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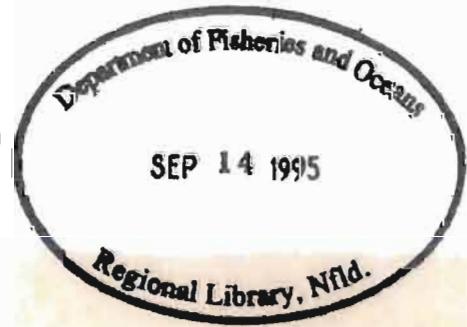
# The Influence of Sublethal Crude Oil Exposure on Long Term Survival, Escapement and Harvest of Pink Salmon **(*Oncorhynchus gorbuscha*)**

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**Canadian Data Report of  
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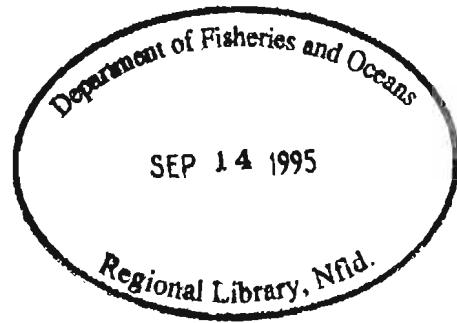
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The Influence of Sublethal Crude Oil Exposure  
on Long Term Survival, Escapement and Harvest of Pink  
Salmon (Oncorhynchus gorbuscha)

by

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## PREFACE

The potential for accidental release of large quantities of crude oil into the nearshore marine environment off the British Columbia coast prompted an examination of the potential consequences of such events to local ecosystems. The Department of Fisheries and Oceans, with funding from the Panel on Energy Research and Development, undertook this investigation to assess the long term influence on pink salmon fry following short term (10 d) exposure to sublethal doses of crude oil water soluble fraction.

Pink salmon fry from the Quinsam River Salmon Hatchery near Campbell River, B.C. were selected because of their economic status, the known sensitivity of this species to oil, and their importance in nearshore food webs. Field work was conducted in 1990, 1991 and 1992.

The study examined the effect of oil exposure on long term ocean survival to harvest and escapement of pink salmon fry. In addition the study measured the influence of oil exposure on growth, hydrocarbon avoidance, and liver, kidney, and gill cellular morphology, during the exposure period. The crude oil exposure period and dose represent concentrations and durations of exposure to be expected in semi-protected waters following an offshore oil well blowout. The following report is one of a series which describe the results of this investigation.

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## ABSTRACT

Fink, R., R. Alexander, W. Bengeyfield, I.K. Birtwell and C.D. McAllister. 1995. The influence of sublethal crude oil exposure on long term survival, escapement and harvest of pink salmon (Oncorhynchus gorbuscha). Can. Data Rep. Fish. Aquat. Sci. 949: 78 p.

Recently salt water acclimated, coded-wire tagged and adipose-clipped Quinsam River pink salmon fry (Oncorhynchus gorbuscha) were exposed to one of two sublethal concentrations of the water soluble fraction (WSF) of North Slope crude oil. Approximately 30,000 fry in each Control, Low Dose and High Dose treatment groups were exposed each year for three consecutive years, and following a ten day exposure period, were released to Discovery Passage, British Columbia, to complete their two year life cycle. Adipose-clipped adult salmon were captured in the commercial, sport fishery, or in the Quinsam River and their tag codes analyzed and assigned to the appropriate hydrocarbon treatment or control group.

Adult returns with legible coded-wire tags were 169, 317, and 172 for recovery years 1991, 1992, and 1993. The combined harvest and escapement returns for each treatment group were 303, 295, and 293 for the Control, Low Dose and High Dose treatment groups respectively.

The data presented in this report are compiled for three replicate field programs conducted in 1990, 1991, 1992, together with tag code, sex and size analyses for adult pink salmon returning in 1991, 1992 and 1993.

The influence of WSF exposure on short-term and long-term growth, hydrocarbon avoidance, predation by birds and fish, and on the cellular morphology of liver, kidney, and gill tissue was also examined.

**Keywords:** crude oil, water soluble fraction, aquatic toxicity, pink salmon, growth, ocean survival, hydrocarbon avoidance.

## RÉSUMÉ

Fink, R., R. Alexander, W. Bengeyfield, I.K. Birtwell and C.D. McAllister. 1995. The influence of sublethal crude oil exposure on long term survival, escapement and harvest of pink salmon (Oncorhynchus gorbuscha). Can. Data Rep. Fish. Aquat. Sci. 949: 78 p.

Des alevins de saumon rose (Oncorhynchus gorbuscha) de la rivière Quinsam récemment acclimatés à l'eau salée après implantation d'une micromarque codée et ablation de la nageoire adipeuse ont été exposés à une des deux concentrations sublétale d'une fraction hydrosoluble (FHS) de pétrole brut North Slope. Environ 30 000 alevins faisant partie de chacun des groupes de traitement témoins, faible dose et forte dose, ont été exposés chaque année, durant trois années consécutives, et après une période d'exposition de dix jours, ils ont été relâchés dans le passage Discovery, en Colombie-Britannique, pour compléter leur cycle de vie de deux ans. Des saumons adultes ayant subi l'ablation de la nageoire adipeuse ont été capturés au cours des pêches sportives et commerciales, ou dans la rivière Quinsam, et leurs micromarques codées ont été analysées et assignées au group approprié: traitement aux hydrocarbures ou témoin.

Le nombre d'adultes portant des microfiches codées lisibles qui ont réussi la remontée était de 169, 317 et 172 respectivement pour les années de récupération 1991, 1992 et 1993. Le nombre combiné de poissons capturés et des échappées pour chaque groupe de traitement était de 303, 295 et 293 respectivement pour les groupes témoins, faible dose et forte dose.

Les données présentées dans ce rapport sont compilées pour trois programmes subdivisés menés sur le terrain en 1990, 1991 et 1992 ainsi que pour les analyses des microfiches codées, du sexe et de la taille des saumons roses adultes qui sont ^[retournés en 1991, 1992 et 1993.

L'influence de l'exposition à la FHS sur la croissance à court terme et à long terme, l'évitement des hydrocarbures, la prédatation par les oiseaux et les poissons, et sur la morphologie cellulaire des tissus de foie, des reins et des branchies a également été examinée.

Mots clés: pétrole brut, fraction hydrosoluble, toxicité aquatique, saumon rose, croissance, survie océanique, évitement des hydrocarbures

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## INTRODUCTION

In response to the continued presence of oil tanker traffic along the British Columbia coast, together with the possibility of future oil and gas exploration and production (Chevron 1982), several government initiatives were undertaken to examine the potential consequences to Pacific marine ecosystems following a major marine oil spill (FEARO 1986, States/BC Task Force 1990). The Canadian Department of Fisheries and Oceans (DFO) recommended two areas of research including "(1) toxicological studies with juvenile salmon and herring in a stratified water column; and (2) research on the survival of oil-exposed salmonids released to the marine environment using mark-recapture techniques" (cited in Duval et al. 1990). Both these research proposals were submitted to the Panel on Energy Research and Development (PERD) Committee 6.7 for funding. This investigation was conducted in response to the second of these priority research areas. The primary objective of the study was to determine whether exposure of salt water acclimated pink salmon fry to sublethal concentrations of dissolved petroleum hydrocarbons had a significant effect on their subsequent ocean survival.

The experimental protocol called for simultaneous 10-d exposures of three treatment groups, a Control, a Low Hydrocarbon Dose (Low Dose), and a High Hydrocarbon Dose (High Dose). Logistical constraints necessitated replicate experiments conducted over three consecutive years. About 30,000 fry were tagged for each treatment group in each year. In total, over 270,000 pink salmon fry were coded-wire tagged, adipose-clipped for subsequent identification, dosed with crude oil (or remained untreated as controls), and released for long term survival assessment. Acute toxicity of the crude oil water soluble fraction was determined through standard bioassays conducted each year. The influence of hydrocarbon exposure on short term growth was determined using before and after treatment measurements of length and weight.

Secondary study objectives provided additional information about the sublethal effects of hydrocarbon exposure on pink salmon fry, and included examination of the histological effects of hydrocarbon exposure on gill, liver, and kidney tissue (Brand et al. 1995); the influence of hydrocarbon pre-exposure on subsequent hydrocarbon avoidance responses, and on selective predation of pink salmon fry by fish and birds.

This report is a compilation of the data gathered during three separate field programs (Fink et al. 1990, 1991, 1992). A complete analysis of those results together with the study conclusions will be reported separately.

## STUDY AREA

This investigation was conducted near the town of Campbell River, British Columbia, located at the north end of the Strait of Georgia. Juvenile pink salmon fry were obtained at emergence from the Department of Fisheries and Oceans' Quinsam River Salmon Hatchery. The experimental hydrocarbon exposure facility was located on the seaward side of Tyee Spit near the mouth of the Campbell River (Figure 1).

## MATERIALS AND METHODS

### Sea Water Experimental System

The sea water experimental system consists of six components, 1) a pumping system, 2) an oxygenation tower, 3) sea water distribution system, 4) three fish holding troughs, 5) a toxicant preparation system and, 6) an acute lethal bioassay apparatus.

Sea water for the experimental system was pumped from a submerged, screened intake located roughly 2.5 metres above the sea floor (Figure 2). The 1/3 HP Franklin stainless steel submersible well pump was suspended by rope from two 50 L capacity air-filled vinyl floats. Reinforced 5 cm ID PVC hose connected the well pump with a second, in-line, PVC pool pump. From the secondary pump, sea water was delivered to a gravity flow, 2 m x 15 cm rigid PVC oxygenation column filled with 4 cm diameter Bio-rings. Oxygen-saturated sea water ( $9.8\text{-}10.4 \text{ mg}\cdot\text{L}^{-1}$  at 28-30% salinity) was delivered to a 200 L polyethylene header tank and from there distributed by food-grade 2 cm ID flexible PVC tubing to the holding troughs, toxicant preparation system, and the bioassay apparatus.

Twenty-five  $\text{L}\cdot\text{min}^{-1}$  unfiltered sea water was delivered by gravity from the header to each of three fish holding troughs (green epoxy-painted aluminum "Capilano troughs"). These measured 6 m x 1 m x 0.6 m deep and held approximately 2  $\text{m}^3$ . Nylon flyscreens in plywood frames prevented fish from escaping. The 95% replacement time for sea water in the troughs was 4 h according to calculations based on Sprague (1969).

### Coded-wire Tagging

Pink salmon fry from brood years 1989-1991 were uniquely marked and tagged with half-length coded-wire tags during peak emergence (March and April) at the Quinsam River Salmon Hatchery. To ensure the return of adequate numbers of adult fish, 30,000 fry in each of three treatment groups were tagged in each of three consecutive years. This decision was based on the expected survival rate of pink salmon from this facility, which ranged from 2.4 to 14.2% for estuary reared fry during the period 1982-85 (Department of Fisheries and Oceans, unpublished information).

During tagging, emergent fry were selected from one of eleven gravel-lined incubation boxes at the hatchery. Only boxes with the highest rate of fry emergence were selected for tagging. Fish were anaesthetized with 2-phenoxyethanol, and their adipose fins clipped. Clipped fry were tagged using half-length binary-coded wire tags. Tags were embedded in their nasal cavity using a Northwest Marine Technology Ltd. Mark IV tagging machine. Tagged fry were placed in 60 L plastic buckets continuously flushed with fresh "hatchery" water. Complete recovery from the clipping, tagging and anaesthetic took several minutes.

After transport to the seawater holding site, a 24-48 h evaluation of tag loss was made by passing 100-150 individual fish through a North West Marine Technology quality control device (QCD) which used a magnetic field to detect the presence of the coded-wire tag. The percent of successfully tagged fish out of the total number checked was recorded for each subgroup delivered to the holding facility. Similarly, tag retention for each treatment group as a whole was measured at time of release (27-29 days).

### **Transport and Sea Water Acclimation**

Coded-wire tagged pink salmon fry from each treatment group were transported from the hatchery to the experimental facility in aerated 60 L plastic buckets. Loading density ranged from 10-20 g of fish per litre of water during the 15-20 minute trip. Upon arrival, transport buckets were matched to the appropriate holding troughs, and sea water was introduced by siphoning from the rear of the trough using a small diameter hose. The sea water flow rate during acclimation was about  $6 \text{ L} \cdot \text{min}^{-1}$ . Each bucket was equipped with a screened overflow outlet. Complete exchange from fresh water to sea water occurred within 15-30 minutes. A small sample of fish from each bucket was removed by dip net at the end of the acclimation period and held in small floating "net pens" within the troughs for subsequent determination of tag-retention rates. Remaining fry were then poured directly from the bucket into the sea water holding trough. Water temperature and dissolved oxygen in the transport buckets and the experimental troughs were monitored throughout the transport and seawater acclimation period.

### **Water Quality**

Seawater temperature, dissolved oxygen and salinity were monitored twice daily throughout the holding and hydrocarbon exposure periods. Dissolved oxygen was measured with a portable YSI Model 57 DO meter and temperature and salinity were measured with a recording Aanderra Meter (RCM 4). Dissolved oxygen was monitored in the seawater header, toxicant header, and at the head and tail end of each holding trough. Salinity varied only slightly from day to day, and not at all between the various headers and fish troughs. After the first year field program salinity was typically measured in only one of the exposure troughs.

## Fish Husbandry

Under natural conditions, pink salmon fry consume large amounts of food and grow rapidly during early sea life. In the fish holding troughs, attainment of maximum growth rates by satiation feeding would have compromised study objectives in several key areas, including water quality, excessive disturbance to the fish, and acceptable fish loading densities in the troughs. Fry were therefore fed between 3% and 4% of their body weight per day, an amount sufficient to produce moderate growth, while preserving high dissolved oxygen levels, and requiring minimal trough disturbance due to cleaning activity. Fish newly arrived from the tagging operation were introduced to the troughs after the final daily feeding and were not subsequently fed until the following morning. Frozen Biodiet Starter Mash #1 was used for several days followed by Biodiet Starter Mash #2 for the remainder of their impoundment period. Feed was distributed over the entire area of the trough and floated for several minutes. Active surface feeding by recently tagged fish was generally observed to take place within 24 h of arrival. Feeding activity was typically vigorous in all troughs irrespective of treatment throughout the three year investigation.

Fish loading densities in the holding troughs varied from  $0.25 \text{ kg}\cdot\text{L}^{-1}\cdot\text{min}^{-1}$  at the beginning of the exposure period to  $0.42 \text{ kg}\cdot\text{L}^{-1}\cdot\text{min}^{-1}$  at the end. The change in loading density is a reflection of growth of the fry during the experiment.

The sides and bottoms of each trough were siphoned daily after the last feeding period in order to preserve an adequate supply of oxygen, and reduce the potential for disease. Fry mortalities were removed from each trough twice a day, prior to first feeding (morning) and during the cleaning operation after last feeding (evening). Separate numbered dip nets were used for each trough and disinfected between use. Daily fry mortality was recorded for each trough throughout the experiment. Fry mortalities were measured and recorded for standard length ( $\pm 1 \text{ mm}$ ) and wet weight ( $\pm 0.01 \text{ g}$ ), and stored frozen.

## Production of Crude Oil Water Soluble Fraction

Crude oil for the study was donated by the Atlantic Richfield Company (Cherry Point Refinery, Washington, USA) and originated in the Alaskan North Slope Fields (primarily Prudhoe Bay). One 55 gallon (US) drum was used in the 1990 field program, while an additional two drums obtained in 1991 were required to complete the 1991 and 1992 field programs.

The water soluble fraction (WSF) extraction column used in this investigation (Figure 3) was modelled after a similar device described by Moles et al. (1985). The critical element of this extraction column was a pipette plate situated above a continually replenished, floating crude oil layer, which produced a "rain" of small seawater droplets onto the oil surface. Water droplets, having a higher specific gravity than the oil, would sink through it and in so doing would absorb low molecular weight aromatic hydrocarbons from the oil. After passing through the oil layer these droplets would exit the oil/water interface before proceeding down

the glass column to the toxicant header. From there, the toxicant was distributed to either the bioassay apparatus or the fish holding troughs. Fresh crude oil was pumped to the extraction column at the rate of 4-6 ml·min<sup>-1</sup>. Spent crude oil, from which water soluble components had been extracted, was automatically siphoned from the column to a waste storage drum for subsequent transport and special disposal. Total sea water flow through the column averaged 2.2 L·min<sup>-1</sup>.

The system used in this investigation differed from the Moles et al. (1985) version as follows. The diameter of the upper part of the glass column and consequently the surface area and volume of the oil layer were increased to 30 cm from 15 cm to permit higher sea water flow rates and consequently, more product per unit time. The pipette plate was larger in diameter as well, and contained about 150 glass Pasteur pipettes, while the lower part of the column was kept at the 15 cm diameter specified in the original paper. The effect was to maintain similar extraction conditions within the upper part of the column, while delivering a higher volume of WSF to the toxicant header.

During the first year (1990), flow from the seawater header to the top of the extraction column was initially controlled by a diaphragm-driven metering pump. However, the Teflon-coated rubber diaphragm along with two backup diaphragms ruptured within 48 h of the start of the oil exposure, and the entire system was replaced by a gravity driven siphon for the remainder of the study. In 1991 this gravity system was modified to include a Rotoflo Teflon and glass valve to provide more precise flow control.

Maintenance cleaning of the glass column and associated tubing and headers was required during the 10 d exposure period. Cleaning the extraction column and headers was done once each year, usually on day 5 of the exposure period, and took 1-3 h. During 1991 and 1992, a slowly rotating (60 RPM) stirrer was positioned below the bubble layer in order to add a small amount of energy to the system. This helped stabilize the oil/water interface, which otherwise had the tendency to develop water-in-oil emulsions.

### Dissolved Hydrocarbon Determinations

As part of the daily routine, hydrocarbon samples were collected twice daily at mid depth from the inlet and outlet ends of the exposure and control troughs, and from the toxicant header. Additional samples were periodically collected to 1) characterize the stability of WSF concentrations under varying flow conditions, 2) determine the discharge rate of hydrocarbons to Discovery Passage, and 3) characterize the loss by volatilization and biological uptake of hydrocarbons in various parts of the WSF extraction system.

Procedures employed during the 1990 field program did not adequately characterize the WSF produced in the extraction system. Therefore an assessment of hydrocarbon concentrations to which fry were exposed in the first year can only be deduced from post experimental analyses. The oil extraction apparatus was reassembled in October, 1990 to

determine dissolved hydrocarbon concentrations at different sea water flow rates. From these data a *retrospective* estimate of 1990 hydrocarbon concentrations was made. Concentrations reported for the first year study, therefore, are estimates based on the follow-up study conducted after the fry were released.

In 1991 and 1992, samples for dissolved hydrocarbon analyses were collected in new 40-mL glass vials with screw caps and Teflon seals. Vials were inverted at mid-depth in each of the troughs and brought to the surface. A single crystal of mercuric chloride was added as a preservative to prevent biological activity. The lid was then screwed in place so that all air bubbles were excluded. Each vial was labelled for identification and the lid was sealed with black vinyl tape. Samples were stored in small Thermos® brand coolers at  $4 \pm 2$  °C. Samples were shipped by air to AGAT Laboratories (Calgary, Alberta). Analyses were initiated less than 48 hours after sample collection, using a modified EPA 602 method for purgable aromatic hydrocarbons.

In addition to routine hydrocarbon samples, unmarked benzene spike samples were included in the sample shipments as a means of verifying analytical accuracy. With the exception of toxicant header samples, all other samples including control and spike samples were sent for analysis with only code numbers for identification.

### **Acute Lethal Bioassays**

To assess the acute toxicity of the crude oil WSF, 96-h flow-through bioassays were conducted prior to initiation of the hydrocarbon exposure experiment. Four litre glass jars were used as bioassay aquaria and quick-connect garden hose control valves were assembled to provide proportional sea water and toxicant flow. Flow rates were checked three times a day. Each treatment jar received  $0.5 \text{ L} \cdot \text{min}^{-1}$  oxygen saturated sea water. Eighty fish were randomly selected from the three holding troughs and then distributed to eight 4 L glass jars, each having a specific concentration of WSF. Fish loading density was  $0.55 \text{ g} \cdot \text{L}^{-1}$ . The 90% replacement time for sea water in the bioassay containers was 0.4 h. Fry were not fed during the bioassay, however tests were conducted in 1992 to determine whether fry would resume feeding after hydrocarbon exposure.

The bioassay apparatus was modified slightly in 1992 by incorporating a secondary toxicant header to the system to reduce tubing line length. Hydrocarbon concentrations were estimated as percent dilutions from the toxicant header, or in the case of 1992, from the secondary toxicant header, and later converted to  $\text{mg} \cdot \text{L}^{-1}$  dissolved hydrocarbons.

### **Fish Dosing**

The WSF was delivered to the primary exposure troughs by one of three methods. In 1990, diaphragm-operated chemical metering pumps were used to deliver WSF from the toxicant header. These proved unsatisfactory in use, and were replaced during the experiment

by a valve-controlled siphon. This system was continued for the remainder of the exposure period and was used with minor adjustments again in 1991. In 1992, the siphon system was further simplified by the removal of the controlling valves, using instead the height differential between the header tank and the delivery tube outflow to regulate the flow of toxicant. This system proved the most reliable of any used during the study (less than 5% variation per day), requiring the least amount of monitoring or maintenance. Flow rate of toxicant to the Low and High Dose troughs was determined twice daily.

### **Short-term Growth**

To characterize the size of newly emergent fry random samples were obtained during tagging. Each day, 25 fish per treatment group were measured for fork length and weight. Throughout the remainder of the study, standard length (nose to hypural plate) was used for length measurements so that fry mortalities which had suffered fin damage prior to measurement could be directly compared with living fry. The brief experimental holding period was not expected to result in measurable differences in growth between treatment groups, and so changes in length and weight during the experimental period were not initially planned for. However, in 1990, an opportunity arose to obtain size measurements on fry sacrificed for other purposes. Five composite samples of over 100 fry were netted from each trough and surplus water removed through the net mesh with tissue paper. Samples were then placed in pre-weighed, polyethylene, "Ziplock" bags. The bags were weighed to the nearest 0.1 g, and the "bulk" weight later divided by the number of individuals in each bag. To obtain an estimate of standard length, 10 fish from each bag were chosen at random and measured to the nearest 1 mm.

These relatively crude measurements suggested the potential for short-term measurements of growth, and a more rigorous protocol was initiated for the remaining two years of the study. During 1991 and 1992, pre-oil exposure samples were obtained just prior to oil dosing, and compared with samples obtained just prior to release.

Random sampling of each treatment group population was achieved by positioning three persons at even intervals along the length of the trough. At a prearranged signal each individual took a rapid scoop of whatever fry were present in front of him at the time. Captured fry were combined into one bucket. The procedure was then repeated until an estimated 300 fry were obtained. These fry were maintained unfed in running sea water in 60 L plastic pails for 2-12 h, at which time they were dip netted in groups of about 60 fish into a lethal anaesthetic bath of tricaine methane-sulfonate (MS-222). Anaesthetized fry were placed on wet paper towels and covered with wet paper towels. Standard length (nose to hypural plate) was measured to the nearest 1 mm using a transparent plastic ruler, and the fry were immediately transferred to a tared electronic pan balance, and weighed to the nearest 0.01 g. During the 1992 field program, a further 300 fry per group were removed prior to the oil dosing phase to provide a pre-treatment sample (pre-treatment estimates of length and

weight in 1990 and 1991 were obtained from fry sampled during the two-week tagging program rather than just prior to dosing; fork lengths from these samples were converted to standard lengths by subtracting 3 mm).

