HYLEBOS FISH INJURY STUDY
ROUND II

Part 2: Effects of Chemical Contaminants from the Hylebos Waterway on Growth of Juvenile Chinook Salmon

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EXECUTIVE SUMMARY

The Hylebos Waterway of Commencement Bay, an urban estuary in central Puget Sound in the state of Washington, is severely contaminated with a variety of organic and inorganic chemicals. Juvenile salmon inhabit this waterway in the late spring and early summer before initiating their ocean migration. In 1994, Round I of the Hylebos Fish Injury Study was initiated to determine contaminant exposure in juvenile salmonids which migrate through this waterway. The findings showed that juvenile chinook and chum salmon sampled from this site were exposed to a wide range of chemical contaminants, and the levels of exposure were comparable to levels which have previously been shown to cause impaired growth, immunosuppression, and increased mortality following pathogen exposure in juvenile salmon (Collier et al. 1998). Whether juvenile salmon exposed specifically to chemical contaminants characteristic of the Hylebos Waterway suffer injurious biological effects as a result of the exposure, however, was not determined in this initial study.

The objective of the present laboratory study (Part 2 of Round II of the Hylebos Fish Injury Study) was to determine which class of chemical compounds in the contaminants associated with the Hylebos Waterway can alter (impair) the growth of juvenile chinook salmon. Specifically, juvenile salmon were exposed to either 1) hexachlorobutadiene (HCBD), a signature compound of the Hylebos Waterway, 2) an extract made from Hylebos Waterway sediment using methylene chloride as solvent (HWSE-M), 3) an extract made from Hylebos Waterway sediment using pentane as solvent (HWSE-P), 4) a model mixture composed of 10 high-molecular weight polycyclic aromatic hydrocarbons (PAHs) in proportion to PAHs in a sediment sampled from the Hylebos Waterway, 5) the PCB mixture, Aroclor 1254, 6) a reference sediment extract made from Nisqually River estuary sediment (NQSE), or 7) acetone/Emulphor, the solvent vehicle as control. Juvenile chinook salmon were exposed to the chemicals by intraperitoneal injection to ensure consistent delivery of a specific dosage. Growth was assessed by measuring changes in length and weight of the fish after a 60 day exposure period.

Significant ($p \leq 0.05$) differences in growth between juveniles exposed to contaminants and juveniles administered the solvent vehicle or the reference sediment extract were observed. Exposure to the two sediment extracts from the Hylebos Waterway (HWSE-M and HWSE-P), HCBD, as well as to the PCB mixture, Aroclor 1254, were associated with decreased growth of juvenile chinook salmon. These findings support the hypothesis that chemical contaminant exposure of juvenile salmon in the Hylebos Waterway influences their physiology such that their survival potential may be reduced. Because recruitment of salmon appears to be strongly influenced by factors acting on the first year of ocean life (Pearcy 1992), these results suggest that the risk for increased juvenile mortality and subsequent decreased adult recruitment is

potentially greater for juveniles exposed to contaminants during their residence in the Hylebos Waterway. However, the level of increase risk cannot be determined from the current information.

INTRODUCTION

Estuaries are critical habitats for juveniles of several Pacific salmon species during their transition to life in the ocean (Levings and Bouillon 1997). Estuarine habitats provide refuge from predators, rich food supply to support rapid growth, and are where juveniles make the final transition from freshwater to marine conditions (Thorpe 1994). Urban estuaries, however, receive inputs of toxic anthropogenic substances from a variety of sources, and many of these chemicals can accumulate in sediments and thus can be retained in the estuary. There is growing concern that while juvenile salmon are undergoing numerous physiological adaptations during their residence in estuarine environments, any additional stress such as exposure to toxic chemicals, may be injurious to their growth and survival.

The Hylebos Waterway of Commencement Bay, in central Puget Sound, in the state of Washington, is severely contaminated by a variety of organic and inorganic chemicals; and juvenile chinook salmon inhabit this waterway in the late spring and early summer. In 1994, Round I of the Hylebos Fish Injury Study was initiated to determine whether efforts to reduce chemical contaminant input into the waterways of Commencement Bay (contaminant source control) had resulted in improvements in habitat quality, as determined by: 1) decreases in prevalence of liver disease in flatfish, 2) normal reproductive function in flatfish; and 3) minimal contaminant exposure in juvenile salmonids migrating through this waterway. The findings of this study (Round I) showed that there have been no appreciable changes in disease prevalence or apparent contaminant exposure of flatfish from this site since the 1970s. Moreover, female flatfish from the Hylebos Waterway were showing evidence of precocious sexual maturation in young animals and inhibited gonadal development in older fish. More importantly for the report provided below, the results also showed that two species of juvenile salmon sampled from this site were exposed to a wide range of chemical contaminants and in particular showed increased exposure to chlorinated compounds (HCBD, HCB) that are elevated in Hylebos Waterway sediments compared to other sites in Puget Sound. HCBD is considered a marker chemical for the Hylebos Waterway. The levels of exposure to CHs and PAHs are comparable to levels which have previously been shown to cause impaired growth, immunosuppression, and increased mortality following pathogen exposure in juvenile salmon from the contaminated Duwamish Waterway, Puget Sound (Arkoosh et al. 1998, Casillas et al. 1995b). Thess studies provide the scientific rationale for determining if juvenile salmon, exposed to chemical contaminants characteristic of the Hylebos Waterway, exhibit injury from such exposure. However, the level of increased risk cannot be determined from the current information.

In our previous studies (Casillas et al. 1995a, b) designed to assess the effects of contaminants on the growth, juvenile fall chinook salmon were collected from an urban estuary

(Duwamish Waterway) and from non urban estuaries (Skokomish River and Nisqually River) as well as their respective releasing hatcheries. Collected fish were held in the laboratory for up to 90 days and differences in growth were evaluated with respect to previous exposure to urban contaminants. We found that juvenile chinook salmon from the contaminated estuary did not grow as well as fish from the corresponding hatchery on the Green River. In contrast, juvenile fall chinook salmon from the non urban estuaries showed no difference in growth compared to fish from the corresponding hatchery on the Skokomish River. Furthermore, when we measured the concentration of plasma hormones that are involved in regulation of growth in fish, such as thyroxine (T4), triiodothyronine (T_3), and insulin-like growth factor (IGF), we found that fish from the urban estuary had lower IGF levels than fish from the corresponding hatchery as well as from the non urban estuary and hatchery. These findings indicated that juvenile chinook salmon exhibiting contaminant-associated modulation of endocrine factors had impaired overall growth (Casillas et al., 1995a, b). The ecotoxicological implication is that mortality is potentially increased for juvenile salmon using contaminated estuary sites.

Accordingly, having previously shown that juvenile fall chinook and chum salmon are exposed to contaminants during residence in the Hylebos Waterway (Collier et al. 1998), our aim in this study (Part 3 of Round II of the Hylebos Fish Injury Study) was to determine if contaminants associated with the Hylebos Waterway can impair the growth of juvenile chinook salmon. Specifically in June 1997, juvenile chinook salmon were exposed to one of the following compounds or suite of compounds: 1) hexachlorobutadiene (HCBD), a signature compound of the Hylebos Waterway, 2) a methylene chloride extract of sediment from Hylebos Waterway (HWSE-M), 3) a pentane extract of sediment from Hylebos Waterway (HWSE-P), 4) a model mixture composed of 10 high-molecular weight polycyclic aromatic hydrocarbons (PAHs) in proportion to these PAHs in a sediment sample from the Hylebos Waterway, 5) the PCB mixture (Aroclor 1254), 6) a reference sediment extract made from Nisqually River estuary sediment (NQSE), or 7) acetone/Emulphor, the solvent vehicle control. The chemical contaminants were administered at sublethal concentrations. These were determined from the results of the 96 hr LD_{50} experiment for PAHs and PCBs with juvenile chinook salmon (Arkoosh et al. 1994) or based on our experience with sediment extracts. HCBD was administered at 20% of the 96-hr LD_{50} data for fish other than salmonids (Jorgensen et al. 1991). Growth was subsequently measured after a 60 day period. The hypothesis being tested was that growth of juvenile chinook salmon is reduced by contaminant exposure and impairment of growth is dependent on the chemicals or chemical mixtures used.

METHODS

Experiments in the growth study are described in detail in the SAP (Appendix 1). The chemicals identified in the NQSE, HWSE-M, HWSE-P and their concentration are listed in Table 1, 2, 3, respectively. The composition of the PAH model mixture is listed in Table 4.

Exposure Assessment

Information on the level of exposure for each treatment generated in subsequent experiments of the growth study is described in the SAP (Appendix 1).

Statistical methods - growth studies

Differences in mortality among the treatment groups were evaluated using contingency analysis (Zar 1978). Statistical significance of the growth studies were assessed using one factor ANOVA to assess treatment effects and a two factor nested ANOVA to evaluate the influence of tanks on the outcome. Significant differences compared to the control groups of fish (fish receiving acetone/Emulphor or the reference Nisqually River estuary sediment extract) were evaluated using Dunnett's Multiple Comparison Test (Zar 1978) at $\alpha = 0.05$. A one-tailed test was employed, because the hypothesis being tested was whether contaminant treatment reduced growth. ANCOVA was used to evaluate differences in growth over time amongst the treatments at $\alpha = 0.05$.

RESULTS

Sediment Extract Chemistry

The objective of administering HCBD, Aroclor 1254, HWSE-M, HWSE-P, and a model mixture of PAHs was to expose juvenile salmon to compounds representative of chemical contaminants in the Hylebos Waterway. HCBD was administered at a dose of 21 mg/kg of body weight. NQSE was prepared from sediment collected near the mouth of the Nisqually River. Chemical amounts and type in this extract are representative of sediment from a site that is not urbanized (Table 1). Juvenile chinook salmon treated with NQSE served as an alternate control group, providing a more direct opportunity to evaluate the influence of contaminant extracts, via injections, on fish growth. HWSE-M and HWSE-P were prepared from sediment collected near the mouth of the Hylebos Waterway using two different methods. Sediments from the Hylebos Waterway were taken at Stations HY-07, -08, and -09. All sediment sites were designated and analyzed during the sediment injury studies conducted during Phase 1 of the Hylebos Damage Assessment investigations. The objective for preparing these sediment extracts was to obtain test solutions which include chemical compounds that are present in sediment from the Hylebos Waterway using two different methods to isolate non polar toxic CHs and AHs (polar compounds were removed from the extracts by eluting through a silica column). The composition of analytes in the two Hylebos Waterway extracts is listed in Table 2 and 3. The major difference in these methods was that pentane or methylene chloride were used as solvents in the extraction process. In the pentane extract of the Hylebos Waterway sediment (HWSE-P), the proportion of high-molecular weight AHs (HMWAHs) was reduced relative to the CHs; therefore, the ratio of CHs to HMWAHs was increased (from a ratio of 1.7 in the HWSE-M to a ratio of 2.8 in the HWSE-P). As described in the SAP, it was anticipated that a fraction containing reduced levels of both HMWAHs and low-molecular weight AHs (LMWAHs) could be prepared; however, from the perspective of the experimental design, it was not practical to eliminate or greatly reduce the proportion of both HMWAHs and LMWAHs without losing the CHs as well. Nevertheless, using pentane rather than methylene chloride in the extraction process reduced HMWAHs nearly 47% while maintaining the chlorinated butadienes at nearly 88% of original levels (Tables 2 and 3). Hence, these two extraction approaches did provide an opportunity to evaluate whether there is an interaction between HMWAHs and CHs in affecting the growth of juvenile salmon. The chemicals and concentrations present in the HWSE-M represent the full range of chemicals (AHs and CHs) that may be available to fish. The final concentration of chemicals in each of the extracts (NQSE, HWSE-M) was 200 g sediment/ml of acetone, and the final concentration of chemicals in the HWSE-P was 400 g sediment/ml of acetone. A model mixture of polycyclic aromatic hydrocarbons (PAHs) containing 10 high molecular weight PAHs was also prepared to reflect the same ratios of these analytes previously found in sediment during Phase I of the Hylebos Damage Assessment studies at Station HY-24. The PCB mixture, Aroclor 1254, was administered to evaluate the effect of PCBs using a mixture which is representative of PCB congeners found in the Hylebos Waterway sediment. Concentrations of the PCBs, and the model mixture of PAHs given to juveniles were equal to 20% of the 96hr LD_{50} (Arkoosh et al. 1991). All test solutions, including controls were each administered at a volume equivalent to 1.5 μl solution/g fish. Dosages administered to experimental fish were described in detail in the methods section of the Hylebos Interpretive Report /Round II- Tissue concentrations and biochemical responses.

Temperature Profile, Feeding Rates, and Mortalities

Ambient water temperatures during the course of the study ranged from 11.6°C at the start of the study (June 26, 1997) to 12.8 °C at the end of the 60 day growth period (Figure 1). The mean (± SD) of water temperature was 12.2± 0.4 ^{0}C. The small variation in temperature was in part due to drawing seawater from a depth of approximately 50 feet, thereby minimizing the influence of more rapid changes in sea surface temperatures.

Feeding rates ranged from 3.6% to 3.7% body weight/day for each treatment and ranged from 3.5% to 3.7% body weight/day for each of the tanks of juvenile chinook salmon (Table 5). Replicate groups of tanks were maintained for each injected control or treatment group of juvenile chinook salmon, primarily to minimize the risk of loss of all experimental fish for each treatment from an unforeseen catastrophic event.

Recorded mortalities of experimental fish ranged from 5.5% to 18% (11 to 36 animals) after a 60 day growth period from a total of 200 fish for each of the treatment groups (Figure 2). The highest number of mortalities were observed in juveniles receiving either the model PAH mixture or the PCB formulation (Aroclor 1254) with only the group receiving the model PAH mixture exhibiting a significantly higher mortality than the average mortality (9.4%) among all groups. In contrast, the lowest mortalities were observed in juveniles receiving the reference Nisqually sediment extract or the Hylebos Waterway pentane-extract. Most of the mortalities were observed during the first 2 to 3 weeks of the growth study (Table 6). Mortalities were low and stable throughout the remainder of the growth period. At the end of the 60 day period, the number of observed mortalities and the number of fish remaining in all treatments did not always add up to 200. The number of fish at the end of the experiment was typically less (ranged from 1 to 10 fewer animals per tank) than what was expected based on recorded mortalities. This difference was attributed to losses of fish that escaped from the tanks through the exiting water standpipe. or by jumping out of the covered tanks. For example. 3 dead fish were found on the floor one day during the experiment; and we were not able to determine which tank (treatment) they came from, therefore they were not included in our mortality record. Although nets were carefully placed on top of tanks to minimize escapes, it is difficult to make the tanks escape-proof. Moreover, in one instance, we had more fish (2 "extra" fish) in a tank than was expected. These excess fish may be due to an error in the mortality record.

Growth Studies

The average starting size of juvenile chinook salmon in the seven different treatment groups ranged from 93 mm to 94 mm in fork length (Table 7) and 7.9 g to 8.2 g in weight (Table 8). An approximate 43% increase in length and a 290% increase in weight was observed after a 60 day growth period for all fish. At the end of the study period, fork lengths ranged from 133 mm to 135 mm and weights from 29.6 g to 32.1 g for the various treatment groups of fish. Juvenile chinook salmon exposed to the PCBs (Aroclor 1254), HCBD, the HWSE-M, or the HWSE-P were significantly smaller (ANOVA $p \leq 0.05$, Dunnett's One-Tailed Test) in length, or weight than fish exposed to the solvent vehicle. Fish exposed to either the PCBs (Aroclor 1254), HCBD, or the Hylebos Waterway sediment extracts were generally 2 mm shorter in fork length or 2.5 g lighter in mass than fish exposed to the solvent vehicle, or the reference sediment extract (NQSE). It is important to note that the size of juveniles exposed to the two Hylebos Waterway sediment extracts at the end of the of the exposure period may be, in part, due to the significantly smaller lengths and weights of these groups at the start of the experiment. These fish were smaller by approximately 1 mm and 0.3 g at the start of the experiment than fish exposed to the solvent vehicle, or the reference sediment extract (NQSE). However, this difference at the start of the experiment was not considered to affect the differences at the end of the 60-day exposure period. Moreover, because juveniles exposed to either PCBs or HCBD at the start of the experiment were not significantly different in size than fish exposed to the solvent vehicle, or the reference sediment extract (NQSE), the differences after the 60 day exposure period are likely the result of these particular treatments.

The experimental design in this study was to include a replicate tank for each treatment to insure that a treatment was not lost if there was an accidental loss of water to a tank. If, however, we evaluate the differences in length or weight of fish for each of the treatments, and included tanks as a nested variable within the experimental design, the variation with respect to tanks was significant (ANOVA, $p \leq 0.05$), and treatment differences in length or weight were no longer significantly different ($p > 0.05$). The tank effect is attributable to the greater variation between tanks in mean length and weight of juveniles exposed to either PCBs, HCBD, or the model PAH mixture (Figures 3 and 4). In one of the two tanks of fish exposed to either PCBs, HCBD, or the model PAH mixture, mean length or weight falls well below the 95% confidence interval for expected length or weight after a 60 day growth period. This confidence interval was generated from juvenile salmon exposed to the solvent vehicle - acetone:Emulphor, or exposed to the reference sediment extract (NQSE). In the remaining tanks of fish exposed to these three treatments, mean length or weight is above or within the 95% confidence interval for control mean length or weight after a 60 day growth period, thereby contributing to the greater variation in size between tanks. The variation in size between replicate tanks of fish receiving Aroclor 1254 or HCBD was not sufficient to negate the significant effect on size based on treatments alone, whereas the variation between tanks of fish exposed to the model PAH mixture was great enough such that fish undergoing this specific treatment was not significantly different from fish in the control or reference groups. It is important to note that for both Hylebos sediment extracts the mean lengths and weights for the replicate tanks of both extracts fell below the 95% confidence intervals of the expected length and weight for the 60 d growth period.

To evaluate differences in length or weight of juvenile chinook salmon over time and incorporate differences with respect to initial starting size, an ANCOVA was performed using the solvent vehicle as control. The increase in length of juvenile chinook salmon exposed to the PCBs (Aroclor 1254) or HCBD was significantly less (ANCOVA, $p \leq 0.05$) than fish exposed to the solvent vehicle; the NQSE group was not significantly different ($p = 0.7$) from the solvent vehicle group. The initial starting lengths of fish exposed to the Hylebos Waterway sediment extracts (HWSE-M and HWSE-P) were significantly smaller than fish exposed to the solvent vehicle, as noted earlier, and the ANCOVA showed that the increase in length over time was not different than observed for juveniles exposed to the solvent vehicle. However, the increase in weight of juvenile chinook salmon exposed to the PCBs (Aroclor 1254) and HCBD, as well as the HWSE-M and HWSE-P was significantly less (ANCOVA, $p \leq 0.05$) than fish exposed to the solvent vehicle. No difference in starting weights among the treatment groups were observed in this analysis.

Differences in growth of fish can also be visualized by plotting the cumulative frequency distribution of all fish exposed to the various treatments in this study. Although the size distribution in lengths and weights of juvenile chinook salmon at the start of the experiment were not large, the ranges at the end of the 60 day growth period revealed considerable expansion of this distribution. For example, the smallest to the largest fish at the start of the experiment ranged from 85 to 98 mm in fork length and 5.5 to 11.0 g in weight. At the end of the experiment, however, the size range expanded to 112 to 153 mm in fork length and 18.0 to 48.7 g in weight for all treatment groups. Displaying size distribution characteristics provides a better means to visualize differences in growth between groups over the experimental period, but statistical support for interpretation is drawn from the ANCOVA and ANOVA results. When we plot the cumulative weight frequency distribution of juvenile chinook salmon exposed to the solvent vehicle (acetone/Emulphor) and the reference sediment extract from the Nisqually River estuary (NQSE), after a 60 day growth period, the cumulative size distribution is essentially identical (Figure 5). This is consistent with the similarity in average weight of these fish as shown in Table 8. In addition, the plot of the weight distribution of juvenile chinook salmon exposed to the model PAH mixture (Figure 6) as compared to that of juvenile chinook salmon exposed to acetone/Emulphor, does not reveal any significant difference. This, again, is consistent with the overall similarity of the weight of these fish at the end of the experimental period. In contrast, the weight frequency distribution plot of juveniles exposed to HCBD (Figure 7) begins to reveal differences, which become more marked for fish exposed to the PCB mixture (Figure 8), or to the Hylebos Waterway sediment extracts (Figures 9 and 10) when compared to that of fish exposed to acetone/Emulphor. This finding agrees with the results shown in Table 8. It is noteworthy that, although the differences in absolute weight were moderate, the weight distribution pattern of fish exposed to Aroclor 1254 or the Hylebos Waterway sediment extracts revealed a clearer difference when compared to fish from the control groups.

DISCUSSION OF MAJOR FINDINGS

Juvenile chinook salmon exposed to contaminants specific to the Hylebos Waterway showed reduced growth.

The findings from this study showed that chemical contaminant exposure of juvenile salmon in the Hylebos Waterway can decrease their growth. Alterations in growth are linked to increased mortality in wild fish, including salmon (Sissenwine 1984, McGurk 1996). Clearly other ecological factors can also affect growth in fish (Brandt 1992). Although the magnitude of an increase in mortality in relation to the growth inhibition observed cannot be determined from the current findings, the results of this laboratory study are supportive of the hypothesis that chemical contaminants can decrease growth and consequently increase the risk of mortality. Juvenile chinook salmon exposed to contaminants associated with the Hylebos Waterway exhibited slower growth than did juvenile chinook salmon treated with the solvent vehicle or a sediment extract from a reference area. Although the growth suppression was statistically not large, representing a maximum 6% and 7% decrease in length or weight gain, respectively, the reduction was significant. These findings suggest that reduced growth may occur in salmon exposed to some of the chemical contaminants specific to the Hylebos Waterway. At the dosages tested, some of the treatment groups, which represent specific subsets of chemical contaminants characteristic of the Hylebos Waterway, appeared to equally suppress the growth of juvenile chinook salmon. Chlorinated hydrocarbons, characterized by the PCB mixture and HCBD, affected the growth of juvenile chinook salmon. The two sediment extracts from the Hylebos Waterway (HWSE-M and HWSE-P) containing chemical contaminants, including chlorinated hydrocarbons, and polycyclic hydrocarbons, also reduced growth, whereas growth of juvenile salmon over the 60-day period was not significantly affected by the high-molecular weight PAHs. These findings suggest that the chlorinated hydrocarbons including PCBs and the chlorinated butadienes, rather than the aromatic hydrocarbons may be the contaminants primarily contributing to the reduced growth of juvenile chinook salmon exposed to the two Hylebos Waterway sediment extracts. The conclusion of an apparent lack of ability of PAHs to impair growth of juvenile salmon must be tempered when we consider the variation in growth observed between tanks of fish receiving this contaminant type. The mean length and weight of at least one tank of fish receiving the model mixture of PAHs grew as poorly as fish exposed to PCBs or either of the Hylebos Waterway sediment extracts. However, because the duplicate tank of fish grew as well, if not slightly better than the control groups, a significant reduction in growth of juveniles exposed to the model PAH mixture was not evident. Nevertheless, overall chlorinated hydrocarbons, exemplified by the PCBs and HCBD, appeared to be consistently associated with a small but significant reduction in the growth of juvenile salmon under the experimental conditions employed.

Juvenile chinook salmon in this study were injected with sediment extracts or model compounds in order to administer the contaminants at well-defined and controlled dosages to facilitate comparisons among treatment groups. The overall objective was to assess the impacts of chemical contaminant types found in the Hylebos Waterway on growth of juvenile chinook salmon. While juvenile chinook salmon were exposed to chemical contaminants at a dosage higher than realistically present in the environment, they were held under rather optimum conditions (they were well fed and did not have any competition or predators during the experiment). Thus, the impacts on growth of experimental fish may have been minimized when interpreted in the context of the ecosystem and integrated with the activities that fish must undertake to survive in the natural environment.

The reduced growth of salmon exposed to contaminants associated with the Hylebos Waterway observed in this study are consistent with previous findings (Casillas et al. 1995a, b) showing impaired growth and altered immune function in juvenile chinook salmon from the Duwamish Waterway in Elliott Bay, also located in Puget Sound, WA. We found that juvenile salmon from the Duwamish Waterway estuary showing increased exposure to CHs and AHs did not grow as well as juvenile salmon that are out migrating through the reference estuaries of the Nisqually and Skokomish Rivers. In addition, the reduced growth of juveniles exposed to chemical contaminants in the Duwamish Waterway, after a 60 to 90 day period, was of approximately the same magnitude as that observed in this study. It is important to note that the level of exposure to chemical contaminants in fish sampled from the Duwamish estuary was lower than exposure in the laboratory study reported here. The finding of reduced growth in both studies suggests that the threshold for chemical contaminants affecting growth of juvenile salmon is within the range of environmental exposure.

