STUDY OF THE TOXICITY OF LEACHATES
FROM DREDGE SPOILS
CONTAINING WASTE

a report prepared for

REGIONAL OCEAN DUMPING ADVISORY COMMITTEE

FISHERIES AND ENVIRONMENT CANADA

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E.V.S. consultants ltd.

March 25, 1977

Dr. J. C. Davis
Pacific Environmental Institute
4160 Marine Drive
West Vancouver, B.C.

Dear Dr. Davis:

I am pleased to present a final draft of our report entitled:

"Toxicity of Leachates from Dredge Spoil Containing Wood Wastes".

The project was successful in achieving the stated objectives and demonstrated the toxicity of dredge spoil leachates to marine organisms. The report is divided into sections as detailed in the Table of Contents. The introductory section provides the terms of reference, the scope of the project and background literature relevant to the work. The results section summarizes the raw data which follows as Appendix I and II. An abstract of the findings, our recommendations and conclusions precedes the main text of the report for immediate reference.

Your co-operation and assistance was greatly appreciated. We trust that the report meets your requirements at this time. We would of course be pleased to elaborate on any aspect as may be required.

Yours truly

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The following members of E.V.S. Consultants actively participated in this project: P. Borgmann, L. Hoos, R. G. Janssen, J. B. Marliave and G. Vigers. D. Tanchak typed and collated the manuscript.

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E.V.S. CONSULTANTS LTD.

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CONCLUSIONS

1. Dredge spoil leachates containing wood wastes are toxic to the shrimp *Crangon communis* and to the stickleback *Gasterosteus aculeatus*.

2. Dredge spoil leachate was 3.3 times less toxic to *C. communis* (avg. MST in 100% leachate = 56 h) than to *G. aculeatus* (avg. MST in 100% leachate = 16.8 h). Similarly, sodium pentachlorophenate was 4 times less toxic to *C. communis* (96-h LC50 = 245 ppb) than to *G. aculeatus* (96-h LC50 = 50 and 70 ppb). LC50 values for *G. aculeatus* are representative of those normally obtained for NaPCP in our laboratory.

3. The sensitivity of shrimp to toxicant decreased with increasing loading density, in a manner comparable to fish.

4. Egg carrying females collected in December were marginally more sensitive to Batch 1 leachates than immature specimens, but ovigarous females collected in January were significantly more resistant than the normal population when tested with Batch 2 leachates.

5. Parasitized shrimp were significantly more sensitive than the normal population to leachates or sodium pentachlorophenate ($P > 0.5$).

6. Size and sex distributions of shrimp caught in December were quite different to those caught in February. It is postulated that these differences may be a result of parasitism.

7. Shrimp mortalities in bioassay showed no relationship to size/weight distributions.

8. Some leachates exerted an oxygen demand sufficient to enhance the toxic action of leachates by depressing oxygen levels to less than 20% of saturation.

9. Dredge spoil leachate toxicants were unstable and their toxic action decreased with time.

10. Chemical analysis of known toxicants, particularly H_2S, did not correlate with bioassay results.

11. Using the procedures described here, adequate numbers of viable *C. communis* specimens can be obtained for bioassay work. However, their viability decreased rapidly with holding periods longer than three weeks.

12. The use of a reference toxicant, sodium pentachlorophenate, provided useful insights into the relative sensitivity of *C. communis*, effects of loading density on toxicity, and organism viability.

13. *C. communis* is not sufficiently sensitive to define levels of toxicity for protection of the marine environment. However, it may be useful as a bioassay organism for routine monitoring.

RECOMMENDATIONS

On the basis of the findings and conclusions made in this study, it is recommended that:

1. Because of the variable and unstable nature of leachates, the program be continued to assess at least one additional batch of leachates using the procedures described here. Concommitant with the bioassay work, an expanded physical/chemical analytical program should also be undertaken to identify toxic constituents. The anomalies of non-lethality in the presence of initially high sulfide concentrations also warrants more definitive investigation.

2. *C. communis* was 3 times less sensitive to toxic substances than fish. These findings have ramifications for both environmental assessments as well as for bioassay methodology and raises the question of relative sensitivities of marine benthic communities to the effects of dredge spoil containing wood wastes. It is therefore recommended that a study be undertaken to systematically assess the relative sensitivities of marine benthos. In the interim, *C. communis* is recommended as a bioassay organism of appropriate size that is amenable to collection, handling and testing in marine bioassay work.

3. Collection procedures and holding protocols were of an exploratory development nature, and future toxicity assessment studies of this nature should provide for more detailed evaluation of methods of obtaining and maintaining vigorous test stocks of bioassay organisms.

4. Studies be undertaken to evaluate the synergistic effects of low dissolved oxygen and leachate toxicity on selected benthic invertebrates, as such interactions are most likely to occur in situ and may be of major significance.

INTRODUCTION

1.1 PURPOSE AND SCOPE OF INVESTIGATION

This work was done in response to one of three requests originated by the Regional Ocean Dumping Advisory Committee and contracted by the Department of Supply and Services, Science Procurement Branch. The request to E.V.S. Consultants was dated August 18, 1976. Our study complimented two parallel studies conducted, one by Dobrocky Seatech Ltd. on the physical environment of the dump site at Alberni Inlet, and the other by Econotech Services Ltd. on the physical and chemical properties of the dredge spoil and leachate.

The major objective of this project was to assess the acute toxicity of selected benthic invertebrate species to leachates from wood debris and evaluate their response in terms of sensitivity, ease of handling, standardization and applicability in routine bioassay procedures.

The detailed objectives of this program were:

1. To use the sand shrimp *Crangon* spp. as a bioassay test organism.

2. To conduct 96-hour LC50 bioassays on 2 sets of seven leachate samples to be supplied by Econotech Services Ltd.

3. To report results as LC50's (calculated using log-probit plots), together with "s" values, toxicity curves, organism loading density, initial and final pH, salinity and dissolved oxygen.

4. To incorporate "in situ" conditions of dissolved oxygen,

temperature and salinity according to the season in which the bioassay was conducted, where the specimens were collected, and typical conditions in Alberni Inlet.

5. The sensitivity and condition of *Crangon* spp. was assessed by:
   a) standardized duplicate static bioassay using sodium pentachlorophenate as the reference toxicant, and
   b) comparing the sensitivity of *Crangon* spp. with stickleback (*Gasterosteus aculeatus*) to provice a yardstick of comparison with other regulations development programs.
   c) In addition, it became apparent during the course of the work, that the the bioassay data would be of much greater value if the bioassay organisms were examined in terms of the life history, sex, size, and degree of parasitism of the crangonids tested. Accordingly, this was done, although it was not within the terms of reference.

BACKGROUND

2.1 OCEAN DUMPING

The Ocean Dumping Control Act was passed by Parliament in November 1975 to control the dumping of waste and other substances in the ocean. Federal Regional Ocean Dumping Activities Committees (RODAC) have been established to control dumping activities in a manner that avoids deleterious impacts on the environment. The approach taken has been to require proponents that wish to dump dredge spoil or other materials to undertake specific analyses of the material to be dumped. The objective of these analyses was to provide a basis of information on which to assess the potential impact of pre-dump material on biological communities in the receiving environment.

At this time, wood waste in dredgings appear to be a major problem material in terms of large volumes, the number of sites and permit applications. Previous work (section 2.5) has suggested that the main impacts of dumped materials are on the bottom-dwelling organisms, but major questions remain such as:

- How can these impacts be assessed and quantified?
- What chemical or biological assessment procedures can be applied to predumped material to predict its impact on a receiving environment?
- How can monitoring procedures best be standardized to provide environmentally relevant information and yet be consistent with the framework of routine monitoring?

The mode of the effects of dumped materials on biota of the receiving environment may be physical or chemical. In order to address these impacts, a program to collect and monitor dredge spoil under defined conditions is required. Methods used to date have been designed to reflect physical impacts (i.e. grain size), putrification (volatile material) or oxygen demand. One impact that has not been previously addressed is the acute toxicity to benthic organisms of leachates from dredge spoils containing wood wastes. Accordingly, the work reported here was directed at defining this problem in a manner that would form a sound basis for the development of procedures and guidelines for the regulation of ocean dumping activities.

2.2 ALBERNI INLET

The dredge spoil used to provide elutriate for bioassay studies was obtained from an ocean dump site in Alberni Inlet on Vancouver Island, B.C. The physical parameters for laboratory bioassay were, therefore, determined by the oceanographic characteristics of Alberni Inlet, namely:

1. the interchange of water between the fjord and the adjoining water mass of Barkley Sound, and
2. the fluctuating freshwater inflow from the Somass River, which produces variations in the seaward transport of surface water.

The inflow of seawater with its varying properties and subsequent mixing with inlet water, produces major changes in the properties of the fjord basin water mass. These factors, therefore, were considerations in the definition of salinity, dissolved oxygen and temperature regimes for the experimental program.

1. Salinity

Alberni Inlet is a typical B.C. fjord, where precipitation and freshwater inflow exceed evaporation, with the freshwater inflow presenting a characteristic annual cycle. The outflow of this fresh water, with associated entrainment of underlying salt water, produces a horizontal distribution of salinity in the upper layer that usually shows a gradual increase in salinity with distance from the head (Waldichuk, 1960; Harger et al, 1973).

2. Dissolved Oxygen

Minimum dissolved oxygen levels in and above the halocline are usually in excess of 8.0 ppm, other than the inner harbour immediately adjacent to the pulp mill where 7.0 ppm dissolved oxygen have been reported. Below the halocline, a base state of about 4.4 ppm of dissolved oxygen has been suggested, with values ranging up to 5-6 ppm in the vicinity of the dump site (Parker and Sibert, 1973).

3. Temperature

Although the thin surface layer of water is typified by widely fluctuating temperatures, according to the season, deeper waters are characterized by fairly stable temperatures in the range of 6^{o} - $8^{o}C$ (below 20 m).

4. Dump Material at the Alberni Inlet Site

Details of the actual composition of dredgates from the Alberni Inlet site are described elsewhere (Econotech Services Ltd., 1977; Dobrocky Seatech Ltd., 1977). A large integrated pulp mill of 1700 tons per day and a sawmill are located at the head of the inlet. The mills have been operating under an ocean dumping permit to dredge sediment and wood debris to maintain shipping lanes, and dispose of the dredge spoil in Alberni Inlet. The bulk of this dredgate is wood waste in varying stages of decay, the main tree species comprising the wood waste being spruce, hemlock, cedar and Douglas fir.

2.3 BIOASSAYS

1. Selection of a Reference Toxicant

Leachates may fluctuate in character, and the sensitivity of estuarine organisms to toxic wood extractives may range as much as threefold (Buchanan et al, 1976). Bioassays using a pure chemical of known toxicity as a reference test material may provide important insights into the sensitivity of the selected bioassay organisms, particularly with respect to life history, parasitism, acclimation and condition factors. Sodium pentachlorophenate was chosen for this purpose. Alderdice (1963) selected sodium pentachlorophenate to evaluate the interactive effects of oxygen, temperature and salinity regimes on coho fry. Davis and Hoos (1975) used sodium pentachlorophenate as one of two reference test materials in an intercomparison of seven bioassay laboratories. Sodium pentachlorophenate has been used by E.V.S. Consultants in a number of bioassay programs for Environment Canada (E.V.S. Reports #151, 201, 232), both for freshwater and marine situations. In these projects, the use of sodium pentachlorophenate indicated stress conditions for rainbow trout acclimated to salt water, and was also used to compare the sensitivity of herring, rainbow trout and stickleback.