### Fry Release

After 10 days of hydrocarbon exposure, all three groups of pink salmon fry were released to the nearshore marine environment of Discovery Passage adjacent to the study site. Methodology was the same each year, and consisted of the following steps:

- i) One end of a 30 m length of flexible, smooth-walled, 5-cm ID PVC hose was connected to the outlet standpipe of the holding trough and the other end (with suitable solid PVC pipe extensions) was positioned in shallow water 2-3 m beyond the tide line.
- ii) The fish retention screen at the downstream end of the trough was removed by cutting away the silicone sealant holding the outer frame to the trough sides and bottom.
- iii) Sea water flow to the trough was shut off to eliminate its orienting effect on the fry.
- iv) As the standpipe with attached drain hose attached was lowered to the ground fry were siphoned from the trough, through the PVC hose to the nearshore zone.
- v) Fly screen pole seines were used to guide the fry towards the outlet located in the floor of the trough.
- vi) The last few fry in the troughs were encouraged to move towards the drain with a low power jet of sea water.

Treatment groups were released sequentially with the order of release determined randomly. About 45 min was required to drain all three troughs. Transit time within the release hose was about 10-12 s. The release of fry in 1990 and 1991 was conducted under extreme conditions of wind and rain, while calm conditions prevailed in 1992.

### Adult Returns

From August through October in 1991, 1992, and 1993, surveys were conducted by Quinsam River Hatchery employees for returning adipose-clipped adult pink salmon. Surveys included "dead pitches" along the river above and below the hatchery, sampling at the fence trap, and the examination of adult pink salmon used for brood samples and held in hatchery holding ponds. Data for adipose marked fish included a head identification number, sex, length (post-orbital to hypural to the nearest 1 cm) and for some fish, weight (taken to

the nearest 0.1 kg). Heads were removed, labelled, frozen in bags, and later transported to Vancouver for tag-code analyses.

In addition to recoveries of coded-wire tagged adult pink salmon in the Quinsam River heads from adipose fin-clipped pink salmon were also recovered from the commercial fishery, and in several instances, from the salt water sport fishery. The heads were labelled and length (post-orbital to hypural), location, and date of capture were recorded.

Analyses of recovered tag binary codes was completed by Margaret Birch (DFO, Vancouver - 1991 and 1992 returns) and by J.O. Thomas and Associates (Vancouver B.C. - 1993 returns).

### Disease Screening

In 1990 and 1991, subsamples of the experimental populations were removed from the holding troughs before and after the hydrocarbon exposure period, and transported live for disease screening by D. Keiser at the Pacific Biological Station at Nanaimo, B.C. In addition, samples removed for histological studies were examined for pathological conditions as part of those investigations. Results of those disease screenings are described separately, however all fish released were determined to be in good health.

### Hydrocarbon Avoidance

A flow-through Y-maze was constructed from white PVC pipe cut lengthwise to create a small trough (Figure 4). A wall divided the upstream end of the trough into two long channels, while the downstream end was open to both. Sea water alone (control), or sea water and WSF were added to the inflow end of each channel at flow rates of 0.8-1.0 L·min<sup>-1</sup>. A baffle placed just downstream of the discharge lines acted as a diffuser to minimize inflow turbulence and to aid in achieving laminar flow through the maze.

Following unsuccessful trials with single pink fry, in which no clear patterns of hydrocarbon avoidance were detected, the original protocol was modified to incorporate a small school of 6-8 fry for each trial in 1991, and 7 fry for each trial in 1992. Fry were placed in the common area of the maze and allowed to acclimatize for 30 min before the start of each trial. Observations were then taken at exactly one minute intervals and the number of fish in each chamber recorded over a 30 minute test period. The observer was positioned at the downstream side of the apparatus.

Dye tests using food colouring were performed prior to the start of each trial to monitor flow characteristics in the maze. During most trials the dye remained confined to the toxicant channel and the common chamber, while the sea water channel remained uncontaminated. During several dye tests, however, some color was observed to migrate 3-5 cm up the sea

water-only channel as a result of small scale turbulence at the downstream end of the dividing wall, or in response to slight wind driven surface currents. On windy days the top of the maze was covered with clear polyethylene film. The 1992 apparatus with a thinner dividing wall produced less downstream turbulence, and hence less contamination of the seawater channel. The thinner wall resulted in near-laminar flow through the maze, unlike the previous years' apparatus where slight mixing of the two main flows took place.

The channel receiving toxicant was alternated periodically to correct for any channel or other bias. Experiments were conducted outdoors between 1000 and 1800 hours under diffuse natural light conditions. Two types of blind tests were conducted. In the first, both chambers received only sea water (blank tests), while in the second, a neutral observer made all observations, unaware of which was the "toxicant" channel.

The binomial test and Table B.26 (Zar 1984) were used to determine significant differences in the distribution of fry within the maze for the 1991 trials, while  $\chi^2$ , goodness of fit (Zar 1984), was used to determine significance of each trial in 1992. In order to determine the effect of hydrocarbon concentration and hydrocarbon pre-exposure on avoidance responses in pink salmon fry we calculated "average responses" for each treatment group by combining trials conducted with similar hydrocarbon concentrations. Where multiple trials were available, 95% confidence limits were determined.

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Table 1. Summary of coded-wire tagging of pink salmon fry, 1990.

Treatment groups	Tag code	Tagging dates	Delivered		Removed		Release numbers	Estimated tags released		
			Tagged Fish	% of total delivered	Cum. morts	Cum. sampled		Tag retention	CWT tagged	Adipose clip only
High	H20102	26 Mar - 2 Apr	21136	64.9				0.922	17661	
	H20501	3 - 4 Apr	5897	17.8				0.922	4844	
	H20502	4 - 5 Apr	5290	17.3				0.922	4708	
	<b>Total</b>		<b>32323</b>	<b>100.0</b>	<b>598</b>	<b>2210</b>	<b>29515</b>	<b>0.922</b>	<b>27213</b>	<b>2302</b>
Low	H20404	26 Mar - 2 Apr	17555	56.6				0.906	14393	
	H20405	2 - 6 Apr	13652	43.4				0.906	11036	
	<b>Total</b>		<b>31207</b>	<b>100.0</b>	<b>891</b>	<b>2248</b>	<b>28068</b>	<b>0.906</b>	<b>25430</b>	<b>2638</b>
										14
Control	H20101	26 Mar - 3 Apr	18826	59.8				0.912	15917	
	H20401	3 Apr - 6 Apr	7165	22.0				0.912	5856	
	H20402	6 Apr	4404	12.8				0.912	3407	
	H20202	6 Apr	1590	5.4				0.912	1437	
	<b>Total</b>		<b>31985</b>	<b>100.0</b>	<b>655</b>	<b>2145</b>	<b>29185</b>	<b>0.912</b>	<b>26617</b>	<b>2568</b>
<b>All groups</b>			<b>95515</b>		<b>2144</b>	<b>6603</b>	<b>86768</b>	<b>0.913</b>	<b>79259</b>	<b>7509</b>

Table 2. Summary of coded-wire tagging of pink salmon fry, 1991.

Treatment groups	Tag code	Tagging dates	Delivered		Removed		Release numbers	Estimated tags released		
			Tagged Fish	% of total delivered	Cum. mortality	Cum. sampled		Tag retention	CWT tagged	Adipose clip only
High	211114	27 Mar - 2 Apr	9376	31.2				0.892	8158	
	211115	3 - 5 Apr	12770	41.8				0.892	11111	
	21121	6 - 9 Apr	7818	21.0				0.892	6803	
	21122	9 Apr	1820	6.0				0.892	1584	
	<b>Total</b>		<b>31784</b>	<b>100.0</b>	<b>319</b>	<b>461</b>	<b>31004</b>	<b>0.892</b>	<b>27656</b>	<b>3348</b>
Low	211110	27 Mar - 2 Apr	8498	25.9				0.858	7044	
	211111	3 - 5 Apr	11414	33.7				0.858	9461	
	211112	6 - 9 Apr	10907	33.9				0.858	9041	
	211113	9 Apr	2209	6.5				0.858	1831	
	<b>Total</b>		<b>33028</b>	<b>100.0</b>	<b>489</b>	<b>630</b>	<b>31909</b>	<b>0.858</b>	<b>27378</b>	<b>4531</b>
Control	21123	27 Mar - 2 Apr	9572	32.6				0.854	7958	
	21124	3 - 5 Apr	13600	45.0				0.854	11307	
	21125	9 Apr	1507	5.0				0.854	1253	
	21126	6 - 9 Apr	6823	17.4				0.854	5673	
	<b>Total</b>		<b>31502</b>	<b>100.0</b>	<b>364</b>	<b>470</b>	<b>30668</b>	<b>0.854</b>	<b>26190</b>	<b>4478</b>
<b>All groups</b>			<b>96314</b>		<b>1172</b>	<b>1561</b>	<b>93581</b>	<b>0.868</b>	<b>81224</b>	<b>12357</b>

Table 3. Summary of coded-wire tagging of pink salmon fry, 1992.

Treatment groups	Tag code	Tagging dates	Delivered		Removed		Release numbers	Estimated tags released		
			Tagged Fish	% of total delivered	Cum. morts	Cum. sampled		Tag retention	CWT tagged	Adipose clip only
High	21131	5 - 9 Mar	10975	34.3				0.770	7945	
	21132	10 - 12 Mar	9746	30.6				0.770	7056	
	21133	13 - 16 Mar	10489	35.1				0.770	7593	
	<b>Total</b>		<b>31210</b>	<b>100.0</b>	<b>892</b>	<b>975</b>	<b>29343</b>	<b>0.770</b>	<b>22594</b>	<b>6749</b>
Low	21137	5 - 9 Mar	10439	34.2				0.773	7624	
	211214	9-11,15-16 Mar	8114	26.0				0.773	5926	
	211215	12 - 15 Mar	12702	39.8				0.773	9277	
	<b>Total</b>		<b>31255</b>	<b>100.0</b>	<b>745</b>	<b>980</b>	<b>29530</b>	<b>0.773</b>	<b>22827</b>	<b>6703</b>
Control	21134	5 - 9 Mar	11536	41.5				0.830	9079	
	21135	10 - 13 Mar	11622	40.5				0.830	9147	
	21136	13 - 16 Mar	7909	18.0				0.830	6224	
	<b>Total</b>		<b>31067</b>	<b>100.0</b>	<b>629</b>	<b>980</b>	<b>29458</b>	<b>0.830</b>	<b>24450</b>	<b>5008</b>
<b>All groups</b>			<b>93532</b>		<b>2266</b>	<b>2935</b>	<b>88331</b>	<b>0.791</b>	<b>69871</b>	<b>18460</b>

Table 4. Pink salmon mortalities collected from the beach 9 h  
after fry release - April 2, 1992.

Recovery group	Trough* No.	Tag codes	Number recovered	% recovered	
<b>High</b>	1	21131	5	7.2	
		21132	5	7.2	
		21133	1	1.4	
		<b>Total</b>	<b>11</b>	<b>15.9</b>	
<b>Low</b>	3	21137	4	5.8	
		211214	2	2.9	
		211215	0	0.0	
		<b>Total</b>	<b>6</b>	<b>8.7</b>	
<b>Control</b>	2	21134	14	20.3	
		21135	12	17.4	
		21136	15	21.7	
		<b>Total</b>	<b>41</b>	<b>59.4</b>	
<b>No pins</b>		<b>Total</b>	<b>11</b>	<b>15.9</b>	
<b>Total recovered:</b>			<b>69</b>	<b>100.0</b>	

\* Trough 2,1 and 3 were the order that fry were released.

Table 5. Trough mortalities:1990

Days	Control Trough 1				High Dose Trough 2				Low Dose Trough 3				Totals		
	Total Fish	Daily Mortality	Cum Mortality	% Mortality	Total Fish	Daily Mortality	Cum Mortality	% Mortality	Total Fish	Daily Mortality	Cum Mortality	% Mortality	Total Fish	Daily morts	
26-Mar	31985	0	0	0.00	32323	0	0	0.00	31207	0	0	0.00	95515	0	
27-Mar		12	12	0.04		10	10	0.03		23	23	0.07		45	
28-Mar		11	23	0.07		19	29	0.09		10	33	0.11		40	
29-Mar		23	46	0.14		15	44	0.14		16	49	0.16		54	
30-Mar		20	66	0.21		22	66	0.20		26	75	0.24		68	
31-Mar		39	105	0.33		19	85	0.26		16	91	0.29		74	
01-Apr		4	109	0.34		3	88	0.27		5	96	0.31		12	
02-Apr		25	134	0.42		10	98	0.30		17	113	0.36		52	
03-Apr		10	144	0.45		39	137	0.42		19	132	0.42		68	
04-Apr		7	151	0.47		13	150	0.46		6	138	0.44		26	
05-Apr		120	271	0.85		24	174	0.54		89	227	0.73		233	
06-Apr		131	402	1.26		21	195	0.60		110	337	1.08		262	
07-Apr		47	449	1.40		13	208	0.64		8	345	1.11		68	
08-Apr		15	464	1.45		5	213	0.66		5	350	1.12		25	
09-Apr		6	470	1.47		1	214	0.66		5	355	1.14		12	
10-Apr		9	479	1.50		2	216	0.67		5	360	1.15		16	
11-Apr		4	483	1.51		4	220	0.68		3	363	1.16		11	
12-Apr		3	486	1.52		0	220	0.68		3	366	1.17		6	
13-Apr		2	488	1.53		5	225	0.70		2	368	1.18		9	
14-Apr		6	494	1.54		5	230	0.71		9	377	1.21		20	
15-Apr		6	500	1.56		6	236	0.73		5	382	1.22		17	
16-Apr		12	512	1.60		16	252	0.78		17	399	1.28		45	
17-Apr		16	528	1.65		12	264	0.82		29	428	1.37		57	
18-Apr		17	545	1.70		17	281	0.87		40	468	1.50		74	
19-Apr		16	561	1.75		37	318	0.98		46	514	1.65		99	
20-Apr		19	580	1.81		48	366	1.13		49	563	1.80		116	
21-Apr		16	596	1.86		32	398	1.23		83	646	2.07		131	
22-Apr		19	615	1.92		95	493	1.53		103	749	2.40		217	
23-Apr		40	655	2.05		105	598	1.85		142	891	2.86		287	
Total	31330	655			31725	598			30316	891			2144	100%	
24 Hour Mortalities *		326	49.8%			122	20.4%			265	29.7%			713	33.3%

\* - fry dying within 24 hours of being delivered to the troughs

Table 6. Trough mortalities:1991

Days	Low Dose Trough 1				High Dose Trough 2				Control Trough 3				Totals		
	Total Fish	Daily Morts	Cum Morts	% Mortality	Total Fish	Daily Morts	Cum Morts	% Mortality	Total Fish	Daily Morts	Cum Morts	% Mortality	Total Fish	Daily morts	
	33028	13	13	0.04	31784	11	11	0.03	31502	5	5	0.02	96314	29	
27-Mar		15	28	0.08		47	58	0.18		29	34	0.11		91	
28-Mar		38	66	0.20		28	86	0.27		42	76	0.24		108	
29-Mar		19	85	0.26		22	108	0.34		15	91	0.29		56	
30-Mar		12	97	0.29		4	112	0.35		16	107	0.34		32	
31-Mar		11	108	0.33		27	139	0.44		24	131	0.42		62	
01-Apr		10	118	0.36		18	157	0.49		9	140	0.44		37	
02-Apr		9	127	0.38		10	167	0.53		23	163	0.52		42	
03-Apr		11	138	0.42		7	174	0.55		19	182	0.58		37	
04-Apr		11	149	0.45		14	188	0.59		11	193	0.61		36	
05-Apr		16	165	0.50		7	195	0.61		9	202	0.64		32	
06-Apr		5	170	0.51		3	198	0.62		2	204	0.65		10	
07-Apr		12	182	0.55		11	209	0.66		14	218	0.69		37	
08-Apr		14	196	0.59		12	221	0.70		19	237	0.75		45	
09-Apr		7	203	0.61		8	229	0.72		12	249	0.79		27	
10-Apr		5	208	0.63		3	232	0.73		5	254	0.81		13	
11-Apr		7	215	0.65		2	234	0.74		3	257	0.82		12	
12-Apr		4	219	0.66		2	236	0.74		6	263	0.83		12	
13-Apr		9	228	0.69		6	242	0.76		6	269	0.85		21	
14-Apr		13	241	0.73		4	246	0.77		5	274	0.87		22	
15-Apr		17	258	0.78		4	250	0.79		4	278	0.88		25	
16-Apr		10	268	0.81		8	258	0.81		13	291	0.92		31	
17-Apr		16	284	0.86		6	264	0.83		6	297	0.94		28	
18-Apr		22	306	0.93		5	269	0.85		7	304	0.97		34	
19-Apr		23	329	1.00		5	274	0.86		10	314	1.00		38	
20-Apr		37	366	1.11		9	283	0.89		10	324	1.03		56	
21-Apr		46	412	1.25		19	302	0.95		22	346	1.10		87	
22-Apr		77	489	1.48		17	319	1.00		18	364	1.16		112	
Total	32539	489			31465	319			31138	364			1172	100%	
Transport		99	20.2%			86	27.0%			131	36.0%			316	27.0%

\* - fry dying within 24 hours of being delivered to the troughs

Table 7. Trough mortalities:1992

Days	High Dose Trough 1				Control Trough 2				Low Dose Trough 3				Totals		
	Total Fish	Daily Morts	Cum Morts	% Mortality	Total Fish	Daily Morts	Cum Morts	% Mortality	Total Fish	Daily Morts	Cum Morts	% Mortality	Total Fish	Daily morts	
05-Mar	31210	14	14	0.04	31067	16	16	0.05	31255	18	18	0.06	93532	48	
06-Mar		27	41	0.13		37	53	0.17		42	60	0.19		106	
07-Mar		21	62	0.20		22	75	0.24		23	83	0.27		66	
08-Mar		41	103	0.33		13	88	0.28		5	88	0.28		59	
09-Mar		33	136	0.44		34	122	0.39		23	111	0.36		90	
10-Mar		13	149	0.48		2	124	0.40		8	119	0.38		23	
11-Mar		76	225	0.72		29	153	0.49		28	147	0.47		133	
12-Mar		24	249	0.80		35	188	0.61		18	165	0.53		77	
13-Mar		14	263	0.84		20	208	0.67		24	189	0.60		58	
14-Mar		15	278	0.89		16	224	0.72		20	209	0.67		51	
15-Mar		31	309	0.99		23	247	0.80		11	220	0.70		65	
16-Mar		15	324	1.04		7	254	0.82		10	230	0.74		32	
17-Mar		0	324	1.04		0	254	0.82		0	230	0.74		0	
18-Mar		1	325	1.04		2	256	0.82		7	237	0.76		10	
19-Mar		2	327	1.05		2	258	0.83		4	241	0.77		8	
20-Mar		2	329	1.05		2	260	0.84		6	247	0.79		10	
21-Mar		5	334	1.07		6	266	0.86		2	249	0.80		13	
22-Mar		4	338	1.08		3	269	0.87		5	254	0.81		12	
23-Mar		8	346	1.11		6	275	0.89		2	256	0.82		16	
24-Mar		10	356	1.14		9	284	0.91		3	259	0.83		22	
25-Mar		11	367	1.18		11	295	0.95		16	275	0.88		38	
26-Mar		15	382	1.22		14	309	0.99		23	298	0.95		52	
27-Mar		48	430	1.38		18	327	1.05		23	321	1.03		89	
28-Mar		54	484	1.55		23	350	1.13		34	355	1.14		111	
29-Mar		62	546	1.75		40	390	1.26		45	400	1.28		147	
30-Mar		60	606	1.94		36	426	1.37		46	446	1.43		142	
31-Mar		65	671	2.15		55	481	1.55		48	494	1.58		168	
01-Apr		83	754	2.42		39	520	1.67		70	564	1.80		192	
02-Apr		73	827	2.65		52	572	1.84		80	644	2.06		205	
03-Apr		65	892	2.86		57	629	2.02		101	745	2.38		223	
Total	30318	892			30438	629			30510	745			2266	100%	
Transport		212	23.8%			177	28.1%			157	21.1%			546	24.1%

\* - fry dying within 24 hours of being delivered to the troughs

Table 8. Fry samples removed from troughs during 1990, 1991, and 1992.

Trough number	Samples of pink salmon from oil-study												
	Tag retentions	Pre-oil len/wts	Post-oil len/wts	Wet wts	Enzymes	Tissue	Metals	Bioassay	Disease screening	Histology	Net pens	Behavior tests	Totals
<b><u>1990</u></b>													
High 2	28	0	0	92	112	100	778	40	20	40	1,000	0	2,210
Low 3	40	0	0	121	112	158	717	40	20	40	1,000	0	2,248
Control 1	42	0	0	74	106	105	667	70	21	60	1,000	0	2,145
<b>Total</b>	<b>110</b>	<b>0</b>	<b>0</b>	<b>287</b>	<b>330</b>	<b>363</b>	<b>2,162</b>	<b>150</b>	<b>61</b>	<b>140</b>	<b>3,000</b>	<b>0</b>	<b>6,603</b>
<b><u>1991</u></b>													
High 2	0	32	300	0	45	0	0	0	64	20	0	0	461
Low 1	0	33	314	0	48	0	0	151	64	20	0	0	630
Control 3	0	37	300	0	50	0	0	0	63	20	0	0	470
<b>Total</b>	<b>0</b>	<b>102</b>	<b>914</b>	<b>0</b>	<b>143</b>	<b>0</b>	<b>0</b>	<b>151</b>	<b>191</b>	<b>60</b>	<b>0</b>	<b>0</b>	<b>1,561</b>
<b><u>1992</u></b>													
High 1	0	305	300	0	0	0	0	59	0	20	0	291	975
Low 3	0	309	300	0	0	0	0	61	0	20	0	290	980
Control 2	0	303	304	0	0	0	0	60	0	23	0	290	980
<b>Total</b>	<b>0</b>	<b>917</b>	<b>904</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>180</b>	<b>0</b>	<b>63</b>	<b>0</b>	<b>871</b>	<b>2,935</b>
<b><u>Combined years</u></b>													
High 2,2,1	28	337	600	92	157	100	778	99	84	80	1,000	291	3,646
Low 3,1,3	40	342	614	121	160	158	717	252	84	80	1,000	290	3,858
Control 1,3,2	42	340	604	74	156	105	667	130	84	103	1,000	290	3,595
<b>Total</b>	<b>110</b>	<b>1,019</b>	<b>1,818</b>	<b>287</b>	<b>473</b>	<b>363</b>	<b>2,162</b>	<b>481</b>	<b>252</b>	<b>263</b>	<b>3,000</b>	<b>871</b>	<b>11,099</b>

\* Majority of metal samples were used for post-oil lengths and weights (trough1=642, trough2=753, and trough3=690).