Chemical contaminants also affect other physiological functions in juvenile salmon. Arkoosh et al. (1991, 1998) showed a suppressed secondary immune response in white blood cells of anterior kidney to specific model antigens and a greater percent of cumulative mortality to *V. anguillarum* after natural exposure to chemical contaminants, including PAHs and PCBs in the waterway. In addition, juvenile salmon exposed to a model PAH, dimethylbenz[a]anthracene (DMBA) or a PCB mixture (Aroclor 1254) in the laboratory exhibited a similar suppressed secondary immune response in white blood cells of anterior kidney to model antigens (Arkoosh et al. 1994). Both PAHs and PCBs are known to induce immunosuppression in other species (Thomas and Hinsdill 1978; Ward et al. 1985). Thus, our findings are consistent with the observations that chemical contaminants, including chlorinated hydrocarbons found in the Hylebos Waterway, could affect a range of physiological functions, including immunocompetence and growth, in juvenile salmon. A follow up study, Round III is being designed to determine the sediment levels of contaminants at which effects (e.g. impaired growth, disease resistance) would be observed.

The ecological significance of reduced growth from exposure to chemical contaminants specific to the Hylebos Waterway is likely to be manifest during the initial phase of early ocean life and consequently could affect their survival potential in the estuary and early ocean environment.

The effect of the reduced growth observed after exposure to contaminants specific to the Hylebos Waterway, although not large, may significantly reduce the ability of juvenile salmon to effectively compete and exist in their natural environment for several reasons. First, fish growth is highly pliable and integrates various habitat conditions, thus growth has been used frequently as an indicator of ecosystem health (Brandt 1992). Moreover, the ability of a fish to achieve its optimum growth rate as a juvenile is not only a relative measure of the fish's health and conditions, it is also a measure of survival and reproductive output potential (Brandt 1992). Thus, growth is linked to a variety of important life functions supporting propagation of the species. The links in growth, survival, and reproduction among fish foster the hypothesis that slower growing or smaller animals, as they proceed through successive life stages, inherently acquire a greater chance of mortality and have lower fecundity at reproduction (Banse and Mosher 1980). In this context, factors such as chemical contaminants, which are shown to reduce growth rate in the pre-adult stages, can be linked to reduced reproductive and survival potential.

Secondly, the reduced growth of juvenile salmon is occurring as they enter the marine environment where mortality is a significant factor in controlling the numbers that are recruited to the fishery and back to their natal streams. Approximately one-half of the loss of pre-adult (egg through juvenile stage) salmon has been shown to occur in the marine environment (Bradford 1995). Predators, inter- and intra-specific competition, food availability, smolt quality and health, and environmental factors (chemical and physical) are all potentially and likely important factors that influence survival of salmon in the estuarine and near shore marine environment. Thus, factors that affect the ability of salmon to function normally in their natural environment in the short-term are likely to influence longer term survival to their reproductive stage. The reduced growth of juvenile salmon shown in the current study is therefore an indication of a decrease in survival potential; especially in an environment where extensive mortality has been documented (Bradford 1995).

Third, the observed reduced growth of juvenile chinook salmon induced by chemical contaminant exposure is occurring during a phase where growth has been shown to be critical to success of the population. Growth of salmon during the first year of ocean life appears to be critical to recruitment success (Pearcy 1992, Unwin 1997, Unwin and Glova 1997, Heath et al. 1997). This understanding is based on the positive relationship between the number of precocious male salmon (fish that mature earlier than-normal) and the commensurate success of the adult population of salmon for each year class (Pearcy 1992, Gudjonsson et al. 1995). Precocious maturation, further, appears to be linked to growth rates. Higher growth rates are associated with a higher proportion of precociously maturing salmon in the population (Friedland and Haas 1996). The issue, however, may not be if an animal is growing or is of a larger size, but rather what is the proportion of fish with the appropriate growth rate. Dickhoff et al. (1995) and Beckman et al. (1997) have shown that out migrating juvenile salmon smolts with the highest growth rates at the time of release, and not necessarily the largest smolts, survived better than juveniles exhibiting slower growth rates. Holtby et al. (1990) supported this contention for juvenile coho salmon, showing that in typical years, fish with higher growth rates survived better than juveniles with slower growth rates. It is in this context that reduced growth caused by factors, such as chemical contaminants, as shown in our study, may have long term ecological consequence for the survival of juvenile salmon inhabiting urban estuaries for part of their life cycle.

Finally, the salmon in the present study were found to have altered growth that extended well past the initial chemical contaminant exposure period, that is, reduced growth was evident two months after the initial exposure. This finding is also supported by a previous field study showing that juvenile salmon collected from the Duwamish estuary and held for two months in uncontaminated seawater exhibited suppressed growth. Our previous studies suggest that although juvenile chinook salmon are only briefly exposed to contaminants in an urban estuary as they migrate to sea, growth altering events persist for at least 2 months, and may extend into their early ocean life. The findings in Round I of these studies showed that during a relatively brief residence in the Hylebos Waterway, juvenile chinook and chum salmon were exposed to significant levels of chemical contaminants which resulted in induction of early biological alterations indicated by elevated hepatic CYP1A and DNA damage. In the present study we demonstrated that contaminants characteristic of sediments from the Hylebos Waterway reduced the growth of juvenile chinook salmon. Because recruitment of fish to the adult stage is considered to be dependent on factors acting during the first year of life (Sissenwine 1984, Pearcy 1992), the potential for contaminants to influence size dependent mortality and mortality rates within the population is a possibility. There is uncertainty in relating the observed reduction in growth as a result of exposure to chemical contaminants described in this study to potential impacts on mortality and population structure. However, the findings from studies cited above suggest that the observed reduction in growth has the potential to increase mortality of juvenile salmon through other ecological interactions (e.g. predation, inability to acquire appropriate prey, disease) which they encounter in their natural habitat.

Quantitating the level of increased risk however, cannot be assessed from the findings of the present study. When we examined the adult return data for fall chinook salmon to urban associated river systems, such as the Puyallup (Hylebos Waterway) or the Green River (Duwamish Waterway), using the Coded Wire Tag database (PFMSC 1993), we found, however, that the average returns during the period of 1971-1991 to these urban systems were less than the average for Puget Sound river systems (Washington State hatcheries) or for major river systems for the entire state of Washington (Table 11). Although we cannot define the causal factors which affect the lower than average adult returns for fish migrating through urban estuaries, as there are many factors which contribute to the outcome, such as predation, food availability, ocean conditions, etc., the finding that chemical contaminants reduce growth of juvenile salmon, and that reduced growth is associated with lower survival potential in chinook salmon (Unwin 1997) is not inconsistent with the lower than average return rates from these urban systems.

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LIST OF ABBREVIATIONS

AHs	aromatic hydrocarbons
CHs	chlorinated hydrocarbons
CYP1A	cytochrome P4501A
DMBA	dimethylbenzanthracene
DNA	deoxyribonucleic acid
GC/MS	gas chromatography/mass spectrometry
HCB	hexachlorobenzene
HCBD	hexachlorobutadiene
HWSE-M	Hylebos Waterway sediment extract prepared with methylene chloride
HWSE-P	Hylebos Waterway sediment extract prepared with pentane
LD	Lethal dose
NOAA	National Oceanic and Atmospheric Administration
NMFS	National Marine Fisheries Service
NWFSC	Northwest Fisheries Science Center
NQSE	Nisqually River sediment extract
PCBs	polychlorinated biphenyls
PAHs	polycyclic aromatic hydrocarbons
SAP	Sampling and Analysis Plan

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EXECUTIVE SUMMARY

The Hylebos Waterway of Commencement Bay, an urban estuary in central Puget Sound in the state of Washington, is severely contaminated with a variety of organic and inorganic chemicals. Juvenile salmon inhabit this waterway in the late spring and early summer before initiating their ocean migration. In 1994, Round I of the Hylebos Fish Injury Study was initiated to determine contaminant exposure in juvenile salmonids which migrate through this waterway. The findings showed that juvenile chinook and chum salmon sampled from this site were exposed to a wide range of chemical contaminants, and the levels of exposure were comparable to levels which have previously been shown to cause impaired growth, immunosuppression, and increased mortality following pathogen exposure in juvenile salmon (Collier et al. 1998). Whether juvenile salmon exposed specifically to chemical contaminants characteristic of the Hylebos Waterway suffer injurious biological effects as a result of the exposure, however, was not determined in this initial study.

The objective of the present laboratory study (Part 2 of Round II of the Hylebos Fish Injury Study) was to determine which class of chemical compounds in the contaminants associated with the Hylebos Waterway can alter (impair) the growth of juvenile chinook salmon. Specifically, juvenile salmon were exposed to either 1) hexachlorobutadiene (HCBD), a signature compound of the Hylebos Waterway, 2) an extract made from Hylebos Waterway sediment using methylene chloride as solvent (HWSE-M), 3) an extract made from Hylebos Waterway sediment using pentane as solvent (HWSE-P), 4) a model mixture composed of 10 high-molecular weight polycyclic aromatic hydrocarbons (PAHs) in proportion to PAHs in a sediment sampled from the Hylebos Waterway, 5) the PCB mixture, Aroclor 1254, 6) a reference sediment extract made from Nisqually River estuary sediment (NQSE), or 7) acetone/Emulphor, the solvent vehicle as control. Juvenile chinook salmon were exposed to the chemicals by intraperitoneal injection to ensure consistent delivery of a specific dosage. Growth was assessed by measuring changes in length and weight of the fish after a 60 day exposure period.

Significant ($p \leq 0.05$) differences in growth between juveniles exposed to contaminants and juveniles administered the solvent vehicle or the reference sediment extract were observed. Exposure to the two sediment extracts from the Hylebos Waterway (HWSE-M and HWSE-P), HCBD, as well as to the PCB mixture, Aroclor 1254, were associated with decreased growth of juvenile chinook salmon. These findings support the hypothesis that chemical contaminant exposure of juvenile salmon in the Hylebos Waterway influences their physiology such that their survival potential may be reduced. Because recruitment of salmon appears to be strongly influenced by factors acting on the first year of ocean life (Pearcy 1992), these results suggest that the risk for increased juvenile mortality and subsequent decreased adult recruitment is potentially greater for juveniles exposed to contaminants during their residence in the Hylebos Waterway. However, the level of increase risk cannot be determined from the current information.

INTRODUCTION

Estuaries are critical habitats for juveniles of several Pacific salmon species during their transition to life in the ocean (Levings and Bouillon 1997). Estuarine habitats provide refuge from predators, rich food supply to support rapid growth, and are where juveniles make the final transition from freshwater to marine conditions (Thorpe 1994). Urban estuaries, however, receive inputs of toxic anthropogenic substances from a variety of sources, and many of these chemicals can accumulate in sediments and thus can be retained in the estuary. There is growing concern that while juvenile salmon are undergoing numerous physiological adaptations during their residence in estuarine environments, any additional stress such as exposure to toxic chemicals, may be injurious to their growth and survival.

The Hylebos Waterway of Commencement Bay, in central Puget Sound, in the state of Washington, is severely contaminated by a variety of organic and inorganic chemicals; and juvenile chinook salmon inhabit this waterway in the late spring and early summer. In 1994, Round I of the Hylebos Fish Injury Study was initiated to determine whether efforts to reduce chemical contaminant input into the waterways of Commencement Bay (contaminant source control) had resulted in improvements in habitat quality, as determined by: 1) decreases in prevalence of liver disease in flatfish, 2) normal reproductive function in flatfish; and 3) minimal contaminant exposure in juvenile salmonids migrating through this waterway. The findings of this study (Round I) showed that there have been no appreciable changes in disease prevalence or apparent contaminant exposure of flatfish from this site since the 1970s. Moreover, female flatfish from the Hylebos Waterway were showing evidence of precocious sexual maturation in young animals and inhibited gonadal development in older fish. More importantly for the report provided below, the results also showed that two species of juvenile salmon sampled from this site were exposed to a wide range of chemical contaminants and in particular showed increased exposure to chlorinated compounds (HCBD, HCB) that are elevated in Hylebos Waterway sediments compared to other sites in Puget Sound. HCBD is considered a marker chemical for the Hylebos Waterway. The levels of exposure to CHs and PAHs are comparable to levels which have previously been shown to cause impaired growth, immunosuppression, and increased mortality following pathogen exposure in juvenile salmon from the contaminated Duwamish Waterway, Puget Sound (Arkoosh et al. 1998, Casillas et al. 1995b). Thess studies provide the scientific rationale for determining if juvenile salmon, exposed to chemical contaminants characteristic of the Hylebos Waterway, exhibit injury from such exposure. However, the level of increased risk cannot be determined from the current information.

In our previous studies (Casillas et al. 1995a, b) designed to assess the effects of contaminants on the growth, juvenile fall chinook salmon were collected from an urban estuary

(Duwamish Waterway) and from non urban estuaries (Skokomish River and Nisqually River) as well as their respective releasing hatcheries. Collected fish were held in the laboratory for up to 90 days and differences in growth were evaluated with respect to previous exposure to urban contaminants. We found that juvenile chinook salmon from the contaminated estuary did not grow as well as fish from the corresponding hatchery on the Green River. In contrast, juvenile fall chinook salmon from the non urban estuaries showed no difference in growth compared to fish from the corresponding hatchery on the Skokomish River. Furthermore, when we measured the concentration of plasma hormones that are involved in regulation of growth in fish, such as thyroxine (T4), triiodothyronine (T_3), and insulin-like growth factor (IGF), we found that fish from the urban estuary had lower IGF levels than fish from the corresponding hatchery as well as from the non urban estuary and hatchery. These findings indicated that juvenile chinook salmon exhibiting contaminant-associated modulation of endocrine factors had impaired overall growth (Casillas et al., 1995a, b). The ecotoxicological implication is that mortality is potentially increased for juvenile salmon using contaminated estuary sites.

Accordingly, having previously shown that juvenile fall chinook and chum salmon are exposed to contaminants during residence in the Hylebos Waterway (Collier et al. 1998), our aim in this study (Part 3 of Round II of the Hylebos Fish Injury Study) was to determine if contaminants associated with the Hylebos Waterway can impair the growth of juvenile chinook salmon. Specifically in June 1997, juvenile chinook salmon were exposed to one of the following compounds or suite of compounds: 1) hexachlorobutadiene (HCBD), a signature compound of the Hylebos Waterway, 2) a methylene chloride extract of sediment from Hylebos Waterway (HWSE-M), 3) a pentane extract of sediment from Hylebos Waterway (HWSE-P), 4) a model mixture composed of 10 high-molecular weight polycyclic aromatic hydrocarbons (PAHs) in proportion to these PAHs in a sediment sample from the Hylebos Waterway, 5) the PCB mixture (Aroclor 1254), 6) a reference sediment extract made from Nisqually River estuary sediment (NQSE), or 7) acetone/Emulphor, the solvent vehicle control. The chemical contaminants were administered at sublethal concentrations. These were determined from the results of the 96 hr LD_{50} experiment for PAHs and PCBs with juvenile chinook salmon (Arkoosh et al. 1994) or based on our experience with sediment extracts. HCBD was administered at 20% of the 96-hr LD_{50} data for fish other than salmonids (Jorgensen et al. 1991). Growth was subsequently measured after a 60 day period. The hypothesis being tested was that growth of juvenile chinook salmon is reduced by contaminant exposure and impairment of growth is dependent on the chemicals or chemical mixtures used.

METHODS

Experiments in the growth study are described in detail in the SAP (Appendix 1). The chemicals identified in the NQSE, HWSE-M, HWSE-P and their concentration are listed in Table 1, 2, 3, respectively. The composition of the PAH model mixture is listed in Table 4.

Exposure Assessment

Information on the level of exposure for each treatment generated in subsequent experiments of the growth study is described in the SAP (Appendix 1).

Statistical methods - growth studies

Differences in mortality among the treatment groups were evaluated using contingency analysis (Zar 1978). Statistical significance of the growth studies were assessed using one factor ANOVA to assess treatment effects and a two factor nested ANOVA to evaluate the influence of tanks on the outcome. Significant differences compared to the control groups of fish (fish receiving acetone/Emulphor or the reference Nisqually River estuary sediment extract) were evaluated using Dunnett's Multiple Comparison Test (Zar 1978) at $\alpha = 0.05$. A one-tailed test was employed, because the hypothesis being tested was whether contaminant treatment reduced growth. ANCOVA was used to evaluate differences in growth over time amongst the treatments at $\alpha = 0.05$.

RESULTS

Sediment Extract Chemistry

The objective of administering HCBD, Aroclor 1254, HWSE-M, HWSE-P, and a model mixture of PAHs was to expose juvenile salmon to compounds representative of chemical contaminants in the Hylebos Waterway. HCBD was administered at a dose of 21 mg/kg of body weight. NQSE was prepared from sediment collected near the mouth of the Nisqually River. Chemical amounts and type in this extract are representative of sediment from a site that is not urbanized (Table 1). Juvenile chinook salmon treated with NQSE served as an alternate control group, providing a more direct opportunity to evaluate the influence of contaminant extracts, via injections, on fish growth. HWSE-M and HWSE-P were prepared from sediment collected near the mouth of the Hylebos Waterway using two different methods. Sediments from the Hylebos Waterway were taken at Stations HY-07, -08, and -09. All sediment sites were designated and analyzed during the sediment injury studies conducted during Phase 1 of the Hylebos Damage Assessment investigations. The objective for preparing these sediment extracts was to obtain test solutions which include chemical compounds that are present in sediment from the Hylebos Waterway using two different methods to isolate non polar toxic CHs and AHs (polar compounds were removed from the extracts by eluting through a silica column). The composition of analytes in the two Hylebos Waterway extracts is listed in Table 2 and 3. The major difference in these methods was that pentane or methylene chloride were used as solvents in the extraction process. In the pentane extract of the Hylebos Waterway sediment (HWSE-P), the proportion of high-molecular weight AHs (HMWAHs) was reduced relative to the CHs; therefore, the ratio of CHs to HMWAHs was increased (from a ratio of 1.7 in the HWSE-M to a ratio of 2.8 in the HWSE-P). As described in the SAP, it was anticipated that a fraction containing reduced levels of both HMWAHs and low-molecular weight AHs (LMWAHs) could be prepared; however, from the perspective of the experimental design, it was not practical to eliminate or greatly reduce the proportion of both HMWAHs and LMWAHs without losing the CHs as well. Nevertheless, using pentane rather than methylene chloride in the extraction process reduced HMWAHs nearly 47% while maintaining the chlorinated butadienes at nearly 88% of original levels (Tables 2 and 3). Hence, these two extraction approaches did provide an opportunity to evaluate whether there is an interaction between HMWAHs and CHs in affecting the growth of juvenile salmon. The chemicals and concentrations present in the HWSE-M represent the full range of chemicals (AHs and CHs) that may be available to fish. The final concentration of chemicals in each of the extracts (NQSE, HWSE-M) was 200 g sediment/ml of acetone, and the final concentration of chemicals in the HWSE-P was 400 g sediment/ml of acetone. A model mixture of polycyclic aromatic hydrocarbons (PAHs) containing 10 high molecular weight PAHs was also prepared to reflect the same ratios of these analytes previously found in sediment during Phase I of the Hylebos Damage Assessment studies at Station HY-24. The PCB mixture, Aroclor 1254, was administered to evaluate the effect of PCBs using a mixture which is representative of PCB congeners found in the Hylebos Waterway sediment. Concentrations of the PCBs, and the model mixture of PAHs given to juveniles were equal to 20% of the 96hr LD_{50} (Arkoosh et al. 1991). All test solutions, including controls were each administered at a volume equivalent to 1.5 μl solution/g fish. Dosages administered to experimental fish were described in detail in the methods section of the Hylebos Interpretive Report /Round II- Tissue concentrations and biochemical responses.

Temperature Profile, Feeding Rates, and Mortalities

Ambient water temperatures during the course of the study ranged from 11.6°C at the start of the study (June 26, 1997) to 12.8 °C at the end of the 60 day growth period (Figure 1). The mean (± SD) of water temperature was 12.2± 0.4 ^{0}C. The small variation in temperature was in part due to drawing seawater from a depth of approximately 50 feet, thereby minimizing the influence of more rapid changes in sea surface temperatures.

Feeding rates ranged from 3.6% to 3.7% body weight/day for each treatment and ranged from 3.5% to 3.7% body weight/day for each of the tanks of juvenile chinook salmon (Table 5). Replicate groups of tanks were maintained for each injected control or treatment group of juvenile chinook salmon, primarily to minimize the risk of loss of all experimental fish for each treatment from an unforeseen catastrophic event.

Recorded mortalities of experimental fish ranged from 5.5% to 18% (11 to 36 animals) after a 60 day growth period from a total of 200 fish for each of the treatment groups (Figure 2). The highest number of mortalities were observed in juveniles receiving either the model PAH mixture or the PCB formulation (Aroclor 1254) with only the group receiving the model PAH mixture exhibiting a significantly higher mortality than the average mortality (9.4%) among all groups. In contrast, the lowest mortalities were observed in juveniles receiving the reference Nisqually sediment extract or the Hylebos Waterway pentane-extract. Most of the mortalities were observed during the first 2 to 3 weeks of the growth study (Table 6). Mortalities were low and stable throughout the remainder of the growth period. At the end of the 60 day period, the number of observed mortalities and the number of fish remaining in all treatments did not always add up to 200. The number of fish at the end of the experiment was typically less (ranged from 1 to 10 fewer animals per tank) than what was expected based on recorded mortalities. This difference was attributed to losses of fish that escaped from the tanks through the exiting water standpipe, or by jumping out of the covered tanks. For example, 3 dead fish were found on the floor one day during the experiment; and we were not able to determine which tank (treatment) they came from, therefore they were not included in our mortality record. Although nets were carefully placed on top of tanks to minimize escapes, it is difficult to make the tanks escape-proof. Moreover, in one instance, we had more fish (2 "extra" fish) in a tank than was expected. These excess fish may be due to an error in the mortality record.

Growth Studies

The average starting size of juvenile chinook salmon in the seven different treatment groups ranged from 93 mm to 94 mm in fork length (Table 7) and 7.9 g to 8.2 g in weight (Table 8). An approximate 43% increase in length and a 290% increase in weight was observed after a 60 day growth period for all fish. At the end of the study period, fork lengths ranged from 133 mm to 135 mm and weights from 29.6 g to 32.1 g for the various treatment groups of fish. Juvenile chinook salmon exposed to the PCBs (Aroclor 1254), HCBD, the HWSE-M, or the HWSE-P were significantly smaller (ANOVA $p \leq 0.05$, Dunnett's One-Tailed Test) in length, or weight than fish exposed to the solvent vehicle. Fish exposed to either the PCBs (Aroclor 1254), HCBD, or the Hylebos Waterway sediment extracts were generally 2 mm shorter in fork length or 2.5 g lighter in mass than fish exposed to the solvent vehicle, or the reference sediment extract (NQSE). It is important to note that the size of juveniles exposed to the two Hylebos Waterway sediment extracts at the end of the of the exposure period may be, in part, due to the significantly smaller lengths and weights of these groups at the start of the experiment. These fish were smaller by approximately 1 mm and 0.3 g at the start of the experiment than fish exposed to the solvent vehicle, or the reference sediment extract (NQSE). However, this difference at the start of the experiment was not considered to affect the differences at the end of the 60-day exposure period. Moreover, because juveniles exposed to either PCBs or HCBD at the start of the experiment were not significantly different in size than fish exposed to the solvent vehicle, or the reference sediment extract (NQSE), the differences after the 60 day exposure period are likely the result of these particular treatments.

The experimental design in this study was to include a replicate tank for each treatment to insure that a treatment was not lost if there was an accidental loss of water to a tank. If, however, we evaluate the differences in length or weight of fish for each of the treatments, and included tanks as a nested variable within the experimental design, the variation with respect to tanks was significant (ANOVA, $p \leq 0.05$), and treatment differences in length or weight were no longer significantly different ($p > 0.05$). The tank effect is attributable to the greater variation between tanks in mean length and weight of juveniles exposed to either PCBs, HCBD, or the model PAH mixture (Figures 3 and 4). In one of the two tanks of fish exposed to either PCBs, HCBD, or the model PAH mixture, mean length or weight falls well below the 95% confidence interval for expected length or weight after a 60 day growth period. This confidence interval was generated from juvenile salmon exposed to the solvent vehicle - acetone:Emulphor, or exposed to the reference sediment extract (NQSE). In the remaining tanks of fish exposed to these three treatments, mean length or weight is above or within the 95% confidence interval for control mean length or weight after a 60 day growth period, thereby contributing to the greater variation in size between tanks. The variation in size between replicate tanks of fish receiving Aroclor 1254 or HCBD was not sufficient to negate the significant effect on size based on treatments alone, whereas the variation between tanks of fish exposed to the model PAH mixture was great enough such that fish undergoing this specific treatment was not significantly different from fish in the control or reference groups. It is important to note that for both Hylebos sediment extracts the mean lengths and weights for the replicate tanks of both extracts fell below the 95% confidence intervals of the expected length and weight for the 60 d growth period.