2. Selection of Bioassay Organism

Acute lethal bioassays for regulatory or routine monitoring of pollutant materials usually (but not always) utilize a fish species as a bioassay organism. Such tests are usually concerned with an aqueous discharge and its effects on the water column. With ocean dumping of dredge spoil materials, however, one is dealing with solids wastes rather than aqueous wastes, and the major impacts are anticipated as being on infaunal and epifaunal benthic communities, rather than on the water column per se. For Alberni Inlet, dumping activities occur in water greater than 50 meters in depth. Accordingly, attention was directed to selecting a sublittoral benthic invertebrate species to assess the toxicity of dredge spoil containing wood waste.

Although fish species likely do not suffer significant effects from these wastes, it is important to know how the sensitivity of a selected invertebrate compares with a fish of known sensitivity. The threespine stickleback *(Gasterosteus aculeatus)*, which has been tested against rainbow trout and herring (E.V.S. Consultants, 1976b) was selected for this purpose.

Initially it was planned to use the coon-striped shrimp, *Pandalus danae* and an ampharetid polychaete as invertebrate test organisms for the study. However, *P. danae* individuals were too large for accepted loading densities while ampharetid polychaetes appeared to be difficult to collect and maintain live. The small sand shrimp, *Crangon communis*, presented no such problems and based on preliminary field collections, was selected as the principal test organism. Further, there is a substantial body of bioassay literature available on this genus. This literature, largely excerpted from E.V.S. Consultants (1976a), is discussed below in relation to species, sensitivity, toxicant or pollutant material, test conditions, bioassay methodology and life history.

2.4 BACKGROUND LITERATURE

1. Sensitivity of Crangonids and Other Marine Crustacea to Toxicants

Studies on the effects of dredged materials have, for the most part, used various species of the genus *Crangon*. Other species have included *Palaemon macrodactylus*, *Pandalus* spp., *Leander adspersus*, *Penaeus aztecus*, *Panaeus duorarum*, and *Palaemonetes pugio*. The U.S. Army Engineering District, San Francisco (1975) tested the tolerance of two shrimp species, *Crangon nigricauda* and *P. macrodactylus*, to dredging activities by exposing them to suspended minerals. The U.S. Army tests were conducted in continuous flow, seawater aquaria. In general, *C. nigricauda* was described (along with mussels, striped bass and shiner perch) as being one of the more sensitive species to suspended kaolin. They also tested other shrimps (*C. nigromaculata* and *P. macrodactylus*), sea urchins, isopods, snails, crabs, tunicates and a polychaete for sensitivity to suspended kaolin. With *C. nigricauda*, 19% mortality occurred at 2 ppm suspended kaolin, while 13% occurred at 5 ppm. The more sensitive species were tested for the effect of lowered dissolved oxygen concentrations on bentonite mortality. All species tested had lowered tolerance to suspended bentonite as dissolved oxygen was lowered. Tests with *C. nigricauda* used 14-16 $^{0}/oo$ salinity, while those with *P. macrodactylus* employed 8-12 $^{0}/oo$ salinity. The lethal response of *C. nigricauda* to suspended bentonite was markedly lower at 10^{o}C than at 18^{o}C.

No consistent sensitivity relationship between the 48-h LC50 of *Crangon crangon* and British flatfish was observed with 140 substances ranging from solvents to polychlorinated biphenyls (Portmann and Wilson, 1971). In the same study, *C. crangon* was consistently less sensitive to toxicants than was the oyster *Ostrea edulis*. *C. crangon* were considerably more susceptible than the shorecrab, *Carcinus maenus* in 13 out of 21 experiments. Moore and Dwyer (1974) mention in their review article on oil effects, that lethal toxicity tests have been done using *Crangon* spp. and *Pandalus* spp. In Sweden, Rosenburg et al (1975) found *C. crangon* to be more sensitive to Swedish ECDtar (a bi-product from the plastics industry) than were *Cadus* sp. Static 48-h LC50's in 33 $^{o}/oo$ sea water were 5 and 10 ppm, respectively.

Crangon septemspinosus, an estuarine shrimp, reportedly can tolerate a wide range of thermal-salinity regimes. However, when dissolved oxygen is reduced from 6 ppm to 2 ppm, survival is markedly reduced (Olla, 1974).

Swedmark et al (1973) evaluated lethal and sublethal (behavioural) effects of oil, dispersants and emulsions of oil and dispersants in 32-34 $^{o}/oo$ salinity, on swimming impairment and survival in prawns (*L. adspersus*), hermit crabs and spider crabs; change in swimming activity, equilibrium and breathing rate in cod and flounder; valve closure ability of scallops and mussels; and byssal thread production in the common mussel. It was concluded that crustaceans were more resistant to oil dispersants than were fish or bivalves, but were very susceptible to emulsions of oil and dispersants.

Chin and Allen (1957) tested two size classes of each of two species of penaid shrimp with the insecticide Tri-6 Dust (composed primarily of benzene hexachloride). They found that there was no significant difference between the reactions of the brown shrimp *P. aztecus* and *P. setiferus*, but that there were substantial differences in sensitivity between the two size classes. The estimated 24-h LC50 for smaller shrimp (11-13 mm) was 440 ppb, while that for the larger shrimp (29-50 mm) was only 35 ppb. Reasons for the 10-fold decrease in sensitivity were not readily apparent.

P. aztecus showed a decrease in routine metabolic rate when exposed to a petrochemical waste (Steed and Copeland, 1967). *P. duorarum*, on the other hand, experienced an increase in normal metabolic rate under the same conditions.

The static 96-h LC50 of Aroclor 1016 to *P. aztecus* and the grass shrimp *Palaemonetes pugio* were 10.5 ug/l and 12.5 ug/l respectively (Hansen et al, 1974). The shrimp were not fed during the test, although they could have obtained plankton from the unfiltered sea water. The shrimp were more sensitive than were pinfish (96-h LC50 of 100 ug/l). Sublethal concentrations of Aroclor 1254 caused mortalities in *P. aztecus* when salinity was changed from 30 $^{o}/oo$ to 12 $^{o}/oo$ in eight hours (Nimmo and Bahner, 1974), although controls tolerated 0-69 $^{o}/oo$ salinity. Hansen et al (1974) also tested *P. pugio* for lethal response to 7 organochlorine and 5 organophosphorous insecticides. Test animals were collected with a beach seine, and were fed on chopped quahog clams. Tests were static, with salinity at 24 $^{o}/oo$ and temperature at 20^{o}C. Resistance of shrimp varied with salinity regime and insecticide. Shrimp were more resistant to the organophosphates (phosdrin and DDVP) at salinities of 18 $^{o}/oo$ and lower, but shrimp subjected to the organochlorine insecticides (DDT, endrin or heptachlor) were most susceptible at 12 $^{o}/oo$ (the lowest salinity tested) and appeared slightly more resistant at 36 $^{o}/oo$. Pesticide-induced mortality in shrimp increased directly with temperature over the range of 10^{o} to 30^{o}C.

Heitz et al (1974) studied the response to crude oil of stomach-hepatopancreas enzymes in *Penaeus* sp. and found little change, while Anderson et al (1974) found little change in respiration of *P. pugio* and *P. aztecus* on exposure to water-soluble fractions of oil. Couch et al (1974) studied the histology, ultrastructure and pathology of *P. duorarum* in relation to toxicant exposure.

2. Life History of Crangonids

The life history of Crangonids is poorly documented and the information included here is of a general nature, derived from accounts by Johnson and Snook, 1967; Barnes, 1968; and Hickman, 1966.

Crangonids are crustacean arthropods belonging to the subclass Malacostraca, order Decapoda, suborder Natantia. As such, their first three pairs of thoracic appendages are modified as maxillipeds, with at least some of the remaining five pairs being chelate legs. The head and thoracic segments are fused together dorsally, and the sides of the overhanging carapace enclose the gills within well-defined, lateral branchial chambers. They are characterized by a laterally compressed body, well-developed abdomen, and legs modified for swimming. The carapace of the cephalothorax extends to form a projecting rostrum.

Crangonids are bottom-dwellers, swimming intermittently, but spending the majority of their time burrowed into the sediment with only their antennules and antennae protruding. Burrowing is accomplished by beating the pleopods to excavate a cavity, and flexing the abdomen to move backward into the opening. The antennae and antennules push sediment over the carapace.

It is thought that crangonid shrimp are not sexually mature until two years of age. There is no record of the type of sex change found in some pandalid shrimp, crangonids being male or female from birth till death (Butler, 1964). Following copulation, the eggs are extruded, being fertilized as they are released. The eggs are trapped as they are released by the female in a cavity formed by flexing the abdomen far forward. A cementing material associated with the egg membrane attaches the eggs to the female's pleopods. Cleavage is spiral and determinate, resulting in the metamorphic formation of a protozoea larva. After approximately two months, hatching occurs, with development of the protozoea to the zoea and parva (or post-larva) taking place while the immature shrimp is a free-living member of the zooplankton. The parva then takes up the adult's life style, settling to the ocean floor and becoming an intermittent burrower.

3. <u>Parasites of Test Crangonids</u>

A variety of organisms can be parasitic on shrimp. Two were commonly found on the test species *Crangon communis* - one an isopod and the other a barnacle. The parasitic isopod was identified as *Argeia pugettensis*. Ricketts and Calvin (1968) report that one in every 20 to 30 specimens of *C. communis* caught commercially in Puget Sound is noticeably afflicted with this parasite. *A. pugettensis* belongs to the suborder Epicaridia and as such, requires two hosts to complete its life cycle. The egg hatches to an epicardium larva. Using its claw-like appendages and piercing-sucking mouthparts, the epicardium attaches to a free-swimming copepod. Here it undergoes six molts, metamorphosing first to a microniscus and then to a cryptoniscus. The cryptoniscus leaves its copepod host and attaches to the second host (in this case, *C. communis*), by entering the branchial chamber. Here it undergoes ecdysis to form a bophyridium which lacks swimming appendages. The first cryptoniscus to attach to the host always develops into a female, with all subsequent larvae attaching to the same host becoming males (Cheng, 1964). One can easily recognize the presence of *A. pugettensis* on *C. communis* by the large swelling of the branchial carapace overlying the point of parasitic attachment.

Even more obvious on the exterior of *C. communis* than the isopod, was the parasite *Sylon hippolytes*, appearing very much like a many-fingered blob of pink chewing gum on the ventral surface of the abdomen. *Sylon* is a member of the cirripedian order Rhizocephala. It was characterized by a highly modified sac-like body enclosing a visceral mass of primarily gonads. Body segmentation was not apparent and the animal lacks cirri, sense organs, and an alimentary tract. A root-like system of tubes extends into the interior of the host in all directions, through which nourishment from host body fluids are absorbed. The species is hermaphroditic, with the eggs developing in a brood chamber. Nauplius larvae escape from a pore in the sac which is also used for intake of oxygenated water. After several molts, the nauplius metamorphoses to a cypris. The cypris attaches by its hooked antennae to a decapod host (in this case *C. communis*). A cyprid larva is undifferentiated sexually. Once attached to the host, the protoplasm of the larva dedifferentiates to form a ball of embryonic cells which is injected into the host via a style in the antenna which penetrates the host's exoskeleton. This mass of cells is carried by the host's blood to the region of the alimentary canal near the juncture of the thorax and abdomen. Here the cells form a tumor with root-like processes wrapped around the alimentary canal. Further growth is directed posteriorly, with the body increasing in size and number of dendritic outgrowths (Cheng, 1964).