Table 9. Feeding totals, conversion rates, and weight gains for pink salmon fry. \*

Year	Trough no.	Treatment Group	Tagged fish	Total feed (kg)	Mean weight start (g)	Mean weight end (g)	Mean weight gain (g)	No. days	% wt gain per day	Mean weight gain per day (g)	Feeding conversion rate	Mean % body wt fed per day
1990	2	High dose	32,323	6.00	0.25	0.43	0.18	28	1.50	0.006	1.03	2.65
	3	Low dose	31,207	5.85	0.26	0.37	0.11	28	1.06	0.004	1.70	2.57
	1	Control	31,985	5.72	0.25	0.43	0.18	28	1.50	0.006	0.99	2.55
		Total	95,515	17.57	0.25	0.41	0.16	28	1.35	0.006	1.24	2.59
1991	2	High dose	31,784	5.02	0.22	0.32	0.10	27	1.16	0.004	1.58	2.66
	1	Low dose	33,028	5.03	0.22	0.29	0.07	27	0.89	0.003	2.18	2.56
	3	Control	31,502	5.02	0.22	0.32	0.10	27	1.16	0.004	1.59	2.68
		Total	96,314	15.07	0.22	0.31	0.09	27	1.07	0.003	1.78	2.64
1992	1	High dose	31,210	5.95	0.22	0.36	0.14	29	1.34	0.005	1.36	2.99
	3	Low dose	31,255	5.96	0.22	0.35	0.13	29	1.28	0.004	1.47	2.99
	2	Control	31,067	5.94	0.22	0.35	0.13	29	1.28	0.004	1.47	3.00
		Total	93,532	17.85	0.22	0.35	0.13	29	1.30	0.005	1.43	2.99

\* - 1990 fry weights are bulk weights which included excess water and are not directly comparable to 1991 and 1992 data

Table 10. Effect of hydrocarbon exposure on fry length.

Year	Trough no.	Treatment Group	Mean length start (mm)	Mean length end (mm)	Mean length gain (mm)	No. days	% length gain per day	Mean length gain per day (mm)
1990	2	High dose	29.00	35.78	6.78	28	0.68	0.242
	3	Low dose	29.00	34.10	5.10	28	0.53	0.182
	1	Control	29.00	34.80	5.80	28	0.60	0.207
		Total	<b>29.00</b>	<b>34.89</b>	<b>5.89</b>	<b>28</b>	<b>0.60</b>	<b>0.210</b>
1991	2	High dose	28.23	33.50	5.27	27	0.58	0.195
	1	Low dose	28.44	32.76	4.32	27	0.49	0.160
	3	Control	28.38	33.88	5.50	27	0.60	0.204
		Total	<b>28.35</b>	<b>33.38</b>	<b>5.03</b>	<b>27</b>	<b>0.56</b>	<b>0.186</b>
1992	1	High dose	28.97	34.92	5.95	29	0.59	0.205
	3	Low dose	28.72	35.13	6.41	29	0.63	0.221
	2	Control	28.61	35.04	6.43	29	0.63	0.222
		Total	<b>28.77</b>	<b>35.03</b>	<b>6.26</b>	<b>29</b>	<b>0.62</b>	<b>0.216</b>

Table 11. Summary of lengths for pink salmon fry and adults.

Release year	Trough No.	Fork length (mm)			Standard length (mm)						Post-orbital - hypural length (mm)								
		Quinsam hatchery			Pink salmon fry						Escapement recoveries								
		Emergence			Pre-oil exposure			Post-oil exposure			Adult males			Adult females					
		n	Mean	S.D.	n	Mean	S.D.	n	Mean	S.D.	n	Mean	S.D.	n	Mean	S.D.	n	Mean	S.D.
<b><u>1990</u></b>																			
High	2				50	<b>35.78</b>	4.5	27	<b>391.30</b>	24.50	36	<b>396.70</b>	20.30	63	<b>394.40</b>	22.20			
Low	3				50	<b>34.10</b>	4.4	22	<b>393.70</b>	26.00	22	<b>400.00</b>	12.90	44	<b>396.80</b>	20.50			
Control	1				50	<b>34.80</b>	3.60	31	<b>385.90</b>	26.10	30	<b>396.40</b>	17.80	61	<b>391.00</b>	22.80			
<b><u>1991</u></b>																			
High	2	290	<b>31.23</b>	1.65				315	<b>33.50</b>	2.1	64	<b>371.45</b>	22.27	43	<b>371.65</b>	13.38	107	<b>371.53</b>	19.13
Low	1	292	<b>31.44</b>	1.41				334	<b>32.76</b>	2.5	55	<b>372.45</b>	23.57	55	<b>374.22</b>	17.63	110	<b>373.34</b>	20.74
Control	3	325	<b>31.38</b>	1.57				320	<b>33.88</b>	2.5	54	<b>366.93</b>	23.99	46	<b>372.07</b>	16.45	100	<b>369.29</b>	20.93
<b><u>1992</u></b>																			
High	1	275	<b>31.97</b>	0.70	305	<b>30.39</b>	1.7	300	<b>34.92</b>	2.6	14	<b>393.20</b>	26.50	36	<b>391.10</b>	19.00	50	<b>391.70</b>	21.10
Low	3	300	<b>31.72</b>	0.43	309	<b>31.70</b>	2	300	<b>35.13</b>	2.8	29	<b>398.20</b>	24.00	33	<b>394.80</b>	18.30	62	<b>396.40</b>	21.10
Control	2	275	<b>31.61</b>	0.52	303	<b>31.40</b>	1.8	300	<b>35.04</b>	2.8	37	<b>387.60</b>	27.70	22	<b>393.70</b>	18.50	59	<b>389.80</b>	24.60

Table 12. Summary of weights for pink salmon fry and adults

Release year	Trough No.	Weight (g)												Weight (kg)														
		Quinsam hatchery						Pink salmon fry						Escapement recoveries						Adult males			Adult females			Adults (both sexes)		
		Emergence			Pre-oil exposure			Post-oil exposure			n			n			n			n			n					
		n	Mean	S.D.	n	Mean	S.D.	n	Mean	S.D.	n	Mean	S.D.	n	Mean	S.D.	n	Mean	S.D.	n	Mean	S.D.	n	Mean	S.D.			
<b>1990</b>																												
High	2	225	<b>0.25</b>	0.02				753	<b>0.43</b>		14	<b>1.44</b>	0.25	13	<b>1.34</b>	0.16	27	<b>1.39</b>	0.21									
Low	3	250	<b>0.26</b>	0.02				690	<b>0.37</b>		11	<b>1.47</b>	0.32	11	<b>1.36</b>	0.14	22	<b>1.41</b>	0.25									
Control	1	250	<b>0.25</b>	0.03				642	<b>0.43</b>		17	<b>1.28</b>	0.23	16	<b>1.35</b>	0.15	33	<b>1.31</b>	0.20									
<b>1991</b>																												
High	2	290	<b>0.22</b>	0.03				315	<b>0.32</b>	0.07	32	<b>1.09</b>	0.24	26	<b>1.02</b>	0.10	58	<b>1.06</b>	0.19									
Low	1	292	<b>0.22</b>	0.03				334	<b>0.29</b>	0.08	37	<b>1.13</b>	0.25	27	<b>1.11</b>	0.17	64	<b>1.12</b>	0.22									
Control	3	325	<b>0.22</b>	0.02				320	<b>0.32</b>	0.08	41	<b>1.08</b>	0.24	24	<b>1.07</b>	0.12	65	<b>1.08</b>	0.20									
<b>1992</b>																												
High	1	275	<b>0.22</b>	0.01	305	<b>0.24</b>	0.05	300	<b>0.36</b>	0.09	14	<b>1.36</b>	0.30	26	<b>0.89</b>	0.58	40	<b>1.02</b>	0.56									
Low	3	300	<b>0.22</b>	0.01	309	<b>0.27</b>	0.07	300	<b>0.35</b>	0.10	27	<b>1.26</b>	0.47	27	<b>1.10</b>	0.55	54	<b>1.16</b>	0.53									
Control	2	275	<b>0.22</b>	0.01	303	<b>0.28</b>	0.06	300	<b>0.35</b>	0.09	33	<b>1.12</b>	0.54	15	<b>0.85</b>	0.65	48	<b>1.02</b>	0.59									

\* In 1990 bulk weights were used to estimate fry weight.

Table 13. Summary of condition factors for pink salmon fry and adults

Release year	Trough number	Condition factor (g/mm <sup>3</sup> x 10,000)						Condition factor (g/mm <sup>3</sup> x 10,000)						Escapement recoveries					
		Quinsam hatchery			Pink salmon fry			Adult males			Adult females			Adults (both sexes)					
		Emergence			Pre-oil exposure			Post-oil exposure *			n	Mean	S.D.	n	Mean	S.D.			
<b><u>1990 *</u></b>																			
High	2				753	<b>0.92</b>		14	<b>2.27</b>	0.18	13	<b>2.22</b>	0.32	27	<b>2.25</b>	0.25			
Low	3				690	<b>0.94</b>		11	<b>2.51</b>	0.72	11	<b>2.11</b>	0.28	22	<b>2.31</b>	0.57			
Control	1				642	<b>1.00</b>		17	<b>2.40</b>	0.29	16	<b>2.18</b>	0.33	33	<b>2.29</b>	0.32			
<b><u>1991</u></b>																			
High	2	290	<b>0.74</b>	0.12				315	<b>0.84</b>	0.08	32	<b>2.06</b>	0.15	26	<b>1.98</b>	0.15	58	<b>2.02</b>	0.15
Low	1	292	<b>0.72</b>	0.09				334	<b>0.81</b>	0.09	37	<b>2.08</b>	0.17	27	<b>2.00</b>	0.27	64	<b>2.04</b>	0.22
Control	3	325	<b>0.72</b>	0.09				320	<b>0.82</b>	0.07	41	<b>2.11</b>	0.18	24	<b>2.01</b>	0.24	65	<b>2.08</b>	0.21
<b><u>1992</u></b>																			
High	1	275	<b>0.68</b>	0.04	305	<b>0.85</b>	0.13	300	<b>0.82</b>	0.08	14	<b>2.20</b>	0.13	26	<b>2.00</b>	0.17	40	<b>2.07</b>	0.18
Low	3	300	<b>0.69</b>	0.02	309	<b>0.84</b>	0.11	300	<b>0.81</b>	0.08	27	<b>1.26</b>	0.47	27	<b>1.97</b>	0.55	54	<b>2.05</b>	0.41
Control	2	275	<b>0.70</b>	0.02	303	<b>0.89</b>	0.12	300	<b>0.81</b>	0.07	33	<b>2.09</b>	0.19	15	<b>2.05</b>	0.15	48	<b>2.08</b>	0.18

\* In 1990 bulk weights were used to estimate fry condition factor.

Table 14. Pink salmon fry wet and dry weight measurements

Variable	Treatment Group *		
	Control (n=60)	Low Dose (n=60)	High Dose (n=60)
% Moisture (Transformed)	<b>63.460</b>	<b>63.790</b>	<b>63.620</b>
S.D.	0.892	0.561	0.588
Mean Wet Weight (g)	<b>0.393</b>	<b>0.359</b>	<b>0.438</b>
S.D.	0.119	0.124	0.154
Mean Dry Weight (g)	<b>0.079</b>	<b>0.071</b>	<b>0.087</b>
S.D.	0.025	0.026	0.032
Mean Length (mm) **	<b>37</b>	<b>36</b>	<b>38</b>
S.D.	3.260	3.387	3.760

\* - data from 1990 fry only

\*\* - fork length

## Statistical Summary

Variable	Treatment	Compared with	Significance Level *	Critical t-value	T-test Result	% Difference Between Means
% Moisture	control	low dose	0.05	1.980	<b>2.457</b>	-0.5
	control	high dose			1.160	-0.3
	high dose	low dose			1.649	-0.3
Wet Weight (g)	control	low dose	0.05	1.980	1.519	8.7
	control	high dose			1.792	-11.5
	high dose	low dose			<b>3.088</b>	18.0
Dry Weight (g)	control	low dose	0.05	1.980	1.717	10.1
	control	high dose			1.652	-10.1
	high dose	low dose			<b>3.115</b>	18.4
Length (mm) **	control	low dose	0.05	1.980	1.648	2.7
	control	high dose			1.401	-2.7
	high dose	low dose			<b>2.908</b>	5.3

\* - two tailed - 120 degrees of freedom

Table 15. No. of returning adults vs fry mortality or hydrocarbon exposure \*

Treatment group	Year	Cumulative Fry Mortality			Number of Returning Adults
		Mortality before oil (%)	Mortality after oil (%)	Corrected mortality (%)	
Control	1990	1.53	2.05	0.52	62
	1991	0.83	1.16	0.33	100
	1992	0.91	2.02	1.11	60
Low Dose	1990	1.18	2.86	1.68	44
	1991	0.66	1.48	0.82	110
	1992	0.83	2.38	1.55	62
High Dose	1990	0.70	1.85	1.15	63
	1991	0.74	1.00	0.26	107
	1992	1.14	2.86	1.72	50

\* Escapement adults only

Table 16. Summary of the pink salmon tag recoveries for 1991, 1992, and 1993.

Year	Treatment Group	Tag code	Commercial Catch	Quinsam River Escapement			Combined Recovery
				Males	Females	All Fish	
<b>1991</b>	High Dose	H20102	16	21	32	53	69
		H20501	2	3	3	6	8
		H20502	2	3	1	4	6
		Total	20	27	36	63	83
	Low Dose	H20404	8	16	18	34	42
		H20405	7	6	4	10	17
		Total	15	22	22	44	59
	Control	H20101	6	20	22	42	48
		H20401	1	8	6	14	15
		H20402	2	3	3	6	8
		Total	9	31	31	62	71
	All groups		44	80	89	169	213
	Sample size		46	115	140	255	301
	Adult tag retention		96% *	70%	64%	66%	
<b>1992</b>	High Dose	211114	6	20	11	31	37
		211115	20	27	16	43	63
		21121	10	15	15	30	40
		21122	1	2	1	3	4
		Total	37	64	43	107	144
	Low Dose	211110	8	9	13	22	30
		211111	15	18	18	36	51
		211112	7	25	21	46	53
		211113	2	3	3	6	8
		Total	32	55	55	110	142
	Control	21123	13	16	10	26	39
		21124	14	24	22	46	60
		21125	3	2	2	4	7
		21126	10	12	12	24	34
		Total	40	54	46	100	140
	All groups		109	173	144	317	426
	Sample size		243	239	205	444	687
	Adult tag retention		45%	72%	70%	71%	

\* - fish without CWT not reported in 1991

Table 16. (cont.)

Year	Treatment Group	Tag code	Commercial Catch	Quinsam River Escapement			Combined Recovery		
				Males	Females	All Fish			
<u>1993</u>	High Dose	21131	6	4	11	15	21		
		21132	3	5	14	19	22		
		21133	7	5	11	16	23		
		Total	16	14	36	50	66		
	Low Dose	21137	14	9	15	24	38		
		211214	8	5	7	12	20		
		211215	10	15	11	26	36		
	Total		32	29	33	62	94		
	Control	21134	15	16	8	24	39		
		21135	10	15	11	26	36		
		21136	7	6	4	10	17		
	Total		32	37	23	60	92		
All groups			80	80	92	172	252		
Sample size			517	130	147	277	794		
Adult tag retention			15%	62%	63%	62%			

Combined year totals

	Commercial Catch	Quinsam River Escapement			Combined
		Males	Females	All Fish	
High Dose	73	105	115	220	293
Low Dose	79	106	110	216	295
Control	81	122	100	222	303
All groups	233	333	325	658	891

Table 17. Actual vs expected adult recovery by year and treatment group.

Treatment group	Tag code	Tag Days	% Distrib. of codes	Estimated no. of tags released	Adult returns by tag code			Goodness of Fit *						
					Actual recovery	Expected recovery	% difference	Critical value (0.95)	Chi Squared	df				
<b><u>1990</u></b>														
High Dose	H20102	1-9	64.9	17661	53	41	19.23	<b>5.99</b>	<b>10.38</b>	2				
	H20501	10-11	17.8	4844	6	11	-8.28	Significant (P=0.95)						
	H20502	10-11	17.3	4708	4	11	-10.95							
	<b>Total</b>		<b>100.0</b>	<b>27213</b>	<b>63</b>									
Low Dose	H20404	1-8	56.6	14393	34	25	20.67	<b>3.84</b>	<b>6.84</b>	1				
	H20405	8-12	43.4	11036	10	19	-20.67	Significant (P=0.95)						
	<b>Total</b>		<b>100.0</b>	<b>25430</b>	<b>44</b>									
Control	H20101	1-9	59.8	15917	42	37	7.94	7.81	4.48	3				
	H20401	10-12	22.0	5856	14	14	0.58							
	H20402	12	12.8	3407	6	8	-3.12							
	H20202	12	5.4	1437	0	3	-5.40							
	<b>Total</b>		<b>100.0</b>	<b>26617</b>	<b>62</b>									
	<b>Total</b>				<b>79259</b>	<b>169</b>								
<b><u>1991</u></b>														
High Dose	211114	1-7	31.2	8629	31	33	-2.23	7.81	4.58	3				
	211115	8-10	41.8	11560	43	45	-1.61							
	21121	11-14	21.0	5808	30	22	7.04							
	21122	14	6.0	1659	3	6	-3.20							
	<b>Total</b>		<b>100.0</b>	<b>27656</b>	<b>107</b>									
Low Dose	211110	1-7	25.9	7091	22	28	-5.90	7.81	3.73	3				
	211111	8-10	33.7	9226	36	37	-0.97							
	211112	11-14	33.9	9281	46	37	7.92							
	211113	14	6.5	1780	6	7	-1.05							
	<b>Total</b>		<b>100.0</b>	<b>27378</b>	<b>110</b>									
Control	21123	1-7	32.6	8538	26	33	-6.60	7.81	4.06	3				
	21124	8-10	45.0	11786	46	45	1.00							
	21125	14	5.0	1310	4	5	-1.00							
	21126	11-14	17.4	4557	24	17	6.60							
	<b>Total</b>		<b>100.0</b>	<b>26190</b>	<b>100</b>									
	<b>Total</b>				<b>79710</b>	<b>317</b>								

Table 17. (cont.)

Treatment group	Tag code	Tag Days	% Distrib. of codes	Estimated no. of CWT released	Adult returns by tag code			Goodness of Fit *		
					Actual recovery	Expected recovery	% difference	Critical value (0.95)	Chi Squared	df
<b>1993</b>										
High Dose	21131	1-5	34.3	7750	15	17	-4.30	5.99	1.30	2
	21132	5-8	30.6	6914	19	15	7.40			
	21133	9-12	35.1	7931	16	18	-3.10			
	<b>Total</b>		<b>100.0</b>	<b>22594</b>	<b>50</b>					
Low Dose	21137	1-5	34.2	7807	24	21	4.51	5.99	1.48	2
	211214	5-12	26.0	5926	12	16	-6.61			
	211215	8-11	39.8	9085	26	25	2.14			
	<b>Total</b>		<b>100.0</b>	<b>22827</b>	<b>62</b>					
Control	21134	1-5	41.5	10147	24	25	-1.50	5.99	0.21	2
	21135	5-9	40.5	9902	26	24	2.83			
	21136	9-12	18.0	4401	10	11	-1.33			
	<b>Total</b>		<b>100.0</b>	<b>24450</b>	<b>60</b>					
	<b>Total</b>				<b>69871</b>	<b>172</b>				

\* - Dixon and Massey, 1969

Table 18. Tag location summary for 1993 escapement adults

<u>Treatment Group</u>	<u>Tag Code</u>	<u>Tag Location</u>				<u>Total Recoveries</u>
		<u>Cartilage</u>	<u>Nares *</u>	<u>Eyes *</u>	<u>Jaw *</u>	
High Dose	21131	7	4	4	0	15
	21132	5	5	9	0	19
	21133	1	8	7	0	16
Low Dose	21137	8	13	3	0	24
	211214	4	6	2	0	12
	211215	7	9	10	0	26
Control	21134	8	8	8	0	24
	21135	7	8	10	1	26
	21136	2	3	5	0	10
Totals		49	64	58	1	172

\* Anomalous tag placement locations susceptible to higher tag loss rates than cartilage placement

Table 19. Commercial and sportfish head recovery for 1990, 1991, and 1992

Recovered treatment groups	Tag code	Head recoveries									
		Catch areas							Heads with codes	Heads without codes	Total
		11	12	13	20	26	27	98	Other		
<b>1991</b>											
High	H20102	0	11	4	0	0	0	1	0	16	0
High	H20501	0	2	0	0	0	0	0	0	2	2
High	H20502	0	1	1	0	0	0	0	0	2	2
Low	H20404	0	5	2	0	0	0	1	1	9	9
Low	H20405	0	4	2	0	0	0	1	0	7	7
Control	H20101	0	2	3	0	0	0	0	1	6	6
Control	H20401	0	0	1	0	0	0	0	0	1	1
Control	H20402	0	0	1	1	0	0	0	1	3	3
Control	H20202	0	0	0	0	0	0	0	0	0	0
Lost data		0	0	0	0	0	0	0	0	0	0
no pin		0	2	0	0	0	0	0	0	2	2
		0	27	14	1	0	0	3	3	46	48
<b>1992</b>											
High	211114	0	1	5	0	0	0	0	0	6	6
High	211115	0	2	12	0	0	0	6	0	20	20
High	21121	0	0	9	0	0	0	1	0	10	10
High	21122	0	0	0	0	0	0	1	0	1	1
Low	211110	0	1	6	0	0	0	1	0	8	8
Low	211111	0	3	8	0	0	0	4	0	15	15
Low	211112	0	2	3	0	0	0	2	0	7	7
Low	211113	0	1	1	0	0	0	0	0	2	2
Control	21123	0	1	0	0	11	0	1	0	13	13
Control	21124	0	2	10	0	0	0	2	0	14	14
Control	21125	0	0	3	0	0	0	0	0	3	3
Control	21126	1	1	7	0	0	0	1	0	10	10
no data		0	0	2	0	0	1	0	0	3	3
no pin		1	20	64	3	1	15	26	1	0	131
		2	34	130	3	12	16	45	1	109	134
<b>1993</b>											
High	21131	0	0	6	0	0	0	0	0	6	6
High	21132	0	0	3	0	0	0	0	0	3	3
High	21133	0	0	7	0	0	0	0	0	7	7
Low	21137	0	1	13	0	0	0	0	0	14	14
Low	211214	0	0	8	0	0	0	0	0	8	8
Low	211215	0	0	10	0	0	0	0	0	10	10
Control	21134	0	0	15	0	0	0	0	0	15	15
Control	21135	0	1	8	0	0	0	0	1	10	10
Control	21136	0	0	7	0	0	0	0	0	7	7
blank code		0	0	3	0	0	0	0	0	3	3
no data		0	0	4	0	0	0	0	0	4	4
no pin		4	31	366	0	0	2	0	27	0	430
		4	33	450	0	0	2	0	28	80	517
stubby adipose mark		2	12	152	0	0	0	0	13	6	178
clean adipose mark		2	19	221	0	0	2	0	15	74	259
		4	31	373	0	0	2	0	28	80	517

Table 20. Comparison of mean lengths and weights of escapement adults

Sex		Treatment Group	Mean Length (mm)	Standard Deviation	Mean Weight (kg)	Standard Deviation	n	ANOVA 1-Factor p=0.05
Males	1991	Control	385.90	26.11	1.28	0.23	31	ns
		Low Dose	393.73	25.99	1.47	0.32	22	ns
		High Dose	391.30	24.52	1.44	0.25	27	ns
	1992	Control	366.93	23.99	1.08	0.24	54	ns
		Low Dose	372.45	23.57	1.13	0.25	55	ns
		High Dose	371.45	22.27	1.09	0.24	64	ns
	1993	Control	387.57	27.66	1.26	0.39	37	ns
		Low Dose	398.24	23.99	1.36	0.32	27	ns
		High Dose	393.21	26.45	1.36	0.30	14	ns
Females	By Year	1991	<b>389.88</b>	<b>25.44</b>	<b>1.38</b>	0.27	80	
		1992	<b>370.36</b>	23.22	<b>1.10</b>	0.24	173	< 91/93
		1993	<b>392.43</b>	26.29	<b>1.31</b>	0.35	78	
	Treatment	Control	378.01	27.34	1.18	0.31	122	ns
		Low Dose	383.92	26.83	1.26	0.32	104	ns
		High Dose	379.46	25.29	1.23	0.30	105	ns
	1991	Control	396.37	17.80	1.35	0.15	31	ns
		Low Dose	399.95	12.94	1.36	0.14	22	ns
		High Dose	398.03	18.96	1.34	0.16	36	ns
Females	1992	Control	372.07	16.45	1.07	0.12	46	
		Low Dose	374.22	17.63	<b>1.11</b>	0.17	55	> High Dose
		High Dose	371.65	13.38	<b>1.02</b>	0.10	43	
	1993	Control	393.68	18.45	1.30	0.18	23	ns
		Low Dose	394.85	18.33	1.30	0.30	33	ns
		High Dose	391.14	19.00	1.23	0.19	36	ns
	By Year	1991	<b>397.94</b>	17.08	<b>1.35</b>	0.15	89	
		1992	<b>372.76</b>	16.02	<b>1.07</b>	0.14	144	92 < 91/93
		1993	<b>393.10</b>	18.49	<b>1.27</b>	0.24	92	
	Treatment	Control	384.36	20.74	1.21	0.19	100	ns
		Low Dose	385.55	20.44	1.23	0.25	110	ns
		High Dose	385.90	20.45	1.17	0.20	115	ns

Table 21. Hydrocarbon avoidance statistics (1991).