To evaluate differences in length or weight of juvenile chinook salmon over time and incorporate differences with respect to initial starting size, an ANCOVA was performed using the solvent vehicle as control. The increase in length of juvenile chinook salmon exposed to the PCBs (Aroclor 1254) or HCBD was significantly less (ANCOVA, $p \leq 0.05$) than fish exposed to the solvent vehicle; the NQSE group was not significantly different ($p = 0.7$) from the solvent vehicle group. The initial starting lengths of fish exposed to the Hylebos Waterway sediment extracts (HWSE-M and HWSE-P) were significantly smaller than fish exposed to the solvent vehicle, as noted earlier, and the ANCOVA showed that the increase in length over time was not different than observed for juveniles exposed to the solvent vehicle. However, the increase in weight of juvenile chinook salmon exposed to the PCBs (Aroclor 1254) and HCBD, as well as the HWSE-M and HWSE-P was significantly less (ANCOVA, $p \leq 0.05$) than fish exposed to the solvent vehicle. No difference in starting weights among the treatment groups were observed in this analysis.

Differences in growth of fish can also be visualized by plotting the cumulative frequency distribution of all fish exposed to the various treatments in this study. Although the size distribution in lengths and weights of juvenile chinook salmon at the start of the experiment were not large, the ranges at the end of the 60 day growth period revealed considerable expansion of this distribution. For example, the smallest to the largest fish at the start of the experiment ranged from 85 to 98 mm in fork length and 5.5 to 11.0 g in weight. At the end of the experiment, however, the size range expanded to 112 to 153 mm in fork length and 18.0 to 48.7 g in weight for all treatment groups. Displaying size distribution characteristics provides a better means to visualize differences in growth between groups over the experimental period, but statistical support for interpretation is drawn from the ANCOVA and ANOVA results. When we plot the cumulative weight frequency distribution of juvenile chinook salmon exposed to the solvent vehicle (acetone/Emulphor) and the reference sediment extract from the Nisqually River estuary (NQSE), after a 60 day growth period, the cumulative size distribution is essentially identical (Figure 5). This is consistent with the similarity in average weight of these fish as shown in Table 8. In addition, the plot of the weight distribution of juvenile chinook salmon exposed to the model PAH mixture (Figure 6) as compared to that of juvenile chinook salmon exposed to acetone/Emulphor, does not reveal any significant difference. This, again, is consistent with the overall similarity of the weight of these fish at the end of the experimental period. In contrast, the weight frequency distribution plot of juveniles exposed to HCBD (Figure 7) begins to reveal differences, which become more marked for fish exposed to the PCB mixture (Figure 8), or to the Hylebos Waterway sediment extracts (Figures 9 and 10) when compared to that of fish exposed to acetone/Emulphor. This finding agrees with the results shown in Table 8. It is noteworthy that, although the differences in absolute weight were moderate, the weight distribution pattern of fish exposed to Aroclor 1254 or the Hylebos Waterway sediment extracts revealed a clearer difference when compared to fish from the control groups.

DISCUSSION OF MAJOR FINDINGS

Juvenile chinook salmon exposed to contaminants specific to the Hylebos Waterway showed reduced growth.

The findings from this study showed that chemical contaminant exposure of juvenile salmon in the Hylebos Waterway can decrease their growth. Alterations in growth are linked to increased mortality in wild fish, including salmon (Sissenwine 1984, McGurk 1996). Clearly other ecological factors can also affect growth in fish (Brandt 1992). Although the magnitude of an increase in mortality in relation to the growth inhibition observed cannot be determined from the current findings, the results of this laboratory study are supportive of the hypothesis that chemical contaminants can decrease growth and consequently increase the risk of mortality. Juvenile chinook salmon exposed to contaminants associated with the Hylebos Waterway exhibited slower growth than did juvenile chinook salmon treated with the solvent vehicle or a sediment extract from a reference area. Although the growth suppression was statistically not large, representing a maximum 6% and 7% decrease in length or weight gain, respectively, the reduction was significant. These findings suggest that reduced growth may occur in salmon exposed to some of the chemical contaminants specific to the Hylebos Waterway. At the dosages tested, some of the treatment groups, which represent specific subsets of chemical contaminants characteristic of the Hylebos Waterway, appeared to equally suppress the growth of juvenile chinook salmon. Chlorinated hydrocarbons, characterized by the PCB mixture and HCBD, affected the growth of juvenile chinook salmon. The two sediment extracts from the Hylebos Waterway (HWSE-M and HWSE-P) containing chemical contaminants, including chlorinated hydrocarbons, and polycyclic hydrocarbons, also reduced growth, whereas growth of juvenile salmon over the 60-day period was not significantly affected by the high-molecular weight PAHs. These findings suggest that the chlorinated hydrocarbons including PCBs and the chlorinated butadienes, rather than the aromatic hydrocarbons may be the contaminants primarily contributing to the reduced growth of juvenile chinook salmon exposed to the two Hylebos Waterway sediment extracts. The conclusion of an apparent lack of ability of PAHs to impair growth of juvenile salmon must be tempered when we consider the variation in growth observed between tanks of fish receiving this contaminant type. The mean length and weight of at least one tank of fish receiving the model mixture of PAHs grew as poorly as fish exposed to PCBs or either of the Hylebos Waterway sediment extracts. However, because the duplicate tank of fish grew as well, if not slightly better than the control groups, a significant reduction in growth of juveniles exposed to the model PAH mixture was not evident. Nevertheless, overall chlorinated hydrocarbons, exemplified by the PCBs and HCBD, appeared to be consistently associated with a small but significant reduction in the growth of juvenile salmon under the experimental conditions employed.

Juvenile chinook salmon in this study were injected with sediment extracts or model compounds in order to administer the contaminants at well-defined and controlled dosages to facilitate comparisons among treatment groups. The overall objective was to assess the impacts of chemical contaminant types found in the Hylebos Waterway on growth of juvenile chinook salmon. While juvenile chinook salmon were exposed to chemical contaminants at a dosage higher than realistically present in the environment, they were held under rather optimum conditions (they were well fed and did not have any competition or predators during the experiment). Thus, the impacts on growth of experimental fish may have been minimized when interpreted in the context of the ecosystem and integrated with the activities that fish must undertake to survive in the natural environment.

The reduced growth of salmon exposed to contaminants associated with the Hylebos Waterway observed in this study are consistent with previous findings (Casillas et al. 1995a, b) showing impaired growth and altered immune function in juvenile chinook salmon from the Duwamish Waterway in Elliott Bay, also located in Puget Sound, WA. We found that juvenile salmon from the Duwamish Waterway estuary showing increased exposure to CHs and AHs did not grow as well as juvenile salmon that are out migrating through the reference estuaries of the Nisqually and Skokomish Rivers. In addition, the reduced growth of juveniles exposed to chemical contaminants in the Duwamish Waterway, after a 60 to 90 day period, was of approximately the same magnitude as that observed in this study. It is important to note that the level of exposure to chemical contaminants in fish sampled from the Duwamish estuary was lower than exposure in the laboratory study reported here. The finding of reduced growth in both studies suggests that the threshold for chemical contaminants affecting growth of juvenile salmon is within the range of environmental exposure.

Chemical contaminants also affect other physiological functions in juvenile salmon. Arkoosh et al. (1991, 1998) showed a suppressed secondary immune response in white blood cells of anterior kidney to specific model antigens and a greater percent of cumulative mortality to *V. anguillarum* after natural exposure to chemical contaminants, including PAHs and PCBs in the waterway. In addition, juvenile salmon exposed to a model PAH, dimethylbenz[a]anthracene (DMBA) or a PCB mixture (Aroclor 1254) in the laboratory exhibited a similar suppressed secondary immune response in white blood cells of anterior kidney to model antigens (Arkoosh et al. 1994). Both PAHs and PCBs are known to induce immunosuppression in other species (Thomas and Hinsdill 1978; Ward et al. 1985). Thus, our findings are consistent with the observations that chemical contaminants, including chlorinated hydrocarbons found in the Hylebos Waterway, could affect a range of physiological functions, including immunocompetence and growth, in juvenile salmon. A follow up study. Round III is being designed to determine the sediment levels of contaminants at which effects (e.g. impaired growth, disease resistance) would be observed.

The ecological significance of reduced growth from exposure to chemical contaminants specific to the Hylebos Waterway is likely to be manifest during the initial phase of early ocean life and consequently could affect their survival potential in the estuary and early ocean environment.

The effect of the reduced growth observed after exposure to contaminants specific to the Hylebos Waterway, although not large, may significantly reduce the ability of juvenile salmon to effectively compete and exist in their natural environment for several reasons. First, fish growth is highly pliable and integrates various habitat conditions, thus growth has been used frequently as an indicator of ecosystem health (Brandt 1992). Moreover, the ability of a fish to achieve its optimum growth rate as a juvenile is not only a relative measure of the fish's health and conditions, it is also a measure of survival and reproductive output potential (Brandt 1992). Thus, growth is linked to a variety of important life functions supporting propagation of the species. The links in growth, survival, and reproduction among fish foster the hypothesis that slower growing or smaller animals, as they proceed through successive life stages, inherently acquire a greater chance of mortality and have lower fecundity at reproduction (Banse and Mosher 1980). In this context, factors such as chemical contaminants, which are shown to reduce growth rate in the pre-adult stages, can be linked to reduced reproductive and survival potential.

Secondly, the reduced growth of juvenile salmon is occurring as they enter the marine environment where mortality is a significant factor in controlling the numbers that are recruited to the fishery and back to their natal streams. Approximately one-half of the loss of pre-adult (egg through juvenile stage) salmon has been shown to occur in the marine environment (Bradford 1995). Predators, inter- and intra-specific competition, food availability, smolt quality and health, and environmental factors (chemical and physical) are all potentially and likely important factors that influence survival of salmon in the estuarine and near shore marine environment. Thus, factors that affect the ability of salmon to function normally in their natural environment in the short-term are likely to influence longer term survival to their reproductive stage. The reduced growth of juvenile salmon shown in the current study is therefore an indication of a decrease in survival potential; especially in an environment where extensive mortality has been documented (Bradford 1995).

Third, the observed reduced growth of juvenile chinook salmon induced by chemical contaminant exposure is occurring during a phase where growth has been shown to be critical to success of the population. Growth of salmon during the first year of ocean life appears to be critical to recruitment success (Pearcy 1992, Unwin 1997, Unwin and Glova 1997, Heath et al. 1997). This understanding is based on the positive relationship between the number of precocious male salmon (fish that mature earlier than normal) and the commensurate success of the adult population of salmon for each year class (Pearcy 1992, Gudjonsson et al. 1995). Precocious maturation, further, appears to be linked to growth rates. Higher growth rates are associated with a higher proportion of precociously maturing salmon in the population (Friedland and Haas 1996). The issue, however, may not be if an animal is growing or is of a larger size, but rather what is the proportion of fish with the appropriate growth rate. Dickhoff et al. (1995) and Beckman et al. (1997) have shown that out migrating juvenile salmon smolts with the highest growth rates at the time of release, and not necessarily the largest smolts, survived better than juveniles exhibiting slower growth rates. Holtby et al. (1990) supported this contention for juvenile coho salmon, showing that in typical years, fish with higher growth rates survived better than juveniles with slower growth rates. It is in this context that reduced growth caused by factors, such as chemical contaminants, as shown in our study, may have long term ecological consequence for the survival of juvenile salmon inhabiting urban estuaries for part of their life cycle.

Finally, the salmon in the present study were found to have altered growth that extended well past the initial chemical contaminant exposure period, that is, reduced growth was evident two months after the initial exposure. This finding is also supported by a previous field study showing that juvenile salmon collected from the Duwamish estuary and held for two months in uncontaminated seawater exhibited suppressed growth. Our previous studies suggest that although juvenile chinook salmon are only briefly exposed to contaminants in an urban estuary as they migrate to sea, growth altering events persist for at least 2 months, and may extend into their early ocean life. The findings in Round I of these studies showed that during a relatively brief residence in the Hylebos Waterway, juvenile chinook and chum salmon were exposed to significant levels of chemical contaminants which resulted in induction of early biological alterations indicated by elevated hepatic CYP1A and DNA damage. In the present study we demonstrated that contaminants characteristic of sediments from the Hylebos Waterway reduced the growth of juvenile chinook salmon. Because recruitment of fish to the adult stage is considered to be dependent on factors acting during the first year of life (Sissenwine 1984, Pearcy 1992), the potential for contaminants to influence size dependent mortality and mortality rates within the population is a possibility. There is uncertainty in relating the observed reduction in growth as a result of exposure to chemical contaminants described in this study to potential impacts on mortality and population structure. However, the findings from studies cited above suggest that the observed reduction in growth has the potential to increase mortality of juvenile salmon through other ecological interactions (e.g. predation, inability to acquire appropriate prey, disease) which they encounter in their natural habitat.

Quantitating the level of increased risk however, cannot be assessed from the findings of the present study. When we examined the adult return data for fall chinook salmon to urban associated river systems, such as the Puyallup (Hylebos Waterway) or the Green River (Duwamish Waterway), using the Coded Wire Tag database (PFMSC 1993), we found, however, that the average returns during the period of 1971-1991 to these urban systems were less than the average for Puget Sound river systems (Washington State hatcheries) or for major river systems for the entire state of Washington (Table 11). Although we cannot define the causal factors which affect the lower than average adult returns for fish migrating through urban estuaries, as there are many factors which contribute to the outcome, such as predation, food availability, ocean conditions, etc., the finding that chemical contaminants reduce growth of juvenile salmon, and that reduced growth is associated with lower survival potential in chinook salmon (Unwin 1997) is not inconsistent with the lower than average return rates from these urban systems.

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Table 1. Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon. Concentrations of selected aromatic hydrocarbons, chlorinated butadienes, pesticides, and polychlorinated biphenyls in sediment extract from the Nisqually River (NQSE) that was used in the laboratory experiment. Values are reported as ng/g sediment.

Analyte	ng/g sediment[a]	Analyte	ng/g sediment
Aromatic Hydrocarbons		Pesticides	
naphthalene	1	hexachlorobenzene	< 0.02
2-methylnaphthalene	1	lindane (gamma-BHC)	< 0.039
1-methylnaphthalene	1	heptachlor	0.035
biphenyl	< 0.2	aldrin	< 0.029
2,6-dimethylnaphthalene	1	heptachlorepoxide	< 0.024
acenaphthylene	< 0.2	oxychlordane	< 0.03
acenaphthene	< 0.3	trans-chlordane	0.16
2,3,5-trimethylnaphthalene	2	nonachlor-III	n/a
fluorene	< 0.3	alpha-chlordane	< 0.02
phenanthrene	2	trans-nonachlor	< 0.018
anthracene	< 0.2	cis-nonachlor	< 0.028
1-methylphenanthrene	1	dieldrin	< 0.023
fluoranthene	1	mirex	< 0.016
pyrene	1	o,p'-DDE	< 0.04
benz[a]anthracene	0.4	p,p'-DDE	0.32
chrysene	0.8	o,p'-DDD	< 0.038
benzo[b]fluoranthene	0.5	p,p'-DDD	0.098
benzo[k]fluoranthene	< 0.2	o,p'-DDT	< 0.015
benzo[e]pyrene	0.4	p,p'-DDT	0.056
benzo[a]pyrene	< 0.2		
perylene	2	PCBs	
indeno[1,2,3-cd]pyrene	< 0.2	trichlorobiphenyl - 18	< 0.053
dibenz[a,h]anthracene	< 0.2	trichlorobiphenyl - 28	0.13
benzo[g,h,i]perylene	0.3	tetrachlorobiphenyl - 44	0.11
dibenzothiophene	< 0.2	tetrachlorobiphenyl - 52	< 0.037
		tetrachlorobiphenyl - 66	0.067
		pentachlorobiphenyl - 101	0.039
Chlorinated Butadienes[b]		pentachlorobiphenyl - 105	< 0.023
Trichlorobutadiene	<0.05	pentachlorobiphenyl - 118	< 0.025
Tetrachlorobutadiene	<0.05	hexachlorobiphenyl - 128	< 0.019
Pentachlorobutadiene	<0.05	hexachlorobiphenyl - 138	0.19
Hexachlorobutadiene	<0.05	hexachlorobiphenyl - 153	0.13
		heptachlorobiphenyl - 170	0.084
		heptachlorobiphenyl - 180	0.14
		heptachlorobiphenyl - 187	0.037
		octachlorobiphenyl - 195	< 0.013
		nonachlorobiphenyl - 206	0.017
		decachlorobiphenyl - 209	0.088

[a] Concentrations were calculated on a wet weight basis where 1 µl of the bulk extract corresponds to 0.2 g of sediment.

[b] Concentrations of the butadienes were calculated using a response factor of 1 with GC/MS total ion current areas.

Table 2. Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon. Concentrations of selected aromatic hydrocarbons, chlorinated butadienes, pesticides, and polychlorinated biphenyls in sediment extract from the Hylebos Waterway (HWSE-M) that was used in the laboratory experiment. Values are reported as ng/g sediment.

Analyte	ng/g sediment[a]
Aromatic Hydrocarbons	
naphthalene	46
2-methylnaphthalene	22
1-methylnaphthalene	14
biphenyl	8
2,6-dimethylnaphthalene	14
acenaphthylene	3
acenaphthene	25
2,3,5-trimethylnaphthalene	9
fluorene	32
phenanthrene	130
anthracene	41
1-methylphenanthrene	17
fluoranthene	180
pyrene	150
benz[a]anthracene	65
chrysene	99
benzo[b]fluoranthene	72
benzo[k]fluoranthene	52
benzo[e]pyrene	49
benzo[a]pyrene	48
perylene	18
indeno[1,2,3-cd]pyrene	28
dibenz[a,h]anthracene	9
benzo[g,h,i]perylene	31
dibenzothiophene	34
Chlorinated Butadienes[b]	
Trichlorobutadiene	520
Tetrachlorobutadiene	590
Pentachlorobutadiene	170
Hexachlorobutadiene	130

Analyte	ng/g sediment
Pesticides	
hexachlorobenzene	140
lindane (gamma-BHC)	3.2
heptachlor	5
aldrin	1.6
heptachlorepoxide	30
oxychlordane	1.2
trans-chlordane	6.5
nonachlor-III	n/a
alpha-chlordane	2.6
trans-nonachlor	5.0
cis-nonachlor	1.1
dieldrin	1.3
mirex	2.1
o,p'-DDE	1.7
p,p'-DDE	0.46
o,p'-DDD	7.2
p,p'-DDD	4.1
o,p'-DDT	9.9
p,p'-DDT	< 0.0097
PCBs	
trichlorobiphenyl - 18	2.5
trichlorobiphenyl - 28	5.8
tetrachlorobiphenyl - 44	2.3
tetrachlorobiphenyl - 52	4.6
tetrachlorobiphenyl - 66	5.1
pentachlorobiphenyl - 101	4.0
pentachlorobiphenyl - 105	1.1
pentachlorobiphenyl - 118	4.8
hexachlorobiphenyl - 128	1.8
hexachlorobiphenyl - 138	4.7
hexachlorobiphenyl - 153	4.9
heptachlorobiphenyl - 170	2.6
heptachlorobiphenyl - 180	10
heptachlorobiphenyl - 187	2.9
octachlorobiphenyl - 195	2.7
nonachlorobiphenyl - 206	15
decachlorobiphenyl - 209	34

[a] Concentrations were calculated on a wet weight basis where 1 µl of the bulk extract corresponds to 0.2 g of sediment.

[b] Concentrations of the butadienes were calculated using a response factor of 1 with GC/MS total ion current areas.

Table 3. Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon. Concentrations of selected aromatic hydrocarbons, chlorinated butadienes, pesticides, and polychlorinated biphenyls in sediment extract from the pentane extraction of sediment from the Hylebos Waterway (HWSE-P) that was used in the laboratory experiment. Values are reported as ng/g sediment.

Analyte	ng/g sediment[a]	Analyte	ng/g sediment
Aromatic Hydrocarbons		Pesticides	
naphthalene	26	hexachlorobenzene	110
2-methylnaphthalene	18	lindane (gamma-BHC)	2.0
1-methylnaphthalene	10	heptachlor	0.8
biphenyl	6	aldrin	< 0.06
2,6-dimethylnaphthalene	10	heptachlorepoxide	21
acenaphthylene	0.9	oxychlordane	< 0.07
acenaphthene	28	trans-chlordane	< 0.06
2,3,5-trimethylnaphthalene	28	nonachlor-III	< 0.06
fluorene	28	alpha-chlordane	2.0
phenanthrene	140	trans-nonachlor	5.0
anthracene	47	cis-nonachlor	0.4
1-methylphenanthrene	10	dieldrin	2.0
fluoranthene	170	mirex	2.0
pyrene	170	o,p'-DDE	1.0
benz[a]anthracene	23	p,p'-DDE	0.4
chrysene	33	o,p'-DDD	20
benzo[b]fluoranthene	6	p,p'-DDD	1.0
benzo[k]fluoranthene	5	o,p'-DDT	< 0.1
benzo[e]pyrene	9	p,p'-DDT	< 0.1
benzo[a]pyrene	10		
perylene	2	PCBs	
indeno[1,2,3-cd]pyrene	0.3	trichlorobiphenyl - 18	17
dibenz[a,h]anthracene	< 0.02	trichlorobiphenyl - 28	6.0
benzo[g,h,i]perylene	1.0	tetrachlorobiphenyl - 44	1.0
dibenzothiophene	12	tetrachlorobiphenyl - 52	3.0
		tetrachlorobiphenyl - 66	< 0.08
		pentachlorobiphenyl - 101	3.0
Chlorinated Butadienes[b]		pentachlorobiphenyl - 105	< 0.06
Trichlorobutadiene	480	pentachlorobiphenyl - 118	< 0.07
Tetrachlorobutadiene	450	hexachlorobiphenyl - 128	0.8
Pentachlorobutadiene	160	hexachlorobiphenyl - 138	2.0
Hexachlorobutadiene	150	hexachlorobiphenyl - 153	4.0
		heptachlorobiphenyl - 170	1.0
		heptachlorobiphenyl - 180	9.0
		heptachlorobiphenyl - 187	2.0
		octachlorobiphenyl - 195	2.0
		nonachlorobiphenyl - 206	12
		decachlorobiphenyl - 209	31

[a] Analyte concentrations calculated on a sediment wet weight basis.

[b] Concentrations of the butadienes were calculated using a response factor of 1 with GC/MS total ion current areas.

Table 4. Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon. High molecular weight hydrocarbons that comprise the PAH model mixture. The compounds were combined in acetone at the same ratios as they were present in the sediment at station 24 of the Hylebos Waterway to a concentration equivalent to 400 g sediment extracted per ml of acetone.

PAH Analyte and concentration (ng/µl)			
Fluoranthene	5000	Benz[k]fluoranthene	1920
Pyrene	460	Benzo[a]pyrene	1540
Benz[a]anthracene	1640	Indeno[1,2,3-cd]pyrene	2400
Chrysene	3200	Dibenz[a,h]anthracene	220
Benz[b]fluoranthene	5000	Benzo[g,h,i]perylene	1880

Table 5. Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon. Estimated average feeding rate per day (% body weight) for juvenile chinook salmon exposed for 60 days in Phase II experiment.

		% Body weight fed/day[a]	
Treatment	Tank	Average/Tank	Average/Treatment
Acetone/Emulphor	C	3.6	3.6
Acetone/Emulphor	L	3.6	
NQSE	I	3.5	3.6
NQSE	N	3.6	
Model PAH Mixture	E	3.7	3.7
Model PAH Mixture	M	3.7	
Aroclor 1254	A	3.7	3.7
Aroclor 1254	F	3.6	
HCBD	J	3.7	3.6
HCBD	P	3.7	
HWSE-M	G	3.6	3.6
HWSE-M	K	3.6	
HWSE-P	H	3.6	3.6
HWSE-P	O	3.6	

[a]Periodic adjustment of feed amounts were based on an estimated growth rate of 1 gram/fish/week.

Table 6. Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon. Weekly mortality of juvenile chinook salmon various extracts in Phase II experiment.