Among the severe changes possibly occurring in the host of rhizocephalan parasites is castration. The gonads of the host are retarded in development (i.e. multiplication and differentiation of gametocytes are hindered) and actual destruction of sex cells occurs, resulting in atrophy of the gonads. In many cases, there is also a sex reversal. Recent work by Charniaux-Cotton (1974) has shown that in most male malacostrican crustacea, differentiation of primary and secondary sex characteristics are controlled by the secretion of a pair of glands called the androgenics, located on the subterminal region of the sperm duct. In the female, these glands do not develop and control of ovarian differentiation is thought to be spontaneous. The ovary itself produces a hormone responsible for differentiation of secondary sexual characteristics. It is hypothesized that the barnacle parasite actually interferes with the functioning of the androgenic glands, which in turn cause the castration of male hosts. In juvenile shrimp, loss of the function of the androgenics may result in the development of female primary and secondary sex characteristics or sex reversal.

2.5 BIOLOGICAL EFFECTS OF DREDGE SPOIL AND THEIR ELUTRIATES

A substantial amount of literature can be found regarding the physical impacts of dredge spoil on the biota of dump sites. Such effects include burial of benthos, suffocation by clogged respiratory systems, increased turbidity, decline in primary productivity, loss of oxygen, loss of spawning and/or rearing habitats, release of nutrients to the water column, and release of pollutants to the water column. Most authorities agree that dredging impacts are rarely single factor disturbances. A change in one environmental characteristic usually results in ramifications throughout the entire system. Three good review articles on the general aspects of the effects of dredge spoil dumping are those by Copeland and Dickens (1969), Sherk (1971) and Thompson (1973).

Studies regarding shrimp in relation to dredge spoil are very much less abundant than are general impact studies. The U.S. Army Corps of Engineers (U.S. Army Engineering District, 1975) studied a variety of species in relation to dredge disposal in San Francisco Bay, including the shrimp *Crangon nigromaculata*, *C. nigricauda*, *C. franciscorum*, and *P. macrodactylus*. Under conditions of low temperature and saturated dissolved oxygen, survival of *C. nigricauda* (3-5 cm) was high even in high concentrations of suspended bentonite (used to simulate dredgate). Survival was reduced in increased temperature even when dissolved oxygen was saturated. A reduction in dissolved oxygen to 5 ppm dramatically reduced tolerance to suspended bentonite. There was a general tendency for smaller specimens to survive longer than larger ones; while there didn't appear to be any difference between ovigerous and non-ovigerous specimen survival rates. In suspended kaolin, the 200-h LC50 was 50 g/l for *C. nigromaculata*. The LC50 for *C. nigricauda* could not be calculated owing to large numbers of deaths due to cannibalism. However, this species was thought to be more sensitive than *C. nigromaculata*. The 200-h LC50 for *P. macrocactylus* was 77 g/l, indicating that this species was less sensitive to kaolin suspension than was *C. nigromaculata*.

Haefner (1969) reported little mortality in *Crangon septemspinosa* in clear, oxygen-saturated water at low temperature. A second series of tests (Haefner, 1970) revealed that a lowering of dissolved oxygen level to 2-3 ppm increased mortality of non-ovigerous specimens to 20% to 30%, and of ovigerous females to 40% to 50%.

Chang and Levings (1976) did experiments with various benthic species regarding sediment-type preferences (including substrates from dredge sites, some containing wood wastes). Studies with *Crangon alaskensis* indicated that sand was the preferred substrate, although mud could also be inhabited. Larger size particles and toxic materials were detrimental, while a depth of 1 to 2 cm of heavy material precluded burrowing by the species.

Pease (1974) reported one of the few studies available regarding leachates from wood debris. The tree species involved were similar to those processed at the MacMillan Bloedel facilities on Alberni Inlet. Although Pease's research concentrated on log dumping and rafting rather than dredging of wood wastes, some of his results are applicable to the present work. In general, the benthic epifauna were unaffected by wood debris in the log booming areas except at sites in use for long periods of time. However, the benthic infaunal abundance was noticeably reduced in all areas littered with wood debris. Leachates from red cedar, yellow cedar, hemlock, and spruce were toxic to pink salmon fry, especially in tests with fresh water. Spruce was the most toxic tree species in fresh water, while yellow cedar was the most toxic in 20 $^{0}/_{00}$ sea water.

The most applicable research found regarding the effects of wood debris leachate on shrimp was a study by Buchanan et al (1976). Toxicity tests using spruce and hemlock leachates were run on pink shrimp (*Pandalus borealis*) adults and larvae, crab (*Cancer magister*) adults and pink salmon (*Oncorhynchus gorbuscha*) fry. Spruce extracts were more toxic than were hemlock extracts to all invertebrates tested. However, hemlock extracts were more toxic to salmon fry. The invertebrates were generally less sensitive to all extracts than were salmon fry. Spruce bark particles with extracts were 2 to 6 times more toxic to shrimp larvae than were the extracts alone. Hemlock tests with larval shrimp showed only slight toxic effects at 1000 mgl^{-1}, with no mortalities after 96 hour exposure. With adult shrimp, spruce extracts were most toxic, although an LC50 could not be calculated. No mortalities occurred in hemlock extracts even after 96 hours.

METHODS

3.1 FIELD PROCEDURES

1. Field Collection of *Crangon* sp.

Shrimp (*Crangon* sp.) were collected with the fishing boat, Active Lass in waters between Passage Island and Fisherman's Cove, B.C. in the fall and winter of 1976 and 1977. This area was located at the southern extremity of Howe Sound, a fjord located 15 miles northwest of Vancouver (Figure 1). The transects were conducted about one mile offshore from Fisherman's Cove in waters about 120 m deep. This area was characterized by a soft mud bottom that was generally more snag-free than other locations considered. Organisms were collected by means of an otter trawl. The trawl was usually towed a total distance of one mile. It took a considerable distance to set and raise the trawl, so the bottom distance actually sampled was estimated at approximately one quarter mile. The otter trawl was twelve feet wide by three feet high at the opening with a mesh size at the cod end of 0.5 in. *Crangon* sp. were hand segregated from other organisms and debris at the completion of each haul. Three trips were required in November, and three in February to obtain an adequate supply of organisms. Normally, five hauls could be made per trip with each haul yielding 60-90 organisms

2. Transport of *Crangon* sp.

Shrimp were truck transported from the Pacific Environmental Institute in West Vancouver to the laboratories of E.V.S. Consultants in 50 gallon plastic buckets. Dissolved oxygen levels were maintained with compressed oxygen or air compressors via immersed diffusors. Ambient salinity ranged from 24 to 28 $^{o}/oo$ and ambient temperature ranged from 8 to 10^{o}C. Transport times did not exceed 1.5 hours.

3. Collection of Stickleback

Dip netting was used for the collection of threespine stickleback. A long-handled net consisting of 1/2" stretched mesh, 2' mouth diameter, with a 9' handle was found effective. These dimensions permitted a fast entry of the net into schooling fish. The net and handle were plunged straight into the water, under the school, so that no water passed through the mouth and meshes (which would slow the net's speed). Once under the school, the net mouth was immediately raised up through the school and out of the water. Sweeping the net through the water toward the school was not successful as it allowed the school time to detect and evade the net. It was found that only one net sweep could be made toward a school, after which the escaping fish would disperse and avoid the area of the collector. However, they would reassemble a short distance away for repeated dip-netting although it was always necessary to approach the schools quietly and without sudden movements. Several thousand stickleback were collected by this method in a few hours. No stickleback were lost in transit and mortalities in the stickleback holding tanks were less than 0.1% throughout the study.

Stickleback were collected in Coal Harbour, Vancouver, B.C. off the wharves of the Royal Vancouver Yacht Club. Surface water salinities were 18-20 ppt and temperature was 10-12^{o}C during fall and winter collections.

3.2 LABORATORY PROCEDURES

1. Holding Facilities

Fish were held in square tanks with rounded corners, 200 l volume at the Pacific Environmental Institute or the Vancouver Public Aquarium. The tanks were provided with through-flows of sea water at a turnover rate of about once per hour. Sea water temperatures varied between 8^{0} and 12^{0}C, and salinities varied from 22 to 28 ppt. The sea water inlets directed flows around the tank walls to create circular currents. Screened standpipe overflows were positioned centrally. At the Aquarium, the tanks were provided with coarse sand on the bottom and with ample aeration. Overhead banks of fluorescent lights were on for about 9-10 hours during the day. Indirect lighting from other work areas provided low-level illumination at night.

Oval shaped tanks of 200 liters were used for shorter term holding of fish immediately prior to bioassay. These holding tanks were static rather than through-flowing. Artificial sea salts/natural sea water (50/50) were used to provide the desired salinities. The tanks were held in a cold room adjusted to either 10^{0} or 15^{0}C, with a simulated natural photoperiod of 14 hours light and 10 hours dark (including twilight periods), and low illumination during the night period.

Artificial sea water was prepared from a commercial source, RILA Marine Mix (Rila Products Ltd., Teaneck, New Jersey) a day before requirement for testing. Approximately 1 pound of RILA Mix made 3 U.S. gallons of artificial sea water of a salinity ranging 26-28 ppt. Usually a small amount of residual salts remained undissolved after thorough mixing. An initial cloudy appearance was also noted, but this and the residual salt cleared within 2 to 4 hours. The following day, quantities were siphoned as required.

2. Stock Maintenance Procedures

Feeding and sanitation procedures were followed daily. Ground trout chow was introduced 1-3 times daily, with additional, irregular feedings of other food items (live or frozen brine shrimp, frozen euphausiids, chopped canned shrimp, chopped fish fillets, ground up blue mussels and fish parts).

With the through flow holding facilities, sanitation involved daily cleaning the overflow screens and less regular washings of the bottom sand depending on stock density and fouling rate. With the static holding tanks, bottoms were siphoned one or two times daily (according to organism density) and surface scum at the tank edges was removed at the same times. An Eheim power filter (model 2018) was rotated among tanks, daily on weekdays, along with continual operation of air-lift cellulose acetate fibre filters.

3. Leachates and Reference Toxicants

Dredge spoil leachates were supplied by Econotech Services in two batches, each consisting of seven samples. Batch 1, received December 3, 1976, was the initial leachate decanted from dredge spoil samples collected in Alberni Inlet late in November 1976. Batch 2, received February 9, 1977, were leachates from the same dredge spoil material after it had been placed in lysimeters at 4^{o}C for two months. Since all leachates contained greater than 20 ppt salinity, pH adjustments were not made and these samples had ambient values of 7.0 - 8.0.