Control Fish -Blank (no tox)

Trials	No. Counts			%		
	Toxicant	Seawater	Mixture	Toxicant	Seawater	Mixture
	43	100	37	23.89	55.56	20.56
	100	65	45	47.62	30.95	21.43
	97	70	43	46.19	33.33	20.48
<b>Mean</b>	<b>80.0</b>	<b>78.3</b>	<b>41.7</b>	<b>39.2</b>	<b>39.9</b>	<b>20.8</b>
<b>SD</b>	32.1	18.9	4.2	13.3	13.6	0.5
<b>5% conf.</b>	36.3	21.4	4.7	15.1	15.4	0.6
<b>+ conf.</b>	43.7	56.9	37.0	24.2	24.6	20.2
<b>- conf.</b>	116.3	99.8	46.4	54.3	55.3	21.4
<b>n</b>	3	3	3	3	3	3

Control Fish : 2.45 ppm hydrocarbons

Trials	No. Counts			%		
	Toxicant	Seawater	Mixture	Toxicant	Seawater	Mixture
	10	138	32	5.56	76.67	17.78
	2	118	60	1.11	65.56	33.33
	19	135	26	10.56	75.00	14.44
<b>Mean</b>	<b>10.3</b>	<b>130.3</b>	<b>39.3</b>	<b>5.7</b>	<b>72.4</b>	<b>21.9</b>
<b>SD</b>	8.5	10.8	18.1	4.7	6.0	10.1
<b>5% conf.</b>	9.6	12.2	20.5	5.3	6.8	11.4
<b>+ conf.</b>	0.7	118.1	18.8	0.4	65.6	10.4
<b>- conf.</b>	20.0	142.5	59.9	11.1	79.2	33.3
<b>n</b>	3	3	3	3	3	3

Control Fish : 0.58 ppm hydrocarbons

Trials	No. Counts			%		
	Toxicant	Seawater	Mixture	Toxicant	Seawater	Mixture
	22	127	31	12.22	70.56	17.22
	6	137	37	3.33	76.11	20.56
	13	139	28	7.22	77.22	15.56
	12	132	36	6.67	73.33	20.00
	15	151	44	7.14	71.90	20.95
<b>Mean</b>	<b>13.6</b>	<b>137.2</b>	<b>35.2</b>	<b>7.3</b>	<b>73.8</b>	<b>18.9</b>
<b>SD</b>	5.8	9.0	6.1	3.2	2.8	2.4
<b>5% conf.</b>	5.1	7.9	5.4	2.8	2.5	2.1
<b>+ conf.</b>	8.5	129.3	29.8	4.5	71.4	16.8
<b>- conf.</b>	18.7	145.1	40.6	10.1	76.3	20.9
<b>n</b>	5	5	5	5	5	5

Control Fish : 0.19 ppm hydrocarbons

Trials	No. Counts			%		
	Toxicant	Seawater	Mixture	Toxicant	Seawater	Mixture
	27	144	39	12.86	68.57	18.57
	10	162	38	4.76	77.14	18.10
<b>Mean</b>	<b>18.5</b>	<b>153.0</b>	<b>38.5</b>	<b>8.8</b>	<b>72.9</b>	<b>18.3</b>
<b>SD</b>	12.0	12.7	0.7	5.7	6.1	0.3
<b>5% conf.</b>	16.7	17.6	1.0	7.9	8.4	0.5
<b>+ conf.</b>	1.8	135.4	37.5	0.9	64.5	17.9
<b>- conf.</b>	35.2	170.6	39.5	16.7	81.3	18.8
<b>n</b>	2	2	2	2	2	2

Table 21. (cont.)

## Control Fish : 0.09 ppm hydrocarbons

Trials	No. Counts			% Toxicant Seawater Mixture		
	Toxicant	Seawater	Mixture	Toxicant	Seawater	Mixture
	158	12	40	75.24	5.71	19.05
	103	59	48	49.05	28.10	22.86
n	8.00	145	57	3.81	69.05	27.14
Mean	<b>89.7</b>	<b>72.0</b>	<b>48.3</b>	<b>42.7</b>	<b>34.3</b>	<b>23.0</b>
SD	75.9	67.4	8.5	36.1	32.1	4.0
5% conf.	85.9	76.3	9.6	40.9	36.3	4.6
+ conf.	3.8	-4.3	38.7	1.8	-2.1	18.4
- conf.	175.5	148.3	58.0	83.6	70.6	27.6
n	3	3	3	3	3	3

## Low Dose Fish : 2.45 ppm hydrocarbons

Trials	No. Counts			% Toxicant Seawater Mixture		
	Toxicant	Seawater	Mixture	Toxicant	Seawater	Mixture
	7	147	26	3.89	81.67	14.44
	2	153	25	1.11	85.00	13.89
Mean	<b>4.5</b>	<b>150.0</b>	<b>25.5</b>	<b>2.5</b>	<b>83.3</b>	<b>14.2</b>
SD	3.5	4.2	0.7	2.0	2.4	0.4
5% conf.	4.9	5.9	1.0	2.7	3.3	0.5
+ conf.	-0.4	144.1	24.5	-0.2	80.1	13.6
- conf.	9.4	155.9	26.5	5.2	86.6	14.7
n	2	2	2	2	2	2

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## Low Dose Fish : 0.19 ppm hydrocarbons

Trials	No. Counts			% Toxicant Seawater Mixture		
	Toxicant	Seawater	Mixture	Toxicant	Seawater	Mixture
	9	164	37	4.29	78.10	17.62
	28	126	56	13.33	60.00	26.67
Mean	<b>18.5</b>	<b>145.0</b>	<b>46.5</b>	<b>8.8</b>	<b>69.0</b>	<b>22.1</b>
SD	13.4	26.9	13.4	6.4	12.8	6.4
5% conf.	18.6	37.2	18.6	8.9	17.7	8.9
+ conf.	-0.1	107.8	27.9	-0.1	51.3	13.3
- conf.	37.1	182.2	65.1	17.7	86.8	31.0
n	2	2	2	2	2	2

## Low Dose Fish : 0.09 ppm hydrocarbons

Trials	No. Counts			% Toxicant Seawater Mixture		
	Toxicant	Seawater	Mixture	Toxicant	Seawater	Mixture
	23	185	32	9.58	77.08	13.33
	18	166	26	8.57	79.05	12.38
Mean	<b>20.5</b>	<b>175.5</b>	<b>29.0</b>	<b>9.1</b>	<b>78.1</b>	<b>12.9</b>
SD	3.5	13.4	4.2	0.7	1.4	0.7
5% conf.	4.9	18.6	5.9	1.0	1.9	0.9
+ conf.	15.6	156.9	23.1	8.1	76.1	11.9
- conf.	25.4	194.1	34.9	10.1	80.0	13.8
n	2	2	2	2	2	2

Table 21. (cont.)

## High Dose Fish : 2.45 ppm hydrocarbons

Trials	No. Counts			%		
	Toxicant	Seawater	Mixture	Toxicant	Seawater	Mixture
	15	104	61	8.33	57.78	33.89
	7	150	23	3.89	83.33	12.78
<b>Mean</b>	<b>11.0</b>	<b>127.0</b>	<b>42.0</b>	<b>6.1</b>	<b>70.6</b>	<b>23.3</b>
<b>SD</b>	5.7	32.5	26.9	3.1	18.1	14.9
<b>5% conf.</b>	7.8	45.1	37.2	4.4	25.0	20.7
+ conf.	3.2	81.9	4.8	1.8	45.5	2.6
- conf.	18.8	172.1	79.2	10.5	95.6	44.0
<b>n</b>	2	2	2	2	2	2

## High Dose Fish : 0.19 ppm hydrocarbons

Trials	No. Counts			%		
	Toxicant	Seawater	Mixture	Toxicant	Seawater	Mixture
	13	155	42	6.19	73.81	20.00
	18	148	44	8.57	70.48	20.95
<b>Mean</b>	<b>15.5</b>	<b>151.5</b>	<b>43.0</b>	<b>7.4</b>	<b>72.1</b>	<b>20.5</b>
<b>SD</b>	3.5	4.9	1.4	1.7	2.4	0.7
<b>5% conf.</b>	4.9	6.9	2.0	2.3	3.3	0.9
+ conf.	10.6	144.6	41.0	5.0	68.9	19.5
- conf.	20.4	158.4	45.0	9.7	75.4	21.4
<b>n</b>	2	2	2	2	2	2

## High Dose Fish : 0.09 ppm hydrocarbons

Trials	No. Counts			%		
	Toxicant	Seawater	Mixture	Toxicant	Seawater	Mixture
	79	91	40	37.62	43.33	19.05
	19	163	28	9.05	77.62	13.33
<b>Mean</b>	<b>49.0</b>	<b>127.0</b>	<b>34.0</b>	<b>23.3</b>	<b>60.5</b>	<b>16.2</b>
<b>SD</b>	42.4	50.9	8.5	20.2	24.2	4.0
<b>5% conf.</b>	58.8	70.6	11.8	28.0	33.6	5.6
+ conf.	-9.8	56.4	22.2	-4.7	26.9	10.6
- conf.	107.8	197.6	45.8	51.3	94.1	21.8
<b>n</b>	2	2	2	2	2	2

Table 22. Hydrocarbon avoidance by pink salmon fry (1991).

Date	Treatment Group	Toxicant Position	Hydrocarbon Conc. (ppm)	Number of Fish	Number of Observations			Percent Distribution			Significance 0.001
					Toxicant	Seawater	Mixed	Toxicant	Seawater	Mixed	
16 Apr	Control	Left	2.30	6	10	138	32	5.56	76.67	17.77	*
16 Apr	Control	Left	2.30	6	2	118	60	1.11	65.56	33.33	*
17 Apr	Control	Right	2.66	6	19	135	26	10.56	75.00	14.44	*
18 Apr	Control	Right	0.73	6	22	127	31	12.22	70.56	17.22	*
18 Apr	Control	Right	0.73	6	6	137	37	3.33	76.11	20.56	*
19 Apr	Control	Right	0.41	6	13	139	28	7.22	77.22	15.56	*
19 Apr	Control	Right	0.41	6	12	132	36	6.67	73.33	20.00	*
19 Apr	Control	-	-	6	43	100	37	23.89	55.56	20.55	ns
20 Apr	Control	-	-	7	100	65	45	47.62	30.95	21.43	ns
20 Apr	Control	Left	0.09	7	158	12	40	75.24	5.72	19.04	*
20 Apr	Control	Left	0.12	7	103	59	48	49.05	28.10	22.85	*
20 Apr	Control	Left	0.22	7	27	144	39	12.86	68.57	18.57	*
21 Apr	Control	Left	0.22	7	10	162	38	4.76	77.15	18.09	*
22 Apr	Control	Left	0.08	7	8	145	57	3.81	69.05	27.14	*
23 Apr	Control	Right	0.60	7	15	151	44	7.15	71.90	20.95	*
17 Apr	Low dose	Right	2.66	6	7	147	26	3.89	81.67	14.44	*
18 Apr	Low dose	Left	2.29	6	2	153	25	1.11	85	13.89	*
21 Apr	Low dose	Left	0.18	7	9	164	37	4.29	78.1	17.61	*
21 Apr	Low dose	Right	0.19	7	28	126	56	13.33	60	26.67	*
22 Apr	Low dose	Left	0.09	8	23	185	32	9.58	77.08	13.34	*
23 Apr	Low dose	Right	0.09	7	18	166	26	8.57	79.05	12.38	*
17 Apr	High dose	Right	2.66	6	15	104	61	8.33	57.78	33.89	*
18 Apr	High dose	Left	2.29	6	7	150	23	3.89	83.33	12.78	*
21 Apr	High dose	Left	0.18	7	13	155	42	6.19	73.81	20.00	*
21 Apr	High dose	Right	0.16	7	18	148	44	8.57	70.48	20.95	*
22 Apr	High dose	-	-	7	97	70	43	46.19	33.33	20.48	ns
22 Apr	High dose	Left	0.08	7	79	91	40	37.62	43.33	19.05	ns
23 Apr	High dose	Right	0.08	7	19	163	28	9.05	77.62	13.33	*

Table 23. Hydrocarbon avoidance statistics (1992).

Control Fish : no toxicant

Trials	No. Counts			% Toxicant Seawater Mixture		
	Toxicant	Seawater	Mixture	Toxicant	Seawater	Mixture
92	86	32		43.81	40.95	15.24
92	89	29		43.81	42.38	13.81
94	102	14		44.76	48.57	6.67
90	85	35		42.86	40.48	16.67
85	95	30		40.48	45.24	14.29
<b>Mean</b>	<b>90.6</b>	<b>91.4</b>	<b>28.0</b>	<b>43.1</b>	<b>43.5</b>	<b>13.3</b>
<b>SD</b>	3.4	7.1	8.2	1.6	3.4	3.9
<b>5% conf.</b>	2.4	4.9	5.7	1.4	3.0	3.4
<b>+ conf.</b>	88.2	86.5	22.3	41.7	40.6	9.9
<b>- conf.</b>	93.0	96.3	33.7	44.6	46.5	16.7
<b>n</b>	5	5	5	5	5	5

Control Fish : 0.12 - 0.16 ppm hydrocarbons

Trials	No. Counts			% Toxicant Seawater Mixture		
	Toxicant	Seawater	Mixture	Toxicant	Seawater	Mixture
97	89	24		46.19	42.38	11.43
54	132	24		25.71	62.86	11.43
24	160	26		11.43	76.19	12.38
<b>Mean</b>	<b>58.3</b>	<b>127.0</b>	<b>24.7</b>	<b>27.8</b>	<b>60.5</b>	<b>11.7</b>
<b>SD</b>	36.7	35.8	1.2	17.5	17.0	0.5
<b>5% conf.</b>	25.4	24.8	0.8	19.8	19.3	0.6
<b>+ conf.</b>	32.9	102.2	23.9	8.0	41.2	11.1
<b>- conf.</b>	83.8	151.8	25.5	47.5	79.7	12.4
<b>n</b>	3	3	3	3	3	3

Control Fish : 0.19 - 0.23 ppm hydrocarbons

Trials	No. Counts			% Toxicant Seawater Mixture		
	Toxicant	Seawater	Mixture	Toxicant	Seawater	Mixture
90	96	24		42.86	45.71	11.43
46	154	10		21.90	73.33	4.76
64	128	18		30.48	60.95	8.57
<b>Mean</b>	<b>66.7</b>	<b>126.0</b>	<b>17.3</b>	<b>31.7</b>	<b>60.0</b>	<b>8.3</b>
<b>SD</b>	22.1	29.1	7.0	10.5	13.8	3.3
<b>5% conf.</b>	15.3	20.1	4.9	11.9	15.7	3.8
<b>+ conf.</b>	51.3	105.9	12.5	19.8	44.3	4.5
<b>- conf.</b>	82.0	146.1	22.2	43.7	75.7	12.0
<b>n</b>	3	3	3	3	3	3

Control Fish : 0.32 ppm hydrocarbons

Trials	No. Counts			% Toxicant Seawater Mixture		
	Toxicant	Seawater	Mixture	Toxicant	Seawater	Mixture
28	169	13		13.33	80.48	6.19
<b>Mean</b>	<b>28.0</b>	<b>169.0</b>	<b>13.0</b>	<b>13.3</b>	<b>80.5</b>	<b>6.2</b>
<b>SD</b>	1	1	1	1	1	1

Table 23. (cont.)

Low Dose Fish : no toxicant

Trials	No. Counts			% Toxicant Seawater Mixture		
	Toxicant	Seawater	Mixture	43.81	48.10	8.10
	92	101	17			
Mean	<b>92.0</b>	<b>101.0</b>	<b>17.0</b>	<b>43.8</b>	<b>48.1</b>	<b>8.1</b>
SD						
5% conf.						
+ conf.						
- conf.						
n	1	1	1	1	1	1

Low Dose Fish : 0.12 -0.16 ppm hydrocarbons

	No. Counts			% Toxicant Seawater Mixture		
	Toxicant	Seawater	Mixture	38.10	46.67	15.24
	80	98	32			
	71	109	30			
	53	115	42			
Mean	<b>68.0</b>	<b>107.3</b>	<b>34.7</b>	<b>32.4</b>	<b>51.1</b>	<b>16.5</b>
SD	13.7	8.6	6.4	6.5	4.1	3.1
5% conf.	9.5	6.0	4.5	7.4	4.6	3.5
+ conf.	58.5	101.4	30.2	25.0	46.5	13.0
- conf.	77.5	113.3	39.1	39.8	55.8	20.0
n	3	3	3	3	3	3

Low Dose Fish : 0.34 ppm hydrocarbons

Trials	No. Counts			% Toxicant Seawater Mixture		
	Toxicant	Seawater	Mixture	17.43	65.15	17.43
	42	157	42			
Mean	<b>42.0</b>	<b>157.0</b>	<b>42.0</b>	<b>17.4</b>	<b>65.1</b>	<b>17.4</b>
SD						
5% conf.						
+ conf.						
- conf.						
n	1	1	1	1	1	1

Table 23. (cont.)

## High Dose Fish : no toxicant

Trials	No. Counts			% Toxicant Seawater Mixture		
	Toxicant	Seawater	Mixture	46.67	43.81	9.52
	98	92	20			
Mean	<b>98.0</b>	<b>92.0</b>	<b>20.0</b>	<b>46.7</b>	<b>43.8</b>	<b>9.5</b>
SD						
5% conf.						
+ conf.						
- conf.						
n	1	1	1	1	1	1

## High Dose Fish : 0.12 ppm hydrocarbons

Trials	No. Counts			% Toxicant Seawater Mixture		
	Toxicant	Seawater	Mixture	39.52	45.71	14.76
	83	96	31			
	94	98	18			
Mean	<b>88.5</b>	<b>97.0</b>	<b>24.5</b>	<b>42.1</b>	<b>46.2</b>	<b>11.7</b>
SD	7.8	1.4	9.2	3.7	0.7	4.4
5% conf.	5.4	1.0	6.4	5.1	0.9	6.1
+ conf.	83.1	96.0	18.1	37.0	45.3	5.6
- conf.	93.9	98.0	30.9	47.3	47.1	17.7
n	2	2	2	2	2	2

## High Dose Fish : 0.32 ppm hydrocarbons

Trials	No. Counts			% Toxicant Seawater Mixture		
	Toxicant	Seawater	Mixture	7.14	83.33	9.52
	15	175	20			
Mean	<b>15.0</b>	<b>175.0</b>	<b>20.0</b>	<b>7.1</b>	<b>83.3</b>	<b>9.5</b>
SD						
5% conf.						
+ conf.						
- conf.						
n	1	1	1	1	1	1

Table 24. Hydrocarbon avoidance by pink salmon fry (1992)

Date	Treatment Group	Toxicant Position	Hydrocarbon Conc. (ppm)	Number of Fish	Number of Observations			Percent Distribution			Chi Squared
					Toxicant	Seawater	Mixed	Toxicant	Seawater	Mixed	
28 Mar	Control	-	0.00	7	92	86	32	43.8	41.0	15.2	ns
29 Mar	Control	-	0.00	7	92	89	29	43.8	42.4	13.8	ns
30 Mar	Control	-	0.00	7	94	102	14	44.8	48.6	6.7	ns
01 Apr	Control	-	0.00	7	90	85	35	42.9	40.5	16.7	ns
01 Apr	Control	-	0.00	7	85	95	30	40.5	45.2	14.3	ns
02 Apr	Control	B	0.12	7	97	89	24	46.2	42.4	11.4	ns
30 Mar	Control	B	0.16	7	54	132	24	25.7	62.9	11.4	0.001
01 Apr	Control	A	0.13	7	24	160	26	11.4	76.2	12.4	0.001
03 Apr	Control	B	0.19	7	90	96	24	42.9	45.7	11.4	ns
03 Apr	Control	B	0.21	7	46	154	10	21.9	73.3	4.8	0.001
03 Apr	Control	B	0.23	7	64	128	18	30.5	61.0	8.6	0.001
28 Mar	Control	B	0.32	7	28	169	13	13.3	80.5	6.2	0.001
02 Apr	High Dose	-	0.00	7	98	92	20	46.7	43.8	9.5	ns
01 Apr	High Dose	A	0.12	7	83	96	31	39.5	45.7	14.8	ns
02 Apr	High Dose	B	0.12	7	94	98	18	44.8	46.7	8.6	ns
28 Mar	High Dose	B	0.32	7	15	175	20	7.1	83.3	9.5	0.001
01 Apr	Low Dose	-	0.00	7	92	101	17	43.8	48.1	8.1	ns
02 Apr	Low Dose	B	0.12	7	80	98	32	38.1	46.7	15.2	ns
30 Mar	Low Dose	B	0.16	7	71	109	30	33.8	51.9	14.3	0.01
01 Apr	Low Dose	A	0.13	7	53	115	42	25.2	54.8	20.0	0.001
29 Mar	Low Dose	A	0.34	7	42	157	42	17.4	65.1	17.4	0.001

Table 25. Materials and Dimensions of 1991 and 1992 Avoidance "Y"-mazes.  
 (See Figure 12)

Component	1991			Dimension (cm)			Material	1992			Dimension (cm)		
	Material	Length	Width *	Thickness	Length	Width *		Length	Width *	Thickness	Length	Width *	Thickness
"Y"-maze	white PVC pipe	93	15	0.5	white PVC pipe	137	15	0.5					
End walls	wood composite **	15	8	1.3	clear acrylic	15	8	0.6					
Flow diffuser	polyester wool ***			~ 3	white polystyrene (2mm pore size)	15	8	0.4					
Dividing wall	wood composite **	55		1.3	white polystyrene	90		0.4					
Toxicant flow control	Glass stopcock 3-4mm ID				Rotoflo teflon/ glass valve 1mm ID								

\* width at widest point

\*\* Oriented Strand Board (OSB) surface treated with clear silicone sealant

\*\*\* aquarium filter wool

**Table 26. 1990 WSF Extraction Column Assessment**

Experimental Condition	Substance	Concentration (mg/L)
<b>Control (Sea Water Blank) (SW header overflow) (1741h 16-Oct)</b>	Benzene	ND2
	Toluene	ND2
	Ethylbenzene	ND2
	Xylenes	ND2
	<b>Total</b>	<b>ND2</b>
<b>Tox. header inflow 2.25 L/min (from delivery tube) (1744h 16-Oct)</b>	Benzene	1.70
	Toluene	2.30
	Ethylbenzene	0.20
	Xylenes	0.97
	<b>Total</b>	<b>5.20</b>
<b>Below oil layer* 2.25 L/min. (minor particulates) (1747h 16-Oct)</b>	Benzene	1.00
	Toluene	2.00
	Ethylbenzene	ND10
	Xylenes	0.70
	<b>Total</b>	<b>3.70</b>
<b>Toxicant header 2.25 L/min. (mid-depth) (1755h 16-Oct)</b>	Benzene	1.40
	Toluene	0.74
	Ethylbenzene	0.12
	Xylenes	0.92
	<b>Total</b>	<b>3.18</b>
<b>Toxicant header 2.25 L/min. (mid-depth) (Duplicate Analysis) (1755h 16-Oct)</b>	Benzene	1.40
	Toluene	1.00
	Ethylbenzene	0.12
	Xylenes	0.72
	<b>Total</b>	<b>3.24</b>
<b>Tox. header inflow 2.25 L/min. (1756h 16-Oct)</b>	Benzene	1.30
	Toluene	0.94
	Ethylbenzene	0.27
	Xylenes	1.20
	<b>Total</b>	<b>3.71</b>
<b>Toxicant header 2.25 L/min. (1804h 16-Oct)</b>	Benzene	ND2
	Toluene	1.00
	Ethylbenzene	ND3
	Xylenes	ND2
	<b>Total</b>	<b>1.00</b>

Table 26 (cont.)