		Week									
Treatment	Tank	1	2	3	4	5	6	7	8	9[a]	Total
Acetone/Emulphor	C	3	4	1	0	0	0	0	0	0	8
Acetone/Emulphor	L	0	7	1	0	0	0	0	1	0	9
NQSE	I	0	2	2	0	0	0	0	0	0	4
NQSE	N	1	2	2	1	0	0	1	0	0	7
Model PAH Mixture	E	1	13	3	0	0	0	0	0	0	17
Model PAH Mixture	M	1	9	7	1	1	0	0	0	0	19
Aroclor 1254	A	3	4	2	0	1	0	1	1	0	12
Aroclor 1254	F	4	4	5	0	0	0	0	0	0	13
HCBD	J	0	3	2	2	0	0	0	0	0	7
HCBD	P	0	3	3	0	0	1	0	0	0	7
HWSE-M	G	0	3	5	1	0	0	0	0	0	9
HWSE-M	K	3	2	2	0	0	1	0	0	0	8
HWSE-P	H	1	0	4	1	0	0	1	1	0	8
HWSE-P	O	0	2	1	0	0	0	0	0	0	3

[a] Mortalities recorded for week 9 only included the last 4 days of the experimental period.

Table 7. Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon. Fork length (± SD) of juvenile chinook salmon (by treatment) at the beginning and end of a 60 day exposure in Phase II experiment.

	Day 0		Day 60	
Treatment	Sample size	Length (mm)	Sample size	Length (mm)
Acetone/Emulphor	200	94 ± 3	179	135 ± 7
NQSE	200	94 ± 3	183	135 ± 7
Model PAH Mixture	200	93 ± 3	155	135 ± 7
Aroclor 1254	200	94 ± 3	170	133 * ± 6
HCBD	200	94 ± 3	167	134 * ± 7
HWSE-M	200	93 * ± 3	177	133 * ± 6
HWSE-P	200	93 * ± 3	189	133 * ± 6

* Indicates value is significantly different (ANOVA $p \leq 0.05$, Dunnett's Multiple Comparison Test) than control (Acetone/Emulphor).

Table 8. Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon. Weight (± SD) of juvenile chinook salmon (by treatment) at the beginning and end of a 60 day exposure in Phase II experiment.

	Day 0		Day 60	
Treatment	Sample size	Weight (g)	Sample size	Weight (g)
Acetone/Emulphor	200	8.2 ± 1.0	179	32.1 ± 5.4
NQSE	200	8.1 ± 1.0	183	32.0 ± 5.5
Model PAH Mixture	200	7.9 * ± 0.9	155	31.1 ± 5.5
Aroclor 1254	200	8.0 ± 0.9	170	29.6 * ± 4.8
HCBD	200	8.0 ± 1.0	167	30.8 ± 5.4
HWSE-M	200	7.9 * ± 0.9	177	29.9 * ± 4.4
HWSE-P	200	7.9 * ± 1.0	189	30.1 * ± 4.7

* Indicates value is significantly different (ANOVA $p \leq 0.05$, Dunnett's Multiple Comparison Test) than control (Acetone/Emulphor).

Table 9. Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon. Fork length (± SD) of juvenile chinook salmon (by tank) at the beginning and end of a 60 day exposure in Phase II experiment.

		Day 0		Day 60	
Tank	Treatment	Sample size	Length (mm)	Sample size	Length (mm)
C	Acetone/Emulphor	100	94 ± 3	90	135 ± 6
L	Acetone/Emulphor	100	94 ±3	89	136 ± 7
I	NQSE	100	94 ± 3	95	136 ± 7
N	NQSE	100	94 ± 3	88	134 ± 7
E	Model PAH Mixture	100	94 ± 3	77	132 ± 7
M	Model PAH Mixture	100	93 ± 2.9	78	137 ± 7
A	Aroclor 1254	100	94 ± 3	84	135 ± 6
F	Aroclor 1254	100	94 ± 3	86	130 ± 6
J	HCBD	100	95 ± 3	84	131 ± 7
P	HCBD	100	94 ± 3	83	136 ± 6
K	HWSE	100	93 ± 3	89	133 ± 6
G	HWSE	100	93 ± 3	88	133 ± 6
H	HWSE-P	100	93 ± 4	90	132 ± 6
O	HWSE-P	100	93 ± 3	99	134 ± 6

Table 10. Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon. Weight (± SD) of juvenile chinook salmon (by tank) at the beginning and end of a 60 day exposure in Phase II experiment.

		Day 0		Day 60	
Tank	Treatment	Sample size	Weight (g)	Sample size	Weight (g)
C	Acetone/Emulphor	100	8.3 ± 1.0	90	31.4 ± 4.9
L	Acetone/Emulphor	100	8.1 ± 1.0	89	32.8 ± 5.8
I	NQSE	100	8.2 ± 1.0	95	32.7 ± 5.5
N	NQSE	100	8.0 ± 1.0	88	31.3 ± 5.4
E	Model PAH Mixture	100	8.0 ± 1.0	77	29.2 ± 5.3
M	Model PAH Mixture	100	7.9 ± 0.9	78	33.0 ± 5.0
A	Aroclor 1254	100	7.9 ± 1.0	84	31.6 ± 4.7
F	Aroclor 1254	100	8.1 ± 0.9	86	27.6 ± 4.1
J	HCBD	100	8.2 ± 1.0	84	28.5 ± 5.2
P	HCBD	100	7.8 ± 1.0	83	33.1 ± 4.7
K	HWSE-M	100	7.9 ± 0.9	89	29.8 ± 4.5
G	HWSE-M	100	7.9 ± 1.0	88	30.1 ± 4.4
H	HWSE-P	100	7.9 ± 1.0	90	29.3 ± 4.8
O	HWSE-P	100	7.9 ± 0.9	99	30.9 ± 4.5

Table 11. Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon. Average recoveries (includes saltwater recoveries and return to the hatcheries) of fall chinook salmon for major river systems of the Puget Sound basin during the period 1971 to 1991 derived from the Coded Wire Tag database (PFMSC 1993).

River System	% FW Returns	% SW Recovery	% Total Returns
Nooksack	0.24	3.83	4.07
Samish	0.15	1.44	1.60
Skagit	0.34	1.77	2.11
Skykomish	0.02	0.95	0.97
Issaquah	0.14	0.60	0.74
Green	0.16	0.50	0.66
Puyallup	0.05	0.54	0.59
Garrison	0.04	0.22	0.26
Deschutes	0.11	1.63	1.74
Minter Cr.	0.09	1.07	1.16
Coulter Cr.	0.09	0.15	0.24
Skokomish	0.12	0.38	0.50
Hood Canal	0.22	1.09	1.31
Elwha	0.12	0.59	0.76
Willapa Bay	0.23	0.80	1.03
Overall/Puget Sound	0.13	1.03	1.16
Overall/Washington State	**0.14**	**0.95**	**1.08**

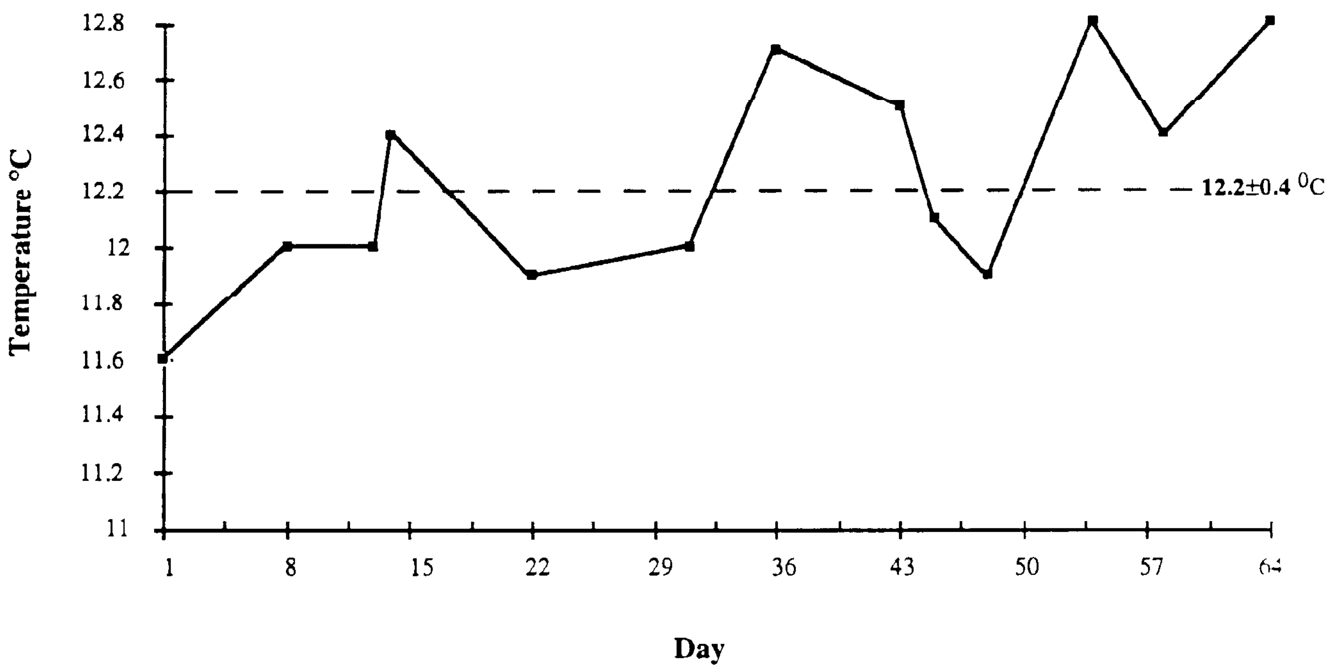


Figure 1. Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon. Water temperature recorded during the experimental period of June 26 to August 25, 1997.

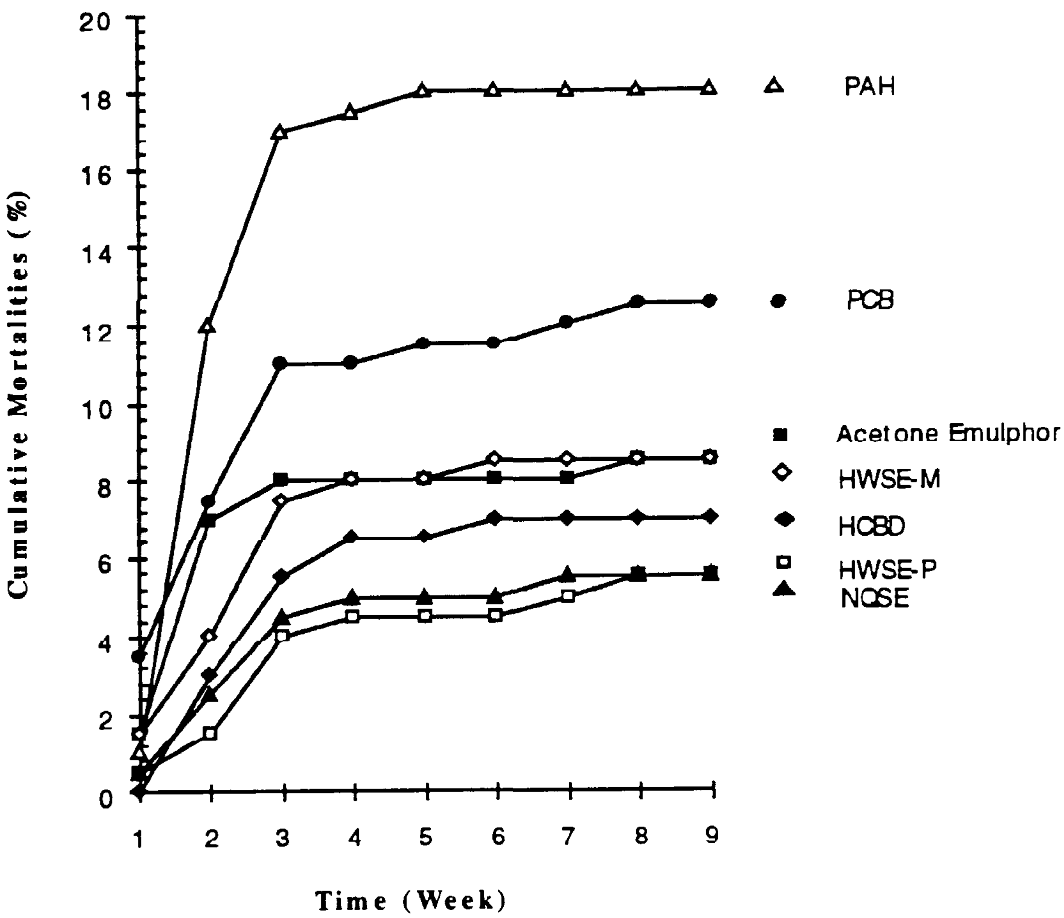


Figure 2. Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon. Cumulative percent mortalities (weekly) of juvenile chinook salmon in Phase II experiment.

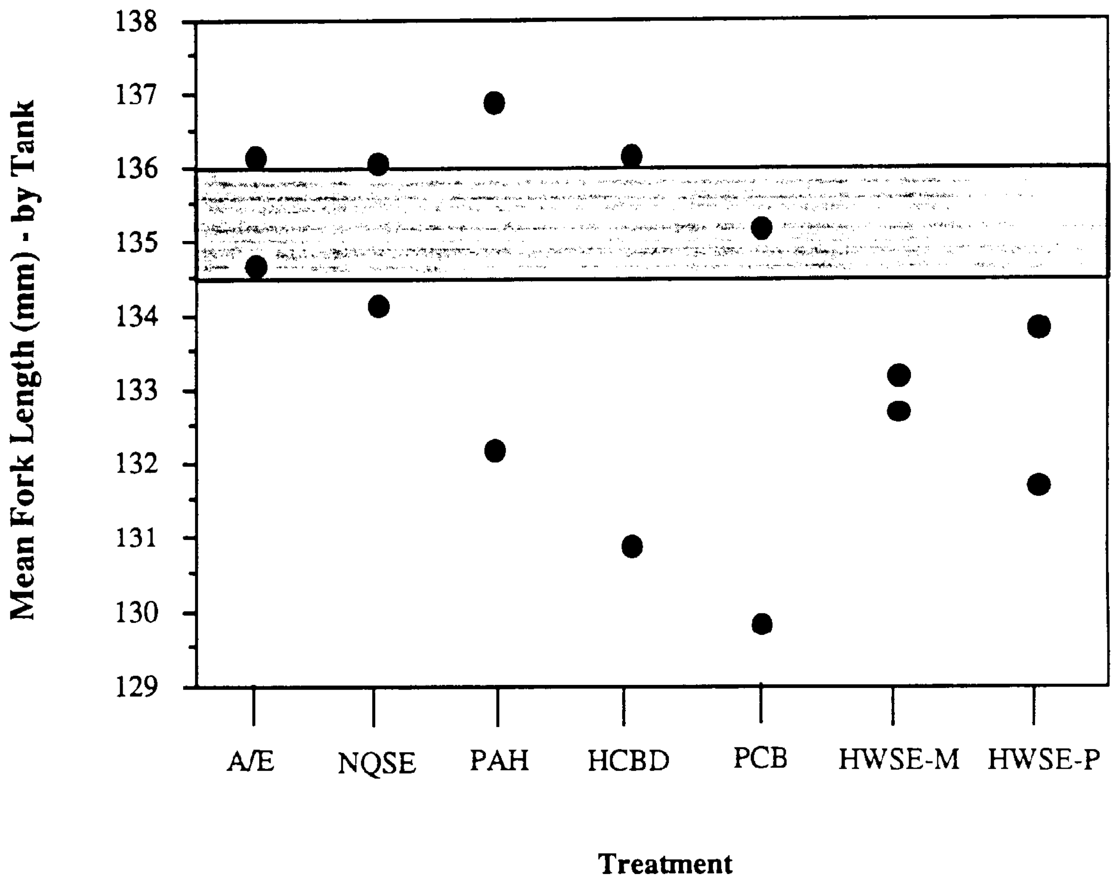


Figure 3. Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon. Mean fork length (by tank) of juvenile chinook salmon in Phase II experiment. Shaded area represents the 95% confidence interval of mean fork length for juvenile salmon exposed to the solvent vehicle (acetone:Emulphor) or the reference sediment extract from the Nisqually River estuary.

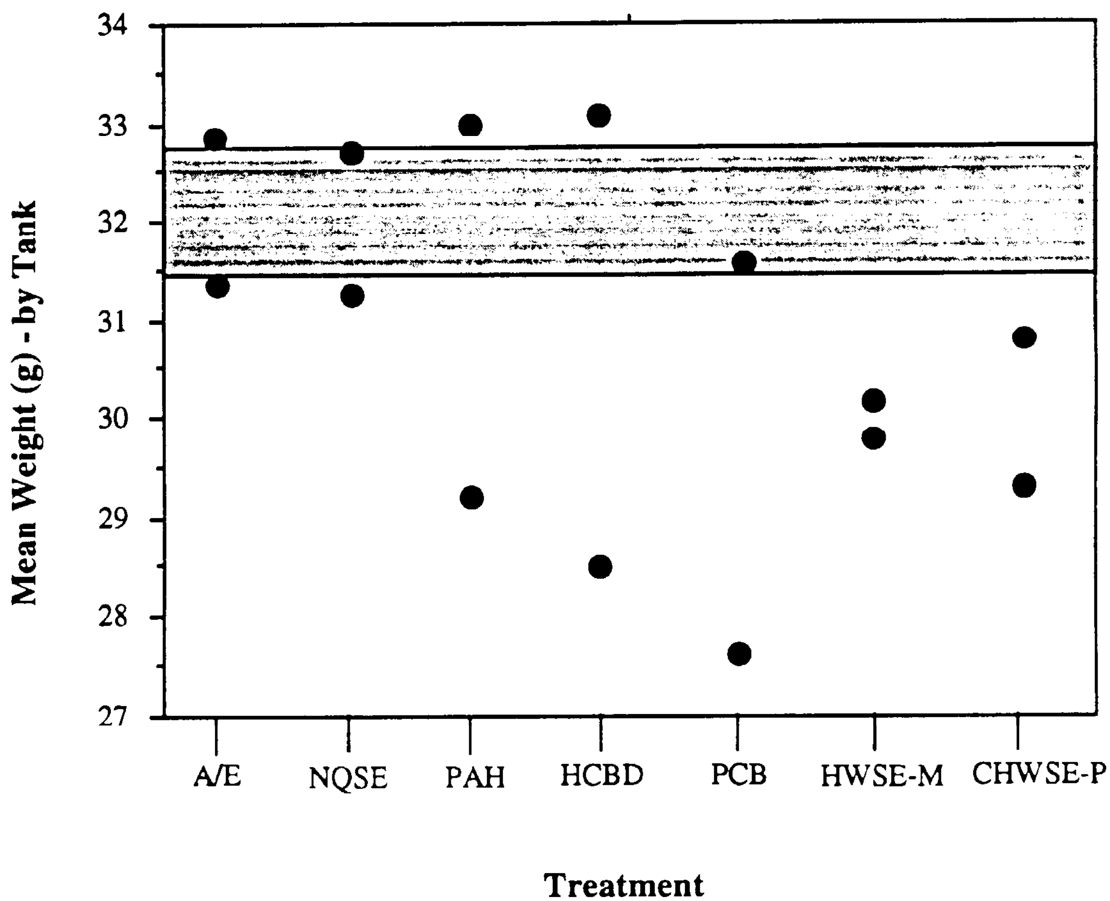


Figure 4. Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon. Mean weight (by tank) of juvenile chinook salmon in Phase II experiment. Shaded area represents the 95% confidence interval of mean weight for juvenile salmon exposed to the solvent vehicle (acetone:Emulphor) or the reference sediment extract from the Nisqually River estuary.

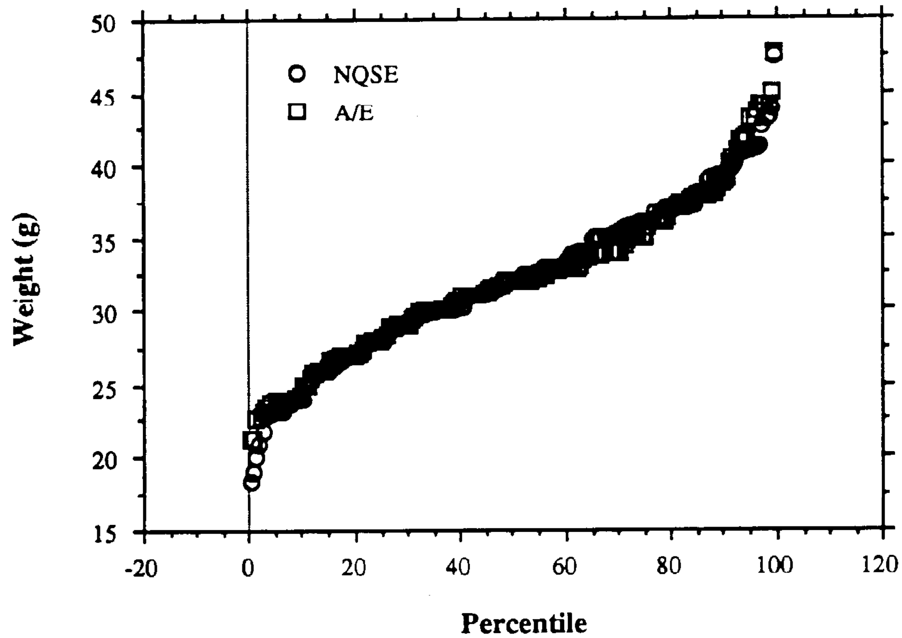


Figure 5. Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon. Cumulative weight frequency distribution of juvenile chinook salmon after a 60 day exposure to Acetone/Emulphor (the solvent vehicle as control) or the reference Nisqually River estuary sediment extract.

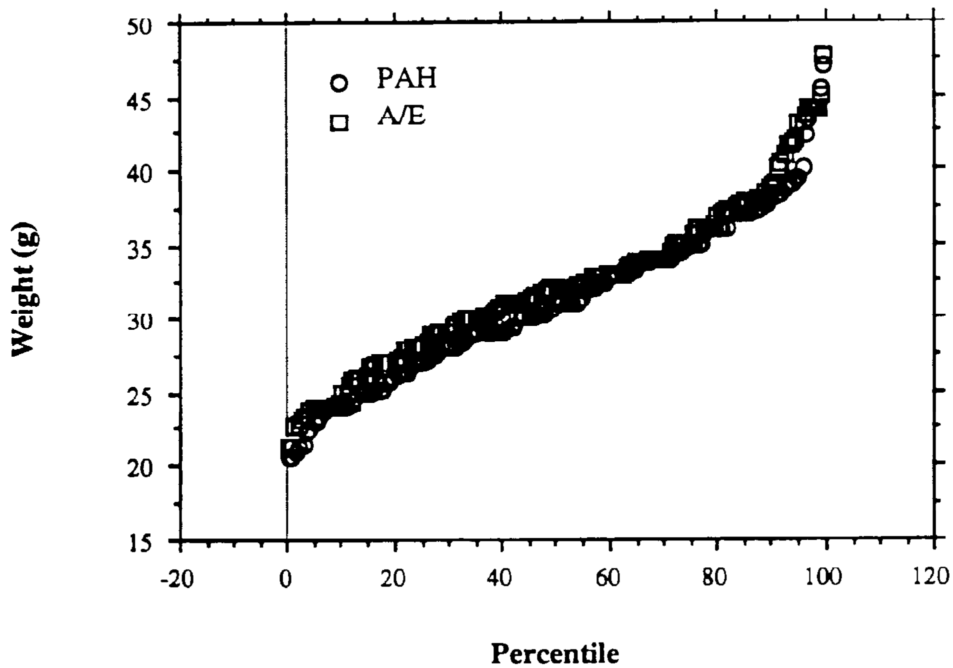


Figure 6. Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon. Cumulative weight frequency distribution of juvenile chinook salmon after a 60 day exposure to Acetone/Emulphor (the solvent vehicle as control) or the model PAH mixture.

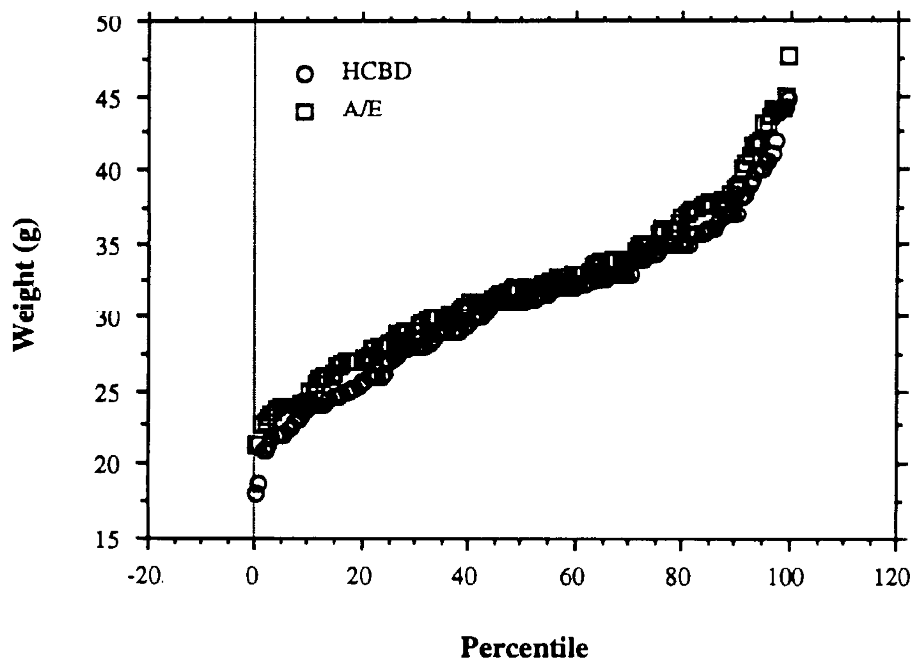


Figure 7. Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon. Cumulative weight frequency distribution of juvenile chinook salmon after a 60 day exposure to Acetone/Emulphor (the solvent vehicle as control) or hexachlorobutadiene (HCBD).