A stock solution of NaPCP (14,418 ppb) was prepared from reagent grade 2, 3, 4, 5, 6 - pentachlorophenate (M.W. 266.36) by the addition of NaOH according to the method of Alderdice (1963) for use as a reference toxicant. Approximate volumes of a 1:100 or 1:1000 dilution of stock solution were used to give the desired test concentrations and prepared immediately prior to bioassay preparation. The range of concentrations used was 5 to 600 ppb.

All test solutions were made by mixing with an appropriate volume of dilution water. Dilution water consisted of tap water, dechlorinated by passage through a 3.5 ft^3 charcoal filter installed on-line, or salt water as described above. This water also supplied all freshwater flow through holding tanks and was used for the preparation of artificial sea water. The water had a temperature range of $10 \pm 2^{o}C$, a total hardness of 4-12 mgl^{-1} as $CaCO_3$ and a pH range of 6.2 - 6.8.

4. Bioassay Procedures

Bioassays of leachates and sodium pentachlorophenate (NaPCP) were conducted with stickleback (0.25 - 0.45 g) and *Crangon communis* (0.1 - 4.6 g). To determine the relative toxicities of the seven leachate samples, median survival times (MST's) were determined in 100% leachate using the saltwater stickleback. The limited volumes of leachate sample available dictated the type of bioassay. Further, only five fish could be used per leachate and comply with an accepted loading density of 0.5 gl^{-1}. However with NaPCP, full static 96-h LC50 bioassays were conducted with stickleback.

Test solutions were aerated prior to and during bioassay. However, dissolved oxygen levels were not always greater than 90% saturation and sometimes more than 10% saturation was difficult to achieve. Fish were not fed for 48 hours prior to starting the bioassays nor for the duration of the test.

Static 96-h LC50 bioassays were also conducted with *Crangon communis* in serial dilutions of toxicant and leachate. Dissolved oxygen and pH levels were checked every 24 hours. To initiate 96-h LC50's, 10 organisms were added to each tank containing sufficient volume to give a loading density of less than 1.0 gl^{-1}. Percent survival was recorded at 15 and 30 min. and 1, 2, 4, 8, 24, 48, 72 and 96 hours. Incidental observations of mortalities at other times were also recorded. Dead animals were removed with forceps as they were found, weighed and measured (weight and length, and incidence of gill clogging, parasites and pregnancy was noted). A bioassay temperature of 15°C was chosen initially for December work since it characterized the coastal situation of British Columbia above a depth of 30 meters (Hoos, 1973). For similar reasons, a salinity of 25 ‰ was also chosen. Dissolved oxygen was measured using a YSI model 54 oxygen probe with stirrer. Salinities were monitored by a YSI Salinity-Conductivity meter, model 33. Bioassays were conducted in February at 10°C because of lower holding temperatures.

It was intended to calculate 96-h LC50's by fitting a line to log-probit data, expressed as concentration vs. percent mortality at 96 hours according to the nomographic procedures of Litchfield and Wilcoxon (1949). However, data did not permit calculation, and LC50's were estimated graphically from the log-probit plots. For each 96-h LC50 bioassay, cumulative percent mortalities were plotted against exposure time on log-probit by the method described by Bliss (1937). Median survival times (MST) were estimated from the log-probit lines and MST plotted versus toxicant concentration on log-log paper to obtain a toxicity curve (Sprague, 1969; Brown, 1971).

All raw bioassay data are presented in Appendices I and II.

RESULTS AND DISCUSSION

4.1 COLLECTION AND HANDLING CHARACTERISTICS OF *CRANGON* SP.

Field collections were undertaken at various times from October, 1976 to February, 1977. A summary is presented in Table 1. On October 21, 1976, four samples of 10 min duration (bottom time) were trawled. About 97 *Crangon* sp. were caught and transported to the Vancouver Public Aquarium for holding. An initial heavy mortality was observed which reached 33% at 72 hours. Subsequent mortality over the following two weeks equalled 7.7%.

On November 11, 1976, three trawls of 10 min duration were completed by the "Active Lass" using a smaller mesh size. This resulted in a larger catch of about 200 *Crangon* sp. per haul. A total of 670 shrimp were thus acquired and transported to the Vancouver Public Aquarium. Both October 21 and November 11 trawls included large quantities of clay and debris which increased on-deck handling and sorting times. On-deck handling times were about 30 min, usually as the result of removing excessive debris from around the specimens, as well as extricating the appendages of specimens imbedded in clay. The high mortality of the crangonid shrimp from these cruises was probably due to one or more of the following factors:

i) duration of on-bottom trawl time
ii) on-deck handling times extending up to one-half hour per haul
iii) limited on-deck holding facilities resulting in immobilized shrimp piling up in drifts

On-bottom travel time was considered to be the most important factor and as a result, it was reduced to 3-5 min.

On December 1, 1976, three trawls were taken with the "Active Lass" yielding about 190 crangonid shrimp. On December 3, five trawls were made yielding about 495 shrimp. All trawls were of 3 min duration bottom line. On-deck handling time was under 10 min for each haul. Specimens caught December 3 were particularly active and resumed a normal posture in holding tubs immediately after removal from the trawl (only 2 to 3% were "belly-up" or on their side). The 72 hour handling mortality for the Dec. 3 trip was under 2% (1.8% at Vancouver Aquarium, 1.5% at Pacific Environmental Institute) and for the December 1 trip, 6.8% and 5.5%, respectively at the two holding facilities. In comparing the handling mortalities for 3 minute versus 10 minute hauls, a three to five fold reduction in mortality was observed, which corresponded to the proportion of *Crangon* sp. which failed to re-establish equilibrium in the holding tubs. The improved viability was attributed to a decrease in the amount of fish, debris and clay in the net, thereby reducing factors of suffocation and crushing. Thus, it appeared that on-bottom trawl time was a major factor in mortality among collected specimens.

On-deck handling time (10 and 30 min for 3 and 10 min hauls, respectively) corresponded to on-bottom trawling time, but the catch rate was higher in hauls of shorter duration, with an average of 31 per min for 3 min hauls versus 13 per min for 10 min hauls. Lower catch rates in longer hauls may have resulted from increased escapement as the finer meshed cod end filled. Therefore, specimens from 10 min hauls were probably caught early in the haul, which increased the opportunity for damage from crushing or suffocation. It was concluded that three min trawls were efficient and yielded viable specimens for bioassay.

Feeding preferences were not rigorously ascertained, but several varieties of food were presented to the crangonids. Some feeding was noted during the day but only a few individuals displayed this activity. Feeding appeared to be predominantly at night since food disappeared from the bottom of the tanks overnight. This correlates with the increased activity observed late in the evening. In addition, signs of cannibalism were apparent.

However, a reduction in vigor of *Crangon* sp. resulted after a 2-3 week period under the imposed laboratory conditions. Stocks were maintained successfully for periods of two weeks with daily mortalities at less than 1% such that bioassay results were consistent. Longer holding periods resulted in a decreased vigor and increased morbidity. Although individuals were observed to feed, further studies are required to examine food suitability and the requirements for the maintenance of a vigorous stock over extended periods of time.

4.2 ARTIFICIAL SEA WATER TOLERANCE

In order to assess tolerance to artificial sea water (RILA), crangonids were exposed to different concentrations of RILA salts and sea water. A control consisted of pure sea water, as obtained from the Vancouver Public Aquarium. Results appear in Table 7, Appendix I. One individual expired in 100% RILA salt water and, although deductions made are inconclusive, it was decided to use only natural sea water for the experimental program.

4.3 DREDGE SPOIL LEACHATE BIOASSAYS

1. Leachate Oxygen Demand

Two batches of dredge spoil leachates consisting of seven samples each were provided by Econotech Services on December 3, 1976 (Batch 1) and February 9, 1977 (Batch 2). Leachate samples in Batch 1 were difficult to aerate to oxygen levels acceptable for bioassay. This was particularly true for samples B, C and D, where 2 minutes of vigorous mechanical aeration did not satisfy oxygen demands. The trend of these observations was substantiated by chemical analysis for BOD_5 and COD (Table 2).

By contrast, leachate samples from Batch 2 presented no serious problem in achieving oxygen levels of 6.2 - 11.5 mgl^{-1} by mechanical aeration. Chemical analysis for BOD_5 indicated levels comparable to Batch 1, and COD's were higher than for Batch 1. There are two possible explanations: fresh leachate has a high immediate oxygen demand which decreased with lysimeter storage; alternatively, the differences may be due to artifacts between chemical analysis and bioassay. Suspended material in samples was allowed to settle before aliquots were decanted for BOD_5 and COD analysis (P. Thomas, pers. comm.), whereas, a fully mixed sample with solids suspended was used for shrimp and stickleback bioassays.

The low oxygen values observed in some leachate bioassays were similar to those reported by Parker and Sibert (1973) and R. A. W. Hoos (pers. comm.) for the dumpsite in Alberni Inlet. Davis (1976), Hicks and DeWitt (1971), Pickering (1968), and others have documented the increase in sensitivity of fish to toxicants at low oxygen concentrations. Olla (1974) reported increased mortalities in *C. septemspinosus* when dissolved oxygen values were reduced from 6.0 ppm to 2.0 ppm. Clearly, interactions of this nature warrant better definition both with respect to the organisms selected for bioassay, and tolerable in situ conditions.

2. Threespine Stickleback, *Gasterosteus aculeatus trachurus*

With the first batch of seven leachate samples provided by Econotech on December 3, 1976, all samples, except E, had MST values less than 96 hours, which demonstrated clearly that six of the seven dredge spoil leachates were acutely toxic to stickleback. Sample E exhibited toxic effects during the first four hours of the bioassay (60% survival @ 4 hours) but further effects were not observed to 96 hours. By contrast, none of the second batch of leachate samples obtained February 9, 1977 were acutely toxic to stickleback. MST's for all samples in Batch 2 were greater than 96 hours (Table 2, Table 8, Appendix 1).

3. Sand Shrimp, *Crangon* sp.

Raw data for acute lethal bioassays of Batch 1 leachate with crangonids are presented in Tables 9-16 and results for the seven dredge spoil leachate bioassays from Batch 2 are detailed in Tables 18-24. 96-h LC50 values and MST's are summarized in Table 3. In Batch 1, only samples A, B and C were acutely lethal to crangonids. For samples A and B, there was adequate sample to repeat MST bioassays in 100% leachate. Results are shown in Table 10 and Table 3, in brackets. These tests were conducted 14 days after the initial Batch 1 bioassays, and indicated that substantial decrease in toxicity occurred during the intervening period. Dredge spoil leachate may contain a number of unstable constituents including hydrogen sulfide (cf Table 3) and decreased toxicity could be the result of storage or mechanical aeration. Davis and Mason (1973) reported variable toxicity of pulpmill wastes with storage and aeration, and E.V.S. Consultants (1976c) have described the unstable nature and rapid attenuation of leachate toxicity in situ.