Experimental Condition	Substance	Concentration (mg/L)
<b>Control</b> (1104h 17 Oct)	Benzene	ND2
	Toluene	ND2
	Ethylbenzene	ND2
	Xylenes	ND2
	<b>Total</b>	<b>ND</b>
<b>Tox. header inflow</b> 1.95 L/min. (1106h 17 Oct)	Benzene	1.80
	Toluene	1.40
	Ethylbenzene	0.30
	Xylenes	1.50
	<b>Total</b>	<b>5.00</b>
<b>Tox. header inflow</b> 1.95 L/min. (1108h 17 Oct)	Benzene	1.80
	Toluene	2.50
	Ethylbenzene	0.22
	Xylenes	0.67
	<b>Total</b>	<b>5.19</b>
<b>Tox. header inflow</b> 2.20 L/min. (1218h 17 Oct)	Benzene	1.30
	Toluene	2.20
	Ethylbenzene	0.20
	<b>Total</b>	<b>4.23</b>
<b>Tox. header inflow</b> 2.37 L/min. (1338h 17 Oct)	Benzene	0.83
	Toluene	1.40
	Ethylbenzene	0.11
	Xylenes	0.34
	<b>Total</b>	<b>2.68</b>
<b>Benzene Sample</b> 5 uL in 530 mls SW diluted by 50% in SW expect 0.47 ppm benzene ** (1340h 17 Oct)	Benzene	0.50
	Toluene	0.24
	Ethylbenzene	ND5
	Xylenes	0.01
	<b>Total</b>	<b>0.75</b>

ND - Not Detected at lower limit indicated in ppb

\* Second sample planned for below oil layer not taken due to particulate contamination of sampling tube

\*\* Some contamination possible since volume was diluted using a plastic volumetric cylinder used to measure toxicant header flow rates

Table 27. 1991 WSF Hydrocarbon Analyses

## Trough 1- Low Dose

Date	Source	Sample ID No.	Time	Dissolved Hydrocarbons (mg/L)	(ug/L)
13 Apr	T1	C1	19:00	0.0430	43.0
14 Apr	T1A	D1	10:05	0.0565	56.5
14 Apr	T1B	D2	10:08	0.0538	53.8
14 Apr	T1A	D8	19:06	0.0980	98.0
14 Apr	T1B	D9	19:08	0.0750	75.0
15 Apr	T1A	E1	09:44	0.0450	45.0
15 Apr	T1B	E2	09:46	0.0663	66.3
15 Apr	T1A	E9	18:00	0.0116	11.6
15 Apr	T1B	E10	18:05	0.0133	13.3
16 Apr	T1A	F1	09:05	0.0427	42.7
16 Apr	T1B	F2	09:09	0.0527	52.7
16 Apr	T1A	F9	17:53	0.0556	55.6
16 Apr	T1B	F10	17:57	0.0588	58.8
17 Apr	T1A	G1	08:45	0.0629	62.9
17 Apr	T1B	G2	08:49	0.0787	78.7
17 Apr	T1A	G8	19:00	0.0583	58.3
17 Apr	T1B	G9	19:04	0.0582	58.2
18 Apr	T1A	H1	09:19	0.0322	32.2
18 Apr	T1B	H2	09:19	0.0372	37.2
18 Apr	T1A	H24	18:00	0.0440	44.0
18 Apr	T1B	H25	18:02	0.0480	48.0
18 Apr	T1CNTR	H31	23:30	0.0850	85.0
19 Apr	T1A	I1	08:44	0.0650	65.0
19 Apr	T1B	I2	08:46	0.0880	88.0
19 Apr	T1A	I9	18:17	0.0470	47.0
19 Apr	T1B	I10	18:20	0.0660	66.0
20 Apr	T1A	J2	08:50	0.0570	57.0
20 Apr	T1B	J3	08:50	0.0540	54.0
20 Apr	T1A	J9	19:35	0.0370	37.0
20 Apr	T1B	J10	19:38	0.0350	35.0
21 Apr	T1A	K1	09:40	0.0550	55.0
21 Apr	T1B	K2	09:43	0.0590	59.0
21 Apr	T1A	K9	18:47	0.0570	57.0
21 Apr	T1B	K10	18:50	0.0620	62.0
21 Apr	T1A	L1	09:55	0.0720	72.0
21 Apr	T1B	L2	09:57	0.0590	59.0
21 Apr	T1A	L8	19:00	0.0474	47.4
21 Apr	T1B	L9	19:02	0.0471	47.1
21 Apr	T1A	M1	11:00	0.0441	44.1
21 Apr	T1B	M2	11:05	0.0376	37.6
					Low Dose Mean 54.15
					S.D. 17.51

Table 27. (Cont.)

## Trough 2- High Dose

Date	Source	Sample ID No.	Time	Dissolved Hydrocarbons (mg/L)	(ug/L)
13 Apr	T2	C2	19:05	0.3100	310
14 Apr	T2A	D3	10:08	0.4100	410
14 Apr	T2B	D4	10:09	0.5240	524
14 Apr	T2A	D10	19:10	0.4950	495
14 Apr	T2B	D11	19:12	0.4300	430
15 Apr	T2A	E3	09:47	0.4320	432
15 Apr	T2B	E4	09:49	0.4530	453
15 Apr	T2A	E11	18:10	0.4140	414
15 Apr	T2B	E12	18:15	0.3920	392
16 Apr	T2A	F3	09:12	0.3549	354.9
16 Apr	T2B	F4	09:15	0.3632	363.2
16 Apr	T2A	F11	18:01	0.3540	354
16 Apr	T2B	F12	18:06	0.3498	349.8
17 Apr	T2A	G3	08:53	0.2830	283
17 Apr	T2B	G4	08:57	0.2662	266.2
17 Apr	T2A	G10	19:08	0.3080	308
17 Apr	T2B	G11	19:11	0.3030	303
18 Apr	T2A	H3	09:20	0.2730	273
18 Apr	T2B	H4	09:20	0.2570	257
18 Apr	T2A	H26	18:04	0.3070	307
18 Apr	T2B	H27	18:20	0.3210	321
18 Apr	T2CNTR	H32	23:33	0.3690	369
19 Apr	T2A	I3	08:48	0.3270	327
19 Apr	T2B	I4	08:50	0.3290	329
19 Apr	T2A	I11	18:22	0.3600	360
19 Apr	T2B	I12	18:25	0.3540	354
20 Apr	T2A	J4	08:54	0.3620	362
20 Apr	T2B	J5	08:54	0.3670	367
20 Apr	T2A	J11	19:41	0.3400	340
20 Apr	T2B	J12	19:44	0.3640	364
21 Apr	T2A	K3	09:47	0.3400	340
21 Apr	T2B	K4	09:50	0.3350	335
21 Apr	T2A	K11	18:52	0.3520	352
21 Apr	T2B	K12	18:55	0.3140	314
21 Apr	T2A	L3	10:00	0.3460	346
21 Apr	T2B	L4	10:02	0.3320	332
21 Apr	T2A	L10	19:05	0.3230	323
21 Apr	T2B	L11	19:07	0.2860	286
21 Apr	T2A	M3	11:10	0.3090	309
21 Apr	T2B	M4	11:12	0.2903	290.3
18 Apr	T2C	H13	11:34	0.2940	294
				High Dose Mean	348.62
				S.D.	58.38

Table 27. (Cont.)

## Trough 3 - Control

Date	Source	Sample ID No.	Time	Dissolved Hydrocarbons (mg/L)	Hydrocarbons (ug/L)
13 Apr	T3	C3	19:10	0.0030	3.00
14 Apr	T3A	D5	10:09	0.0090	9.00
14 Apr	T3B	D6	10:12	0.0170	17.00
14 Apr	T3A	D12	19:14	0.0025	2.50
14 Apr	T3B	D13	19:16	0.0040	4.00
15 Apr	T3A	E5	09:50	0.0090	9.00
15 Apr	T3B	E6	09:52	0.0440	44.00
15 Apr	T3A	E13	18:20	0.0008	0.80
15 Apr	T3B	E14	18:25	0.0011	1.10
16 Apr	T3A	F5	09:18	N.D.	0.00
16 Apr	T3B	F6	09:22	0.0091	9.10
16 Apr	T3A	F13	18:10	0.0088	8.80
16 Apr	T3B	F14	18:14	0.0015	1.50
17 Apr	T3A	G5	09:01	0.0310	31.00
17 Apr	T3B	G6	09:05	0.0210	21.00
17 Apr	T3A	G12	19:15	0.0041	4.10
17 Apr	T3B	G13	19:19	0.0020	2.00
18 Apr	T3A	H5	09:22	0.2390	0.00
18 Apr	T3B	H6	09:24	N.D.	0.00
18 Apr	T3A	H28	18:24	0.0340	34.00
18 Apr	T3B	H29	18:27	0.0330	33.00
19 Apr	T3A	I5	08:52	N.D.	0.00
19 Apr	T3B	I6	08:54	0.0010	1.00
19 Apr	T3A	I13	18:27	N.D.	0.00
19 Apr	T3B	I14	18:30	N.D.	0.00
20 Apr	T3A	J6	08:57	N.D.	0.00
20 Apr	T3B	J7	08:57	N.D.	0.00
20 Apr	T3A	J13	19:47	N.D.	0.00
20 Apr	T3B	J14	19:50	N.D.	0.00
21 Apr	T3A	K5	09:53	N.D.	0.00
21 Apr	T3B	K6	09:56	N.D.	0.00
21 Apr	T3A	K13	18:57	N.D.	0.00
21 Apr	T3B	K14	19:00	N.D.	0.00
21 Apr	T3A	L5	10:05	N.D.	0.00
21 Apr	T3A	L12	19:10	N.D.	0.00
21 Apr	T3B	L13	19:12	N.D.	0.00
21 Apr	T3A	M5	11:15	N.D.	0.00
21 Apr	T3B	M6	11:17	N.D.	0.00
				Control Mean	6.21
				S.D.	11.37

Table 27. (Cont.)

**Toxicant Header**

Date	Source	Sample ID No.	Time	Dissolved Hydrocarbons (mg/L)	(ug/L)
13 Apr	TOX HD	C4	19:15	8.4	8350.0
14 Apr	TOX HD	D7	10:15	3.3	3310.0
14 Apr	TOX HD	D14	19:19	7.9	7930.0
15 Apr	TOX HD	E8	09:57	6.7	6660.0
15 Apr	TOX HD	E15	18:30	7.4	7360.0
16 Apr	TOX HD	F7	09:26	7.3	7340.0
16 Apr	TOX HD	F15	18:18	7.6	7560.0
17 Apr	TOX HD	G7	09:10	13.2	13220.0
17 Apr	TOX HD	G14	19:23	8.9	8920.0
18 Apr	TOX HD	H7	09:26	7.9	7899.0
18 Apr	TOX HD	H30	18:30	7.1	7140.0
18 Apr	TOX HD	H33	23:35	7.8	7770.0
19 Apr	TOX HD	I7	08:55	7.4	7420.0
19 Apr	TOX HD	I8	18:15	8.9	8930.0
20 Apr	TOX HD	J8	09:01	9.4	9430.0
20 Apr	TOX HD	J15	19:54	8.2	8170.0
21 Apr	TOX HD	K7	10:00	8.7	8710.0
21 Apr	TOX HD	K8	18:45	8.4	8380.0
21 Apr	TOX HD	L7	10:10	8.0	7990.0
21 Apr	TOX HD	L14	19:15	8.0	7990.0
21 Apr	TOX HD	M7	11:20	7.7	7660.0

Toxicant Header Mean 8006.62  
 S.D. 1701.38

Table 28. 1992 WSF hydrocarbon analyses

Sample ID	Date	Time	Day	Aromatic Hydrocarbon Concentration *			
				Toxicant Header	High Dose	Low Dose	Control
EE1-EE4	25 Mar	1000	0.81	4.099	0.1689	0.0352	0.0012
EE6-EE9	25 Mar	1615	1.01	3.324	0.4740	0.0526	0.0322
FF1-FF4	26 Mar	800	1.61	3.652	0.2118	0.0288	0.0006
FF5-FF8	26 Mar	1800	2.11	3.786	0.2105	0.0330	0.0005
GG1-GG4	27 Mar	800	2.61	3.505	0.1632	0.0071	0.0011
GG11-GG14	27 Mar	1700	3.01	2.741	0.1858	0.0225	0.0010
HH1-HH4	28 Mar	1030	3.81	2.956	0.1631	0.0138	0.0011
HH5-HH8	28 Mar	1900	4.11	3.425	0.1769	0.0268	0.0027
II1-II4	29 Mar	1000	4.71	3.351	0.1845	0.0320	0.0019
II5-II8	29 Mar	1745	5.01	3.471	0.1587	0.0243	0.0012
JJ1-JJ4	30 Mar	1145	5.81	2.924	0.1862	0.0300	0.0009
JJ5-JJ8	30 Mar	1845	6.21	3.646	0.1866	0.0306	0.0006
KK1-KK4	31 Mar	1030	6.71	2.849	0.1577	0.0239	0.0016
KK5-KK8	31 Mar	1845	7.11	3.522	0.1958	0.0296	0.0016
LL1-LL4	01 Apr	1030	7.71	2.122	0.1074	0.0204	0.0009
LL5-LL8	01 Apr	1700	8.01	3.166	0.1588	0.0273	0.0004
MM1-MM4	02 Apr	800	8.61	2.542	0.1291	0.0174	0.0006
MM9-MM14	02 Apr	1500	9.01	2.847	0.1570	0.0135	0.0005
NN1-NN4	03 Apr	930	9.71	3.262	0.1633	0.0221	0.0002
NN5-NN8	03 Apr	1545	10.00	3.759	0.0272	0.0159	0.0001
Mean				3.2475	0.1783	0.0253	0.0025
Standard Deviation				0.4677	0.0784	0.0096	0.0068
Variance				0.2188	0.0061	0.0001	0.0000

\* excludes naphthalene

Table 29. Additional Hydrocarbon Samples (1991 data)

Date	Day	Time	Sample ID	Sample Location	Dissolved Hydrocarbons (mg/L)
21 Apr	9.8	11:25	M9	BEACH	0.0089
15 Apr	1.7	09:54	E7	BZ1.0PPM	0.5140
16 Apr	3.2	17:48	F8	BZ1.0PPM	3.5820
18 Apr	5.0	12:36	H17	BZ1.0PPM	0.4127
20 Apr	6.7	08:46	J1	BZ1.0PPM	0.1500
21 Apr	8.7	10:07	L6	BZ1.0PPM	0.4520
17 Apr	4.2	19:30	G16	HD OVFL	0.0112
17 Apr	4.2	19:27	G15	TR OUTFL	0.0746
21 Apr	9.8	11:22	M8	TR OUTFL	0.0067

Table 30. Additional hydrocarbon samples (1992 data)

Date	Time	Sample ID	Sample Description/Location	Dissolved Hydrocarbons (mg/L)
19 Mar	1125	AA1	SECONDARY TOXICANT HEADER	6.7600
20 Mar	1839	BB1	SECONDARY TOXICANT HEADER	17.3800
21 Mar	1720	CC1	SECONDARY TOXICANT HEADER	19.4500
22 Mar	1000	DD4	20 % BIOASSAY JAR	3.6290
22 Mar	1000	DD3	COLUMN OUTPUT TUBE	4.5000
22 Mar	1000	DD5	SECONDARY SEAWATER HEADER	0.6700
22 Mar	1000	DD2	SECONDARY TOXICANT HEADER	4.0170
25 Mar	1400	EE5	AVOIDANCE SAMPLE 10% TOX	0.2986
27 Mar	1630	GG5	COLUMN OUTPUT	3.7520
27 Mar	1630	GG7	MAIN SEA WATER HEADER	0.0009
27 Mar	1630	GG10	SEA WATER AND FISH FOOD	0.0009
27 Mar	1630	GG8	TAP WATER:NALGENE BOTTLE	0.0027
02 Apr	1500	MM7	BEACH/SURF ZONE	0.0307
02 Apr	1500	MM12	COLUMN OUTPUT TUBE	3.0280
02 Apr	1500	MM6	COMBINED TROUGH OUTFLOW	0.0366
02 Apr	1500	MM5	HIGH DOSE DELIVERY TUBE	2.1900
02 Apr	1500	MM11	TANK 1 HEAD	0.1570
02 Apr	1500	MM10	TANK 1 MIDDLE	0.0155
02 Apr	1500	MM8	TANK 1 TAIL	0.0920
03 Apr	1602	NN9	AVOIDANCE (5.52% WSF)	0.1280
03 Apr	1745	NN10	AVOIDANCE (6.34% WSF)	0.1594
03 Apr	1745	NN11	WHOLE CRUDE OIL 1992B	

Table 31A. Distribution of dissolved hydrocarbons  
within one trough (April 18, 1991)

Time	Sample ID	Location *	Hydrocarbons (mg/L) **
0920	H3	T2A	0.2730
1030	H8	T2A	0.2599
1130	H11	T2A	0.2970
1230	H14	T2A	0.3080
1430	H18	T2A	0.3217
1530	H21	T2A	0.2958
1804	H26	T2A	0.3070
0920	H4	T2B	0.2570
1030	H9	T2B	0.2540
1132	H12	T2B	0.2710
1232	H15	T2B	0.2970
1432	H19	T2B	0.3250
1532	H22	T2B	0.3072
1820	H27	T2B	0.3210
1034	H10	T2C	0.2513
1134	H13	T2C	0.2940
1234	H16	T2C	0.2990
1434	H20	T2C	0.2956
1534	H23	T2C	0.3016

\* Samples taken from mid-depth

\*\* Location codes      T2A = head of trough 2  
                           T2B = middle of trough 2  
                           T2C = tail of trough 2

\*\*\* Reported as total dissolved aromatic hydrocarbons  
                           excluding naphthalene

**Table 31B. Ratios of WSF hydrocarbon components**

Component	1990				1991				1992			
	Component mg/L	Total WSF mg/L	Ratio of Component:Total	Mean S.D.	Component mg/L	Total WSF mg/L	Ratio of Component:Total	Mean S.D.	Component mg/L	Total WSF mg/L	Ratio of Component:Total	Mean S.D.
Benzene	1.7	5.2	0.327	<b>0.355</b>	4.3	9.41	0.457	<b>0.422</b>	2.2	4.27	0.515	<b>0.506</b>
	1	3.7	0.270	0.058	4.5	9.44	0.477	0.030	2.1	4.46	0.471	0.018
	1.4	3.18	0.440		3.3	7.77	0.425		2.1	4.03	0.521	
	1.4	3.24	0.432		3.6	9.23	0.390		2.3	4.342	0.530	
	1.3	3.71	0.350		3.7	9.13	0.405		2	3.934	0.508	
	1.8	5	0.360		3.4	8.23	0.413		1.8	3.541	0.508	
	1.8	5.19	0.347		3.3	8.04	0.410		4	8	0.500	
	0.83	2.68	0.310		3.2	8.01	0.400		2.3	4.683	0.491	
Toluene	2.3	5.2	0.442	<b>0.383</b>	3.6	9.41	0.383	<b>0.381</b>	1.5	4.27	0.351	<b>0.385</b>
	2	3.7	0.541	0.127	3.6	9.44	0.382	0.005	1.8	4.46	0.404	0.021
	0.74	3.18	0.233		2.9	7.77	0.373		1.5	4.03	0.372	
	1	3.24	0.309		3.5	9.23	0.379		1.6	4.342	0.368	
	0.94	3.71	0.253		3.5	9.13	0.383		1.6	3.934	0.407	
	1.4	5	0.280		3.2	8.23	0.389		1.4	3.541	0.395	
	2.5	5.19	0.482		3.1	8.04	0.385		3	8	0.375	
	1.4	2.68	0.522		3	8.01	0.375		1.9	4.683	0.406	
Ethyl benzene	0.2	5.2	0.038	<b>0.041</b>	0.33	9.41	0.035	<b>0.033</b>	0.11	4.27	0.026	<b>0.021</b>
	0.001	3.7	0.000	0.021	0.27	9.44	0.029	0.004	0.11	4.46	0.025	0.003
	0.12	3.18	0.038		0.2	7.77	0.026		0.079	4.03	0.020	
	0.12	3.24	0.037		0.32	9.23	0.035		0.082	4.342	0.019	
	0.27	3.71	0.073		0.33	9.13	0.036		0.064	3.934	0.016	
	0.3	5	0.060		0.27	8.23	0.033		0.061	3.541	0.017	
	0.22	5.19	0.042		0.29	8.04	0.036		0.18	8	0.023	
	0.11	2.68	0.041		0.26	8.01	0.032		0.093	4.683	0.020	
Xylenes	0.97	5.2	0.187	<b>0.221</b>	1.1	9.405	0.117	<b>0.141</b>	0.46	4.27	0.108	<b>0.089</b>
	0.7	3.7	0.189	0.076	1	9.436	0.106	0.023	0.45	4.46	0.101	0.013
	0.92	3.18	0.289		0.91	7.77	0.117		0.35	4.03	0.087	
	0.72	3.24	0.222		1.5	9.23	0.163		0.36	4.342	0.083	
	1.2	3.71	0.323		1.4	9.13	0.153		0.27	3.934	0.069	
	1.5	5	0.300		1.3	8.23	0.158		0.28	3.541	0.079	
	0.67	5.19	0.129		1.3	8.044	0.162		0.82	8	0.103	
	0.34	2.68	0.127		1.2	8.01	0.150		0.39	4.683	0.083	
Naphthalene					0.075	9.405	0.008	<b>0.023</b>	0.074	4.27	0.017	<b>0.008</b>
					0.066	9.436	0.007	0.020	0.026	4.46	0.006	0.005
					0.46	7.77	0.059		0.021	4.03	0.005	
					0.31	9.23	0.034		0.02	4.342	0.005	
					0.2	9.13	0.022		0.023	3.934	0.006	
					0.06	8.23	0.007		0.022	3.541	0.006	
					0.054	8.044	0.007		0.049	8	0.006	
					0.35	8.01	0.044		0.066	4.683	0.014	

Table 31C. Summary of WSF components ratios (1990-1992)

Component		Ratio of individual component to total dissolved hydrocarbons reported *		
		1990 **	1991	1992
Benzene	Mean	<b>0.355</b>	<b>0.422</b>	<b>0.506</b>
	S.D.	0.058	0.030	0.018
Toluene	Mean	<b>0.383</b>	<b>0.381</b>	<b>0.385</b>
	S.D.	0.127	0.005	0.021
Ethyl benzene	Mean	<b>0.041</b>	<b>0.033</b>	<b>0.021</b>
	S.D.	0.021	0.004	0.003
Xylenes	Mean	<b>0.221</b>	<b>0.141</b>	<b>0.089</b>
	S.D.	0.076	0.023	0.013
Naphthalene	Mean	not detected	<b>0.023</b>	<b>0.008</b>
	S.D.	-	0.020	0.005

\* 8 samples from each year

\*\* retrospective analyses

Table 32. Trough temperature (1990).