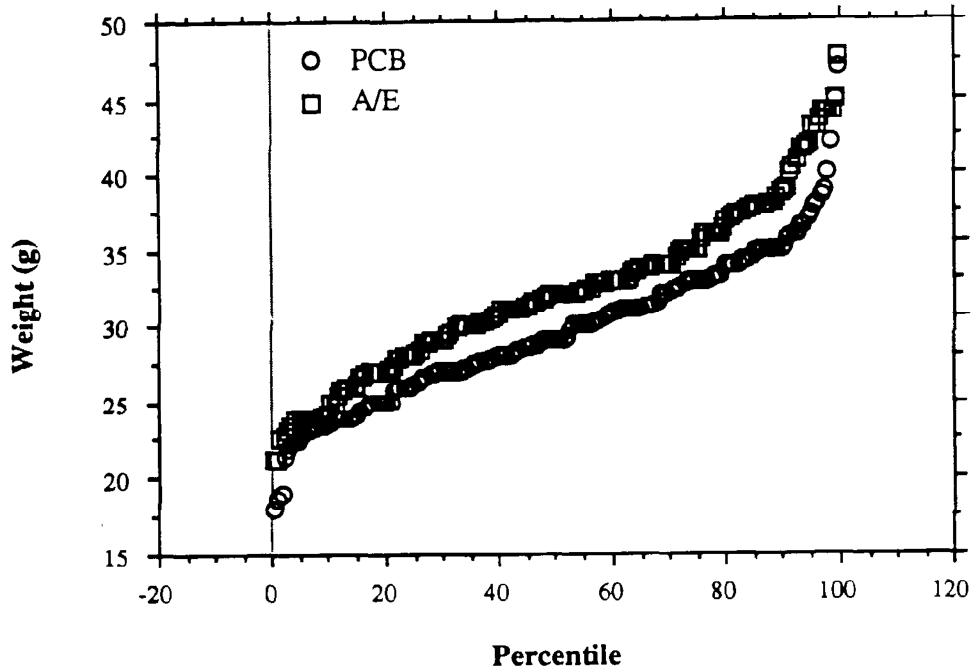


Figure 8. Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon. Cumulative weight frequency distribution of juvenile chinook salmon after a 60 day exposure to Acetone/Emulphor (the solvent vehicle as control) or the PCB mixture (Aroclor 1254).

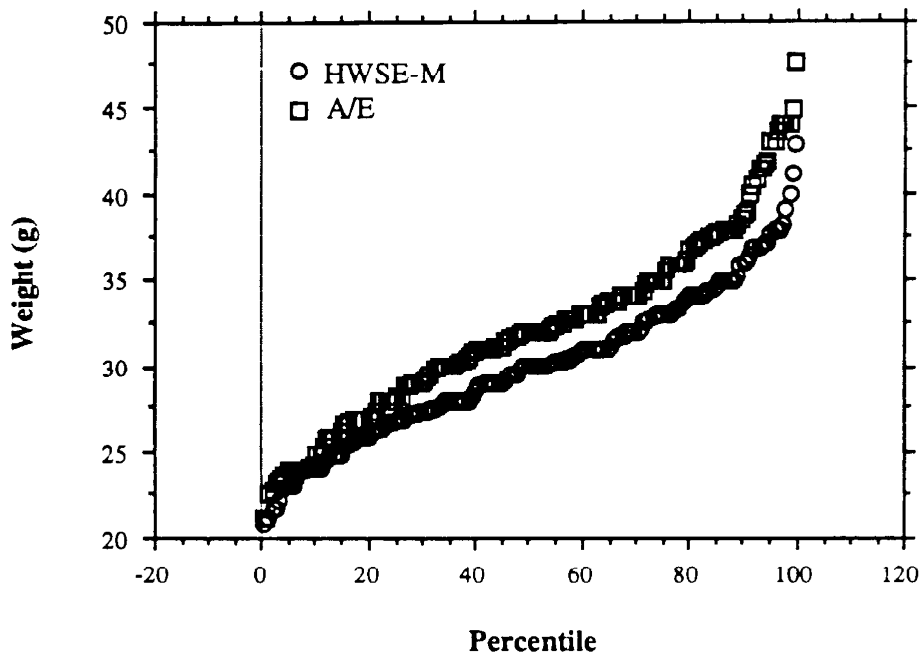


Figure 9. Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon. Cumulative weight frequency distribution of juvenile chinook salmon after a 60 day exposure to Acetone/Emulphor (the solvent vehicle as control) or the sediment extract from the Hylebos Waterway (HWSE-M).

Hylebos Fish Injury Study - Round II, Part 2
Individual Data and Quality Assurance Results
CASE NARRATIVE

Effects of Chemical Contaminants from the Hylebos Waterway on Growth of Juvenile Chinook Salmon

Determination of Feeding Amounts

Food portions were measured by weight and determined for each tank. Portions were intended to be based on delivery of food at a rate of 4% of the total body weight of fish per day throughout the experiment. Initial feed amounts were based on starting weight of all fish in each tank: however, these amounts were not adjusted in the first 27 days of the experiment, thus feeding rates declined during this initial period. Starting on day 28, portions were adjusted weekly for accrued mortalities and an estimated growth rate of 1g/fish/week (in each tank). The growth rate was determined in an unrelated study in the previous year. Food amounts were adjusted to achieve the estimated feeding rate at the desired 4% of body weight per day.

Mortality

Mortalities for each tank were collected (usually daily and once on weekends) and entered into a database designed for the study. At the conclusion of the experiment, final numbers of fish measured plus recorded morts, did not equal starting numbers. Differences generally ranged from 1-10 fewer animals than expected in each tank. These differences can be attributed to fish which escaped either through netting covering the top of the tank or through the drain standpipe, although extensive effort was employed to minimize these losses. On some occasions, fish found on the floor could not be attributed to any one tank. These discoveries, therefore, were not recorded. Additionally, one tank (O) was found to contain 2 more fish than expected. These excess fish can not be factually accounted for, but may be attributed to an error in recording mortalities.

Growth Measurements

Generally, fish length was measured as fork length. However, at the end of the experiment, total lengths of 35 fish (each from tanks A, E, F, G, H, K, M, and O) were measured instead of fork lengths. The remaining length of fish in tanks A, E, F, G, H, K, M, and O were measured as fork length. When the error was realized, all subsequent measures of fish (from tanks C, I, J, L, N, and P) included both fork and total lengths. Fork length was then calculated for fish for which total length was only measured using the average ratio of fork length to total length for fish from tanks C, I, J, L, N, and P to calculate fork length of fish for which total length was only measured, using the following equation:

$$FL_{2i} = (FL_1/TL_1) \times TL_{2i}$$

where (FL_1/TL_1) is the average ratio of fork to total length for fish from tanks C, I, J, L, N, and P; TL_{2i} is the measured total length of individual fish from tanks A, E, F, G, H, K, M, and O , and FL_{2i} is the calculated fork length for $fish_i$ from these tanks. The resulted calculated fork lengths were then grouped with measured fork lengths of the remaining fish for analysis of treatment effects on length.

Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon.

Data tables of length and weight of juvenile chinook salmon at the beginning of a 60 day exposure, Round II, Part 2.

Treatment: PCB **Tank#:** A

Date: 6/26/97

Fish#	Fork Length	Weight
1	98	9.5
2	96	8.9
3	98	9.2
4	97	8.7
5	98	9.7
6	91	7.1
7	88	5.9
8	92	7.4
9	94	7.8
10	98	9.2
11	90	7.4
12	96	8.9
13	95	8.4
14	98	9.4
15	97	8.6
16	93	8.3
17	98	9.1
18	98	9.3
19	89	6.7
20	87	6.3
21	98	9.0
22	96	8.5
23	97	9.5
24	98	9.9
25	97	8.8
26	95	8.0
27	95	8.6
28	96	8.5
29	95	8.6
30	90	6.5
31	94	7.6
32	89	6.9
33	98	9.2
34	91	7.2
35	94	7.6

Fish#	Fork Length	Weight
36	95	8.7
37	93	7.6
38	94	8.6
39	95	7.8
40	93	7.9
41	91	7.1
42	96	9.1
43	91	7.4
44	91	7.3
45	97	8.7
46	93	8.7
47	88	7.1
48	94	8.0
49	93	7.8
50	93	7.5
51	88	6.5
52	97	9.1
53	87	6.5
54	95	7.4
55	95	8.2
56	94	7.9
57	87	6.5
58	94	8.3
59	89	6.4
60	95	7.9
61	96	8.9
62	96	6.6
63	97	9.4
64	98	8.0
65	87	5.9
66	91	7.2
67	94	7.7
68	96	7.2
69	97	8.8
70	94	6.4

Fish#	Fork Length	Weight
71	92	7.1
72	95	8.0
73	96	7.8
74	93	8.5
75	92	7.8
76	95	8.3
77	97	8.2
78	87	6.2
79	95	8.0
80	93	7.9
81	96	8.8
82	95	7.2
83	98	9.6
84	97	8.6
85	96	9.1
86	92	7.0
87	94	8.6
88	93	8.3
89	96	8.7
90	93	7.8
91	94	7.9
92	92	6.9
93	89	6.3
94	95	8.0
95	91	7.2
96	91	7.3
97	91	6.3
98	92	7.4
99	89	6.7
100	98	9.1

Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon.

Data tables of length and weight of juvenile chinook salmon at the beginning of a 60 day exposure, Round II, Part 2.

ment.

Treatment: ACE/EMUL **Tank#:** C

Date: 6/26/97

Fish#	Fork Length	Weight
1	96	9.1
2	104	7.5
3	96	10.1
4	96	6.8
5	97	9.4
6	99	8.2
7	92	8.1
8	102	8.1
9	92	7.7
10	92	8.2
11	97	7.8
12	95	8.4
13	97	9.0
14	99	9.7
15	97	9.2
16	90	7.2
17	94	8.0
18	91	7.6
19	93	8.7
20	92	8.0
21	91	7.2
22	97	9.3
23	97	9.5
24	94	7.4
25	95	8.2
26	98	9.1
27	87	6.3
28	95	8.2
29	92	8.1
30	95	8.5
31	88	6.7
32	94	7.6
33	90	7.4
34	93	7.9
35	94	8.3
36	96	9.5
37	91	7.3
38	93	8.0
39	98	10.0
40	96	8.4
41	95	8.2
42	93	8.6
43	90	7.7
44	92	7.5
45	98	9.8
46	88	6.3
47	96	9.3
48	98	9.7
49	91	7.0
50	98	10.4
51	98	9.3
52	95	8.4
53	96	8.3
54	96	8.5
55	93	7.4
56	89	7.3
57	93	8.3
58	89	6.7
59	94	8.6
60	95	9.0
61	90	7.1
62	89	6.4
63	96	8.7
64	87	6.1
65	98	11.2
66	87	9.3
67	95	7.5
68	91	7.6
69	97	8.7
70	93	8.0
71	94	7.8
72	95	8.8
73	97	9.4
74	96	9.9
75	98	9.4
76	92	7.9
77	93	7.8
78	95	8.2
79	98	9.5
80	96	5.8
81	97	9.8
82	96	8.6
83	91	7.9
84	93	7.4
85	96	8.5
86	95	8.3
87	95	8.7
88	95	8.1
89	96	8.3
90	95	8.0
91	94	8.7
92	91	7.5
93	95	8.5
94	92	7.8
95	98	9.7
96	95	8.1
97	90	7.0
98	96	8.0
99	96	9.0
100	93	7.7

Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon.

Data tables of length and weight of juvenile chinook salmon at the beginning of a 60 day exposure, Round II, Part 2.

Treatment: PAHs **Tank#:** E

Date: 6/26/97

Fish#	Fork Length	Weight
1	98	10.0
2	93	6.9
3	97	8.9
4	97	9.1
5	98	9.6
6	96	8.9
7	96	8.0
8	97	7.7
9	96	9.0
10	98	8.9
11	96	9.0
12	97	8.6
13	92	7.3
14	96	8.6
15	98	9.6
16	92	8.0
17	97	8.2
18	90	6.4
19	88	6.6
20	90	7.4
21	93	7.4
22	94	8.7
23	96	8.5
24	96	8.0
25	93	7.6
26	96	8.3
27	96	8.8
28	93	8.1
29	88	6.8
30	92	8.3
31	88	6.5
32	91	7.2
33	87	6.4
34	90	7.1
35	96	9.4

Fish#	Fork Length	Weight
36	91	7.4
37	94	8.2
38	89	6.3
39	92	7.6
40	90	7.6
41	86	6.0
42	92	7.8
43	98	9.4
44	98	9.0
45	97	8.0
46	95	7.9
47	98	9.5
48	91	6.9
49	96	8.1
50	89	7.3
51	89	6.8
52	91	7.1
53	95	8.4
54	98	9.3
55	96	8.3
56	92	7.9
57	98	10.3
58	91	7.3
59	92	8.7
60	95	8.1
61	96	9.5
62	93	8.2
63	92	7.6
64	93	7.8
65	94	8.7
66	97	9.4
67	95	8.0
68	92	7.9
69	96	8.3
70	90	6.2

Fish#	Fork Length	Weight
71	97	8.8
72	90	7.2
73	90	6.3
74	92	7.4
75	92	7.5
76	90	7.5
77	95	8.6
78	95	8.2
79	94	8.2
80	93	7.4
81	93	7.8
82	93	8.2
83	89	6.6
84	94	7.9
85	90	7.1
86	95	7.8
87	98	9.1
88	94	7.7
89	89	6.8
90	87	6.6
91	93	6.8
92	88	6.2
93	95	8.4
94	93	8.0
95	97	9.0
96	95	8.1
97	98	8.7
98	97	9.5
99	95	7.9
100	95	8.4

Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon.

Data tables of length and weight of juvenile chinook salmon at the beginning of a 60 day exposure, Round II, Part 2.

Treatment: PCB **Tank#:** F

Date: 6/26/97

Fish#	Fork Length	Weight
1	91	7.7
2	93	7.6
3	89	7.0
4	95	8.3
5	98	8.8
6	97	9.2
7	92	7.7
8	94	8.6
9	97	8.8
10	92	7.9
11	95	8.2
12	94	8.5
13	91	7.8
14	90	7.1
15	93	8.3
16	97	9.1
17	95	8.5
18	93	7.3
19	91	7.2
20	91	8.3
21	98	9.5
22	95	8.8
23	89	6.6
24	91	6.0
25	98	9.5
26	95	8.2
27	93	7.7
28	97	10.1
29	91	7.6
30	92	7.0
31	88	6.7
32	94	7.9
33	95	8.6
34	95	8.6
35	95	9.4

Fish#	Fork Length	Weight
36	96	8.3
37	94	8.4
38	94	7.7
39	98	8.9
40	87	6.1
41	96	9.2
42	98	9.5
43	95	8.6
44	94	7.1
45	96	9.0
46	94	7.9
47	92	7.8
48	98	8.9
49	89	6.7
50	99	9.6
51	98	8.1
52	97	8.4
53	96	9.2
54	98	8.9
55	93	7.1
56	91	7.2
57	96	8.7
58	96	8.7
59	95	7.7
60	89	7.0
61	95	8.5
62	92	7.8
63	95	8.5
64	94	8.0
65	91	6.7
66	89	6.9
67	97	8.7
68	91	7.4
69	95	8.6
70	96	8.7

Fish#	Fork Length	Weight
71	94	7.1
72	95	8.6
73	96	8.3
74	90	6.7
75	89	6.5
76	91	6.7
77	92	7.3
78	98	8.8
79	98	10.3
80	92	8.2
81	92	7.3
82	93	8.0
83	94	8.6
84	93	8.2
85	95	8.5
86	96	8.7
87	93	7.9
88	93	7.3
89	93	8.2
90	97	9.0
91	90	7.2
92	92	7.8
93	92	8.1
94	95	8.7
95	95	8.2
96	94	7.9
97	90	6.9
98	97	9.0
99	89	6.7
100	94	6.9

Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon.

Data tables of length and weight of juvenile chinook salmon at the beginning of a 60 day exposure, Round II, Part 2.

Treatment: HWSE-M **Tank#:** G

Date: 6/26/97

Fish#	Fork Length	Weight	Fish#	Fork Length	Weight	Fish#	Fork Length	Weight
1	98	9.5	36	94	8.3	71	96	9.3
2	96	9.0	37	98	9.2	72	95	8.4
3	96	9.0	38	87	6.6	73	91	7.6
4	96	8.5	39	93	8.5	74	95	8.7
5	90	6.6	40	92	7.3	75	90	6.8
6	90	7.2	41	95	8.1	76	95	8.7
7	97	8.9	42	87	6.0	77	90	7.6
8	93	8.2	43	89	6.3	78	90	6.9
9	91	7.4	44	91	7.5	79	94	8.3
10	96	8.2	45	89	6.9	80	97	7.7
11	92	8.0	46	90	7.3	81	87	6.6
12	93	8.0	47	98	9.6	82	95	8.0
13	94	7.4	48	88	7.2	83	96	8.5
14	93	7.8	49	90	6.5	84	90	6.8
15	96	9.2	50	91	7.1	85	93	8.2
16	92	7.7	51	90	6.8	86	96	9.1
17	97	9.7	52	91	7.3	87	87	6.3
18	91	7.0	53	98	9.1	88	90	7.0
19	97	8.6	54	95	8.7	89	94	7.1
20	87	6.3	55	91	7.8	90	90	7.3
21	95	8.5	56	92	7.9	91	91	7.3
22	89	6.4	57	98	9.6	92	92	8.2
23	84	8.1	58	95	9.2	93	98	9.5
24	86	8.5	59	92	7.6	94	87	6.5
25	87	6.3	60	95	8.4	95	95	8.5
26	98	9.3	61	92	7.8	96	93	8.3
27	91	6.3	62	96	8.7	97	96	8.7
28	89	6.2	63	88	6.3	98	97	8.6
29	95	8.8	64	97	8.9	99	93	7.9
30	92	7.5	65	87	6.8	100	92	7.5
31	91	7.2	66	93	7.4			
32	97	9.4	67	94	7.7			
33	97	8.0	68	87	6.6			
34	93	8.5	69	92	7.5			
35	95	8.0	70	93	7.8			

Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon.

Data tables of length and weight of juvenile chinook salmon at the beginning of a 60 day exposure, Round II, Part 2.

Treatment: HWSE-P **Tank#:** H

Date: 6/26/97

Fish#	Fork Length	Weight
1	95	7.9
2	96	8.8
3	96	9.4
4	94	8.1
5	95	8.7
6	94	8.6
7	94	8.0
8	91	7.6
9	87	6.9
10	90	7.2
11	96	9.4
12	90	7.9
13	90	8.2
14	96	8.6
15	97	10.9
16	95	9.2
17	90	7.8
18	95	7.2
19	95	8.9
20	91	7.5
21	93	8.0
22	88	6.6
23	89	6.9
24	96	7.3
25	89	6.3
26	97	8.7
27	96	9.1
28	92	6.7
29	95	8.0
30	89	7.1
31	97	9.6
32	92	8.0
33	97	9.5
34	98	7.4
35	87	5.9

Fish#	Fork Length	Weight
36	98	8.8
37	97	9.9
38	88	6.2
39	93	7.9
40	88	6.9
41	87	6.5
42	97	8.2
43	95	8.8
44	92	7.8
45	93	7.9
46	96	9.1
47	93	7.3
48	94	8.1
49	95	8.9
50	91	9.1
51	88	6.4
52	87	6.7
53	87	7.2
54	87	6.3
55	97	9.1
56	87	6.6
57	91	7.3
58	96	8.9
59	97	9.3
60	95	8.6
61	91	7.8
62	92	7.6
63	90	6.3
64	98	8.9
65	92	8.2
66	98	9.3
67	92	7.6
68	92	7.9
69	96	7.7
70	93	8.1

Fish#	Fork Length	Weight
71	98	9.4
72	89	7.1
73	97	8.2
74	87	6.3
75	89	6.2
76	87	6.2
77	87	6.2
78	92	7.7
79	96	6.6
80	86	9.1
81	92	7.6
82	90	7.4
83	93	7.8
84	92	6.9
85	92	7.7
86	96	9.3
87	92	7.2
88	93	7.9
89	89	7.3
90	91	8.1
91	96	8.0
92	89	8.5
93	92	7.7
94	96	8.5
95	87	6.3
96	96	8.1
97	89	7.4
98	96	8.6
99	87	6.4
100	92	7.9

Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon.

Data tables of length and weight of juvenile chinook salmon at the beginning of a 60 day exposure, Round II, Part 2.

Treatment: NQSE **Tank#:** I

Date: 6/26/97

Fish#	Fork Length	Weight	Fish#	Fork Length	Weight	Fish#	Fork Length	Weight
1	98	8.8	36	94	7.3	71	86	6.2
2	89	7.9	37	96	8.8	72	93	8.0
3	92	6.9	38	90	6.9	73	96	8.7
4	95	7.0	39	93	7.2	74	90	6.3
5	92	7.2	40	97	9.3	75	90	7.4
6	96	8.8	41	88	7.0	76	95	8.8
7	93	7.8	42	94	8.8	77	98	9.6
8	96	8.8	43	90	6.7	78	90	7.3
9	97	9.3	44	98	9.2	79	97	9.3
10	98	9.3	45	90	7.5	80	93	6.6
11	95	7.8	46	95	8.9	81	97	9.6
12	98	8.7	47	94	9.0	82	94	8.0
13	95	7.8	48	98	9.3	83	95	9.3
14	95	8.2	49	97	9.3	84	89	6.8
15	92	7.7	50	98	8.9	85	96	9.0
16	95	8.3	51	95	7.7	86	97	9.2
17	92	7.2	52	95	8.6	87	91	7.4
18	94	8.0	53	95	8.0	88	97	9.2
19	97	8.5	54	94	7.7	89	98	9.0
20	91	7.2	55	96	8.8	90	93	7.1
21	98	8.6	56	93	8.1	91	98	9.2
22	88	6.3	57	95	8.5	92	97	8.5
23	98	10.1	58	94	8.4	93	89	7.0
24	97	8.8	59	91	7.2	94	97	9.1
25	94	9.0	60	96	8.9	95	93	8.0
26	93	7.3	61	95	8.8	96	93	8.0
27	98	8.8	62	94	8.3	97	93	7.1
28	93	7.6	63	92	6.8	98	89	7.2
29	94	7.5	64	98	10.2	99	98	9.9
30	95	7.2	65	96	8.6	100	94	8.8
31	94	8.5	66	98	9.6			
32	93	7.4	67	89	6.8			
33	94	8.2	68	98	9.8			
34	94	8.0	69	97	8.8			
35	87	6.1	70	94	8.0			

Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon.

Data tables of length and weight of juvenile chinook salmon at the beginning of a 60 day exposure, Round II, Part 2.

Treatment: HCBD **Tank#:** J

Date: 6/26/97

Fish#	Fork Length	Weight
1	96	8.5
2	88	6.6
3	99	9.8
4	98	8.5
5	99	9.1
6	95	8.2
7	97	9.5
8	96	8.7
9	89	7.0
10	95	7.7
11	97	9.8
12	98	10.4
13	98	9.4
14	93	7.7
15	96	9.0
16	93	7.7
17	98	9.4
18	97	10.0
19	96	8.4
20	98	9.1
21	90	6.7
22	91	7.1
23	96	9.0
24	97	7.7
25	97	9.2
26	95	8.2
27	96	8.7
28	98	8.0
29	96	9.0
30	98	9.9
31	87	6.7
32	92	7.7
33	89	6.8
34	95	9.0
35	87	7.7

Fish#	Fork Length	Weight
36	94	8.3
37	93	7.7
38	97	9.1
39	89	7.4
40	96	9.3
41	97	8.7
42	94	8.2
43	91	6.8
44	99	9.5
45	94	8.8
46	93	7.6
47	97	8.3
48	89	7.2
49	89	7.7
50	93	8.3
51	99	9.3
52	98	9.3
53	92	8.0
54	97	8.7
55	88	7.2
56	95	7.5
57	94	8.4
58	89	7.3
59	91	7.4
60	95	8.3
61	97	9.5
62	99	9.2
63	98	8.3
64	93	7.7
65	89	7.0
66	98	9.4
67	90	7.2
68	98	9.4
69	98	9.0
70	90	7.0

Fish#	Fork Length	Weight
71	90	7.0
72	96	8.6
73	92	7.6
74	97	8.9
75	93	7.2
76	92	7.6
77	98	7.6
78	89	6.8
79	96	8.9
80	96	8.3
81	92	7.5
82	96	8.7
83	95	7.5
84	92	7.5
85	93	7.2
86	95	8.2
87	90	6.8
88	92	7.5
89	99	9.5
90	99	8.6
91	94	8.6
92	93	7.4
93	94	7.1
94	94	7.9
95	98	10.0
96	98	10.3
97	98	6.7
98	97	7.9
99	96	8.1
100	91	6.7

Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon.