Leachates from the second batch of samples obtained in February, were all non-toxic to shrimp. Comparison of chemical analyses of leachates from Batch 1 and Batch 2 indicated an increase in most constituents analyzed which is opposite to the trend in bioassay results. It is quite conceivable that the principle toxic constituents have not been analyzed for or identified in the present work. Hydrogen sulfide was a likely toxicant. However, chemical analytical data is presented in Table 2 showing levels of H_2S ranged from 0.1 to 0.9 ppm for 5 dredge spoil leachate samples. Samples B and C far exceeded reported minimum lethal levels, being 167 and 5.1 ppm, respectively. Levels of 1.0 to 1.2 ppm have been shown toxic, as the minimum lethal concentration to several salmonid species (Haydu et al, 1952), as well as levels of 1.82 to 7.00 ppm H_2S to catfish fry (Bonn and Follis, 1967). It is apparent that more extensive analyses of dredge spoil leachates are required in order to identify and define deleterious components. Volatile constituents such as ammonia, phenolics, fatty acids and resin acids are among the possible components. The anomalies of non-lethality in the presence of initially high sulfide concentrations also warrants more definitive investigation.

The behavior of shrimp in leachate bioassay was characteristic. During the first few hours of bioassay a blanket of sediment usually settled out, ranging from a trace to 3 to 5 cm deep at the 100% test concentration. *Crangon* sp. were observed to bury themselves with only antennae, rostrum and eyes visible. Under these conditions, no swimming activity was noted although individuals exhibited a strong escape reflex when prodded. Buried animals also displayed increased movement of antennae in comparison to individuals that were in aquaria offering no cover. This behavior suggests a possible preference for a muddy bottom, at least during daytime hours. This relates to the shrimp's natural habitat at which they were collected by trawl. For example, one individual crangonid was situated immediately adjacent to the glass and a "breathing chamber" was noticeable around the entrance to the carapace respiratory organs.

4.4 REFERENCE TOXICANT BIOASSAYS WITH NaPCP

1. Threespine Stickleback

Toxicity data for stickleback is tabulated in Tables 25 and 26, Appendix 1 and summarized in Table 4. 96-h LC50 values of 50 and 70 ppb NaPCP were obtained with stickleback for Batch 1 and Batch 2, respectively. Loading densities were recorded as 0.64 and 0.78 gl^{-1} and salinities were 25 $^{0}/oo$ for the two bioassays. Loading densities are sufficiently different to possibly account for the different LC50 values obtained for NaPCP (Vigers and Clarke, 1975). Alternatively the decrease in sensitivity was associated with larger fish (0.35 vs. 1.0 g), so size may be a factor. Temperature affects NaPCP toxicity such that an increase in toxicity is obtained with an increase in temperature, as in the case of juvenile sockeye salmon (Alderdice, 1973). The Batch 1 bioassays were conducted at 15^{o}C, Batch 2 at 10^{o}C, and a decrease in toxicity would be consistent with this temperature difference. Stickleback displayed a sensitivity to sodium pentachlorophenate similar to that reported for rainbow trout (E.V.S. Consultants, 1976b; Davis and Hoos, 1975).

2. Sand Shrimp

The sensitivity of *Crangon* sp. to sodium pentachlorophenate was also determined. Results are tabulated in Table 27, Appendix I for Batch 1. These particular animals, from the October 21, 1976 collection trip, were moribund upon receipt with a high degree of mortality in the holding tanks. A bioassay was conducted, test animal condition notwithstanding.

Anomalous results were obtained, with death at all test concentrations, confirming the animals' observed condition.

A second sodium pentachlorophenate bioassay on animals collected December 1 and 3, 1976 resulted in a 96-h LC50 of 245 ppb (Table 28, Appendix I), summarized in Table 4. The mean weight was 1.31 ± 0.76 g with an average loading density of 0.82 gl^{-1}. This stock of animals was used in the Batch 1 leachate bioassays. This LC50 value indicated a three to five-fold difference in sensitivity relative to the three-spine stickleback. This difference in sensitivity between stickleback and mature crangonids is consistent with the differences observed in sensitivity to Batch 1 dredge spoil leachates. It is also consistent with the findings of Buchanan et al (1976) that pink salmon fry were three to four times more sensitive than the adult prawn *Pandalus borealis* to toxic wood extractions.

In order to determine the effect of loading density on *Crangon* sp. toxicity, the LC50 value of 245 ppb was tested with the following ratios: 0.2/0.5/1.0/5.0/and 10.0 gl^{-1} (Table 32, Appendix I, and Figure 2). These data indicated that loading density is an important variable for crangonid bioassays. MST's over 96 hours indicated that a reduction in toxicity with increased loading was not observed at or below 1.0 gl^{-1}. At loading densities of 2, 5 and 10 gl^{-1}, a reduction in toxicity was observed. At 10 gl^{-1}, 245 ppb sodium pentachlorophenate was nearly nontoxic with 90% survival at 96 hours.

Shrimp stocks used in Batch 2 leachate bioassays were assessed with NaPCP to compare sensitivity with the December stock. Results are tabulated in Tables 29 to 31, Appendix I. This particular stock (collected January 18 & 25 and Feburary 1, 1977) was not bioassayed with NaPCP until February 14, 1977, the week following bioassay of the second batch of dredge spoil leachates.

During the intervening period, excessive morbidity set in. As a result, there were unacceptable mortalities in controls and no clearly defined LC50 could be obtained. Mortalities up to 24 h compared with the response of crangonids tested in December, but no definitive pattern existed beyond 24 h. Holding conditions and elapsed time from collection were very similar between the two batches and would not account for the observed mortalities. For example, elapsed holding time in December was 25 days and in February it was 24 days.

Tatem et al (1976) noted an increase in sensitivity of grass shrimp (*Palaemonetes pugio*) to dodecyl sodium sulphate (DSS) in a study determining the effect of seasonal variation in the resistance of these crustaceans and their response to DSS after various holding periods in the laboratory. However, the February reference toxicant bioassay did not permit a comparison with the results of Tatem et al (1976).

Behaviorally, the crangonids did not display the characteristic twitching, flexing symptoms under the toxic influence of NaPCP as is usual with piscine species. In the test tanks, shrimp remained relatively quiescent, resting in a natural position on the bottom. However, the quiescence may have been due to inherent diurnal behavior with peak activity at night.

4.5 RELATION OF POPULATION CHARACTERISTICS TO RELATIVE TOXICITY OF *CRANGON* SP.

Three crangonids were collected, as follows: *Crangon communis*, *C. alaskensis* and *C. resima*. The distribution was predominantly *C. communis* (99.4% for December catches, 98.6% for the February catches, *C. alaskensis* comprising most of the remainder). No division at the species level was attempted prior to bioassay. Rather, "mixed bag" bioassays were conducted with a random selection of individuals. Individual characteristics were recorded as animals expired, including size, number of individuals parasitized, number of ovigarous females, moults and degree of gill clogging. Raw data is compiled in Appendix II, Tables 33-53 for each test concentration.

In order to assess the relationship between total mortalities at 96 h and characteristics of the *Crangon communis* population sample, animals were examined and tabulated as they expired for each test concentration for both dredge spoil leachate and NaPCP bioassays. Population was examined in terms of species, weight, parasitism, sex and sexual maturity. It was difficult to distinguish between males and non-ovigarous females. Therefore, all individuals were sexed as immature animals or ovigarous females. Since the population sample was predominantly *C. communis*, individuals of other crangonid species encountered were excluded in the statistical analyses. Weights were read as ± 1 standard deviation. Tabulations of each sample and test concentration are presented in Appendix I and summarized in Table 5.

The population structure in terms of weight distribution is outlined in Figures 3 and 4. The mean weight of Batch 1 crangonids was 1.71 ± 0.22 g (1 S.D.) versus 1.56 ± 0.24 g (1 S.D.) for Batch 2 animals. Interestingly, the population was monomodal for

Batch 1 and bimodal for Batch 2. The peak at the lower end of the weight scale for the February catch consisted entirely of immature specimens. Ovigarous females all weighed more than 1.2 g and represented the heavier members of the population.

Table 6 presents a comparison of parasitism, numbers of ovigarous females and *C. alaskensis* between Batch 1 and 2 populations (see Figures 5 and 6). The total population was included, with both those tested with the leachates and the reference toxicant. There was a significant increase in the numbers of egg-bearing females in February (Figure 4). Little change was seen in the degree of parasitism encountered between the two populations. *Sylon hippolytes* represented 94.6% of the encountered parasites. Only one female (*C. alaskensis*) was encountered with both eggs and the parasite (December catch). Some of the larger individuals infected by *Sylon hippolytes* may have been suppressed from producing ova due to retardation of gonad development as indicated by Cheng (1964) for the rhizocephalan parasite. Parasitism was significant in mortalities for Batch 1 leachate bioassays ($P > 0.5$). The occurrence of parasitism in death of specimens collected for Batch 2 bioassays was also significant ($P > 0.5$), being higher than in the total population sample. Egg carrying females collected in December were marginally more sensitive to Batch 1 leachates than immature specimens, but ovigarous females collected in January were significantly more resistant than the normal population (Table 4). Interestingly, for *Crangon nigricauda*, no apparent difference existed in the resistance to suspended bentonite between ovigarous and non-ovigarous individuals (U.S. Army Engineering District, 1975).

Mortalities in bioassay showed no relationship to size/weight distributions (Table 5), and differences between live and dead specimens was not significant ($P < 0.5$). Batch 2 data for sodium pentachlorophenate were not included due to high mortalities in controls. Table 6 includes those that expired in the early stages of the bioassay in relation to the "norm". Thus, conceivably, a mixed batch bioassay can be conducted, with respect to size/weight distributions. However, ovigarous females and parasitized animals should be excluded if one wishes to obtain a homogeneous response in acute lethal bioassays with *C. communis*.

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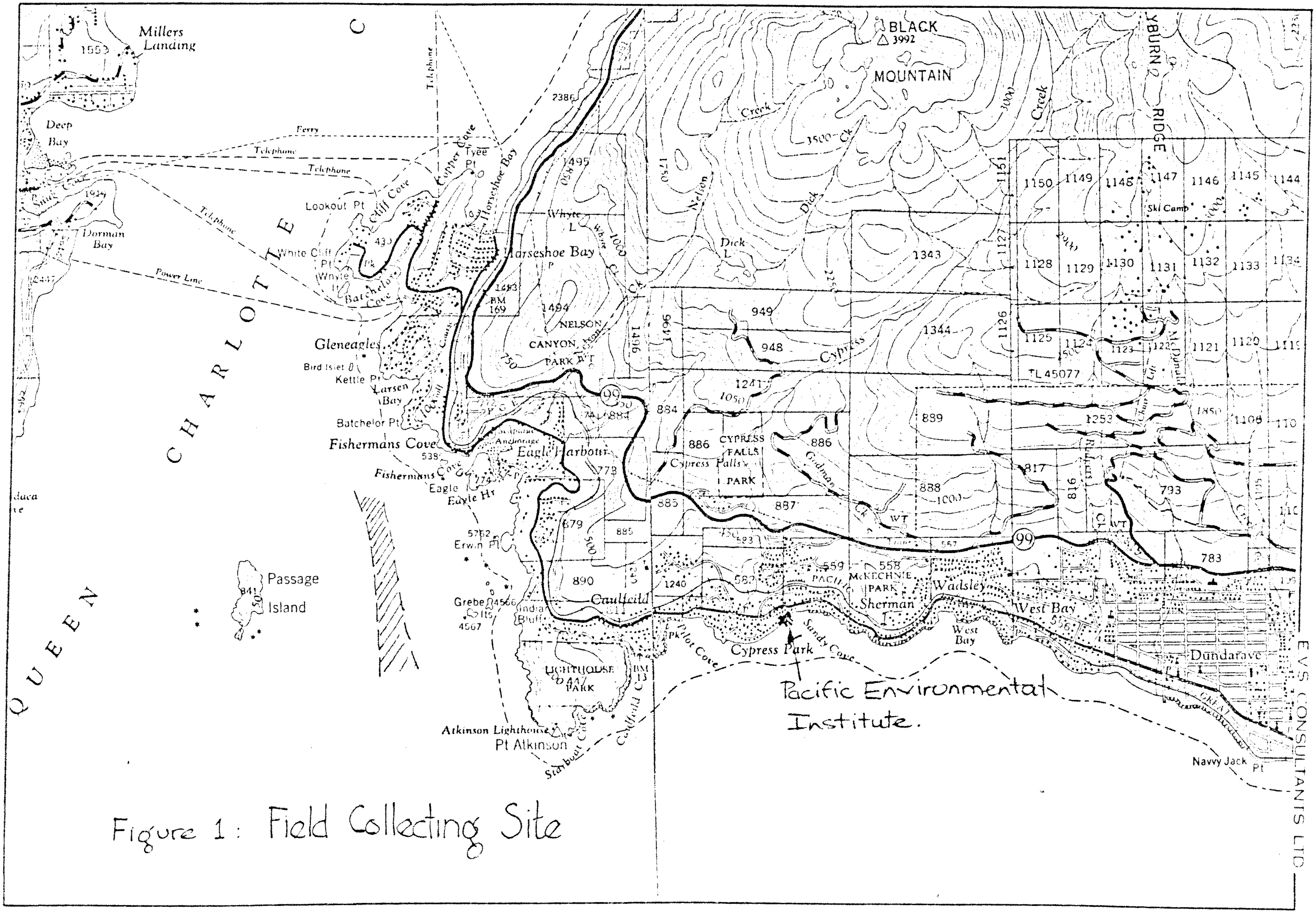


