Salmonids				
Coho salmon	Water (11 days)	Mortality	31,800 µg/L	EPA, 1985b
Flatfish				
Speckled sanddab (*Citharichthys stigmaeus*)	Water	96-hr LC 50	30,000 µg/L	Mance, 1987
Crab				
Dungeness crab zoea	Water	96-hr LC 50	3,440 µg/L	Mance, 1987
Chromium (Continued)				

Table F-1. (Continued)

CHEMICAL/SPECIES	MEDIUM	ENDPOINT	CONC.	REFERENCE
BIVALVE MOLLUSC				
Blue mussel larva	Water	48-hr EC 50 Abnormal development	4,470 μg/L	Mance, 1987
BENTHIC INVERTEBRATES				
Benthic community composition	Sediment	Reduced abundance	260 mg/kg	PTI, 1988
Phoxocephalid amphipod (*Rhepoxynius abronius*)	Sediment	10-day LC 50	270 mg/kg	Long and Morgan, 1991
COPPER				
FLATFISH				
(*Paralichthys dentatus*) larva	Water	96-hr LC 50	28 μg/L	Mance, 1988
Winter flounder adult	Water	96-hr LC 50	129 - 2,000 μg/L	Mance, 1988
CRAB				
Dungeness crab zoea	Water	96-hr LC 50	49 μg/L	Mance, 1988
BENTHIC INVERTEBRATES				
Benthic community composition	Sediment	Reduced abundance	530 mg/kg	PTI, 1988
Phoxocephalid amphipod (*Rhepoxynius abronius*)	Sediment	10-day LC 50	1300 mg/kg	Long and Morgan, 1991
LEAD				
FLATFISH				
Plaice (*Pleuronectes platessa*)	Water	96-hr LC 50	180,000 μg/L	Maddock and Taylor, 1980, as cited in Eisler, 1988b
CRAB				
Dungeness crab zoea	Water	96-hr LC 50	575 μg/L	Mance, 1987
BIVALVE MOLLUSC				
Blue mussel larva	Water	48-hr EC 50 Abnormal development	476 μg/L	Mance, 1987

Table F-1. (Continued)

CHEMICAL/SPECIES	MEDIUM	ENDPOINT	CONC.	REFERENCE
BENTHIC INVERTEBRATES				
Benthic community composition	Sediment	Reduced abundance	450 mg/kg	PTI, 1988
Phoxocephalid amphipod (*Rhepoxynius abronius*)	Sediment	10-day LC 50	660 mg/kg	Long and Morgan, 1991
MERCURY				
FLATFISH				
Winter flounder larva	Water	96-hr LC 50	1,320-1,960 µg/L	EPA, 1985c
CRAB				
Dungeness crab larva	Water	96-hr LC 50	6.6 µg/L	EPA, 1985c
BIVAVLE MOLLUSC				
Blue mussel	Water	96-hr LC 50	5.8 µg/L	EPA, 1985c
BENTHIC INVERTEBRATES				
Benthic community composition	Sediment	Reduced abundance	2.1 mg/kg	PTI, 1988
Phoxocephalid amphipod (*Rhepoxynius abronius*)	Sediment	10-day LC 50	2.1-13.1 mg/kg	Long and Morgan, 1991
NICKEL				
CRAB				
Dungeness crab zoea	Water	96-hr LC 50	4,360 µg/L	Mance, 1987
BIVAVLE MOLLUSC				
Blue mussel larva	Water	48-hr EC 50 Abnormal development	891 µg/L	Mance, 1987
BENTHIC INVERTEBRATES				
Benthic community composition	Sediment	Reduced abundance	>140 mg/kg	PTI, 1988
Phoxocephalid amphipod (*Rhepoxynius abronius*)	Sediment	10-day LC 50	>140 mg/kg	Long and Morgan, 1991

Table F-1. (Continued)

CHEMICAL/SPECIES	MEDIUM	ENDPOINT	CONC.	REFERENCE
SELENIUM				
CRAB				
Dungeness crab zoea	Water	96-hr LC 50 (not reached)	10,000 µg/L	Mance, 1987
SILVER				
FLATFISH				
Winter flounder embryos	Water (9 days)	30 % larval mortality, reduced growth, yolk sac deformed	180 µg/L	Mance, 1987
CRAB				
Dungeness crab zoea	Water	96-hr LC 50	55 µg/L	Mance, 1987
BIVALVE MOLLUSC				
Blue mussel larva	Water	48-hr EC 50 Abnormal development	14 µg/L	Mance, 1987
Blue mussel adults	Water	Reduced growth (1-yr exposure)	50 µg/L	Mance, 1987
BENTHIC INVERTEBRATES				
Benthic community composition	Sediment	Reduced abundance	>6.1 mg/kg	PTI, 1988
Phoxocephalid amphipod (*Rhepoxynius abronius*)	Sediment	10-day LC 50	6.1 mg/kg	Long and Morgan, 1991
ZINC				
SALMONIDS				
Steelhead trout yearling (*Oncorhynchus mykiss*)	Water	48-hr LC 50	35,000 µg/L	Mance, 1987
FLATFISH				
Winter flounder larva	Water	96-hr LC 50	4,920-18,200 µg/L	Mance, 1987

Table F-1. (Continued)

CHEMICAL/SPECIES	MEDIUM	ENDPOINT	CONC.	REFERENCE
ZINC (CONTINUED)				
CRAB				
Dungeness crab zoea	Water	96-hr LC 50	456 µg/L	Mance, 1987
BIVALVE MOLLUSC				
Blue mussel larva	Water	48-hr EC 50 Abnormal development	175 µg/L	Mance, 1987
Blue mussel adult	Water (22 days)	Reduced growth	10 µg/L	Mance, 1987
	Water	96-hr LC 50	2,500-4,300 µg/L	
BENTHIC INVERTEBRATES				
Benthic community composition	Sediment	Reduced abundance	410 mg/kg	PTI, 1988
Phoxocephalid amphipod (*Rhepoxynius abronius*)	Sediment	10-day LC 50	276 & 960 mg/kg	Long and Morgan, 1991

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