Data tables of length and weight of juvenile chinook salmon at the beginning of a 60 day exposure, Round II, Part 2.

Treatment: HWSE-M **Tank#:** K

Date: 6/26/97

Fish#	Fork Length	Weight	Fish#	Fork Length	Weight	Fish#	Fork Length	Weight
1	90	7.3	36	89	6.5	71	94	7.9
2	95	8.4	37	88	6.9	72	95	8.0
3	90	6.7	38	91	7.2	73	90	7.5
4	90	7.7	39	96	8.4	74	92	7.8
5	96	9.2	40	92	7.4	75	91	7.1
6	95	8.6	41	96	9.6	76	91	7.5
7	96	9.8	42	95	8.7	77	97	9.8
8	97	6.7	43	98	9.4	78	87	6.2
9	92	7.6	44	89	6.5	79	95	8.9
10	96	6.8	45	92	6.8	80	91	7.5
11	92	7.4	46	91	7.5	81	89	7.1
12	97	9.4	47	93	8.1	82	95	8.3
13	97	10.1	48	93	7.5	83	96	9.2
14	89	6.7	49	90	7.1	84	96	9.9
15	93	7.6	50	96	8.5	85	88	7.4
16	93	7.9	51	90	7.2	86	92	8.8
17	92	7.0	52	90	6.9	87	96	8.9
18	94	8.2	53	89	6.7	88	89	7.4
19	98	8.8	54	91	8.0	89	95	9.0
20	89	7.9	55	91	7.1	90	92	8.1
21	92	7.5	56	90	7.3	91	89	7.0
22	95	8.1	57	95	7.9	92	89	7.4
23	94	8.0	58	95	8.7	93	89	6.3
24	92	7.5	59	95	8.7	94	91	7.8
25	92	7.3	60	90	7.7	95	92	7.9
26	90	7.3	61	95	9.0	96	91	7.4
27	90	7.2	62	95	8.2	97	89	6.9
28	90	7.4	63	92	7.4	98	91	7.3
29	97	9.1	64	97	8.7	99	88	6.7
30	89	6.2	65	97	9.1	100	90	6.4
31	90	7.2	66	97	9.3			
32	95	8.0	67	92	8.0			
33	95	8.4	68	94	8.0			
34	91	7.8	69	95	9.1			
35	93	7.2	70	96	9.6			

Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon.

Data tables of length and weight of juvenile chinook salmon at the beginning of a 60 day exposure, Round II, Part 2.

Treatment: ACE/EMUL **Tank#:** L

Date: 6/26/97

Fish#	Fork Length	Weight	Fish#	Fork Length	Weight	Fish#	Fork Length	Weight
1	90	6.0	36	95	8.2	71	95	8.3
2	89	6.2	37	96	8.9	72	88	6.6
3	91	7.3	38	89	6.9	73	96	8.7
4	96	9.2	39	95	7.9	74	96	8.7
5	88	6.1	40	90	6.9	75	94	7.6
6	96	7.7	41	97	9.1	76	96	9.1
7	98	7.1	42	97	9.1	77	96	9.5
8	90	7.2	43	92	7.7	78	92	7.6
9	98	9.9	44	98	9.2	79	94	8.3
10	89	6.2	45	95	8.6	80	92	7.4
11	89	7.1	46	97	9.3	81	92	7.5
12	92	7.1	47	94	8.5	82	93	7.8
13	95	8.3	48	98	9.8	83	95	8.8
14	95	8.5	49	93	8.2	84	94	8.2
15	97	8.4	50	94	8.5	85	90	8.4
16	98	8.5	51	95	7.2	86	96	9.1
17	98	10.1	52	90	6.6	87	96	8.5
18	94	7.2	53	97	9.1	88	95	8.6
19	95	9.2	54	94	8.6	89	97	9.6
20	96	6.1	55	95	8.5	90	89	7.0
21	95	7.3	56	89	6.9	91	93	8.3
22	95	8.1	57	93	7.6	92	94	8.2
23	95	7.0	58	98	7.1	93	90	7.6
24	98	10.3	59	92	7.5	94	95	8.4
25	95	8.5	60	91	8.6	95	94	7.4
26	90	7.7	61	95	8.8	96	90	7.3
27	95	8.8	62	94	7.9	97	97	8.7
28	93	8.5	63	87	6.7	98	96	8.9
29	92	8.5	64	96	9.8	99	97	6.5
30	93	7.5	65	92	8.6	100	96	8.5
31	94	8.3	66	95	8.9			
32	92	6.5	67	95	9.1			
33	94	8.4	68	90	7.2			
34	92	7.4	69	92	8.1			
35	98	9.0	70	93	7.9			

Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon.

Data tables of length and weight of juvenile chinook salmon at the beginning of a 60 day exposure, Round II, Part 2.

Treatment: PAHs **Tank#:** M

Date: 6/26/97

Fish#	Fork Length	Weight
1	94	7.7
2	98	9.3
3	94	8.0
4	90	7.4
5	93	8.0
6	95	7.9
7	89	6.9
8	92	8.6
9	90	6.9
10	89	6.2
11	91	6.7
12	95	8.1
13	94	8.4
14	93	7.5
15	96	8.5
16	95	8.3
17	94	8.2
18	98	9.4
19	92	7.5
20	98	8.8
21	87	6.0
22	92	7.6
23	94	7.6
24	90	7.0
25	90	7.5
26	95	7.5
27	94	7.8
28	95	8.1
29	96	9.0
30	87	6.5
31	91	7.0
32	89	5.9
33	92	7.6
34	93	7.2
35	92	6.3

Fish#	Fork Length	Weight
36	93	8.0
37	98	9.6
38	89	6.9
39	91	7.1
40	93	7.6
41	96	8.3
42	98	9.2
43	97	8.9
44	97	8.9
45	97	9.4
46	92	7.7
47	96	8.9
48	98	9.8
49	95	7.6
50	93	8.1
51	90	6.7
52	93	7.5
53	90	6.9
54	88	6.7
55	98	9.0
56	98	8.5
57	98	9.5
58	90	6.7
59	90	6.9
60	94	7.9
61	92	7.9
62	96	7.8
63	90	7.0
64	90	7.1
65	97	8.8
66	91	7.1
67	94	7.8
68	91	7.3
69	91	6.9
70	97	8.0

Fish#	Fork Length	Weight
71	90	7.8
72	97	8.5
73	91	7.4
74	90	7.2
75	95	8.2
76	91	7.0
77	95	8.3
78	93	7.9
79	94	8.1
80	97	9.6
81	95	8.9
82	90	7.2
83	97	9.4
84	90	9.7
85	97	7.7
86	94	7.4
87	95	8.6
88	90	7.1
89	95	7.8
90	95	8.6
91	96	8.5
92	94	8.1
93	89	7.7
94	89	7.1
95	92	8.3
96	95	8.8
97	93	7.2
98	93	8.7
99	90	7.6
100	94	8.2

Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon.

Data tables of length and weight of juvenile chinook salmon at the beginning of a 60 day exposure, Round II, Part 2.

Treatment: NQSE **Tank#:** N

Date: 6/26/97

Fish#	Fork Length	Weight
1	98	9.3
2	97	9.0
3	96	9.9
4	90	7.2
5	94	7.8
6	98	9.2
7	95	8.5
8	96	9.1
9	93	7.6
10	97	9.0
11	95	8.3
12	89	6.5
13	95	8.1
14	89	6.3
15	96	8.8
16	89	6.5
17	95	7.9
18	95	8.7
19	94	8.6
20	98	9.1
21	97	9.1
22	97	9.5
23	97	8.9
24	89	6.9
25	93	7.3
26	96	8.0
27	97	9.2
28	94	7.4
29	90	7.1
30	90	7.0
31	94	8.7
32	96	8.8
33	97	8.8
34	94	8.3
35	91	6.4

Fish#	Fork Length	Weight
36	89	7.0
37	91	7.1
38	97	9.1
39	93	7.9
40	91	7.5
41	87	6.7
42	95	8.0
43	98	9.2
44	97	8.8
45	95	9.4
46	95	8.4
47	92	7.7
48	89	7.3
49	89	6.2
50	91	7.2
51	89	6.9
52	88	6.4
53	89	6.9
54	96	8.9
55	87	5.9
56	98	9.2
57	96	8.7
58	91	7.1
59	94	8.2
60	93	7.5
61	96	8.8
62	90	6.6
63	93	8.1
64	98	9.0
65	96	9.7
66	98	8.6
67	92	8.0
68	95	8.5
69	97	8.5
70	88	6.4

Fish#	Fork Length	Weight
71	97	9.0
72	94	7.7
73	93	8.1
74	95	8.7
75	89	6.7
76	90	6.6
77	94	8.2
78	95	8.3
79	90	7.0
80	97	9.1
81	88	6.4
82	97	8.7
83	98	9.2
84	90	7.0
85	91	7.1
86	98	9.5
87	93	7.8
88	89	7.6
89	98	8.7
90	93	7.2
91	96	9.3
92	96	8.9
93	89	6.7
94	91	7.4
95	91	7.6
96	95	9.8
97	95	8.5
98	94	8.2
99	94	8.5
100	89	7.0

Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon.

Data tables of length and weight of juvenile chinook salmon at the beginning of a 60 day exposure, Round II, Part 2.

Treatment: HWSE-P **Tank#:** O

Date: 6/26/97

Fish#	Fork Length	Weight	Fish#	Fork Length	Weight	Fish#	Fork Length	Weight
1	88	5.7	36	92	8.2	71	91	7.6
2	97	9.4	37	95	8.6	72	94	8.1
3	89	7.1	38	92	8.1	73	90	6.5
4	92	7.5	39	95	8.6	74	93	8.5
5	92	7.8	40	94	8.5	75	88	6.8
6	97	8.5	41	98	9.0	76	90	7.4
7	89	6.9	42	87	6.7	77	91	7.5
8	98	9.3	43	91	6.9	78	96	8.5
9	92	7.7	44	95	9.6	79	95	8.6
10	92	8.9	45	96	8.5	80	97	9.0
11	89	7.0	46	90	7.3	81	93	7.3
12	95	7.4	47	89	7.2	82	92	8.6
13	88	6.0	48	96	8.6	83	95	8.9
14	94	8.3	49	90	7.3	84	91	7.7
15	87	6.0	50	91	7.6	85	93	8.2
16	93	7.9	51	90	5.6	86	96	8.9
17	87	6.8	52	92	7.4	87	87	6.3
18	92	8.2	53	88	6.9	88	95	8.7
19	93	8.1	54	92	7.4	89	98	10.1
20	98	9.6	55	92	7.8	90	92	7.6
21	88	6.8	56	96	8.5	91	88	7.3
22	92	7.5	57	98	10.0	92	90	8.3
23	91	7.4	58	96	8.4	93	95	9.3
24	93	7.6	59	98	7.7	94	91	7.6
25	97	7.1	60	95	9.2	95	95	9.2
26	88	6.8	61	95	8.6	96	95	8.6
27	89	6.7	62	90	7.4	97	90	6.8
28	96	8.6	63	90	7.6	98	95	7.7
29	94	9.3	64	91	7.4	99	95	8.5
30	95	8.3	65	94	7.9	100	96	8.6
31	92	8.0	66	92	7.9			
32	95	8.4	67	91	6.6			
33	95	8.7	68	91	8.1			
34	94	8.5	69	94	8.3			
35	96	9.4	70	96	9.2			

Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon.

Data tables of length and weight of juvenile chinook salmon at the beginning of a 60 day exposure, Round II, Part 2.

Treatment: HCBD **Tank#:** P

Date: 6/26/97

Fish#	Fork Length	Weight
1	93	7.4
2	97	7.4
3	90	7.4
4	98	7.9
5	91	6.4
6	91	8.9
7	98	9.2
8	90	6.8
9	96	7.4
10	91	7.4
11	98	8.7
12	97	7.5
13	98	8.4
14	96	8.4
15	93	7.6
16	96	8.1
17	95	9.0
18	98	8.6
19	94	8.0
20	98	9.6
21	92	7.1
22	98	9.8
23	89	6.8
24	96	8.2
25	92	7.4
26	91	7.6
27	92	7.4
28	97	8.5
29	93	8.2
30	97	8.7
31	90	7.1
32	87	5.5
33	89	6.6
34	94	8.0
35	89	6.1
36	96	8.4
37	93	7.3
38	95	7.5
39	98	9.4
40	98	8.3
41	98	9.6
42	93	6.2
43	92	7.4
44	97	6.5
45	93	8.5
46	97	8.9
47	90	6.8
48	96	6.6
49	93	7.1
50	94	7.6
51	92	8.0
52	93	7.4
53	98	9.9
54	94	7.5
55	93	7.4
56	98	9.3
57	94	7.6
58	96	7.0
59	98	8.9
60	97	9.4
61	90	7.2
62	88	7.0
63	96	8.2
64	91	7.0
65	98	9.5
66	98	9.3
67	94	8.2
68	95	7.5
69	95	8.3
70	95	8.8
71	91	7.5
72	95	7.8
73	96	8.1
74	96	8.5
75	95	9.0
76	90	7.3
77	90	6.5
78	88	6.7
79	87	5.9
80	91	7.0
81	97	9.2
82	90	6.8
83	93	7.5
84	94	7.0
85	93	8.0
86	87	6.0
87	94	8.6
88	94	8.0
89	93	8.0
90	94	8.0
91	94	7.8
92	90	6.5
93	91	7.3
94	92	7.3
95	94	7.4
96	98	9.3
97	97	8.6
98	95	8.7
99	91	7.8
100	93	7.4

Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon.

Data tables of length and weight of juvenile chinook salmon at the end of a 60 day exposure, Round II, Part 2.

Treatment: PCB

Tank#: A

Date: 8/25/97

Fish#	Meas. Fork Length	Total Length	Calc. Fork Length	Weight
1		142	134	32.0
2		143	135	30.0
3		146	138	33.0
4		152	143	38.5
5		151	142	40.0
6		146	138	33.0
7		146	138	34.0
8		133	125	25.0
9		134	126	24.0
10		162	153	47.0
11		144	136	29.0
12		140	132	30.0
13		160	151	45.0
14		148	140	35.0
15		143	135	29.0
16		145	137	34.0
17		148	140	35.0
18		136	128	25.0
19		148	140	35.0
20		151	142	38.0
21		139	131	29.0
22		140	132	35.0
23		146	138	31.0
24		141	133	31.0
25		147	139	36.0
26		141	133	30.0
27		133	125	24.0
28		147	139	33.0
29		144	136	31.0
30		141	133	29.0
31		139	131	27.0
32		131	124	24.0
33		148	140	33.0
34		135	127	27.0

Fish#	Meas. Fork Length	Total Length	Calc. Fork Length	Weight
35		142	134	29.0
36	134			30.3
37	129			26.7
38	135			34.3
39	130			24.2
40	134			28.7
41	135			30.4
42	130			27.6
43	137			35.9
44	135			32.8
45	137			31.4
46	138			36.4
47	138			33.2
48	145			38.9
49	130			27.7
50	128			23.7
51	136			32.0
52	143			37.4
53	140			34.0
54	140			34.5
55	152			42.1
56	130			27.0
57	141			37.0
58	140			33.3
59	142			35.8
60	132			28.6
61	140			37.8
62	135			33.9
63	130			28.4
64	131			26.9
65	138			34.3
66	128			27.6
67	136			31.2
68	133			30.5

Fish#	Meas. Fork Length	Total Length	Calc. Fork Length	Weight
69	137			33.2
70	138			34.2
71	132			29.0
72	130			27.5
73	135			28.6
74	135			31.6
75	122			23.2
76	132			27.9
77	126			26.2
78	141			32.2
79	130			26.8
80	135			31.3
81	138			31.2
82	133			28.7
83	139			36.4
84	128			27.8

Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon.

Data tables of length and weight of juvenile chinook salmon at the end of a 60 day exposure, Round II, Part 2.

Treatment: Acetone Emulphor **Tank#:** C

Date: 8/25/97

Fish#	Meas. Fork Length	Total Length	Calc. Fork Length	Weight
1	134	140		31.0
2	139	145		35.0
3	135	143		27.0
4	138	143		30.0
5	137	143		32.0
6	138	145		35.0
7	137	145		35.0
8	137	146		32.0
9	140	148		36.0
10	126	133		25.0
11	140	150		38.0
12	135	143		31.0
13	130	140		32.0
14	128	140		31.0
15	133	142		32.0
16	131	139		29.0
17	130	139		29.0
18	135	143		33.0
19	131	140		30.0
20	129	135		28.0
21	141	152		40.0
22	134	143		29.0
23	135	145		34.0
24	149	160		43.0
25	129	136		28.0
26	123	131		24.0
27	125	135		24.0
28	140	147		37.0
29	139	145		34.0
30	129	139		27.0
31	131	140		32.0
32	134	142		34.0
33	139	148		35.0
34	149	156		45.0
35	128	135		26.0
36	135			29.1
37	130			28.3
38	145			41.5
39	143			38.3
40	140			34.8
41	139			33.7
42	136			32.3
43	122			21.2
44	123			23.4
45	123			23.5
46	133			27.1
47	137			32.2
48	123			24.0
49	137			32.4
50	130			26.8
51	141			36.0
52	136			31.1
53	134			29.6
54	134			31.5
55	139			33.0
56	130			26.7
57	140			32.8
58	144			37.6
59	135			30.3
60	135			30.2
61	140			35.0
62	142			37.7
63	133			31.2
64	139			33.7
65	133			28.8
66	144			40.8
67	142			37.3
68	134			31.4
69	131			26.7
70	136			32.8
71	137			31.7
72	125			24.2
73	140			34.4
74	135			29.8
75	129			24.3
76	143			38.6
77	140			32.0
78	134			32.8
79	133			29.8
80	137			32.5
81	125			23.8
82	126			24.0
83	137			32.1
84	126			23.2
85	143			37.5
86	133			30.8
87	136			33.7
88	130			27.9
89	137			31.9
90	126			24.2

Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon.

Data tables of length and weight of juvenile chinook salmon at the end of a 60 day exposure, Round II, Part 2.

Treatment: PAH **Tank#:** E

Date: 8/25/97

Fish#	Meas. Fork Length	Total Length	Calc. Fork Length	Weight
1		135	127	24.0
2		152	143	38.0
3		135	127	24.0
4		142	134	29.0
5		136	128	30.0
6		146	138	36.0
7		145	137	34.0
8		142	134	32.0
9		145	137	31.0
10		152	143	36.0
11		129	122	21.0
12		138	130	24.0
13		147	139	34.0
14		131	124	23.0
15		132	125	25.0
16		134	126	24.0
17		143	135	40.0
18		131	124	25.0
19		146	138	29.0
20		134	126	25.0
21		151	142	37.0
22		133	125	24.0
23		134	126	24.0
24		138	130	27.0
25		147	139	35.0
26		136	128	25.0
27		151	142	37.0
28		140	132	30.0
29		142	134	30.0
30		142	134	29.0
31		146	138	31.0
32		147	139	35.0
33		141	133	29.0
34		140	132	30.0
35		135	127	27.0
36	124			22.4
37	127			25.6
38	130			28.3
39	134			27.5
40	143			38.3
41	128			26.3
42	129			25.2
43	135			32.1
44	136			31.4
45	132			29.0
46	120			20.5
47	123			22.3
48	131			27.3
49	136			29.4
50	145			39.3
51	132			28.5
52	140			37.4
53	126			24.7
54	120			20.6
55	134			26.7
56	132			28.9
57	127			26.4
58	131			28.0
59	127			23.6
60	139			32.9
61	136			32.4
62	130			29.0
63	128			24.1
64	112			21.3
65	130			28.0
66	126			25.1
67	143			38.4
68	135			30.0
69	137			33.3
70	128			25.6
71	131			28.1
72	150			46.9
73	137			29.2
74	137			33.7
75	135			31.0
76	125			23.3
77	139			34.2

Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon.

Data tables of length and weight of juvenile chinook salmon at the end of a 60 day exposure, Round II, Part 2.

Treatment: PCB

Tank#: F

Date: 8/25/97

Fish#	Meas. Fork Length	Total Length	Calc. Fork Length	Weight
1		145	137	35.0
2		134	126	26.0
3		135	127	27.0
4		138	130	28.0
5		130	123	24.0
6		143	135	31.0
7		135	127	26.0
8		138	130	28.0
9		141	133	31.0
10		142	134	30.0
11		135	127	27.0
12		145	137	34.0
13		144	136	30.0
14		138	130	25.0
15		134	126	26.0
16		125	118	19.0
17		121	114	18.0
18		142	134	33.0
19		138	130	28.0
20		138	130	26.0
21		149	141	35.0
22		144	136	33.0
23		135	127	28.0
24		129	122	22.0
25		134	126	24.0
26		143	135	31.0
27		136	128	27.0
28		135	127	25.0
29		141	133	30.0
30		135	127	25.0
31		141	133	31.0
32		140	132	27.0
33		141	133	32.0
34		136	128	27.0

Fish#	Meas. Fork Length	Total Length	Calc. Fork Length	Weight
35		132	125	25.0
36	122			21.5
37	123			22.9
38	124			24.8
39	122			24.4
40	130			26.4
41	131			34.7
42	125			24.2
43	133			26.7
44	133			28.8
45	125			23.9
46	119			18.7
47	138			30.7
48	136			30.2
49	137			30.7
50	125			22.5
51	129			25.9
52	127			27.5
53	133			32.5
54	128			26.5
55	140			34.8
56	135			29.7
57	134			28.5
58	132			28.4
59	128			23.7
60	125			23.4
61	129			28.2
62	127			23.3
63	126			23.3
64	129			23.4
65	136			30.9
66	121			27.1
67	138			33.0
68	136			32.6

Fish#	Meas. Fork Length	Total Length	Calc. Fork Length	Weight
69	142			35.7
70	132			29.0
71	122			22.3
72	125			22.5
73	136			30.9
74	135			29.2
75	130			28.1
76	138			33.1
77	127			26.0
78	138			35.0
79	130			27.1
80	128			27.4
81	138			32.4
82	124			23.4
83	126			24.7
84	139			35.2
85	128			25.0
86	116			22.8

Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon.

Data tables of length and weight of juvenile chinook salmon at the end of a 60 day exposure, Round II, Part 2

Treatment: HWSE-M **Tank#:** G

Date: 8/25/97

Fish#	Meas. Fork Length	Total Length	Calc. Fork Length	Weight
1		135	127	25.0
2		140	132	28.0
3		136	128	27.0
4		136	128	30.0
5		135	127	23.0
6		140	132	30.0
7		138	130	26.0
8		141	133	30.0
9		142	134	31.0
10		133	125	25.0
11		145	137	33.0
12		140	132	29.0
13		141	133	28.0
14		143	135	33.0
15		145	137	34.0
16		140	132	30.0
17		147	139	35.0
18		151	142	37.0
19		136	128	25.0
20		145	137	33.0
21		147	139	35.0
22		138	130	29.0
23		149	141	36.0
24		139	131	30.0
25		137	129	28.0
26		131	124	26.0
27		150	142	38.0
28		143	135	31.0
29		143	135	34.0
30		149	141	38.0
31		140	132	31.0
32		134	126	28.0
33		134	126	27.0
34		141	133	30.0

Fish#	Meas. Fork Length	Total Length	Calc. Fork Length	Weight
35		150	142	37.0
36	126			22.9
37	138			34.9
38	135			30.2
39	131			29.5
40	149			41.1
41	137			32.8
42	138			33.3
43	127			24.9
44	130			24.1
45	130			27.2
46	131			28.3
47	136			32.2
48	138			30.9
49	139			35.2
50	136			33.2
51	121			21.7
52	133			29.6
53	136			32.1
54	131			27.9
55	139			34.7
56	142			39.2
57	129			23.9
58	126			26.7
59	140			34.9
60	134			30.6
61	125			24.5
62	135			30.2
63	134			29.2
64	123			24.0
65	140			33.3
66	130			28.5
67	129			26.8
68	140			36.1

Fish#	Meas. Fork Length	Total Length	Calc. Fork Length	Weight
69	137			34.4
70	127			27.2
71	140			32.6
72	132			29.5
73	127			24.6
74	126			23.5
75	136			34.5
76	122			21.1
77	120			20.8
78	133			32.0
79	130			26.7
80	132			28.9
81	135			32.9
82	136			28.9
83	134			31.1
84	139			31.7
85	142			34.9
86	141			31.8
87	133			27.4
88	132			25.4

Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon.