Figure 1: Field Collecting Site

Figure 2. Effect of loading density on Toxicity - *Crangon* sp.
sodium pentachlorophenate

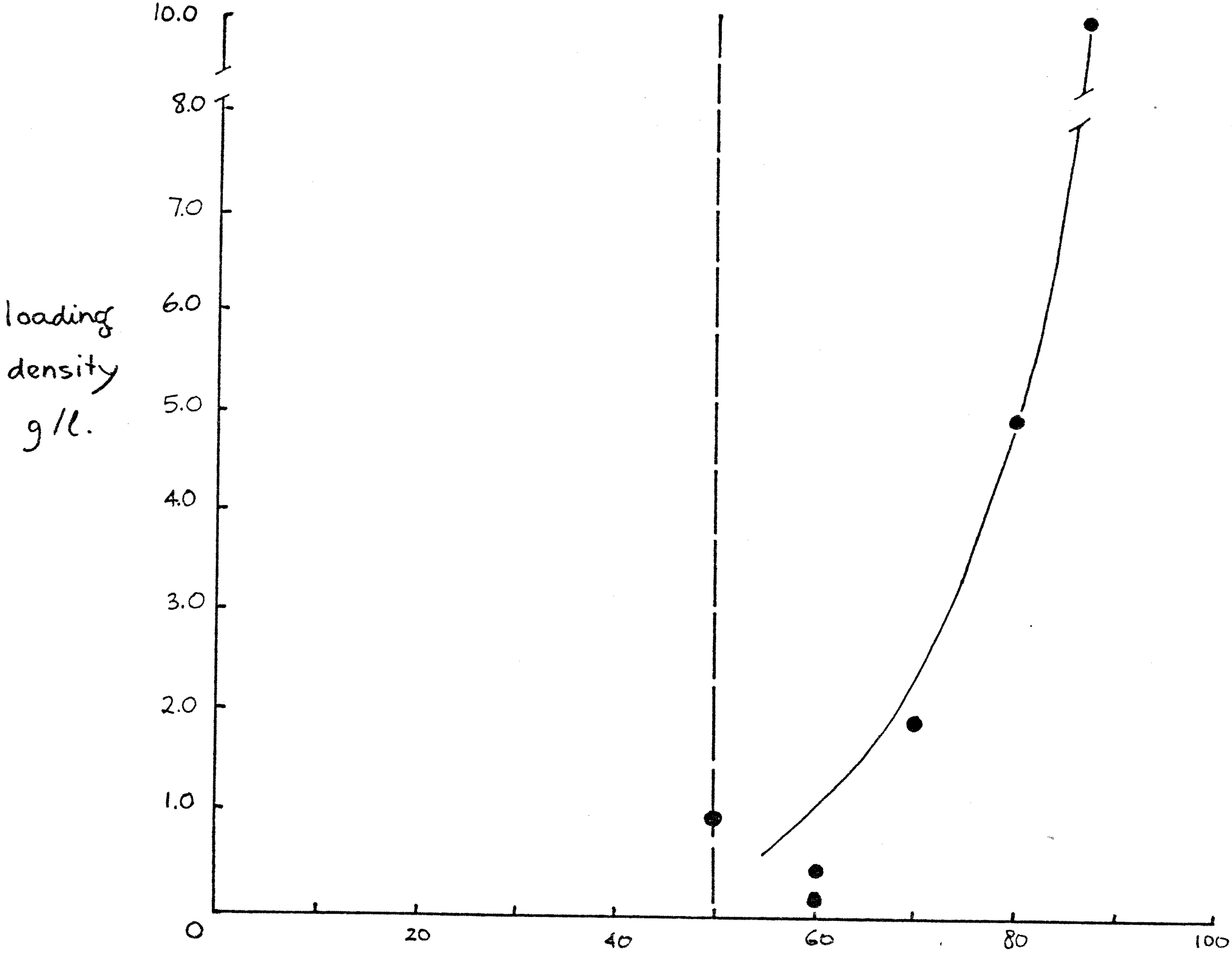
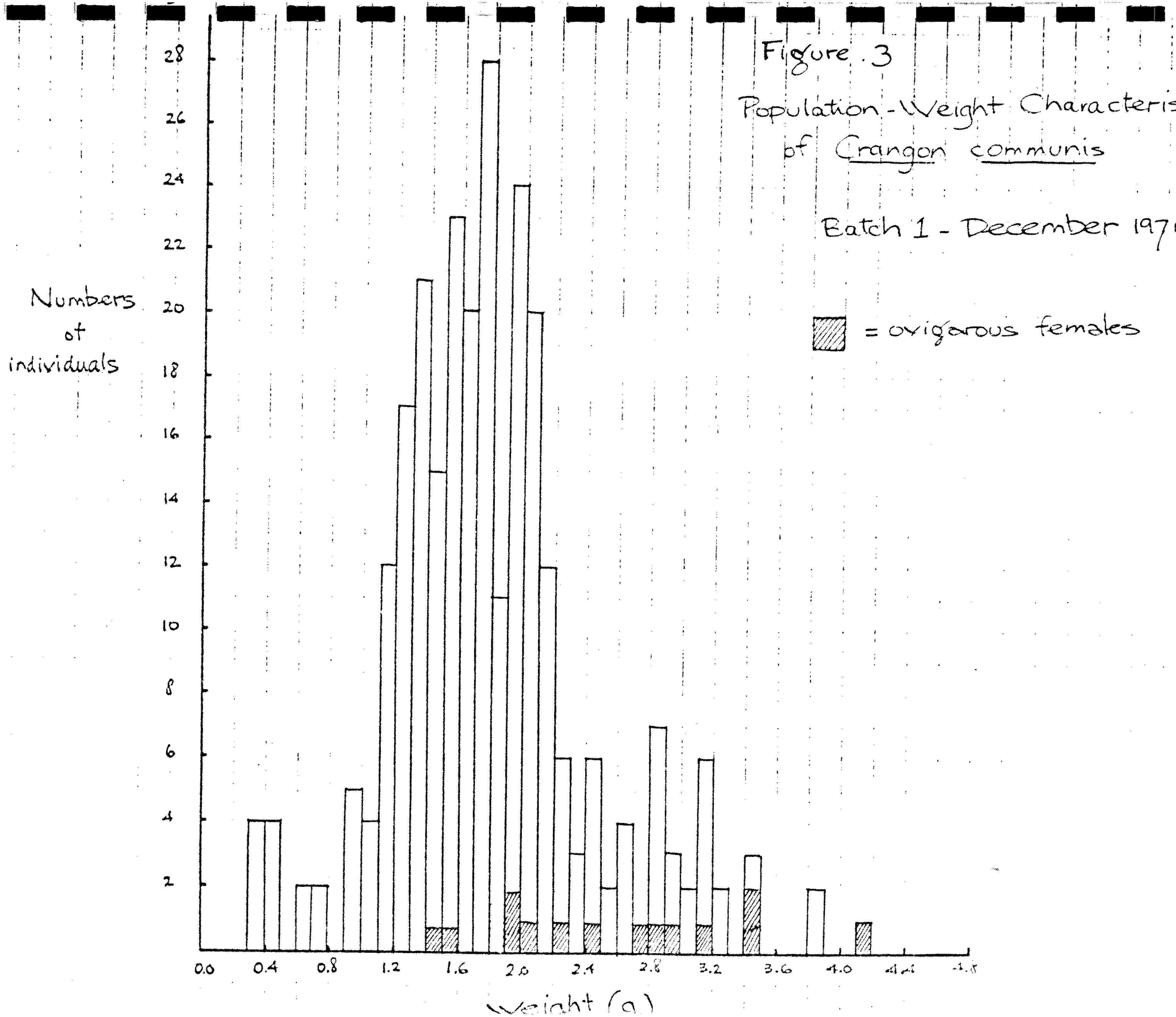


