# Organic Contaminants in Salmonid Spawning Grounds: Occurrences and Effects on the Early Life Stages of Salmonids

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**The thesis is submitted in partial fulfilment of the requirements for the award of degree of Doctor of Philosophy at the University of Portsmouth.**

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## Declaration

Whilst registered as a candidate for the degree of Doctor of Philosophy, I have not registered for any other research award. The results and conclusions embodied in this thesis are the work of the named candidate and have not been submitted for any other academic award.

**Lucy Elizabeth Crooks**

***For Edith Valentine Evans***

*An inspiration to me. A strong minded, stubborn and generous lady, who has left a lasting impression. All characteristics I am proud to have inherited. You always had high aspirations for me and you hoped I would one day become a doctor.*

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## ABSTRACT

The factors regulating salmonid populations remain poorly understood, although contamination of the freshwater environment has been implicated as a causative factor. Depletion of stocks has become an increasing concern and it is believed that the early life stages are potentially the most vulnerable. Reduction in salmonid stocks has been reportedly linked to water quality and this current study has shown that freshwater pollution can affect the survival and development of salmonids. Environmental concentrations measured in this study varied greatly and high levels of sediment-bound contaminants were found, especially polycyclic aromatic hydrocarbons. Concentrations of waterborne contaminants were similar to levels previously measured, with some high level peaks in triazine metabolites. Field studies, as previous literature has suggested, found a higher mortality in river sites of greater sediment and nutrient loading and in sites with a greater proportion of fine sediment (<63µm). The River Avon was found to have a higher concentration of fine sediment and mortality of implanted eggs in this site was significantly higher than in the Rivers Wylye and Nadder. Although mortality of eggs implanted in river field sites was generally high, few morphometrics and biochemical effects were observed. Laboratory studies examined the toxicity of environmentally relevant levels of water-borne and sediment-bound contaminants on the brown trout (*Salmo trutta*) but found few acute effects and no specific trends were observed. The results did reveal a higher frequency of yolk sac oedemas for contaminant-exposed alevins in the laboratory trials compared to the control groups. In general survival was high for both the eyed egg and alevin stages when exposed to the water-borne contaminants. However, survival was greatly reduced when the water-borne contaminant exposures were carried out from the fertilisation stage compared to the eyed stage. Generally, sediment-bound contaminants had a greater effect on survival at the egg stage and mortalities were found to be reduced at the fry stage. Additionally, the results from the comet assays revealed that exposure to sediment-bound organochlorine pesticides and polycyclic aromatic hydrocarbons did induce significant acute effects in the form of DNA damage when compared to the control. Such results could indicate that certain pollutants may be problematic for the species at later stages of their development and on into adulthood.

In general the findings of this research proved largely inconclusive in terms of specific impacts of contaminants on the early developmental stages of Atlantic salmon and brown trout. The results of these studies did show that the presence of common pollutants within the freshwater environment can have impacts on the survival and development of salmonids. These impacts may have serious implications throughout the lifecycle and could impact heavily on recruitment and survival at both the juvenile and adult life stages, potentially leading to a reduction of wild populations.

## LIST OF ABBREVIATIONS

| | |
|---|---|
| **AFW** | Artificial Freshwater |
| **AH** | Acid Herbicides |
| **Amm.** | Ammonia |
| **ATR** | Atrazine |
| **BW** | Body Weight |
| **CEFAS** | Centre for Environment Fisheries and Aquaculture Science |
| **CNT** | Control |
| **DDD** | Dichlorodiphenyldichloroethane |
| **DDE** | Dichlorodiphenyldichloroethylene |
| **DDT** | Dichlorodiphenyltrichloroethane |
| **DEA** | Desethylpropylatrazine |
| **DIA** | Desisopropylatrazine |
| **dnPF** | Days Post-Fertilisation |
| **EA** | Environment Agency |
| **FA** | Fluctuating Asymmetry |
| **FAA** | Free Amino Acids |
| **GCMS** | Gas Chromatography Mass Spectrometry |
| **GFC** | Glass Fibre Cartridge |
| ***K*** | Condition Factor |
| **MCPA** | 2-Methyl-4-Chlorophenoxyacetic Acid |
| **MCPB** | 2-Methyl-4-Chlorophenoxy Butyric Acid |
| **MPL** | Maximum Permissible Level |
| **NAPH** | Naphthalene |
| **NPS** | Ninhydrin Positive Substances |
| **NBF** | Neutrally Buffered Formalin |
| **OCP** | OrganoChlorine Pesticides |
| **OCP+PAH** | OrganoChlorine Pesticides plus Polycyclic Aromatic Hydrocarbons |
| **PAH** | Polycyclic Aromatic Hydrocarbons |

| | |
|---|---|
| **PBS** | Phosphate Buffered Saline |
| **PHEN** | Phenanthrene |
| **POP** | Persistent Organic Pollutants |
| **PROM** | Prometryn |
| **PROP** | Propazine |
| **RO** | Reverse Osmosis |
| **SA:Vol** | Surface Area to Volume Ratio |
| **SEM** | Standard Error of the Mean |
| **SIM** | Simazine |
| **SOL** | Solvent Control |
| **SPE** | Solid Phase Extraction |
| **TAN** | Total Ammonia Nitrogen |
| **TCA** | Trichloroacetic Acid |
| **TRI** | Triazines |
| **WWF** | World Wildlife Fund |
| **YS** | Yolk Sac |
| **YSO** | Yolk Sac Oedema |