Data tables of length and weight of juvenile chinook salmon at the end of a 60 day exposure, Round II, Part 2.

Treatment: HWSE-P **Tank#:** H

Date: 8/25/97

Fish#	Meas. Fork Length	Total Length	Calc. Fork Length	Weight
1		131	124	23.0
2		157	148	46.0
3		140	132	32.0
4		135	127	24.0
5		135	127	27.0
6		145	137	33.0
7		138	130	25.0
8		132	125	27.0
9		139	131	30.0
10		139	131	30.0
11		128	121	23.0
12		130	123	24.0
13		146	138	33.0
14		141	133	32.0
15		135	127	26.0
16		142	134	32.0
17		128	121	23.0
18		134	126	25.0
19		133	125	25.0
20		141	133	27.0
21		141	133	30.0
22		146	138	34.0
23		139	131	31.0
24		141	133	29.0
25		139	131	27.0
26		138	130	27.0
27		138	130	27.0
28		139	131	28.0
29		129	122	23.0
30		141	133	29.0
31		141	133	31.0
32		135	127	26.0
33		140	132	29.0
34		140	132	28.0
35		133	125	26.0
36	124			23.6
37	135			31.2
38	140			36.5
39	140			35.9
40	129			26.8
41	143			38.0
42	132			28.8
43	135			30.9
44	150			48.7
45	135			31.6
46	130			28.5
47	124			24.0
48	135			31.5
49	137			32.3
50	130			26.2
51	127			25.9
52	138			36.4
53	133			29.8
54	136			33.8
55	123			22.3
56	126			24.5
57	126			25.3
58	130			28.9
59	137			32.6
60	145			41.7
61	131			28.5
62	133			27.1
63	146			40.4
64	125			22.1
65	136			29.4
66	127			26.6
67	140			34.8
68	140			34.0
69	130			28.4
70	130			28.2
71	130			28.4
72	131			27.6
73	132			28.2
74	131			29.5
75	130			28.2
76	130			26.6
77	125			23.8
78	133			28.6
79	129			27.1
80	135			32.7
81	128			28.9
82	143			35.2
83	131			29.0
84	138			33.1
85	129			26.4
86	128			26.6
87	133			30.9
88	135			29.1
89	125			24.9
90	130			28.6

Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon.

Data tables of length and weight of juvenile chinook salmon at the end of a 60 day exposure, Round II, Part 2.

Treatment: NQSE **Tank#:** I

Date: 8/25/97

Fish#	Meas. Fork Length	Total Length	Calc. Fork Length	Weight
1	138	146		36.0
2	145	153		40.0
3	135	144		31.0
4	136	145		34.0
5	129	138		28.0
6	142	149		37.0
7	125	133		24.0
8	135	144		34.0
9	128	136		25.0
10	128	136		27.0
11	143	153		37.0
12	137	145		33.0
13	131	138		27.0
14	127	135		27.0
15	145	154		39.0
16	140	149		33.0
17	133	142		30.0
18	147	155		43.0
19	138	148		36.0
20	142	151		41.0
21	128	135		27.0
22	131	139		28.0
23	125	132		24.0
24	138	147		34.0
25	135	143		33.0
26	135	143		32.0
27	130	140		29.0
28	132	138		26.0
29	127	133		23.0
30	133	142		31.0
31	134	144		29.0
32	136	146		33.0
33	142	149		38.0
34	133	141		32.0

Fish#	Meas. Fork Length	Total Length	Calc. Fork Length	Weight
35	135	144		35.0
36	143	151		37.0
37	137			32.6
38	146			40.8
39	139			35.4
40	136			32.8
41	134			30.9
42	146			43.2
43	143			37.0
44	153			47.5
45	135			31.2
46	123			23.1
47	145			36.7
48	146			41.2
49	136			31.1
50	130			27.9
51	136			33.8
52	135			30.0
53	141			38.0
54	149			42.5
55	134			30.0
56	138			30.9
57	141			37.1
58	124			23.6
59	125			23.2
60	129			26.6
61	150			40.7
62	141			34.0
63	134			32.4
64	142			39.0
65	140			34.7
66	140			36.7
67	130			26.1
68	133			31.6

Fish#	Meas. Fork Length	Total Length	Calc. Fork Length	Weight
69	125			25.4
70	122			23.7
71	139			34.0
72	137			32.6
73	145			40.6
74	142			39.4
75	139			35.6
76	129			26.6
77	137			33.8
78	131			28.0
79	131			29.2
80	130			29.7
81	135			32.5
82	139			37.1
83	122			23.1
84	133			30.2
85	142			38.9
86	135			30.1
87	142			39.2
88	136			35.0
89	142			39.1
90	144			39.2
91	139			32.9
92	136			33.1
93	130			25.1
94	134			32.1
95	129			25.6

Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon.

Data tables of length and weight of juvenile chinook salmon at the end of a 60 day exposure, Round II, Part 2.

Treatment: HCBD **Tank#:** J

Date: 8/25/97

Fish#	Meas. Fork Length	Total Length	Calc. Fork Length	Weight
1	125	132		24.0
2	128	135		27.0
3	133	142		30.0
4	135	143		31.0
5	131	139		31.0
6	127	133		29.0
7	125	131		24.0
8	130	136		29.0
9	129	138		26.0
10	133	140		28.0
11	138	147		35.0
12	143	151		37.0
13	128	134		26.0
14	127	137		29.0
15	125	135		26.0
16	122	130		23.0
17	128	137		28.0
18	138	147		33.0
19	134	143		31.0
20	124	131		22.0
21	135	144		32.0
22	131	140		28.0
23	135	144		32.0
24	130	137		29.0
25	138	145		34.0
26	134	141		30.0
27	135	141		31.0
28	121	129		22.0
29	125	134		25.0
30	140	148		36.0
31	135	142		33.0
32	122	131		22.0
33	142	152		40.0
34	115	123		18.0
35	118	127		21.0
36	130			29.4
37	125			23.4
38	130			29.8
39	130			25.7
40	133			28.5
41	126			24.3
42	141			32.7
43	118			18.8
44	140			32.6
45	125			23.2
46	122			22.4
47	135			31.3
48	144			35.6
49	143			35.5
50	140			34.3
51	123			21.2
52	126			26.2
53	131			27.9
54	125			25.0
55	147			38.4
56	138			32.0
57	143			40.6
58	133			32.3
59	128			25.1
60	127			24.7
61	125			23.9
62	130			25.1
63	133			31.0
64	137			31.2
65	137			31.6
66	125			24.8
67	128			25.6
68	126			24.4
69	126			24.0
70	122			24.6
71	142			39.9
72	130			28.2
73	131			27.8
74	150			44.8
75	130			29.5
76	122			23.6
77	123			24.6
78	125			21.8
79	136			28.3
80	128			26.0
81	121			22.8
82	131			30.6
83	130			28.1
84	135			32.1

Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon.

Data tables of length and weight of juvenile chinook salmon at the end of a 60 day exposure, Round II, Part 2.

Treatment: HWSE-M **Tank#:** K

Date: 8/25/97

Fish#	Meas. Fork Length	Total Length	Calc. Fork Length	Weight
1		147	139	34.0
2		133	125	24.0
3		135	127	29.0
4		145	137	32.0
5		142	134	30.0
6		145	137	34.0
7		135	127	27.0
8		132	125	23.0
9		133	125	24.0
10		145	137	33.0
11		142	134	32.0
12		140	132	31.0
13		141	133	29.0
14		140	132	30.0
15		144	136	31.0
16		147	139	34.0
17		138	130	28.0
18		138	130	26.0
19		136	128	28.0
20		138	130	30.0
21		133	125	26.0
22		138	130	31.0
23		144	136	33.0
24		140	132	31.0
25		145	137	38.0
26		133	125	24.0
27		135	127	25.0
28		144	136	29.0
29		146	138	40.0
30		141	133	29.0
31		132	125	24.0
32		145	137	34.0
33		136	128	28.0
34		131	124	23.0
35		140	132	29.0
36	123			22.2
37	133			30.3
38	134			37.2
39	135			31.0
40	129			27.6
41	136			30.3
42	143			38.3
43	131			31.0
44	142			37.1
45	138			35.0
46	132			27.9
47	140			31.6
48	130			27.3
49	128			25.6
50	136			32.0
51	139			32.6
52	140			33.9
53	130			25.9
54	141			36.9
55	128			26.3
56	133			30.5
57	130			27.7
58	130			26.8
59	129			25.7
60	144			37.7
61	129			26.4
62	133			27.5
63	138			37.2
64	128			26.3
65	135			30.5
66	142			36.5
67	136			30.3
68	120			21.8
69	130			27.6
70	138			30.4
71	133			29.4
72	138			33.8
73	140			33.1
74	142			36.2
75	131			27.8
76	121			21.2
77	133			29.8
78	129			27.0
79	130			27.3
80	135			30.7
81	137			34.4
82	131			27.4
83	151			42.9
84	133			26.4
85	128			25.5
86	129			27.4
87	124			22.9
88	136			31.4
89	121			23.9

Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon.

Data tables of length and weight of juvenile chinook salmon at the end of a 60 day exposure, Round II, Part 2.

Treatment: Acetone Emulphor **Tank#:** L

Date: 8/25/97

Fish#	Meas. Fork Length	Total Length	Calc. Fork Length	Weight
1	146	155		38.0
2	138	146		36.0
3	131	141		31.0
4	128	135		30.0
5	138	148		33.0
6	135	143		34.0
7	132	138		28.0
8	128	135		24.0
9	131	141		31.0
10	128	136		30.0
11	124	132		24.0
12	142	148		36.0
13	128	134		26.0
14	138	146		35.0
15	130	137		26.0
16	128	136		29.0
17	131	141		32.0
18	143	150		36.0
19	135	142		33.0
20	135	142		33.0
21	132	139		27.0
22	134	140		30.0
23	137	145		32.0
24	150	160		44.0
25	149	156		44.0
26	131	138		30.0
27	140	147		34.0
28	127	134		24.0
29	132	140		27.0
30	137	147		34.0
31	134	141		28.0
32	145	153		39.0
33	142	149		36.0
34	127	133		25.0

Fish#	Meas. Fork Length	Total Length	Calc. Fork Length	Weight
35	132	141		31.0
36	120			22.7
37	150			40.4
38	125			25.4
39	140			36.8
40	140			33.6
41	144			41.5
42	138			32.7
43	135			30.8
44	136			32.7
45	136			30.6
46	141			37.9
47	141			37.4
48	142			38.9
49	142			35.6
50	141			37.8
51	140			33.6
52	131			28.2
53	135			31.8
54	142			38.0
55	132			27.1
56	130			28.8
57	130			27.0
58	148			44.0
59	138			32.3
60	147			43.6
61	136			33.5
62	133			28.9
63	145			37.8
64	141			37.1
65	150			47.7
66	136			31.2
67	128			25.9
68	135			30.4

Fish#	Meas. Fork Length	Total Length	Calc. Fork Length	Weight
69	131			26.2
70	138			34.0
71	122			22.6
72	141			36.3
73	136			33.1
74	133			29.4
75	137			33.0
76	147			41.9
77	147			44.1
78	136			31.6
79	146			37.9
80	135			30.3
81	144			37.4
82	136			33.8
83	128			27.0
84	145			41.7
85	129			27.4
86	130			27.9
87	120			21.2
88	130			25.8
89	146			43.1

Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon.

Data tables of length and weight of juvenile chinook salmon at the end of a 60 day exposure, Round II, Part 2.

Treatment: PAH **Tank#:** M

Date: 8/25/97

Fish#	Meas. Fork Length	Total Length	Calc. Fork Length	Weight
1		140	132	28.0
2		145	137	31.0
3		142	134	31.0
4		147	139	36.0
5		156	147	44.0
6		152	143	33.0
7		150	142	36.0
8		147	139	34.0
9		139	131	30.0
10		131	124	27.0
11		144	136	33.0
12		150	142	37.0
13		131	124	23.0
14		151	142	39.0
15		145	137	34.0
16		151	142	37.0
17		142	134	37.0
18		150	142	37.0
19		143	135	29.0
20		135	127	26.0
21		151	142	37.0
22		150	142	39.0
23		148	140	33.0
24		159	150	44.0
25		132	125	25.0
26		135	127	28.0
27		145	137	34.0
28		142	134	33.0
29		141	133	31.0
30		140	132	31.0
31		145	137	32.0
32		149	141	35.0
33		142	134	34.0
34		133	125	24.0

Fish#	Meas. Fork Length	Total Length	Calc. Fork Length	Weight
35		139	131	29.0
36	139			34.6
37	123			25.1
38	129			26.1
39	128			27.0
40	137			34.4
41	145			37.6
42	145			37.7
43	131			27.2
44	143			38.1
45	145			39.3
46	135			30.3
47	141			35.9
48	140			30.6
49	141			38.7
50	141			35.0
51	130			29.1
52	130			27.7
53	131			28.4
54	141			35.6
55	132			26.3
56	120			21.4
57	140			31.2
58	143			34.4
59	140			33.3
60	134			30.6
61	140			33.6
62	140			34.8
63	140			37.2
64	131			28.8
65	140			32.8
66	152			43.3
67	144			37.2
68	143			34.0

Fish#	Meas. Fork Length	Total Length	Calc. Fork Length	Weight
69	140			33.7
70	138			33.1
71	137			30.2
72	140			35.9
73	147			42.2
74	136			32.4
75	133			29.3
76	148			45.5
77	133			30.3
78	136			32.2

Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon.

Data tables of length and weight of juvenile chinook salmon at the end of a 60 day exposure, Round II, Part 2.

Treatment: NQSE **Tank#:** N

Date: 8/25/97

Fish#	Meas. Fork Length	Total Length	Calc. Fork Length	Weight
1	140	148		36.0
2	133	142		31.0
3	125	131		26.0
4	128	134		26.0
5	135	145		33.0
6	145	154		41.0
7	117	122		20.0
8	127	136		28.0
9	140	147		35.0
10	118	125		19.0
11	144	153		38.0
12	140	149		37.0
13	127	132		26.0
14	140	149		37.0
15	135	144		33.0
16	137	145		35.0
17	132	137		28.0
18	130	138		31.0
19	128	134		27.0
20	128	134		26.0
21	122	130		23.0
22	140	148		37.0
23	139	147		35.0
24	129	135		27.0
25	124	133		24.0
26	139	147		35.0
27	127	136		29.0
28	130	139		28.0
29	142	149		36.0
30	145	153		41.0
31	131	139		30.0
32	139	146		32.0
33	140	149		37.0
34	142	150		36.0

Fish#	Meas. Fork Length	Total Length	Calc. Fork Length	Weight
35	134	144		32.0
36	136			31.2
37	133			30.2
38	136			32.4
39	141			37.0
40	135			29.8
41	132			28.9
42	125			22.8
43	131			29.2
44	148			40.8
45	140			32.4
46	126			24.0
47	143			39.7
48	132			29.4
49	139			32.3
50	134			30.0
51	143			35.8
52	116			18.3
53	132			31.9
54	134			30.0
55	124			21.0
56	126			23.1
57	138			35.1
58	145			38.2
59	135			29.7
60	145			40.7
61	139			35.7
62	128			26.3
63	126			26.7
64	135			31.9
65	140			35.7
66	142			36.1
67	142			36.8
68	132			29.6

Fish#	Meas. Fork Length	Total Length	Calc. Fork Length	Weight
69	134			29.8
70	132			31.0
71	140			35.3
72	137			31.5
73	140			35.4
74	135			35.1
75	125			23.6
76	137			33.8
77	146			43.7
78	136			33.5
79	130			30.3
80	130			29.5
81	128			27.1
82	132			29.0
83	130			28.5
84	134			29.8
85	135			29.9
86	130			21.8
87	130			27.6
88	146			39.5

Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon.

Data tables of length and weight of juvenile chinook salmon at the end of a 60 day exposure, Round II, Part 2.

Treatment: HWSE-P **Tank#:** O

Date: 8/25/97

Fish#	Meas. Fork Length	Total Length	Calc. Fork Length	Weight
1		143	135	34.0
2		139	131	27.0
3		135	127	25.0
4		141	133	32.0
5		144	136	32.0
6		143	135	32.0
7		142	134	31.0
8		140	132	31.0
9		143	135	30.0
10		138	130	28.0
11		142	134	28.0
12		145	137	34.0
13		133	125	25.0
14		146	138	34.0
15		142	134	32.0
16		142	134	31.0
17		147	139	37.0
18		142	134	29.0
19		146	138	32.0
20		149	141	38.0
21		149	141	34.0
22		130	123	23.0
23		142	134	32.0
24		148	140	33.0
25		148	140	33.0
26		140	132	29.0
27		145	137	33.0
28		138	130	28.0
29		141	133	30.0
30		149	141	36.0
31		144	136	32.0
32		136	128	27.0
33		146	138	35.0
34		140	132	31.0

Fish#	Meas. Fork Length	Total Length	Calc. Fork Length	Weight
35		140	132	29.0
36	125			24.9
37	127			23.4
38	138			35.1
39	133			32.0
40	130			27.6
41	121			22.6
42	147			40.0
43	130			27.7
44	137			37.6
45	130			27.7
46	132			28.6
47	130			26.1
48	130			26.9
49	129			27.3
50	133			29.5
51	121			23.3
52	134			31.0
53	141			35.3
54	131			27.7
55	129			26.2
56	130			27.7
57	134			30.1
58	139			35.9
59	133			30.3
60	136			36.1
61	130			27.8
62	125			24.2
63	136			35.0
64	135			33.2
65	134			33.2
66	143			39.4
67	131			28.1
68	132			30.3

Fish#	Meas. Fork Length	Total Length	Calc. Fork Length	Weight
69	131			30.0
70	123			22.9
71	148			42.8
72	134			28.8
73	130			26.4
74	136			33.6
75	131			26.5
76	133			35.6
77	138			33.7
78	147			36.8
79	134			30.7
80	130			27.1
81	137			30.9
82	131			29.0
83	137			35.2
84	132			29.5
85	138			32.2
86	132			30.5
87	145			41.0
88	131			29.0
89	133			30.0
90	135			30.0
91	137			32.2
92	127			23.2
93	140			36.8
94	128			25.9
95	152			44.5
96	138			35.7
97	135			28.1
98	127			24.0
99	143			33.9

Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon.

Data tables of length and weight of juvenile chinook salmon at the end of a 60 day exposure, Round II, Part 2.

Treatment: HCBD **Tank#:** P

Date: 8/25/97

Fish#	Meas. Fork Length	Total Length	Calc. Fork Length	Weight
1	139	147		35.0
2	140	148		37.0
3	135	144		31.0
4	141	150		37.0
5	133	140		31.0
6	140	149		33.0
7	130	138		26.0
8	137	145		34.0
9	128	136		27.0
10	150	160		44.0
11	140	149		37.0
12	133	142		32.0
13	130	139		28.0
14	128	138		30.0
15	145	154		40.0
16	138	147		35.0
17	138	144		35.0
18	119	127		21.0
19	135	144		35.0
20	130	141		31.0
21	130	139		29.0
22	137	146		33.0
23	145	153		41.0
24	138	144		32.0
25	131	140		28.0
26	132	141		31.0
27	135	144		33.0
28	138	147		35.0
29	143	151		36.0
30	125	132		24.0
31	138	146		34.0
32	119	125		22.0
33	133	142		29.0
34	129	139		29.0

Fish#	Meas. Fork Length	Total Length	Calc. Fork Length	Weight
35	139	145		34.0
36	132			30.4
37	135			32.3
38	134			27.6
39	148			44.2
40	136			35.0
41	140			32.6
42	131			30.9
43	135			32.5
44	130			32.0
45	122			22.2
46	136			31.9
47	145			43.7
48	143			38.2
49	140			36.3
50	136			31.3
51	140			35.7
52	136			33.0
53	128			27.3
54	136			32.9
55	138			36.0
56	135			31.6
57	135			31.5
58	125			25.3
59	134			32.3
60	140			35.7
61	135			31.3
62	146			40.6
63	136			31.6
64	132			29.4
65	140			34.7
66	138			32.6
67	140			36.7
68	140			34.9

Fish#	Meas. Fork Length	Total Length	Calc. Fork Length	Weight
69	140			34.2
70	142			35.7
71	145			39.0
72	140			34.3
73	130			32.4
74	139			32.6
75	138			34.3
76	125			27.1
77	131			31.9
78	131			28.9
79	145			41.8
80	146			38.1
81	140			36.8
82	142			39.4
83	139			34.4

Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon.

Data table containing daily mortalities of juvenile chinook salmon from June 26 to July 25, 1997 in Round II, Part 2.

	Acetone Emulphor		NQSE		HWSE-P		HCBD		HWSE-M		PAH		PCB	
Tank / Day	C	L	I	N	H	O	J	P	G	K	E	M	A	F
1														
2														
3														
4	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
5	2			1	1					2			2	3
6	1											1		1
7										1	1		1	
8	2	1					1				2			
9	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
10	1	4					1		2	2	5	4	4	3
11	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
12	1	2	2	2		2	1	3	1		6	5		1
13	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
14	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
15				1					2		1	3		
16	1	1			2	1	1	3				2	2	1
17	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
18	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
19			2		2		1		3	2	2	2		3
20														
21				1										1
22				1	1				1					
23	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
24	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
25	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
26							2					1		
27														
28														
29														
30	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R

N/R denotes days for which no records were maintained in contrast to a blank which signifies no mortalities recorded on the day indicated.

Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon.

Data table containing daily mortalities of juvenile chinook salmon from July 26 to August 24, 1997 in Round II, Part 2.

	Acetone Emulphor		NQSE		HWSE-P		HCBD		HWSE-M		PAH		PCB	
Tank / Day	C	L	I	N	H	O	J	P	G	K	E	M	A	F
31												1		
32	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
33														
34	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
35													1	
36														
37														
38	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
39														
40										1				
41														
42								1						
43														
44					1								1	
45				1										
46	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
47														
48														
49														
50														
51														
52														
53	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
54														
55		1			1								1	
56														
57														
58	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
59	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
60														

N/R denotes days for which no records were maintained in contrast to a blank which signifies no mortalities recorded on the day indicated.

Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon.

Data table containing daily feed, by weight in grams, for tanks containing chinook salmon, from June 26 through July 25, 1997 as part of the Round II, Part 2

Tank / Day	A	C	E	F	G	H	I	J	K	L	M	N	O	P
26-Jun	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0
27-Jun	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0
28-Jun	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F
29-Jun	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F
30-Jun	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0
1-Jul	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0
2-Jul	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0
3-Jul	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0
4-Jul	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F
5-Jul	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0
6-Jul	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F
7-Jul	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0
8-Jul	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0
9-Jul	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0
10-Jul	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0
11-Jul	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0
12-Jul	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0
13-Jul	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F
14-Jul	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0
15-Jul	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0
16-Jul	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0
17-Jul	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0
18-Jul	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0
19-Jul	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0
20-Jul	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F
21-Jul	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0
22-Jul	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0
23-Jul	42.0	44.0	39.0	40.0	43.0	45.0	46.0	45.0	44.0	44.0	40.0	45.0	46.0	45.0
24-Jul	42.0	44.0	39.0	40.0	43.0	45.0	46.0	45.0	44.0	44.0	40.0	45.0	46.0	45.0
25-Jul	42.0	44.0	39.0	40.0	43.0	45.0	46.0	45.0	44.0	44.0	40.0	45.0	46.0	45.0

N/F indicates days that juvenile chinook salmon were not fed.

Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile chinook salmon.

Data table containing daily feed, by weight in grams, for tanks containing chinook salmon, from July 26 through August 24, 1997 as part of the Round II, Part 2.