Figure 3

Population - Weight Characteristics of *Crangon communis*

Batch 1 - December 1976



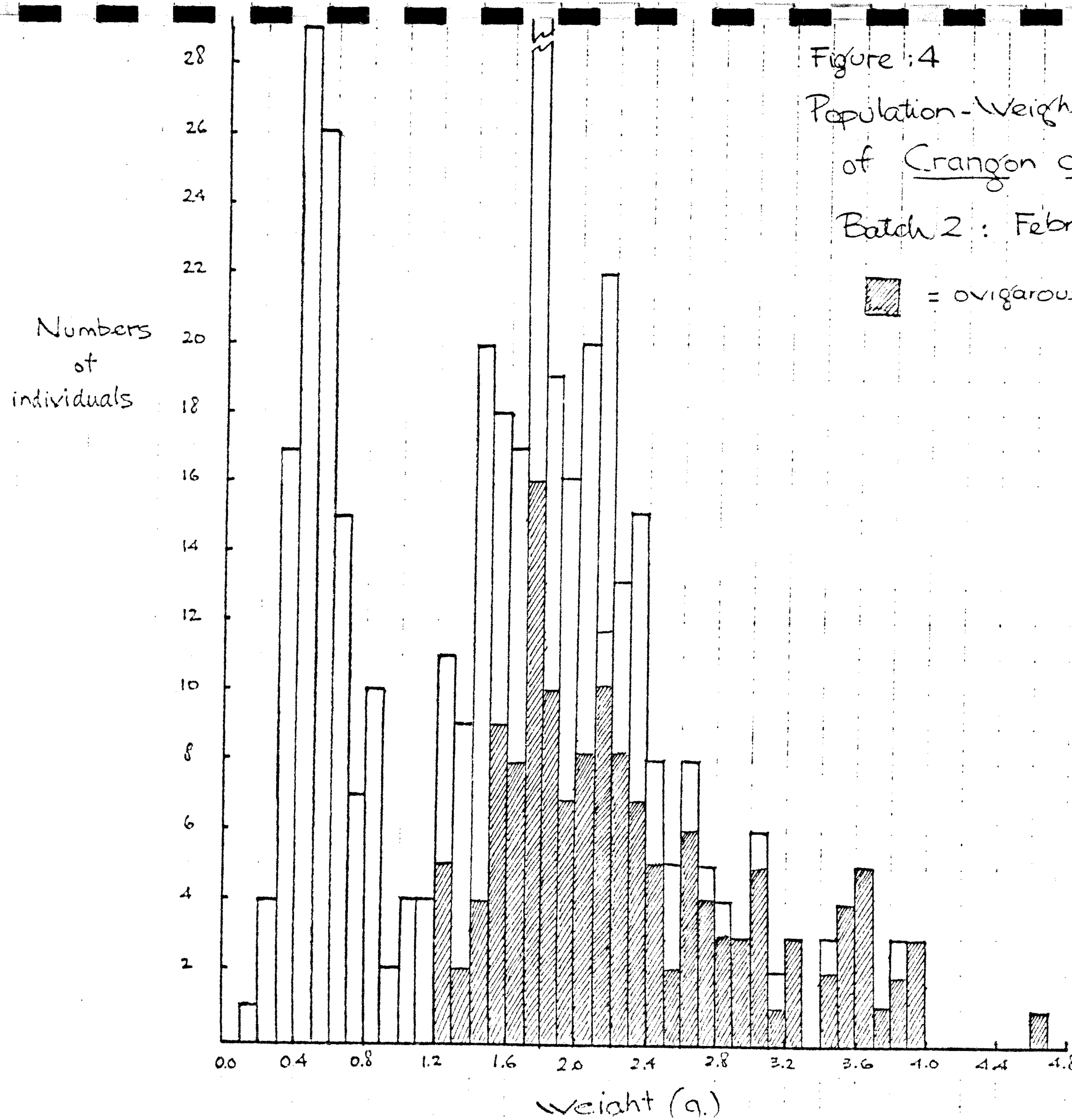


Figure :4

Population-Weight Characteristics of *Crangon communis*

Batch 2 : February, 1977

Figure : 5

Population - Parasitism of *Crangon communis*

Batch 1 : December, 1976

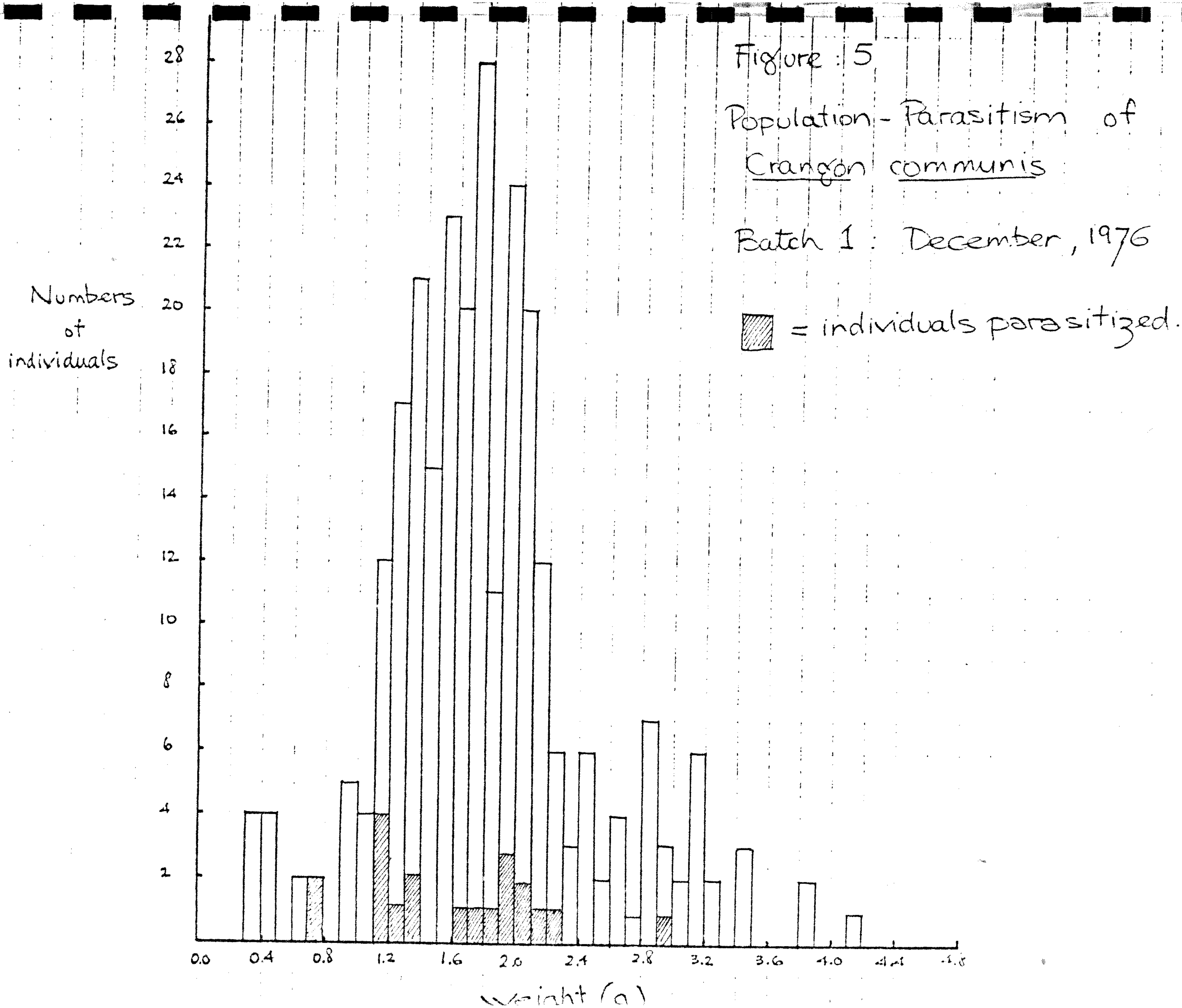


Figure: 6

Population - Parasitism of *Crangon communis*

Batch 2 : February, 1977

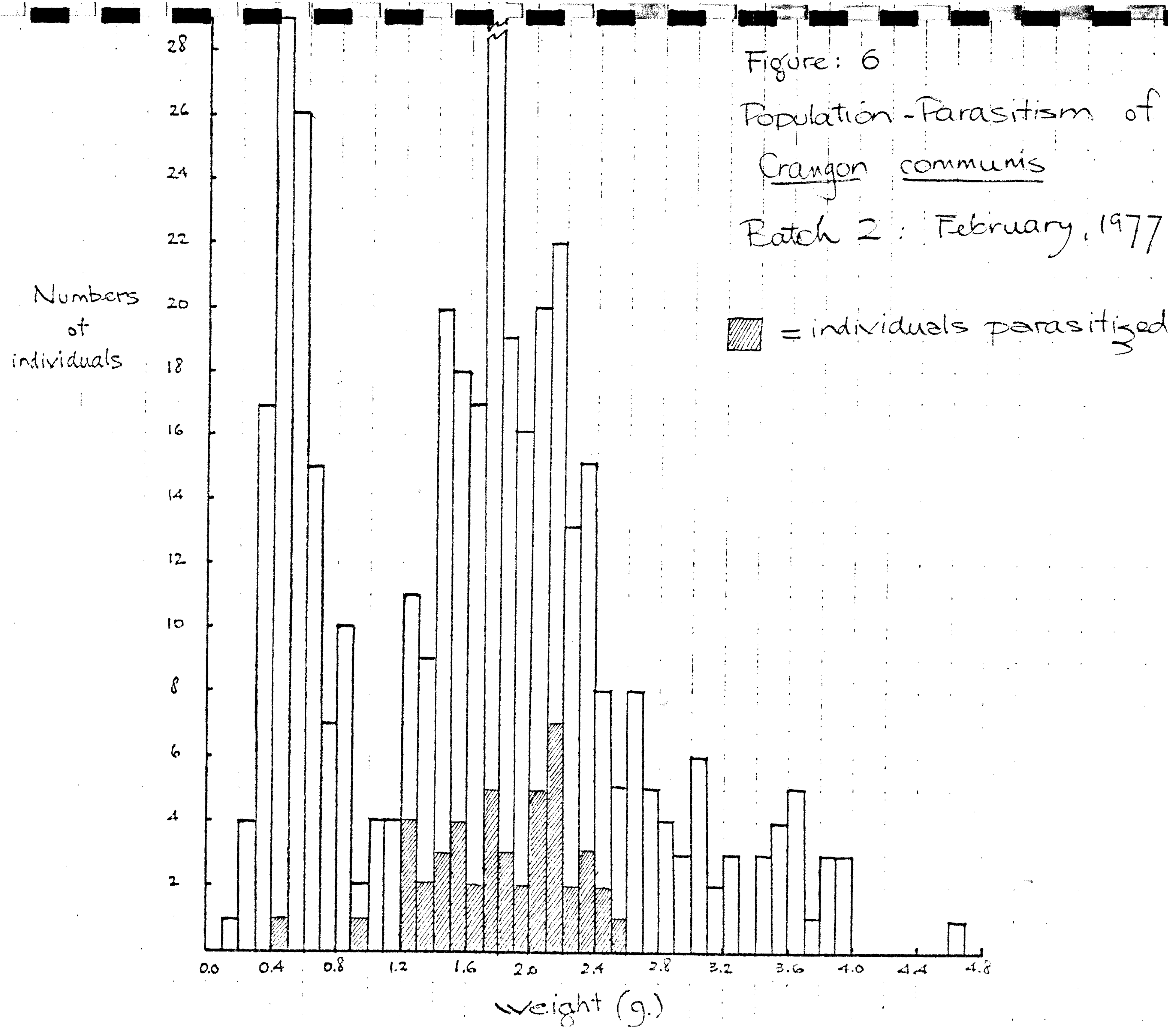


TABLE 1. SUMMARY OF COLLECTION AND HANDLING RECORDS

Cruise Date	No. of Trawls	Bottom Time (min.)	No. of Crangonids per Haul	Total Crangonids for Day	Deck Handling Time/Haul (min.)	Comments
October 21, 1976	4	5 - 10	20 - 30	97	up to 30	moribund
November 11, 1976	3	10	200	670	up to 30	some vigorous
December 1, 1976	3	3 - 5	60 - 75	190	10	vigorous
December 3, 1976	5	3	90 - 100	495	10	vigorous
January 18, 1977*	5(est)	3	90	400	10 or less	vigorous
January 25, 1977*	5(est)	3	100 - 120	400 - 500	10 or less	vigorous
February 1, 1977*	2	3	60	125	10 or less	vigorous