Date	Time	Temperature ( °C )									
		Seawater Header	Filtered Sea Water	Toxicant Header	Trough 1		Trough 2		Trough 3		
					In	Out	In	Out	In	Out	
22-Mar	1650				8.4	8.6					
26-Mar	1645	8.5	8.9	9.2	9.0	9.2	9.0	9.2	9.0	9.2	
27-Mar	845	9.1			8.5	8.5	8.5	8.5	8.4	8.6	
27-Mar	1330	9.2			9.5	10.0	9.3	9.7	9.1	9.8	
28-Mar	830	8.5			8.4	8.6	8.5	8.5	8.4	8.6	
28-Mar	1325	9.2			9.4	10.0	9.5	10.0	9.4	9.9	
28-Mar	1800	8.6			9.0	9.2	9.1	9.2	9.0	9.2	
29-Mar	900	8.6			8.7	8.7	8.6	8.7	8.6	8.8	
29-Mar	1400	9.2			9.6	9.9	9.5	10.1	9.5	9.9	
29-Mar	1838	9.1			8.8	9.0	8.7	8.9	8.6	8.7	
30-Mar	928	9.3			8.8	9.1	8.8	8.9	8.7	8.9	
30-Mar	1330				9.2	9.5	9.2	9.5	9.2	9.5	
30-Mar	1803	8.6			8.9	9.0	8.7	8.8	8.6	8.8	
31-Mar	913	8.6			8.7	8.8	8.6	8.7	8.7	8.7	
31-Mar	1316	9.1			9.1	9.3	9.1	9.3	9.1	9.2	
31-Mar	1851	8.6			8.8	8.9	8.6	8.7	8.6	8.7	
01-Apr	954	8.6			8.7	8.8	8.6	8.7	8.6	8.7	
01-Apr	1319	9.1			9.0	9.2	9.0	9.1	8.9	9.1	
01-Apr	1930	8.7			8.9	9.1	8.8	9.0	8.7	8.9	
02-Apr	855	8.6			8.6	8.8	8.6	8.7	8.6	8.6	
02-Apr	1440	9.3			9.9	10.4	9.9	10.1	9.8	10.1	
02-Apr	1930	8.8			9.0	9.1	8.9	9.1	8.9	9.0	
03-Apr	900	8.6			8.6	8.7	8.6	8.7	8.6	8.7	
03-Apr	1509	9.2			10.0	10.4	9.8	10.1	9.8	10.1	
03-Apr	1737	9.5			9.9	10.3	9.9	10.3	9.8	10.1	
04-Apr	908	8.7			8.8	8.8	8.6	8.8	8.7	8.8	
04-Apr	1305	8.8			9.2	9.7	9.2	9.7	9.2	9.6	
04-Apr	1902	9.2			9.4	9.7	9.5	9.9	9.4	9.8	
05-Apr	917	8.8			8.8	8.8	8.9	8.9	9.0	9.1	
05-Apr	1328	8.9			9.2	9.8	9.3	9.8	9.4	9.9	
05-Apr	1923	9.2			9.2	9.5	9.3	9.6	9.2	9.5	
06-Apr	909	8.8			8.7	8.7	8.7	8.8	8.8	8.9	
06-Apr	1358	9.1			9.7	10.2	9.5	10.0	9.5	10.0	
06-Apr	2004	9.2			9.3	9.5	9.2	9.5	9.3	9.5	
07-Apr	951	9.0			8.9	9.2	8.9	9.1	9.0	9.2	
07-Apr	1454	9.6			10.7	10.9		10.5			
07-Apr	1923	9.2			9.5	9.7	9.6	9.7	9.5	9.7	
08-Apr	1232	9.1			9.2	9.6	9.3	9.4	9.2	9.4	
08-Apr	2011	9.1			9.1	9.2	9.1	9.2	9.1	9.2	
09-Apr	1153	9.6	9.6	10.1	9.5	9.6	9.5	9.7	9.5	9.7	
10-Apr	900	9.1	9.2	9.4	9.1	9.2	9.1	9.2	9.1	9.2	
10-Apr	1835	9.2	9.3	10.0	9.4	9.6	9.4	9.6	9.4	9.6	
11-Apr	845	9.2	9.2	9.4	9.2	9.2	9.2	9.2	9.1	9.2	
11-Apr	1825	9.2	9.2		9.3	9.4	9.3	9.4	9.3	9.4	
12-Apr	1225	9.7	9.6	10.4	9.8	10.2	9.9	10.1	9.9	10.1	
12-Apr	1830	9.3	9.2	9.7	9.4	9.5	9.3	9.5	9.3	9.4	
13-Apr	915	9.2	9.2	9.3	9.2	9.2	9.2	9.2	9.2	9.2	
13-Apr	1720	9.3	9.2	9.5	9.3	9.4	9.3	9.4	9.3	9.4	
14-Apr	1422		9.7		10.4	10.8	10.2	10.9	10.2	10.7	
14-Apr	1805	10.1	9.5	11.3	10.0	10.3	10.1	10.5	10.0	10.5	
15-Apr	1039	9.5	9.5	10.0	9.6	9.7	9.6	9.7	9.6	9.8	
16-Apr	1209	10.0	9.8	10.9	10.0	10.1	9.9	10.1	9.9	10.2	
16-Apr	1920	9.7	9.6	10.7	9.8	10.0	9.9	10.0	9.7	10.1	
17-Apr	1615	10.5	10.5	11.9	11.0	11.3	10.8	11.2	10.9	11.3	
17-Apr	1920	9.8	9.8	10.8	10.1	10.3	10.1	10.3	10.1	10.3	

Table 32. (Cont.)

Date	Time	Temperature ( °C )												
		Seawater			Filtered		Toxicant		Trough 1		Trough 2		Trough 3	
		Header	Sea Water	Header	In	Out	In	Out	In	Out	In	Out		
18-Apr	1103	9.8	10.0	10.4	9.9	10.0	10.0	10.1	9.9	10.1				
18-Apr	1952	9.7	9.9	10.2	9.8	9.9	9.9	9.9	9.8	9.9				
19-Apr	1200	9.5	9.6	9.8	9.5	9.5	9.5	9.5	9.5	9.5				
20-Apr	1345	9.8	9.8	10.7	10.2	10.5	10.1	10.7	10.2	9.8				
20-Apr	2313		9.6		9.4	9.5	9.4	9.5	9.4	9.4				
21-Apr	1500		9.7	10.1	9.7	9.8	9.7	9.8	9.7	9.8				
23-Apr	2040		10.1		9.8	9.7	9.8	9.7	9.8	9.6				

Table 33. Trough temperature (1991)

Date	Time	Sea Water	Temperature ( ° C )					
			Trough 1		Trough 2		Trough 3	
			Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
27-Mar	PM			10.0		10.0		10.5
28-Mar	AM	8.7	9.0	9.1	9.0	9.1	9.0	9.1
28-Mar	PM	9.7	9.0	8.9	8.6	8.8	8.5	8.5
29-Mar	AM	9.6	8.9	8.7	8.5	8.7	8.5	8.4
29-Mar	PM	8.4	8.3	8.3	8.3	8.3	8.3	8.2
30-Mar	AM	8.5	8.5	8.5	8.8	9.1	8.5	8.5
30-Mar	PM	9.1	8.8	8.9	8.8	8.9	8.8	8.8
31-Mar	AM	9.0	8.7	8.6	8.5	8.5	8.5	8.4
31-Mar	PM	9.2	8.7	8.7	8.6	8.7	8.6	8.5
01-Apr	AM	9.6	9.0	8.9	8.8	8.9	8.7	8.8
01-Apr	PM		8.7	8.7	8.6	8.7	8.6	8.6
02-Apr	PM	9.0	8.7	8.6	8.5	8.5	8.5	8.4
03-Apr	PM	9.1	8.7	8.5	8.4	8.5	8.5	8.6
04-Apr	AM	9.1	8.6	8.6	8.6	8.7	8.6	8.7
04-Apr	PM	8.7	8.5	8.5	8.3	8.3	8.3	8.3
05-Apr	AM	9.2	8.6	8.8	8.6	8.8	8.6	8.8
05-Apr	PM	9.0	8.8	8.8	8.6	8.8	8.5	8.7
06-Apr	AM	8.9	8.7	8.7	8.7	8.7	8.7	8.7
06-Apr	PM	9.2	8.5	8.5	8.4	8.4	8.4	8.4
07-Apr	AM	9.2	8.6	8.4	8.4	8.3	8.4	8.3
07-Apr	PM	9.4	8.7	8.7	8.7	8.8	8.6	8.8
08-Apr	AM	8.7	8.7	9.0	8.7	9.0	8.7	9.0
08-Apr	PM	8.7	8.3	8.2	8.2	8.2	8.2	8.2
09-Apr	PM	9.2	8.5	8.5	8.5	8.5	8.4	8.5
10-Apr	AM		9.0	9.1	9.0	9.1	9.0	9.1
10-Apr	PM	9.4	9.0	8.7	8.6	8.8	8.5	8.7
11-Apr	PM	9.4	9.7	10.5	9.7	10.5	9.7	10.8
11-Apr	PM	9.3	8.8	8.9	8.8	9.0	8.7	8.8
12-Apr	PM	9.1	9.5	10.1	9.2	10.2	9.0	10.1
13-Apr	AM	8.8	8.7	8.7	8.7	8.8	8.6	8.8
13-Apr	PM	8.7	8.7	8.8	8.7	8.8	8.7	8.7
14-Apr	AM	9.0	8.9	9.0	9.0	9.0	8.9	9.0
14-Apr	PM		9.0	9.2	9.1	9.4	9.0	9.2
15-Apr	AM	9.0	8.9	9.0	8.9	9.0	8.8	9.1
15-Apr	PM	9.0	9.0	9.2	9.1	9.5	9.0	9.3
16-Apr	AM	9.0	9.1	9.2	9.0	9.3	9.1	9.3
17-Apr	AM	9.0	9.0	9.1	9.0	9.1	9.0	9.1
17-Apr	PM		9.9	10.2	9.9	10.3	10.2	10.5
18-Apr	AM	9.1	9.1	9.3	9.2	9.4	9.1	9.4
18-Apr	PM	9.1	9.2	9.4	9.1	9.4	9.0	9.3
19-Apr	AM	9.0	9.0	9.0	9.0	9.1	9.0	9.0
19-Apr	PM	9.4	9.6	9.8	9.5	9.9	9.4	9.8
20-Apr	AM	9.0	9.0	9.2	9.0	9.2	9.0	9.2
20-Apr	PM	9.8	9.8	10.2	9.7	10.2	9.6	10.1
21-Apr	AM	9.2	9.2	9.4	9.1	9.4	9.1	9.4
21-Apr	PM	9.4	9.4	9.5	9.4	9.6	9.3	9.6
22-Apr	AM	9.0	9.0	9.0	9.0	9.0	9.0	9.0
22-Apr	PM		9.3	9.5	9.3	9.5	9.3	9.4
23-Apr	AM	9.2	9.1	9.2	9.1	9.3	9.1	

Table 34. Trough temperature (1992)

Date	Time	Temperature (° C)							
		Sea Water	WSF Header	Trough 1		Trough 2		Trough 3	
		Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
06 Mar	0920	7.7	8.1	7.9	8.2	7.9	8.2	7.9	8.4
06 Mar	1658	7.8	8.3	8.0	8.2	8.0	8.3	8.0	8.3
07 Mar	0939	7.7	7.8	7.8	7.9	7.8	7.9	7.8	8.0
07 Mar	1715	7.8	8.6	8.0	8.1	8.0	8.2	8.1	8.2
08 Mar	1130	7.8	7.8	8.0	8.1	8.0	8.1	8.0	8.1
08 Mar	1721	7.9	8.8	8.3	8.9	8.4	8.0	8.3	8.9
09 Mar	0840	7.9	7.8	7.8	7.9	7.9	8.3	7.9	8.0
09 Mar	1730	7.9	8.9	8.1	8.3	8.2	8.1	8.1	8.3
10 Mar	1830	8.2	7.8	8.1	8.1	8.1	8.8	8.1	8.2
11 Mar	0918	7.9	7.8	7.9	7.9	8.0	8.0	7.9	8.0
11 Mar	1800	8.0	7.9	8.0	8.0	8.0	8.2	8.0	8.0
12 Mar	1012	7.9	8.2	8.2	8.5	8.3	8.4	8.2	8.4
13 Mar	0919	7.9	8.1	8.1	8.3	8.2	8.4	8.2	8.4
13 Mar	1817	8.0	8.4	8.3	8.2	8.2	8.3	8.2	8.3
14 Mar	0942	7.9	8.3	8.2	8.3	8.2	8.6	8.3	8.5
15 Mar	1051	7.9	8.2	8.2	8.3	8.2	8.4	8.2	8.4
16 Mar	1002	8.1	8.3	8.2	8.3	8.2	8.3	8.2	8.3
16 Mar	1648	8.1	-	8.4	8.5	8.4	8.5	8.4	8.5
17 Mar	0944	8.3	-	8.6	8.9	8.5	8.7	8.5	8.7
17 Mar	1700	8.3	-	8.5	8.6	8.4	8.5	8.4	8.5
18 Mar	0933	8.3	-	8.4	8.4	8.4	8.6	8.4	8.6
18 Mar	1730	8.2	-	8.4	8.5	8.3	8.4	8.3	8.4
19 Mar	1103	8.4	-	8.7	9.3	8.8	9.3	8.7	9.0
20 Mar	0946	8.4	-	8.5	8.7	8.5	8.8	8.6	8.8
20 Mar	1700	-	-	8.4	8.5	8.4	8.5	8.4	8.5
21 Mar	1014	8.4	8.7	8.6	8.7	8.6	8.9	8.6	8.9
21 Mar	1630	8.4	-	8.7	9.0	8.7	8.9	8.6	8.9
22 Mar	1033	8.6	8.9	8.7	8.9	8.8	9.0	8.8	9.0
22 Mar	1613	-	-	9.0	9.2	9.0	9.3	9.4	9.5
23 Mar	1020	8.4	8.7	8.5	8.7	8.5	8.8	8.6	8.9
23 Mar	1735	8.4	9.0	8.6	8.9	8.6	8.9	8.4	8.8
24 Mar	1020	8.5	8.8	8.5	8.8	8.6	8.8	8.7	8.7
25 Mar	1040	8.6	8.9	8.8	9.0	8.8	9.0	8.9	9.1
25 Mar	1850	8.5	9.3	8.8	9.1	8.7	8.9	8.8	9.1
26 Mar	1030	8.6	8.8	8.9	8.7	8.8	9.1	9.0	9.0
26 Mar	1830	8.8	8.2	8.6	8.6	8.8	8.6	8.6	8.6
27 Mar	1030	8.6	8.5	8.7	9.0	8.7	8.8	8.8	8.9
27 Mar	1900	8.6	-	8.5	8.4	8.5	8.6	8.5	8.6
28 Mar	1110	8.5	8.6	8.8	8.9	8.8	9.0	8.8	8.9
28 Mar	1800	8.6	9.4	8.8	9.0	8.8	9.2	8.8	9.1
29 Mar	1045	8.6	8.9	9.0	9.1	9.0	9.1	9.0	9.1
29 Mar	1800	8.5	9.0	8.6	8.8	8.7	8.7	8.9	8.8
30 Mar	1140	8.6	9.2	8.8	9.1	8.7	9.1	8.7	9.1
30 Mar	1840	8.7	9.1	8.9	9.2	8.7	9.1	8.8	8.8
31 Mar	1740	8.7	9.6	9.0	9.5	8.9	9.5	8.9	9.4
01 Apr	1640	*9.7	*10.4	*9.4	*9.8	*9.3	*9.8	*9.4	*10.0
02 Apr	0950	*9.3	*9.6	*9.5	*9.7	*9.5	*9.6	*9.4	*9.5
02 Apr	1830	*9.1	*10.0	*9.1	*9.3	*9.1	*9.4	*9.2	*9.4
03 Apr	1030	*9.0	-	*9.5	*9.8	*9.4	*9.7	*9.4	*9.7

- No data

\* Data unreliable due to instrument failure

Table 35A. Trough dissolved oxygen (1990)

Date	Time	Dissolved Oxygen (mg/L)					
		Seawater		Filtered		Toxicant	
		Header	Sea Water	Header		In	Out
22-Mar	1650					8.8	8.6
26-Mar	1645	8.3				8.4	8.2
27-Mar	845	8.2				8.9	8.7
27-Mar	1330	7.1				7.9	8.0
28-Mar	830	8.3				9.0	8.7
28-Mar	1325	7.3				7.7	7.5
28-Mar	1800	7.7				7.6	7.4
29-Mar	900	7.6				7.8	7.4
29-Mar	1400	7.8				7.5	7.2
29-Mar	1838	8.3				8.0	7.7
30-Mar	928	8.3				8.2	7.7
30-Mar	1330					7.8	7.4
30-Mar	1803	7.8				7.7	7.3
31-Mar	913	7.0				7.0	6.7
31-Mar	1316	8.1				7.2	6.8
31-Mar	1851	7.2				7.0	6.6
01-Apr	954	7.2				7.2	6.9
01-Apr	1319	7.2				7.1	6.8
01-Apr	1930	7.5				7.1	6.7
02-Apr	855	7.4				7.2	6.8
02-Apr	1440	8.3				7.8	7.5
02-Apr	1930	7.2				6.9	6.7
03-Apr	900	7.1				7.1	6.5
03-Apr	1509	7.7				7.2	6.5
03-Apr	1737	8.5				7.4	7.0
04-Apr	908	7.3				7.3	6.7
04-Apr	1305	7.5				6.7	6.5
04-Apr	1902	8.2				7.2	6.7
05-Apr	917	8.2				7.8	7.2
05-Apr	1328	7.8				7.3	6.5
05-Apr	1923	8.4				7.6	6.5
06-Apr	909	8.0				7.5	6.5
06-Apr	1358	7.8				7.3	6.8
06-Apr	2004	7.7				7.3	6.6
07-Apr	951	8.1				7.5	6.5
07-Apr	1454	8.0				7.3	
07-Apr	1923	7.7				7.1	6.1
08-Apr	1232	7.3				7.4	6.7
08-Apr	2011	7.5				7.3	6.6
09-Apr	1153	7.8	7.6	8.1		7.3	6.7
10-Apr	900	6.9	7.2	7.7		6.8	6.1
10-Apr	1835	8.1	7.5	8.1		7.1	6.0

Table 35A. (Cont.)

Date	Time	Dissolved Oxygen (mg/L)												
		Seawater			Filtered		Toxicant		Trough 1		Trough 2		Trough 3	
		Header	Sea	Water	Header			In	Out	In	Out	In	Out	
11-Apr	845	8.1	7.6	8.4		7.4	6.9	7.2	6.6	7.4	6.5			
11-Apr	1825	9.4	9.3			8.3	7.3	8.0	7.0	8.3	7.3			
12-Apr	1225	8.9	8.8	8.6		8.0	7.1	7.7	7.0	7.8	7.1			
12-Apr	1830	9.7	9.7	9.4		8.3	7.5	8.5	7.5	8.7	7.9			
13-Apr	915	9.4	9.2	9.0		8.1	7.6	8.1	7.5	8.2	7.5			
13-Apr	1720	10.2	9.7	9.5		8.2	6.8	8.1	7.2	8.6	7.5			
14-Apr	1422		9.3			7.3	6.2	7.9	6.2	8.1	6.8			
14-Apr	1805	9.8	9.4	8.8		7.9	7.2	8.2	7.1	8.3	7.1			
15-Apr	1039	9.4	9.3	9.1		7.9	7.5	8.3	7.4	8.3	7.2			
16-Apr	1209	9.9	9.9	9.7		8.1	7.5	8.5	7.6	8.5	7.1			
16-Apr	1920	9.8	9.7	9.4		7.9	7.1	8.2	7.4	8.5	6.7			
17-Apr	1615	10.2	10.1	9.6		7.8	7.3	8.3	7.4	8.1	7.2			
17-Apr	1920	10.0	9.9	9.5		7.7	6.9	8.1	7.0	8.2	6.9			
18-Apr	1103	9.6	9.8	9.2		7.8	6.7	7.7	6.9	8.1	6.6			
18-Apr	1952	9.5	9.4	9.0		7.2	6.4	7.7	5.9	8.1	6.0			
19-Apr	1200	10.0	9.7	9.1		7.3	6.6	7.7	6.4	8.1	6.6			
20-Apr	1345	9.8	10.0	9.6		7.3	6.4	8.1	6.2	8.2	6.9			
20-Apr	2313		9.5			8.1	7.0	8.0	7.2	8.3	7.4			
21-Apr	1500		9.4	8.8		7.2	6.3	7.6	6.3	8.0	6.4			
23-Apr	2040		8.9			7.6	6.0	7.3	6.1	7.5	6.5			

Table 35B. Trough dissolved oxygen saturation (1990)

Trough Day	Dissolved Oxygen (mg/L)			Temperature (° C)			Sea Water Salinity (g/L)	Oxygen Saturation (mg/L)	% Oxygen Saturation		
	2 High	3 Low	1 Control	2 High	3 Low	1 Control			2 High	3 Low	1 Control
1											
2	8.3	8.3	8.3	9.1	9.1	9.1	29.7	9.6	86.3	86.3	86.8
3	8.1	8.0	8.0	9.5	9.5	9.8	29.3	9.5	85.1	84.6	84.0
4	7.7	7.7	7.6	9.8	9.7	9.7	29.3	9.5	80.9	80.9	80.3
5	7.3	7.5	7.4	9.8	9.7	9.8	29.3	9.4	78.1	80.2	78.6
6	7.6	7.7	7.6	8.8	8.7	9.0	29.8	9.5	79.7	80.3	79.7
7	7.2	7.5	7.0	9.2	9.2	9.2	29.8	9.5	75.0	78.2	73.5
8	7.1	7.4	7.0	9.1	9.0	9.1	29.9	9.5	74.0	77.6	72.9
9	7.7	8.0	7.7	10.0	10.0	10.2	29.9	9.3	82.6	85.8	82.1
10	6.9	7.1	6.9	10.0	10.0	10.2	29.9	9.3	73.5	75.6	73.5
11	6.7	7.0	6.6	9.5	9.4	9.5	29.9	9.4	71.0	73.7	70.0
12	6.9	7.3	6.9	9.6	9.7	9.5	29.6	9.5	72.9	76.6	72.9
13	6.8	7.1	7.1	9.8	9.8	10.0	29.7	9.4	72.6	75.3	75.3
14			7.3	10.5		10.8	29.5	9.3			78.9
15	6.7	6.7	7.1	9.4	9.3	9.4	29.8	9.4	71.0	71.0	74.8
16	6.8	6.8	7.0	9.6	9.6	9.6	29.8	9.4	71.6	72.1	73.7
17	6.8	6.9	7.0	9.5	9.5	9.5	29.8	9.4	71.6	72.6	74.2
18	6.4	6.6	6.8	9.4	9.4	9.4	29.8	9.4	67.9	70.0	72.1
19	7.4	7.5	7.6	10.0	10.0	10.0	29.8	9.3	78.9	79.9	81.0
20	8.0	8.3	7.9	9.4	9.4	9.4	29.8	9.4	84.8	88.0	83.8
21	7.1	7.5	6.8	10.6	10.5	10.6	29.8	9.2	76.5	80.8	73.2
22	7.7	7.7	7.6	9.7	9.7	9.7	29.9	9.4	81.1	81.7	80.1
23	8.1	7.8	7.8	10.0	10.1	10.1	29.9	9.3	86.4	83.7	83.7
24	7.9	7.7	7.6	11.0	11.1	11.2	29.9	9.1	86.1	83.9	82.8
25	7.3	7.4	7.3	9.9	9.9	9.9	29.6	9.3	78.3	78.9	77.8
26	6.8	7.1	6.8	9.5	9.5	9.5	29.8	9.4	72.1	74.8	72.1
27	7.2	7.6	6.9	10.4	10.0	10.4	29.8	9.3	76.7	81.0	73.5
28	7.6	7.9	7.6	9.8	9.8	9.8	29.8	9.3	81.5	84.2	81.0
29	7.0	7.2	6.8	9.8	9.8	9.8	29.8	9.3	74.7	77.4	72.6
30	6.7	7.0	6.8	9.8	9.7	9.8	29.8	9.3	71.9	75.1	73.0