Tank / Day	A	C	E	F	G	H	I	J	K	L	M	N	O	P
26-Jul	42.0	44.0	39.0	40.0	43.0	45.0	46.0	45.0	44.0	44.0	40.0	45.0	46.0	45.0
27-Jul	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F
28-Jul	42.0	44.0	39.0	40.0	43.0	45.0	46.0	45.0	44.0	44.0	40.0	45.0	46.0	45.0
29-Jul	42.0	44.0	39.0	40.0	43.0	45.0	46.0	45.0	44.0	44.0	40.0	45.0	46.0	45.0
30-Jul	46.0	49.0	43.0	44.0	47.0	48.0	51.0	48.0	48.0	48.0	43.0	49.0	50.0	48.0
31-Jul	46.0	49.0	43.0	44.0	47.0	48.0	51.0	48.0	48.0	48.0	43.0	49.0	50.0	48.0
1-Aug	46.0	49.0	43.0	44.0	47.0	48.0	51.0	48.0	48.0	48.0	43.0	49.0	50.0	48.0
2-Aug	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F
3-Aug	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F
4-Aug	46.0	49.0	43.0	44.0	47.0	48.0	51.0	48.0	48.0	48.0	43.0	49.0	50.0	48.0
5-Aug	46.0	49.0	43.0	44.0	47.0	48.0	51.0	48.0	48.0	48.0	43.0	49.0	50.0	48.0
6-Aug	46.8	50.4	45.4	46.9	50.1	50.6	54.0	50.0	50.1	51.4	45.5	52.7	53.4	51.4
7-Aug	46.8	50.4	45.4	46.9	50.1	50.6	54.0	50.0	50.1	51.4	45.5	52.7	53.4	51.4
8-Aug	46.8	50.4	45.4	46.9	50.1	50.6	54.0	50.0	50.1	51.4	45.5	52.7	53.4	51.4
9-Aug	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F
10-Aug	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F
11-Aug	46.8	50.4	45.4	46.9	50.1	50.6	54.0	50.0	50.1	51.4	45.5	52.7	53.4	51.4
12-Aug	46.8	50.4	45.4	46.9	50.1	50.6	54.0	50.0	50.1	51.4	45.5	52.7	53.4	51.4
13-Aug	49.6	54.0	48.7	50.3	53.7	53.7	57.8	53.6	53.7	55.0	48.7	55.9	57.3	54.5
14-Aug	49.6	54.0	48.7	50.3	53.7	53.7	57.8	53.6	53.7	55.0	48.7	55.9	57.3	54.5
15-Aug	49.6	54.0	48.7	50.3	53.7	53.7	57.8	53.6	53.7	55.0	48.7	55.9	57.3	54.5
16-Aug	49.6	54.0	48.7	50.3	53.7	53.7	57.8	53.6	53.7	55.0	48.7	55.9	57.3	54.5
17-Aug	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F
18-Aug	49.6	54.0	48.7	50.3	53.7	53.7	57.8	53.6	53.7	55.0	48.7	55.9	57.3	54.5
19-Aug	49.6	54.0	48.7	50.3	53.7	53.7	57.8	53.6	53.7	55.0	48.7	55.9	57.3	54.5
20-Aug	52.3	57.5	52.0	53.6	57.4	56.7	61.7	57.2	57.4	58.1	52.0	59.6	61.1	58.2
21-Aug	52.3	57.5	52.0	53.6	57.4	56.7	61.7	57.2	57.4	58.1	52.0	59.6	61.1	58.2
22-Aug	52.3	57.5	52.0	53.6	57.4	56.7	61.7	57.2	57.4	58.1	52.0	59.6	61.1	58.2
23-Aug	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F
24-Aug	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F	N/F

N/F indicates days that juvenile chinook salmon were not fed.

Effects of chemical contaminants from the Hylebos Waterway on the growth of juvenile chinook salmon.

ANOVA results (SuperANOVA, Abacus Concepts Inc., Berkerley, CA).
Evaluation of size (fork length) of juvenile chinook salmon at the beginning of 60-day exposure period with respect to treatment.

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Treatment	6	496.089	82.681	8.543	.0001
Residual	1393	13481.465	9.678		

Dependent: Fork Length (mm)

Means Table
Effect: Treatment
Dependent: Fork Length (mm)

	Count	Mean	Std. Dev.	Std. Error
PCB	200	93.825	2.968	.210
HWSE-M	200	92.640	3.138	.222
HWSE-P	200	92.645	3.275	.232
PAHs	200	93.410	3.053	.216
HCBD	200	94.155	3.216	.227
NCSE	200	93.880	3.120	.221
ACE/EMUL	200	94.070	2.995	.212

Dunnett One-Tailed: mean < control
Effect: Treatment
Dependent: Fork Length (mm)
Significance level: .05

	Vs.	Diff.	Crit. diff.	
ACE/EMUL	HWSE-M	-1.430	.712	S
	HWSE-P	-1.425	.712	S
	PAHs	-.660	.712	
	PCB	-.245	.712	
	NCSE	-.190	.712	
	HCBD	.085	.712	

S = Significantly different at this level.

Dunnett One-Tailed: mean < control
Effect: Treatment
Dependent: Fork Length (mm)
Significance level: .01

	Vs.	Diff.	Crit. diff.	
ACE/EMUL	HWSE-M	-1.430	.899	S
	HWSE-P	-1.425	.899	S
	PAHs	-.660	.899	
	PCB	-.245	.899	
	NCSE	-.190	.899	
	HCBD	.085	.899	

S = Significantly different at this level.

Effects of chemical contaminants from the Hylebos Waterway on the growth of juvenile chinook salmon.

ANOVA results (SuperANOVA, Abacus Concepts Inc., Berkerley, CA).
Evaluation of size (weight) of juvenile chinook salmon at the beginning of 60-day exposure period with respect to treatment.

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Treatment	6	15.003	2.501	2.704	.0130
Residual	1393	1288.206	.925		

Dependent: Weight (g)

Means Table
Effect: Treatment
Dependent: Weight (g)

	Count	Mean	Std. Dev.	Std. Error
PCB	200	8.005	.935	.066
HWSE-M	200	7.858	.942	.067
HWSE-P	200	7.906	.983	.070
PAHs	200	7.929	.917	.065
HCBD	200	8.021	.981	.069
NCSE	200	8.103	.984	.070
ACE/EMUL	200	8.172	.987	.070

Dunnett One-Tailed: mean < control
Effect: Treatment
Dependent: Weight (g)
Significance level: .05

	Vs.	Diff.	Crit. diff.	
ACE/EMUL	HWSE-M	-.315	.220	S
	HWSE-P	-.266	.220	S
	PAHs	-.243	.220	S
	PCB	-.167	.220	
	HCBD	-.151	.220	
	NCSE	-.070	.220	

S = Significantly different at this level.

Dunnett One-Tailed: mean < control
Effect: Treatment
Dependent: Weight (g)
Significance level: .01

	Vs.	Diff.	Crit. diff.	
ACE/EMUL	HWSE-M	-.315	.278	S
	HWSE-P	-.266	.278	
	PAHs	-.243	.278	
	PCB	-.167	.278	
	HCBD	-.151	.278	
	NCSE	-.070	.278	

S = Significantly different at this level.

Effects of chemical contaminants from the Hylebos Waterway on the growth of juvenile chinook salmon.

ANOVA results (SuperAnova, Abacus Concepts Inc., Berkerley, CA).
Evaluation of treatment effects on growth (fork length) of juvenile chinook salmon at the end of 60-day exposure period.

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Treatment	6	1456.512	242.752	5.718	.0001
Residual	1213	51493.378	42.451		

Dependent: Fork Length (mm)

Means Table
Effect: Treatment
Dependent: Fork Length (mm)

	Count	Mean	Std. Dev.	Std. Error
PCB	170	132.505	6.417	.492
HWSE-M	177	132.880	5.674	.426
HWSE-P	189	132.862	5.830	.424
PAH	155	134.541	7.073	.568
HCBD	167	133.468	7.105	.550
NCSE	183	135.108	6.919	.511
A/E	179	135.366	6.568	.491

Dunnett One-Tailed: mean < control
Effect: Treatment
Dependent: Fork Length (mm)
Significance level: .05

	Vs.	Diff.	Crit. diff.	
A/E	PCB	-2.861	1.598	S
	HWSE-P	-2.504	1.556	S
	HWSE-M	-2.486	1.582	S
	HCBD	-1.898	1.605	S
	PAH	-.825	1.637	
	NCSE	-.258	1.568	

S = Significantly different at this level.

Dunnett One-Tailed: mean < control
Effect: Treatment
Dependent: Fork Length (mm)
Significance level: .01

	Vs.	Diff.	Crit. diff.	
A/E	PCB	-2.861	2.017	S
	HWSE-P	-2.504	1.964	S
	HWSE-M	-2.486	1.996	S
	HCBD	-1.898	2.026	
	PAH	-.825	2.066	
	NCSE	-.258	1.979	

S = Significantly different at this level.

Effects of chemical contaminants from the Hylebos Waterway on the growth of juvenile chinook salmon.

ANOVA results (SuperANOVA, Abacus Concepts Inc., Berkerley, CA).
Evaluation of treatment effects on growth (weight) of juvenile chinook salmon at the end of 60-day exposure period.

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Treatment	6	1051.766	175.294	6.704	.0001
Residual	1213	31719.387	26.150		

Dependent: Weight (g)

Means Table
Effect: Treatment
Dependent: Weight (g)

	Count	Mean	Std. Dev.	Std. Error
PCB	170	29.579	4.835	.371
HWSE-M	177	29.937	4.408	.331
HWSE-P	189	30.137	4.709	.342
PAH	155	31.118	5.474	.440
HCBD	167	30.786	5.432	.420
NOSE	183	32.025	5.506	.407
A/E	179	32.080	5.379	.402

Dunnett One-Tailed: mean < control
Effect: Treatment
Dependent: Weight (g)
Significance level: .05

	Vs.	Diff.	Crit. diff.	
A/E	PCB	-2.502	1.254	S
	HWSE-M	-2.143	1.241	S
	HWSE-P	-1.943	1.221	S
	HCBD	-1.294	1.260	S
	PAH	-.962	1.285	
	NOSE	-.056	1.231	

S = Significantly different at this level.

Dunnett One-Tailed: mean < control
Effect: Treatment
Dependent: Weight (g)
Significance level: .01

	Vs.	Diff.	Crit. diff.	
A/E	PCB	-2.502	1.583	S
	HWSE-M	-2.143	1.567	S
	HWSE-P	-1.943	1.541	S
	HCBD	-1.294	1.590	
	PAH	-.962	1.621	
	NOSE	-.056	1.554	

S = Significantly different at this level.

Effects of chemical contaminants from the Hylebos Waterway on the growth of juvenile chinook salmon.

ANOVA results (SuperANOVA, Abacus Concepts Inc., Berkerley, CA).
Evaluation of tank effects nested within treatment effects on growth (fork length) of juvenile chinnok salmon.

Type III Sums of Squares

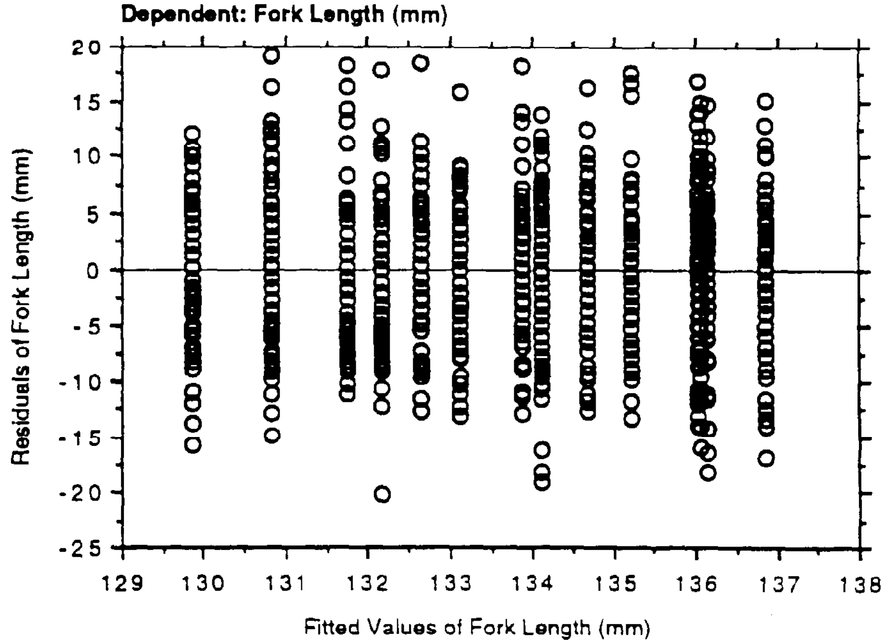
Source	df	Sum of Squares	Mean Square	F-Value	P-Value	Error Term
Treatment	6	1439.736	239.956	.449	.8255	Replicate (Treatm...
Replicate (Treat...	7	3738.401	534.057	13.487	.0001	Residual
Residual	1206	47754.977	39.598			

Dependent: Fork Length (mm)

Residual Summary
Dependent: Fork Length (mm)

SS[e(i)-e(i-1)]	90806.295
number >= 0	594
number < 0	626
Durbin-Watson	1.902
Serial Autocorrelation	.048

Scattergram of Residuals versus Fitted Y
Dependent: Fork Length (mm)



Effects of chemical contaminants from the Hylebos Waterway on the growth of juvenile chinook salmon.

ANOVA results (SuperANOVA, Abacus Concepts Inc., Berkerley, CA). Evaluation of tank effects nested within treatment effects on growth (weight) of juvenile chinook salmon at the end of the 60-day exposure period.

Type III Sums of Squares

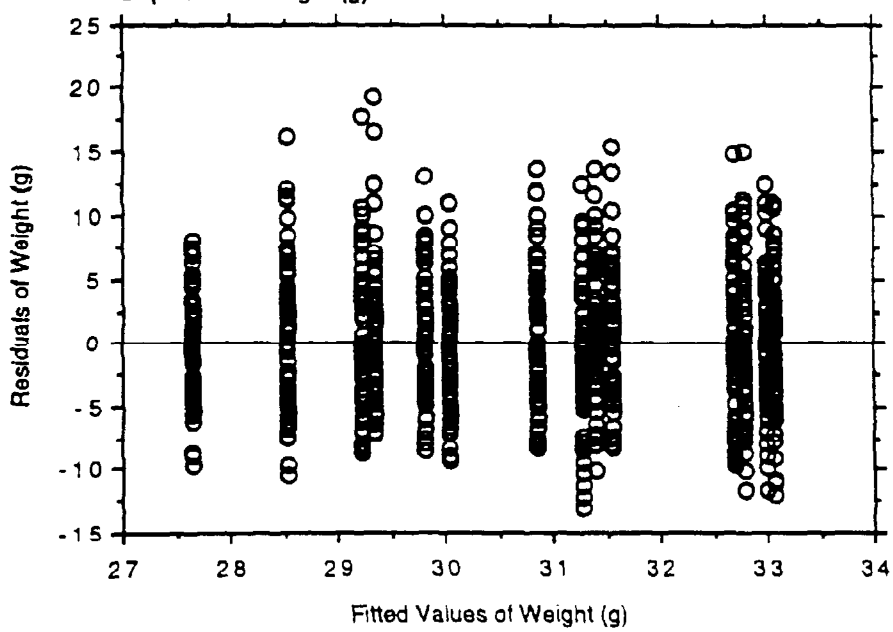
Source	df	Sum of Squares	Mean Square	F-Value	P-Value	Error Term
Treatment	6	1039.479	173.247	.518	.7799	Replicate (Treatm...
Replicate (Treat...	7	2343.162	334.737	13.742	.0001	Residual
Residual	1206	29376.225	24.358			

Dependent: Weight (g)

Residual Summary
Dependent: Weight (g)

SS[e(i)-e(i-1)]	58211.603
number >= 0	579
number < 0	641
Durbin-Watson	1.982
Serial Autocorrelation	.007

Scattergram of Residuals versus Fitted Y
Dependent: Weight (g)



Effects of chemical contaminants from the Hylebos Waterway on the growth of juvenile chinook salmon.

Chi-square analysis (Statview, Abacus Concepts Inc., Berkerley, CA).
Contingency Analysis of mortality (among treatments) of juvenile chinook salmon over the 60-day exposure period.

Summary Table for Treatment, Live/Dead

Num. Missing	0
DF	6
Chi Square	28.617
Chi Square P-Value	<0.0001
G-Squared	26.268
G-Squared P-Value	0.0002
Contingency Coef.	0.142
Cramer's V	0.143

Expected Values for Treatment, Live/Dead

	Live	Dead	Totals
PCB	181.286	18.714	200.000
HWSE-M	181.286	18.714	200.000
HWSE-P	181.286	18.714	200.000
PAH	181.286	18.714	200.000
HCBD	181.286	18.714	200.000
NQSE	181.286	18.714	200.000
ACE/EMUL	181.286	18.714	200.000
Totals	1269.000	131.000	1400.000

Observed Frequencies for Treatment, Live/Dead

	Live	Dead	Totals
PCB	175	25	200
HWSE-M	183	17	200
HWSE-P	189	11	200
PAH	164	36	200
HCBD	186	14	200
NQSE	189	11	200
ACE/EMUL	183	17	200
Totals	1269	131	1400

Post Hoc Cell Contributions for Treatment, Live/Dead

	Live	Dead
PCB	-1.648	1.648
HWSE-M	0.450	-0.450
HWSE-P	2.023	-2.023
PAH	-4.533	4.533
HCBD	1.236	-1.236
NQSE	2.023	-2.023
ACE/EMUL	0.450	-0.450

Cell Chi Squares for Treatment, Live/Dead

	Live	Dead
PCB	0.218	2.111
HWSE-M	0.016	0.157
HWSE-P	0.328	3.180
PAH	1.648	15.966
HCBD	0.123	1.188
NQSE	0.328	3.180
ACE/EMUL	0.016	0.157

Effects of chemical contaminants of Hylebos Waterway on the growth of juvenile chinook salmon.

Chi-square analysis (Statview, Abacus Concepts Inc., Berkerley, CA).
Contingency analysis of mortality (among tanks) of juvenile chinook salmon over the 60-day exposure period.

Summary Table for Tank I.D., Live/Dead

Num. Missing	0
DF	13
Chi Square	31.034
Chi Square P-Value	0.0033
G-Squared	29.945
G-Squared P-Value	0.0048
Contingency Coef.	0.147
Cramer's V	0.149

Percents of Overall Total for Tank I.D., Live/Dead

	Live	Dead	Totals
A	6.286	0.857	7.143
F	6.214	0.929	7.143
K	6.571	0.571	7.143
G	6.500	0.643	7.143
H	6.571	0.571	7.143
O	6.929	0.214	7.143
E	5.929	1.214	7.143
M	5.786	1.357	7.143
J	6.643	0.500	7.143
P	6.643	0.500	7.143
I	6.857	0.286	7.143
N	6.643	0.500	7.143
C	6.571	0.571	7.143
L	6.500	0.643	7.143
Totals	90.643	9.357	100.000

Expected Values for Tank I.D., Live/Dead

	Live	Dead	Totals
A	90.643	9.357	100.000
F	90.643	9.357	100.000
K	90.643	9.357	100.000
G	90.643	9.357	100.000
H	90.643	9.357	100.000
O	90.643	9.357	100.000
E	90.643	9.357	100.000
M	90.643	9.357	100.000
J	90.643	9.357	100.000
P	90.643	9.357	100.000
I	90.643	9.357	100.000
N	90.643	9.357	100.000
C	90.643	9.357	100.000
L	90.643	9.357	100.000
Totals	1269.000	131.000	1400.000

Observed Frequencies for Tank I.D., Live/Dead

	Live	Dead	Totals
A	88	12	100
F	87	13	100
K	92	8	100
G	91	9	100
H	92	8	100
O	97	3	100
E	83	17	100
M	81	19	100
J	93	7	100
P	93	7	100
I	96	4	100
N	93	7	100
C	92	8	100
L	91	9	100
Totals	1269	131	1400

Post Hoc Cell Contributions for Tank I.D., Live/Dead

	Live	Dead
A	-0.942	0.942
F	-1.298	1.298
K	0.484	-0.484
G	0.127	-0.127
H	0.484	-0.484
O	2.265	-2.265
E	-2.723	2.723
M	-3.436	3.436
J	0.840	-0.840
P	0.840	-0.840
I	1.909	-1.909
N	0.840	-0.840
C	0.484	-0.484
L	0.127	-0.127

Cell Chi Squares for Tank I.D., Live/Dead

	Live	Dead
A	0.077	0.746
F	0.146	1.418
K	0.020	0.197
G	1.407E-3	0.014
H	0.020	0.197
O	0.446	4.319
E	0.644	6.243
M	1.026	9.937
J	0.061	0.594
P	0.061	0.594
I	0.317	3.067
N	0.061	0.594
C	0.020	0.197
L	1.407E-3	0.014

Effects of chemical contaminants from the Nylebos Waterway on the growth of juvenile chinook salmon.

ANCOVA results (SuperANOVA, Abacus Concepts Inc., Berkerley, CA). Evaluation of treatment effects on growth (fork length) of juvenile chinook salmon with respest to time over the 60-day exposure period.

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Treatment	6	481.226	80.204	3.217	.0038
Day	1	1056687.743	1056687.743	4.238E4	.0001
Treatment * D...	6	567.124	94.521	3.791	.0009
Residual	2606	64974.843	24.933		

Dependent: Fork Length (mm)

Means Table
Effect: Treatment
Dependent: Fork Length (mm)

	Count	Mean	Std. D...	Std. E...
PCB	370	1.12E2	19.904	1.035
HWSE-M	377	1.12E2	20.607	1.061
HWSE-P	389	1.12E2	20.665	1.048
PAH	355	1.11E2	21.079	1.119
HCBD	367	1.12E2	20.318	1.061
NQSE	383	1.14E2	21.286	1.088
ACE/EMUL	379	1.14E2	21.241	1.091

Model Summary
Dependent: Fork Length (mm)

Count	2620
R	.971
R-Squared	.942
Adj. R-Squared	.942
RMS Residual	4.993

	df	Sum of ...	Mean Squa...	F-Value	P-V...
Model	13	1.061E6	81583.225	3272.126	.0001
Error	2606	6.497E4	24.933		
Total	2619	1.126E6			

Model Coefficient Table
Dependent: Fork Length (mm)

		Beta	Std. Error	t-Test	P-Value
Intercept		93.370	.359	259.998	.0001
Treatment	PCB	-.201	.508	-.395	.6928
	HWSE-M	-1.412	.508	-2.780	.0055
	HWSE-P	-1.407	.508	-2.770	.0056
	PAH	-.657	.508	-1.294	.1958
	HCBD	.119	.508	.234	.8154
	NQSE	-.189	.508	-.372	.7100
	ACE/EMUL	0.000	•	•	•
Day		.700	.009	80.379	.0001
Treatment * Day	PCB, Day	-.044	.012	-3.576	.0004
	HWSE-M, Day	-.018	.012	-1.451	.1470
	HWSE-P, Day	-.018	.012	-1.496	.1349
	PAH, Day	-.003	.013	-.223	.8236
	HCBD, Day	-.034	.012	-2.703	.0069
	NQSE, Day	-.001	.012	-.093	.9255
	ACE/EMUL, Day	0.000	•	•	•

Effects of chemical contaminants from the Hylebos waterway on the growth of juvenile chinook salmon.

ANCOVA results (SuperANOVA, Abacus Concepts Inc., Berkerley, CA). Evaluation of treatment effects on growth (weight) of juvenile chinook salmon with respect to time over the 60-day exposure period.

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Treatment	6	11.976	1.996	.158	.9876
Day	1	338501.948	338501.948	2.673E4	.0001
Treatment * D...	6	467.854	77.976	6.156	.0001
Residual	2606	33007.593	12.666		

Dependent: Weight (g)

Means Table
Effect: Treatment
Dependent: Weight (g)

	Count	Mean	Std. D...	Std. E...
PCB	370	1.8E1	11.273	.586
HWSE-M	377	1.8E1	11.459	.590
HWSE-P	389	1.9E1	11.619	.589
PAH	355	1.8E1	12.089	.642
HCBD	367	18.38	11.949	.624
NQSE	383	2E1	12.574	.642
ACE/EMUL	379	1.9E1	12.529	.644

Model Summary
Dependent: Weight (g)

Count	2620
R	.955
R-Squared	.912
Adj. R-Squared	.911
RMS Residual	3.559

	df	Sum of Squa...	Mean Sq...	F-Value	P-V...
Model	13	340336.481	2.618E4	2066.930	.0001
Error	2606	33007.593	12.666		
Total	2619	373344.074			

Model Coefficient Table
Dependent: Weight (g)

		Beta	Std. Error	t-Test	P-Value
Intercept		7.767	.256	30.346	.0001
Treatment	PCB	-.127	.362	-.352	.7248
	HWSE-M	-.284	.362	-.785	.4328
	HWSE-P	-.238	.362	-.658	.5108
	PAH	-.231	.362	-.639	.5229
	HCBD	-.132	.362	-.365	.7151
	NQSE	-.070	.362	-.193	.8473
	ACE/EMUL	0.000	•	•	•
Day		.405	.006	65.290	.0001
Treatment * Day	PCB, Day	-.040	.009	-4.477	.0001
	HWSE-M, Day	-.031	.009	-3.525	.0004
	HWSE-P, Day	-.028	.009	-3.261	.0011
	PAH, Day	-.012	.009	-1.361	.1737
	HCBD, Day	-.019	.009	-2.186	.0289
	NQSE, Day	2.312E-4	.009	.026	.9789
	ACE/EMUL, Day	0.000	•	•	•