Table 36A. Trough dissolved oxygen (1991)

Date	Time	Dissolved Oxygen (mg/L)							
		Sea Water Header	Toxicant Header	Trough 1		Trough 2		Trough 3	
				Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
29-Mar	17:41	9.8		9.8	9.8	9.9	9.8	10.0	9.9
03-Apr	10:30	9.1		8.9	8.9	9.0	8.8	8.9	8.8
03-Apr	19:00	9.3		9.1	8.9	8.9	8.8	9.0	8.8
04-Apr	09:40	9.3		9.1	8.9	9.0	8.7	9.0	8.7
04-Apr	12:30	9.2		9.0	8.7	8.9	8.6	9.0	8.5
05-Apr	09:25	9.6		9.4	9.1	9.2	8.8	9.2	8.8
05-Apr	18:20	9.4		9.0	8.6	8.9	8.5	8.8	8.4
06-Apr	09:00	9.4		9.1	8.6	9.1	8.3	8.9	8.3
06-Apr	18:00	9.4		9.1	8.7	8.9	8.4	9.0	8.4
07-Apr	09:00	9.4		9.1	8.6	9.1	8.2	9.0	8.2
07-Apr	19:00	9.6		9.1	8.6	9.1	8.5	9.1	8.3
08-Apr	10:30	9.4		9.0	8.5	8.8	8.3	8.9	8.3
08-Apr	18:15	9.4		9.0	8.2	9.0	8.1	9.0	7.9
09-Apr	09:15	9.7		5.1	5.0	5.7	4.7	5.0	4.8
09-Apr	10:00	9.7		8.6	7.5	7.1	8.3	8.2	7.0
09-Apr	11:30	9.7		9.0	8.6	9.0	8.5	9.0	8.3
09-Apr	17:45	9.5	9.1	8.8	8.4	8.7	7.8	8.7	8.0
10-Apr	11:40	9.4	9.1	8.6	8.2	8.6	8.0	8.6	7.9
10-Apr	07:40	9.6	9.1	8.9	8.4	8.8	7.8	8.7	7.7
11-Apr	10:40	9.5	9.3	9.0	8.7	8.7	8.6	8.7	8.5
11-Apr	19:20	9.5		8.7	8.1	8.8	7.7	8.7	7.7
12-Apr	09:30	9.5	9.2	8.6	8.1	8.7	7.4	8.7	7.6
12-Apr	06:30	9.4		8.6	8.2	8.5	7.4	8.7	7.4
13-Apr	09:00	9.4	9.0	8.6	8.0	8.6	7.4	8.4	7.4
13-Apr	18:50	9.4	9.0	8.7	7.8	8.5	6.8	8.3	6.9
14-Apr	10:30	9.3	9.0	8.5	7.8	8.4	7.5	8.2	7.3
14-Apr	07:30	9.3	9.0	8.4	7.6	8.3	6.9	8.3	6.9
15-Apr	09:47	9.4	9.0	8.4	7.9	8.3	7.9	8.2	7.5
15-Apr	07:12	9.3	9.1	8.1	7.6	8.2	6.9	8.1	7.1
16-Apr	09:38	9.3	8.9	8.4	7.8	8.3	7.2	8.2	7.2
16-Apr	18:51	9.2	8.9	8.1	7.4	7.8	6.7	7.8	6.6
17-Apr	09:35	9.3	8.9	8.1	7.6	8.2	7.2	8.1	6.8
17-Apr	16:49	9.2		8.2	7.2	8.3	6.6	7.8	6.6
18-Apr	10:01	9.3	8.9	8.3	7.7	8.2	7.2	8.1	6.9
18-Apr	19:21	9.2		8.1	7.3	7.9	6.6	7.9	5.9
19-Apr	09:05	9.3	8.7	8.2	7.4	8.2	7.1	8.1	6.8
19-Apr	18:21	9.2	8.7	7.7	6.9	8.2	5.9	7.8	5.9
20-Apr	09:12	9.3	6.6	8.1	7.5	8.1	6.9	7.8	6.6
20-Apr	18:43	9.2	8.5	7.8	6.9	8.5	6.1	7.9	5.8
21-Apr	10:10	9.2	8.5	7.8	6.8	8.2	5.7	8.1	5.3
21-Apr	19:10	9.2	8.5	7.8	6.8	8.2	5.7	8.1	5.3
21-Apr	23:30				7.5		6.7		7.3
22-Apr	10:34	9.3	8.6	7.8	6.9	8.1	6.1	8.2	5.9
22-Apr	18:52	9.2	8.4	7.4	7.1	8.0	6.0	7.7	6.0
23-Apr	10:46	9.1	8.4	8.1	6.6	7.8	5.9	7.7	5.3

Table 36B. Trough dissolved oxygen saturation (1991)

Trough Day	Dissolved Oxygen (mg/L)			Temperature (° C)			Sea Water Salinity (g/L)	Oxygen Saturation (mg/L)	% Oxygen Saturation		
	2 High	1 Low	3 Control	2 High	1 Low	3 Control			2 High	1 Low	3 Control
1											
2											
3				10.0	10.0	10.5					
4				8.7	9.0	8.5					
5	9.9	9.8	10.0	8.3	8.3	8.3	29.0	9.7	101.5	101.0	102.6
6				8.9	8.9	8.8	29.4	9.6			
7				8.7	8.7	8.6	29.3	9.7			
8				8.9	9.0	8.8	29.0	9.6			
9				8.5	8.7	8.5	28.3	9.7			
10	8.9	9.0	8.9	8.5	8.6	8.6	29.0	9.7	91.2	92.8	91.8
11	8.8	8.9	8.8	8.3	8.5	8.3	28.9	9.7	90.2	91.2	90.2
12	8.7	8.8	8.6	8.7	8.8	8.6	29.0	9.7	89.7	90.7	88.7
13	8.7	8.9	8.7	8.4	8.5	8.4	28.9	9.7	89.2	91.8	89.7
14	8.8	8.9	8.7	8.8	8.7	8.7	28.7	9.7	90.4	91.0	89.4
15	8.6	8.6	8.5	8.2	8.3	8.2	29.0	9.8	87.2	87.7	86.1
16	8.3	8.6	8.4	8.5	8.5	8.5	28.5	9.7	84.8	88.4	85.8
17	8.3	8.4	8.3	8.7	8.9	8.6	29.1	9.7	85.6	86.6	85.1
18	8.3	8.4	8.2	10.1	10.1	10.3	29.2	9.4	88.0	89.6	87.4
19	8.0	8.4	8.1	9.7	9.8	9.6	29.2	9.5	83.8	88.5	84.8
20	7.7	8.3	7.6	8.8	8.8	8.7	29.5	9.6	80.0	86.3	79.5
21	8.0	8.2	7.8	9.0	9.0	9.0	29.3	9.6	83.2	85.3	81.1
22	7.6	7.9	7.6	9.3	9.1	9.2	29.4	9.6	79.0	82.1	79.5
23	7.3	7.8	7.2	9.2	9.2	9.2	29.5	9.6	75.8	81.1	75.3
24	7.5	7.7	7.2	9.1	9.1	9.1	29.6	9.6	77.9	80.5	75.3
25	7.3	7.7	6.9	9.3	9.3	9.2	29.4	9.6	75.8	80.5	72.2
26	7.1	7.3	6.9	9.7	9.7	9.6	29.2	9.5	74.3	76.9	72.2
27	7.3	7.4	6.9	10.0	10.0	9.9	29.1	9.4	77.8	78.4	73.0
28	7.0	7.3	6.7	9.5	9.5	9.5	29.3	9.5	73.5	77.2	70.8
29	7.0	7.3	6.9	9.0	9.0	9.0	29.4	9.6	73.2	75.8	71.7
30	6.9	7.4	6.5	9.2	9.2	9.1	29.5	9.6	71.7	76.9	68.0

Table 37A. Trough dissolved oxygen (1992)

Date	Time	Sea Water	Toxicant	Dissolved Oxygen (mg/L)							
				Trough 1		Trough 2		Trough 3		Inlet	Outlet
				Inlet	Outlet	Inlet	Outlet	Inlet	Outlet		
06 Mar	0920	9.9	9.3	9.7	9.7	9.7	9.7	9.7	9.6		
06 Mar	1658	9.5	9.1	9.6	9.6	9.5	9.5	9.7	9.6		
07 Mar	0939	9.7	9.2	9.7	9.6	9.6	9.6	9.6	9.6		
07 Mar	1715	10.0	8.9	9.6	9.5	9.3	9.4	9.6	9.5		
08 Mar	1130	10.1	8.9	9.9	9.6	9.7	9.7	9.7	9.5		
08 Mar	1721	9.4	9.0	9.2	9.2	9.2	9.2	9.2	9.2		
09 Mar	0840	9.6	9.4	9.5	9.5	9.5	9.4	9.5	9.4		
09 Mar	1730	9.5	8.6	9.2	9.0	9.2	9.0	9.2	9.1		
10 Mar	1830	9.6	9.1	9.2	9.0	9.1	8.9	9.2	8.2		
11 Mar	0918	9.7	9.2	9.6	9.4	9.5	9.3	9.7	9.3		
11 Mar	1800	9.7	9.1	9.4	9.1	9.4	9.1	9.5	9.0		
12 Mar	1012	9.9	9.2	9.2	9.1	9.3	9.1	9.3	9.2		
13 Mar	0919	9.8	9.0	9.2	9.0	9.2	8.8	9.2	9.0		
13 Mar	1817	9.8	8.8	8.9	8.8	9.1	8.8	9.2	8.8		
14 Mar	0942	10.0	9.1	9.1	9.0	9.1	8.7	9.1	8.9		
15 Mar	1051	9.9	8.8	9.1	8.6	9.0	8.5	9.1	8.4		
16 Mar	1002	10.1	9.2	9.1	8.5	8.9	8.4	9.2	8.5		
16 Mar	1648	10.1		9.2	8.6	9.1	8.5	9.3	8.6		
17 Mar	0944	9.9		9.0	8.5	8.8	8.4	9.0	8.4		
17 Mar	1700	10.0		9.1	8.2	9.0	8.1	9.0	8.2		
18 Mar	0933	9.9		9.1	8.6	9.0	8.5	8.9	8.5		
18 Mar	1730	9.8		8.9	8.0	8.9	7.8	8.9	7.8		
19 Mar	1103	9.7		8.7	8.3	8.7	7.8	8.6	8.3		
20 Mar	0946	9.8		8.8	8.0	8.8	7.7	9.0	8.0		
20 Mar	1700			8.7	7.5	8.4	7.4	8.6	7.4		
21 Mar	1014	9.7	9.1	8.5	7.8	8.6	7.3	8.6	7.4		
21 Mar	1630	9.7		8.6	7.8	8.4	7.5	8.3	7.4		
22 Mar	1033	9.7	9.1	8.4	7.9	8.3	7.7	8.4	7.9		
22 Mar	1613			8.1	7.4	8.1	7.5	8.3	7.7		
23 Mar	1020	9.7	9.0	8.7	7.4	8.7	7.1	8.7	7.3		
23 Mar	1735	9.7	9.0	8.8	7.4	8.5	7.1	8.6	7.7		
24 Mar	1020	9.8	9.8	8.7	7.0	8.6	6.9	8.5	7.2		
25 Mar	1040	9.7	9.2	8.6	7.2	8.4	6.9	8.4	7.2		
25 Mar	1850	9.6	8.6	7.8	7.1	7.8	6.7	8.0	6.6		
26 Mar	1030	9.8	9.0	8.2	7.3	8.3	6.9	8.1	7.3		
26 Mar	1830	9.7	9.0	7.7	7.4	8.4	6.3	7.9	7.3		
27 Mar	1030	9.6	9.0	8.2	6.6	8.2	6.8	8.1	6.9		
27 Mar	1900	9.6		7.5	6.9	7.7	7.0	7.9	7.2		
28 Mar	1110	9.6	9.0	8.0	7.3	7.8	6.8	8.0	7.1		
28 Mar	1800	9.5	9.1	8.6	7.0	8.3	6.7	8.1	7.1		
29 Mar	1045	9.6	9.2	8.4	7.2	8.5	6.6	8.3	7.1		
29 Mar	1800	9.6	8.5	7.8	6.9	8.1	6.6	8.5	6.6		
30 Mar	1140	9.6	8.7	8.2	6.7	8.4	6.4	8.4	6.8		
30 Mar	1840	9.5	8.6	8.7	7.0	8.4	6.8	8.0	6.7		
31 Mar	1100	9.9	9.3	8.6	7	8.3	6.3	8.5	6.7		
31 Mar	1740	9.7	9.1	8.9	7.1	8.2	6.5	8.0	6.8		
01 Apr	1640	*9.7	*10.4	*9.4	*9.8	*9.3	*9.8	*9.4	*10.0		
02 Apr	0950	*9.3	*9.6	*9.5	*9.7	*9.5	*9.6	*9.4	*9.5		
02 Apr	1830	*9.1	*10.0	*9.1	*9.3	*9.1	*9.4	*9.2	*9.4		
03 Apr	1030	*9.0	-	*9.5	*9.8	*9.4	*9.7	*9.4	*9.7		

- no data

\* data unreliable due to instrument failure

Table 37B. Trough dissolved oxygen saturation (1992)

Trough Day	Dissolved Oxygen (mg/L)			Temperature ( ° C)			Sea Water Salinity (g/L)	Oxygen Saturation (mg/L)	% Oxygen Saturation		
	1 High	3 Low	2 Control	1 High	3 Low	2 Control			1 High	3 Low	2 Control
1											
2	9.6	9.7	9.5	8.1	8.2	8.2	28.0	9.9	97.3	97.8	96.3
3	9.6	9.6	9.4	8.1	8.2	8.1	28.2	9.9	96.8	96.8	94.7
4	9.2	9.2	9.2	8.6	8.6	8.2	28.0	9.8	94.3	94.3	94.3
5	9.1	9.2	9.1	8.2	8.2	8.2	28.5	9.8	92.5	93.0	92.5
6	9.1	8.7	9.0	8.1	8.2	8.5	28.6	9.8	92.9	88.8	91.8
7	9.3	9.3	9.3	8.0	8.0	8.1	28.6	9.8	94.0	94.0	94.0
8	9.2	9.3	9.2	8.4	8.3	8.4	28.6	9.7	94.0	95.1	94.6
9	8.9	9.0	9.0	8.3	8.3	8.3	28.4	9.7	91.0	92.5	92.0
10	9.1	9.0	8.9	8.3	8.4	8.4	28.2	9.8	92.7	92.2	91.2
11	8.9	8.8	8.8	8.3	8.3	8.3	28.2	9.8	90.7	89.7	89.7
12	8.9	9.0	8.8	8.5	8.5	8.5	27.9	9.8	91.2	91.7	90.2
13	8.7	8.6	8.6	8.6	8.5	8.5	28.7	9.7	88.9	88.4	88.0
14	8.5	8.4	8.4	8.5	8.4	8.4	28.8	9.7	87.1	86.1	86.1
15	8.5	8.5	8.3	9.0	8.9	9.1	28.7	9.6	88.4	87.8	85.8
16	8.4	8.5	8.3	8.5	8.5	8.5	28.7	9.7	86.3	87.4	84.8
17	8.2	7.9	8.0	8.9	8.8	8.8	28.5	9.6	85.2	81.6	82.6
18	7.8	8.0	7.8	9.1	9.5	9.2	28.3	9.6	80.6	83.2	81.1
19	8.1	8.2	7.8	8.8	8.6	8.8	28.8	9.7	83.5	84.0	80.4
20	7.9	7.9	7.8	8.7	8.7	8.7	28.7	9.7	80.7	80.7	79.7
21	7.5	7.3	7.3	9.0	9.0	8.8	28.1	9.7	77.2	75.6	75.1
22	7.6	7.6	7.4	8.6	8.6	8.7	28.6	9.7	77.6	78.1	75.5
23	7.2	7.6	7.4	8.5	8.6	8.6	28.2	9.8	73.8	77.4	75.3
24	7.8	7.6	7.5	8.9	9.0	9.0	28.2	9.7	80.8	78.8	77.7
25	7.4	7.6	7.4	8.7	8.9	8.7	28.6	9.6	76.4	78.5	76.4
26	7.9	7.4	7.6	9.1	8.8	8.9	28.6	9.6	81.6	76.4	79.0
27	8.0	7.4	7.4	9.3	9.2	9.2	28.6	9.6	83.2	76.9	76.4
28				9.6	9.7	9.6	28.6				
29				9.2	9.3	9.3	28.5				
30				9.7	9.6	9.6	28.6				

Table 38. Trough salinity (1990)

Date	Time	Seawater Header	Salinity ( ° / <sub>oo</sub> )					
			Trough 1		Trough 2		Trough 3	
			In	Out	In	Out	In	Out
22-Mar	1650		29.7	29.7				
26-Mar	1645	29.7	26.1	29.7	29.6	29.6	28.6	29.6
27-Mar	0845	29.4	29.7	29.8	28.3	29.8	29.8	28.7
27-Mar	1330	29.3	29.1	29.4	27.6	24.2	29.2	29.1
28-Mar	0830	29.7	29.1	29.8	29.4	28.9	28.2	29.7
28-Mar	1325	29.3	29.3	29.4	29.3	29.4	29.3	29.3
28-Mar	1800	29.9	29.6	29.4	29.6	29.5	29.5	29.4
29-Mar	0900	29.9	29.8	29.9	29.9	29.9	29.9	29.8
29-Mar	1400	29.3	29.3	29.5	29.5	29.7	29.5	29.6
29-Mar	1838	29.7	29.7	29.5	29.7	29.6	29.7	29.7
30-Mar	0928	29.8	29.9	29.7	29.8	29.9	29.9	29.8
30-Mar	1330		29.8	29.9	29.8	29.8	29.8	29.9
30-Mar	1803	29.8	29.4	29.4	29.6	29.5	29.6	29.5
31-Mar	0913	30.0	29.9	29.9	29.9	29.9	29.9	29.9
31-Mar	1316		29.8	29.9	29.9	29.9	29.9	30.0
31-Mar	1851	29.8	29.5	29.5	29.6	29.6	29.6	29.7
01-Apr	0954	30.0	29.9	29.8	29.9	29.8	29.9	29.9
01-Apr	1319	29.9	29.9	29.9	30.0	30.0	29.9	29.9
01-Apr	1930	29.6	29.5	29.7	29.6	29.6	29.6	29.6
02-Apr	0855	29.8	29.8	29.7	29.8	29.8	29.8	29.8
02-Apr	1440	29.9	30.0	29.8	29.8	29.8	29.8	30.0
02-Apr	1930	29.7	29.6	29.7	29.6	29.7	29.6	29.7
03-Apr	0900	29.5	29.8	29.8	29.8	29.8	29.8	29.9
03-Apr	1509	29.9	29.9	30.0	29.8	29.9	29.9	29.9
03-Apr	1737	29.9	29.7	29.7	29.9	29.8	29.7	29.6
04-Apr	0908	29.5	29.7	29.7	29.9	29.9	29.9	29.9
04-Apr	1305	29.9	29.7	29.7	29.8	29.6	29.7	29.7
04-Apr	1902		29.8	29.9	30.0	30.0	29.9	29.9
05-Apr	0917	29.7	29.8	29.7	29.7	29.7	29.7	29.6
05-Apr	1328	29.6	29.5	29.6	29.6	29.6	29.6	29.6
05-Apr	1923	29.8	29.9	29.9	29.8	29.9	29.8	29.9
06-Apr	0909	30.0	30.0	29.9	30.0	29.8	29.9	29.9
06-Apr	1358	29.7	29.5	29.5	29.5	29.5	29.6	29.5
07-Apr	0951	30.0	29.9	29.7	29.9	29.9	29.9	30.0
07-Apr	1454	29.5	29.5					
08-Apr	1232	29.8	29.8	29.9	29.9	29.9	29.9	29.9
15-Apr	1039		29.9					
18-Apr	1103		29.6					
19-Apr	1200		29.8					
21-Apr	1500		29.8					

Table 39. Trough salinity (1991)

Date	Time	Seawater Header	Salinity ( ° / ‰ )					
			Trough 1		Trough 2		Trough 3	
			Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
28-Mar	1230	28.9	29.2	29.3	29.1	29.2	29.0	29.1
28-Mar	1800	28.7	29.0	29.2	29.4	29.3	29.4	29.4
29-Mar	1115	28.3	28.8	29.0	29.2	29.0	29.2	29.2
29-Mar	1800	29.0	29.4	29.4	29.4	29.4	29.4	29.5
30-Mar	0930	29.4	29.4	29.5	29.2	29.0	29.5	29.5
30-Mar	1818	29.4	29.5	29.4	29.5	29.5	29.5	29.5
31-Mar	0900	28.9	29.3	29.5	29.5	28.9	29.5	29.5
31-Mar	1815	29.3	29.1	29.3	29.3	29.3	29.1	29.1
01-Apr	1023	29.0	29.0	29.2	29.2	29.2	29.2	29.3
01-Apr	1815		29.1	29.2	29.3	29.2	29.3	29.3
02-Apr	0615	28.3	29.2	29.2	29.3	29.1	29.4	29.3
03-Apr	1915	29.0	29.0	29.0	29.2	29.1	29.2	29.2
04-Apr	0910	29.4	29.4	29.5	29.5	29.5	29.5	29.5
04-Apr	1830	28.9	28.9	28.8	29.0	28.9	29.0	29.0
05-Apr	0910	29.3	29.4	29.5	29.4	29.4	29.4	29.4
05-Apr	1820	29.0	29.1	29.1	29.1	29.1	29.2	29.1
06-Apr	1800	28.9	28.9	28.9	29.1	29.0	29.1	29.1
07-Apr	0900	29.0	29.2	29.2	29.3	29.2	29.4	29.4
07-Apr	1900	28.7	28.9	29.1	29.0	29.1	29.0	29.1
08-Apr	0615	29.0	29.0	29.0	29.1	29.0	29.1	29.0
09-Apr	1730	28.5	29.1	29.1	29.1	29.1	29.2	29.1
10-Apr	0741	29.1	28.9	29.2	29.2	29.2	29.1	29.1
11-Apr	1930	29.2	29.2	29.3	29.2	29.3	29.3	29.4
13-Apr	0900	29.4	29.3	29.4	29.3	29.3	29.4	29.3
13-Apr	0705	29.5	29.2	29.5	29.5	29.5	29.5	29.5
14-Apr	1022	29.3	29.3	29.5	29.3	29.4	29.3	29.5
14-Apr	1930		29.5	29.5	29.4	29.5	29.4	29.5
15-Apr	0930	29.3	29.3	29.4	29.4	29.5	29.4	29.5
15-Apr	1927	29.4	29.5	29.5	29.5	29.5	29.4	29.5
16-Apr	1006	29.5	29.4	29.5	29.5	29.5	29.5	29.5
17-Apr	0918	29.6	29.4	29.5	29.5	29.6	29.5	29.6
17-Apr	1630		28.7	29.1	29.1	29.1	29.1	29.1
18-Apr	1015	29.7	29.5	29.6	29.6	29.6	29.6	29.6
18-Apr	1930	29.4	29.4	29.4	29.5	29.5	29.5	29.5
19-Apr	0920	29.7	29.5	29.7	29.7	29.7	29.7	29.8
19-Apr	1857	29.2	29.3	29.4	29.2	29.3	29.3	29.3
20-Apr	0930	29.6	29.6	29.5	29.6	29.5	29.5	29.5
20-Apr	1840	29.1	29.2	29.2	29.1	29.3	29.2	29.3
21-Apr	1005	29.6	29.4	29.5	29.6	29.5	29.6	29.6
21-Apr	2013	29.3	29.3	29.3	29.2	29.3	29.3	29.3
22-Apr	1012	29.4	29.3	29.5	29.5	29.5	29.5	29.5
22-Apr	1852		29.2	29.7	29.7	29.7	29.6	29.7
23-Apr	1047	29.5	29.0	29.5	29.5	29.5	29.4	

Table 40. Trough salinity (1992)

Date	Time	Salinity ( ° / $\infty$ )	Location
06 Mar	0920	28.0	Trough 2
07 Mar	0939	28.2	Trough 2
08 Mar	1130	28.0	Trough 3
09 Mar	0840	28.5	Trough 1
10 Mar	0907	28.6	Trough 2
11 Mar	0918	28.6	Trough 3
12 Mar	1012	28.6	Trough 3
13 Mar	0919	28.4	Trough 2
14 Mar	0942	28.2	Trough 1
15 Mar	1051	28.2	Trough 2
16 Mar	1002	27.9	Trough 2
17 Mar	0944	28.7	Trough 2
18 Mar	0933	28.8	Trough 2
19 Mar	1103	28.7	Trough 2
20 Mar	0946	28.7	Trough 2
21 Mar	1014	28.5	Trough 3
22 Mar	1033	28.3	Trough 2
23 Mar	0914	28.8	Trough 2
24 Mar	1020	28.7	Trough 1
25 Mar	1040	28.1	Trough 2
26 Mar	1030	28.6	Trough 2
27 Mar	1030	28.2	Trough 2
28 Mar	1110	28.2	Trough 2
29 Mar	1045	28.6	Trough 2
30 Mar	1140	28.6	Trough 2
31 Mar	1740	28.6	Trough 2
02 Apr	0950	28.5	Trough 2
03 Apr	1030	28.6	Trough 2

Table 41. Bioassay results (1990).

## 96 Hr Flow Through Bioassay

Elapsed Time (Hrs)	Percent Fry Mortality vs Crude Oil WSF (%) / (mg/L)					
	Control 0	5%WSF (0.2)	20%WSF (0.79)	40%WSF (1.58)	60%WSF (2.38)	80%WSF (3.17)
0	0	0	0	0	0	0
2	0	0	0	0	0	0
13	0	0	0	0	0	0
16	0	0	0	0	0	11
21	0	0	0	0	0	22
26	0	0	0	0	0	44
37	0	0	0	0	10	78
45	0	0	0	0	10	78
52	0	0	0	0	20	89
62	0	0	0	0	20	100
65	0	0	0	0	20	
71	0	0	0	0	20	
87	0	0	0	0	20*	
96	0	0	0	0		

\* - bioassay terminated early to permit beginning of toxicant exposure in main experiment

Table 42. Bioassay results (1991).

Elapsed Time (Hrs)	Percent Fry Mortality vs Crude Oil WSF (%)/ (mg/L)							
	Control	25%WSF (1.9)	50%WSF (3.8)	60%WSF (4.56)	70%WSF (5.32)	80%WSF (6.08)	90%WSF (6.84)	100%WSF (7.6)
0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
7	0	0	10	20	20	10	50	20
12	0	0	10	20	40	30	70	70
17	0	0	10	30	60	50	70	80
21	0	0	10	30	60	70	90	100
23	0	0	10	30	70	70	100	
28	0	0	10	40	70	70		
31	0	0	10	40	70	80		
42	0	0	10	50	80	90		
48	0	0	10	50	90	100		
51	0	0	10	60	90			
65	0	0	20	90	100			
68	0	0	30	90				
71	0	0	30	90				
75	0	0	30	100				
90	0	0	50					
96	0	0	50					

Table 43. Bioassay results (1992).

## Bioassay No. 1

Elapsed Time (Hrs)	Percent Fry Mortality vs Crude Oil WSF (%) / (mg/L)							
	Control	20%WSF	40%WSF	50%WSF	60%WSF	70%WSF	80%WSF	100%WSF
0	0	0	0	0	0	0	0	0
6	0	0	30	10	44	30	40	70
17 *	0	0	60	50	67	90	100	100

\* - Terminated by mistake at 17 hours

## Bioassay No. 2

Elapsed Time (Hrs)	% Crude Oil WSF / (mg/L)							
	Control	20%WSF	40%WSF	50%WSF	60%WSF	70%WSF	80%WSF	100%WSF
0	0	0	0	0 **	0	0	0	0
4.5	0	0	0	9	10	40	30	10
6.5	0	0	0	18	20	80	80	60
23	0	0	60 *	36	70	100	90	100
25	0	0	60 *	36	90		90	
26	0	0	60 *	36	100		100	
30	0	0	70 *	64				
36	0	0	80 *	73				
48	0	0	90 *	82				
53	0	0	100*	82				
70	0	0		91				
96	0	0		91				

\* - Blockage of sea water line resulted in exposure to 100% toxicant for up to 18.5 hours

\*\* - 11 fish present instead of 10

Table 44. Bioassay dissolved hydrocarbon concentrations. \*

Year	Toxicant Header Mean (S.D.)	Concentration of Dissolved Hydrocarbons in Bioassay Dilutions (mg/L)					
		5%WSF	20%WSF	40%WSF	60%WSF	80%WSF	
1990							
	3.96 (0.96)	0.2	0.79	1.58	2.38	3.17	
1991		25%WSF	50%WSF	60%WSF	70%WSF	80%WSF	90%WSF 100%WSF
	7.60 (0.73)	1.90	3.80	4.56	5.32	6.08	6.84 7.60
1992		20%WSF	40%WSF	50%WSF	60%WSF	70%WSF	80%WSF 100%WSF
	5.39 (1.94)	1.08	2.16	2.70	3.23	3.77	4.31 5.39

\* - 1990 toxicant header concentrations based on follow up evaluation of WSF column conducted in Oct 1990.

- 1991-1992 toxicant header concentrations measured during field program.

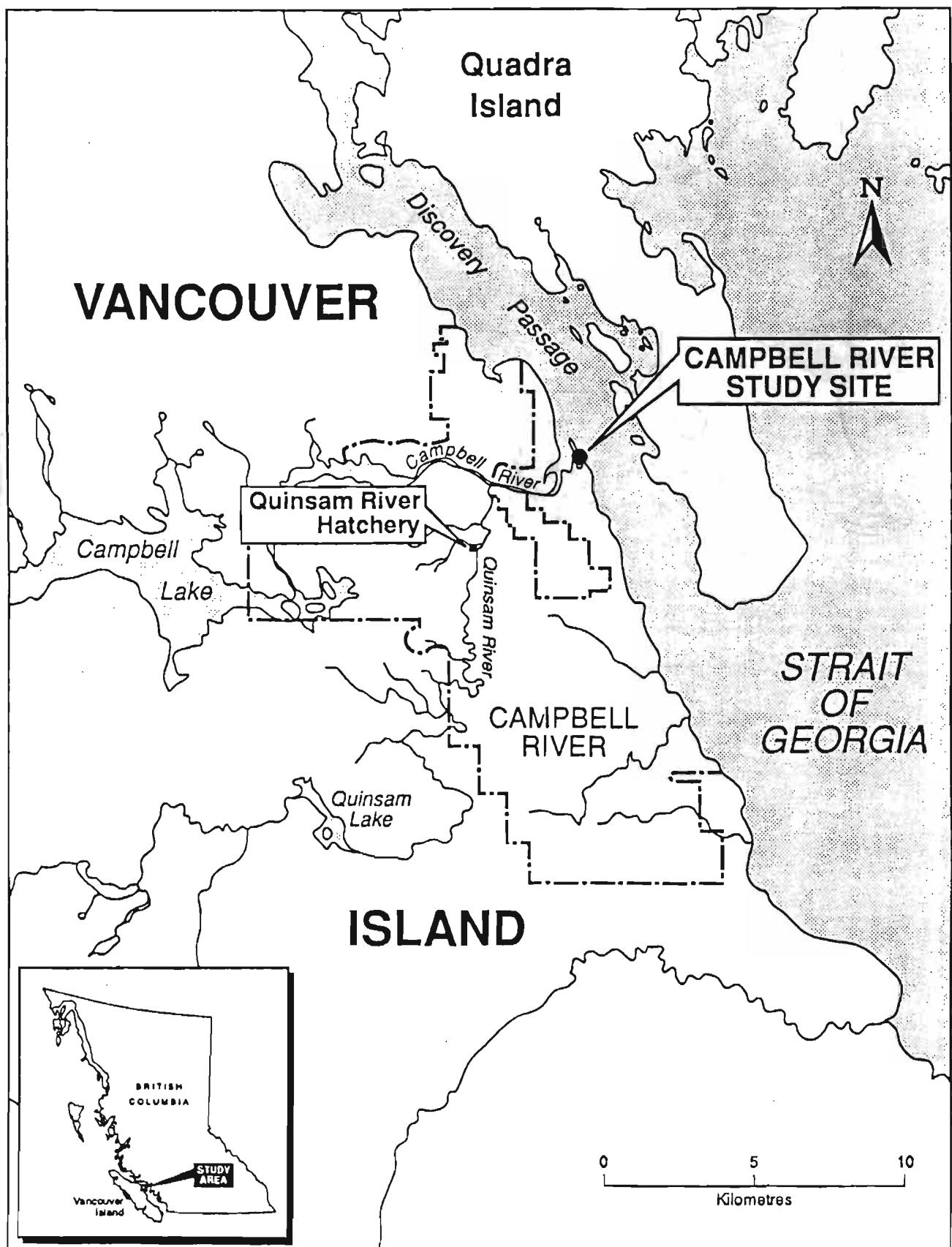
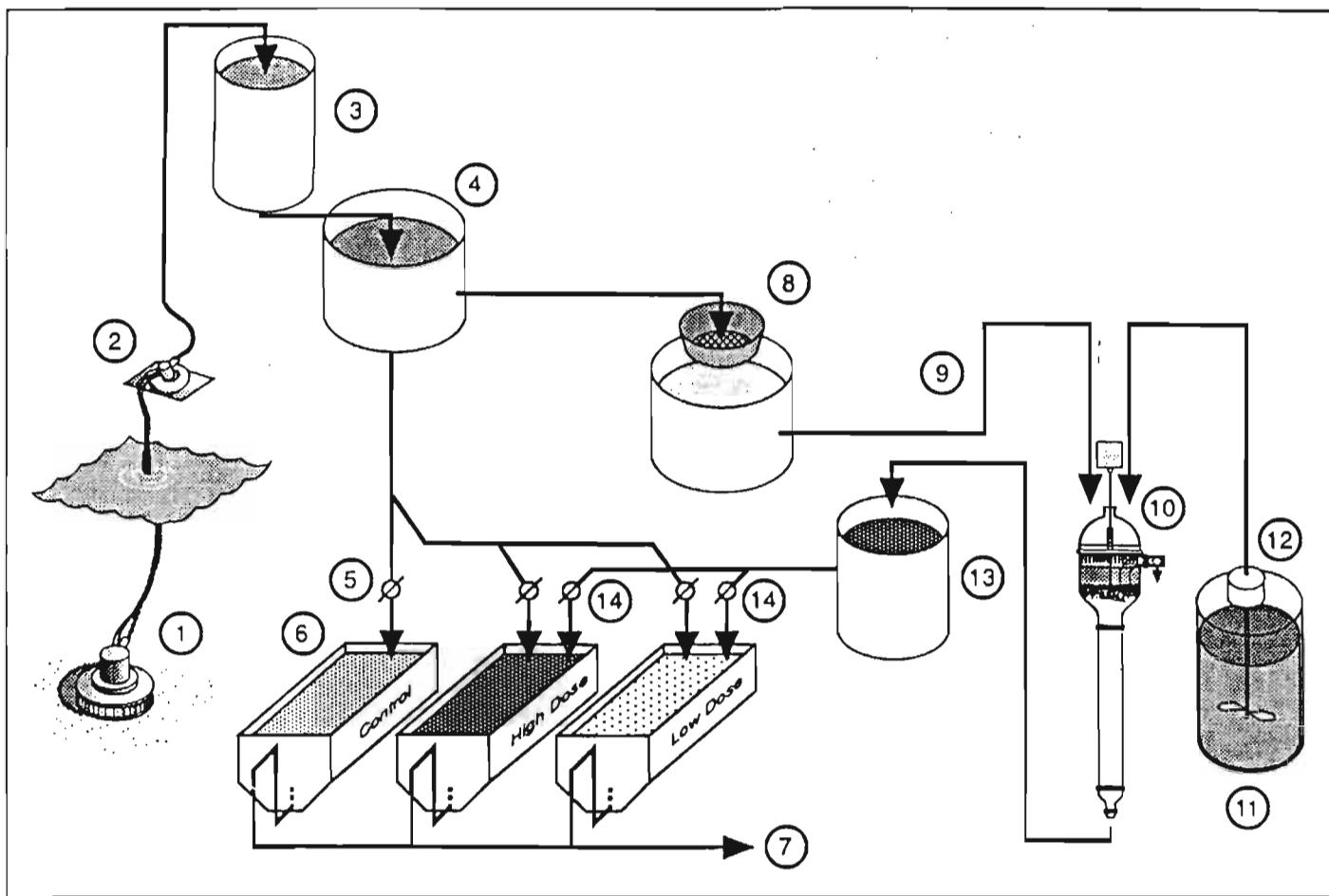
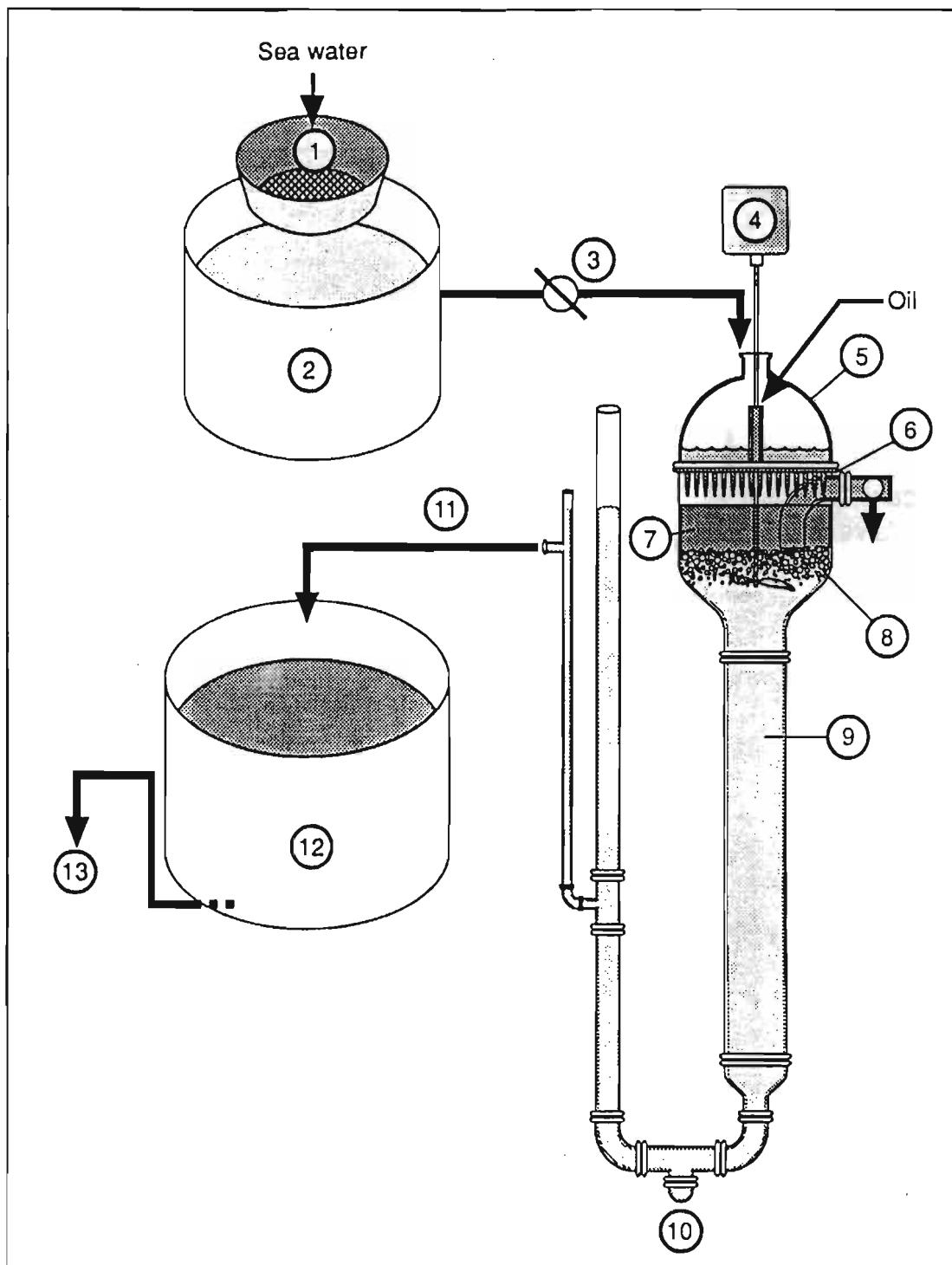


Fig. 1 Study Area near Campbell River, British Columbia.



**Fig. 2. Hydrocarbon dosing apparatus and fish holding troughs.**

[LEGEND: 1. Stainless steel submersible well pump. 2. In-line secondary pump. 3. Aeration column. 4. Main seawater header. 5. PVC control valve. 6. Fish holding trough. 7. Seawater outflow (to waste). 8. Seawater filter. 9. Seawater supply to WSF extraction apparatus. 10. Glass WSF extraction apparatus. 11. Crude oil supply. 12. Crude oil metering pump. 13. WSF reservoir. 14. WSF flow control valves.]



**Fig. 3. Glass WSF extraction column.**

[LEGEND: 1. Filter. 2. Header tank. 3. Flow control valve. 4. Stirring motor. 5. Upper sea water chamber. 6. Pipette plate. 7. Layer of crude oil floating on sea water. 8. Crude oil "bubble layer". 9. Extracted water soluble fraction (WSF). 10. Column clean-out drain. 11. WSF output. 12. WSF reservoir. 13. To fish holding troughs or bioassay apparatus.]

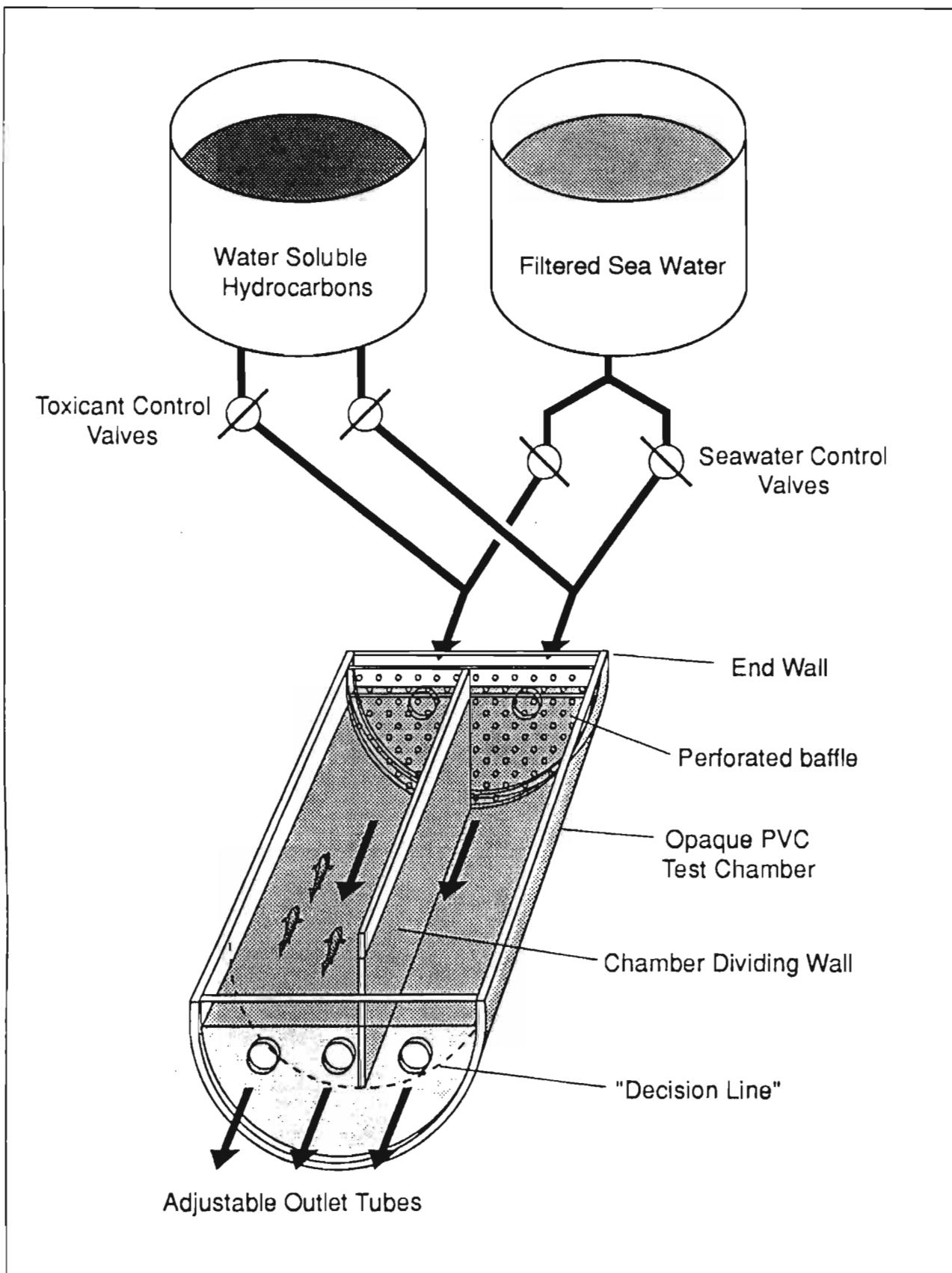


Fig. 4. Hydrocarbon avoidance apparatus.