* collected by P.E.I. staff

TABLE 2. ANALYSIS OF DREDGE SPOIL LEACHATES*

Parameter	Batch 1 - December 3, 1976 Leachate							Batch 2 - February 9, 1977 Leachate						
	A	B	C	D	E	10	12	A	B	C	D	E	10	12
1. Oxygen content (mgl^{-1})	0.1	0.1	0.2	0.2	0.2	2.1	4.9	0.05	N.D.	N.D.	N.D.	2.9	7.2	8.1
2. H_2S (mgl^{-1})	0.9	167	5.1	0.9	0.1	0.1	0.1	190	382	96	30	3.7	0.9	0.8
3. BOD_5 (mgl^{-1})	7	54	18	14	4	2	2	37	32	43	27	7	4	2
4. COD (mgl^{-1})	24	148	118	56	5	15	5	211	261	171	82	21	30	6
5. TOC (mgl^{-1})	52	45	51	85	55	26	25	72	27	35	170	37	23	60

* conducted by Econotech Services

TABLE 3. DREDGE SPOIL LEACHATE BIOASSAY WITH CRANGONIDS AND STICKLEBACKS

	Crangon sp.		*Gasterosteus aculeatus trachurus*
Leachate Sample #	96-h LC50 (%v/v)	M.S.T. (hr. at 100%)	M.S.T. (hr. at 100%)
Batch 1 - December 3/76			
10	>100	>96	7.2
12	>100	>96	12.0
A	39	6.7(96)*	< 0.5
B	12.5	< 0.5(1.5)*	< 0.5
C	56	0.8	< 0.5
D	>100	>96	1.2
E	>100	>96	≃96
Batch 2 - February 9/77			
10	>100	>96	>96
12	>100	>96	>96
A	>100	>96	>96
B	>100	>96	>96
C	>100	>96	>96
D	>100	>96	>96
E	>100	>96	>96

* ( ) conducted 14 days after initial MST

TABLE 4. SODIUM PENTACHLOROPHENATE BIOASSAYS WITH CRANGONIDS AND STICKLEBACK

	Crangon sp. 96-h LC50 estimate (ppb)	*Gasterosteus aculeatus trachurus* 96-h LC50 estimate (ppb)
Batch 1 December 3, 1976	245	50
Batch 2 February 14, 1977	-	70

TABLE 5. POPULATION STRUCTURE FOR *Crangon communis*

Sample #	Average Weight (g)
Batch I - December Leachates	
CONTROLS	1.47 ± 0.44
10	1.62 ± 0.71
12	1.82 ± 0.63
A	2.13 ± 0.62
B	1.47 ± 0.44
C	1.79 ± 0.56
D	1.62 ± 0.74
E	1.79 ± 0.55
all individuals	1.71 ± 0.22
ovigarous individuals	2.35 ± 0.78
Batch II - February Leachates	
CONTROLS	1.89 ± 0.89
10	1.21 ± 0.87
12	1.62 ± 0.91
A	1.82 ± 0.77
B	1.54 ± 0.85
C	1.54 ± 0.88
D	1.26 ± 0.80
E	1.61 ± 0.91
all individuals	1.56 ± 0.24
ovigarous individuals	2.18 ± 0.70

TABLE 6. RELATIONSHIP OF PARASITISM AND EGG BEARING ON MORTALITIES IN BIOASSAY OF *Crangon communis*

	Parasitized	
	% in dead animals	% in population
Batch 1	45	10.4 ($P > 0.5$)
Batch 2	17	12.4 ($P > 0.5$)

	Ovigarous Female Significance	
	% in dead animals	% in population
Batch 1	10	6.7 ($P > 0.5$)
Batch 2	6	36.8 ($P > 0.5$)

APPENDIX I

BIOASSAY DATA FOR DREDGE SPOIL LEACHATES AND SODIUM PENTACHLOROPHENATE

Crangon sp. AND STICKLEBACK

TABLE 7.

Toxicant: Rila Salt Tolerance Test

Species: Crangon sp.

Project #: 371

Temperature: 15 ^{o}C

Salinity: 24 $^{o}/oo$ S

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Sample #	Conc. (% v/v)	Test Date	# of Organisms *	HOURS TO % SURVIVAL												
				1	2	4	18	24	48	72	96					
	100% RILA	08-12	10	100	100	100	100	100	100	90	90					
	50:50	08-12	10	100	100	100	100	100	100	100	100					
	100% seawater	08-12	10	100	100	100	100	100	100	100	100					

*15 liter volume

TABLE 8.

Toxicant: Dredge spoil leachates

Species: Stickleback

Project #: 371

Temperature: 15 °C

Salinity: 24 ‰ S

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Sample #	Conc. (% v/v)	Test Date	# of Organisms	HOURS TO % SURVIVAL										Dissolved O_2		M.S.T.
				1	2	4	18	24	48	72	96			Initial	Final	(hrs.)
10	100	06-12	5	80	80	80	10	0	-					5.0	5.4	7.2
12	100	06-12	5	100	100	100	20	20	20	20	20			5.4	6.0	12.0
A	100	06-12	5	0	-									6.2	6.2	< 1/2
B	100	06-12	5	0	-									2.0	2.0	< 1/2
C	100	06-12	5	0	-									2.4	4.0	< 1/2
D	100	06-12	5	60	20	0	-							3.6	3.9	1.2
E	100	06-12	5	100	80	60	60	60	60	60	60			5.1	5.8	~ 96
CONTROL	0	06-12	5	100	100	100	100	100	100	100	100			10.2	10.4	> 96

TABLE 9.

Toxicant: Dredge Spoil Leachates , Sample 10

Species: Crangon sp.

Project #: 371

Temperature: 15 °C

Salinity: 24 0/00 S

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Sample #	Conc. (% v/v)	Test Date	# of Organisms *	HOURS TO % SURVIVAL										Initial		Final
				1	2	4	18	24	48	72	96			pH	D.O.	D.O.
CONTROL	0	08-12	10	100	100	100	100	100	100	100	100			7.70	10.5	10.8
1	1	08-12	10	100	100	100	100	100	100	100	100			7.70	8.4	9.9
2	18	08-12	10	100	100	100	90	90	90	90	90			7.70	8.6	9.9
3	32	08-12	10	100	100	100	100	100	100	100	100			7.65	8.5	9.9
4	56	08-12	10	100	100	100	100	100	100	100	100			7.65	9.0	10.1
5	100	08-12	10	100	100	100	100	100	100	100	100			7.65	8.2	10.0

*15 liter volume

TABLE 10.

Toxicant: Dredge Spoil Leachates , Sample 12

Species: Crangon sp.

Project #: 371

Temperature: 15 °C

Salinity: 24 o/oo S

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Sample #	Conc. (% v/v)	Test Date	# of Organ- isms *	HOURS TO % SURVIVAL										Initial		Final
				1	2	4	18	24	48	72	96			pH	D.O.	D.O.
CONTROL	0	08-12	10	100	100	100	100	100	100	100	100			7.85	10.5	10.8
1	1	08-12	10	100	100	100	100	100	100	100	100			7.85	10.4	9.2
2	18	08-12	10	100	100	100	100	100	100	100	100			7.85	10.1	9.2
3	32	08-12	10	100	100	100	100	100	100	100	100			7.90	10.1	9.6
4	56	08-12	10	100	100	100	100	100	100	100	100			7.80	10.2	9.8
5	100	08-12	10 **	100	100	100	100	100	100	100	100			7.80	10.1	9.5

*15 liter volume **10 liter volume

TABLE 11.

Toxicant: Dredge Spoil Leachates , Sample A

Species: Crangon sp.

Temperature: 15 °C

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Project #: 371

Salinity: 24 o/oo S

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Sample #	Conc. (% v/v)	Test Date	# of Organisms *	HOURS TO % SURVIVAL										Initial		Final
				1	2	4	18	24	48	72	96			pH	D.O.	D.O.
CONTROL	0	07-12	10	100	100	100	100	90	90	90	90			7.85	11.5	10.8
1	1	07-12	10	100	100	100	100	100	100	100	80			7.65	10.7	10.2
2	18	07-12	10	100	100	100	100	70	70	60	50			7.60	8.1	10.2
3	32	07-12	10	100	100	100	100	90	90	80	70			7.60	5.8	9.9
4	56	07-12	10	100	90	60	60	40	30	30	20			7.60	2.3	10.0
5	100	07-12	10	80	70	40	40	30	30	20	20			7.45	1.1	10.1

*15 liter volume

TABLE 12.

Toxicant: Dredge Spoil Leachates , Sample B

Species: Crangon sp.   Temperature: 15 °C   E.V.S. CONSULTANTS LTD.

Project #: 371   Salinity: 24 °/oo S   page ______ of ______

Sample #	Conc. (% v/v)	Test Date	# of Organ-isms *	HOURS TO % SURVIVAL										Initial		Final
				1	2	4	18	24	48	72	96			pH	D.O.	D.O.
CONTROL	0	07-12	10	100	100	100	100	90	90	90	90			7.85	11.5	10.8
1	1	07-12	10	100	100	100	90	90	70	70	70			7.70	10.4	10.1
2	18	07-12	10	20	20	20	20	20	20	20	20			7.55	4.2	9.7
3	32	07-12	10	0	-									7.45	1.3	5.5
4	56	07-12	10	0	-									7.45	1.4	3.6
5	100	07-12	10	0	-									7.35	0.9	0.8

*15 liter volume

TABLE 15.

Toxicant: Dredge Spoil Leachates, Sample C

Species: Crangon sp. Temperature: 15 °C E.V.S. CONSULTANTS LTD.

Project #: 371 Salinity: 24 ‰ S page ____ of ____

Sample #	Conc. (% v/v)	Test Date	# of Organisms *	HOURS TO % SURVIVAL										Initial		Final
				1	2	4	18	24	48	72	96			pH	D.O.	D.O.
CONTROL	0	07-12	10	100	100	100	100	90	90	90	90			7.85	11.5	10.8
1	1	07-12	10	100	100	100	100	100	90	90	80			7.85	9.4	9.8
2	18	07-12	10	100	100	100	100	100	100	100	100			7.80	6.9	9.8
3	32	07-12	10	100	100	90	80	80	80	80	70			7.70	4.0	9.8
4	56	07-12	10	90	90	80	80	70	70	70	50			7.70	1.8	9.7
5	100	07-12	10	30	0	-								7.60	0.8	1.3

*15 liter volume

TABLE 14.

Toxicant: Dredge Spoil Leachates , Sample D

Species: Crangon sp. Temperature: 15 °C E.V.S. CONSULTANTS LTD.

Project #: 371 Salinity: 24 o/oo S page ____ of ____

Sample #	Conc. (% v/v)	Test Date	# of Organisms *	HOURS TO % SURVIVAL										Initial		Final
				1	2	4	18	24	48	72	96			pH	D.O.	D.O.
CONTROL	0	07-12	10	100	100	100	100	90	90	90	90			7.85	11.5	10.8
1	1	07-12	10	100	100	100	100	100	100	100	100			7.80	8.3	9.8
2	18	07-12	10	100	100	100	100	100	100	100	100			7.70	7.2	9.4
3	32	07-12	10	100	100	100	100	100	90	90	90			7.70	6.4	9.5
4	56	07-12	10	100	100	100	100	90	90	90	90			7.65	5.3	9.5
5	100	07-12	10	100	100	100	100	100	100	80	80			7.80	4.8	9.6

*15 liter volume

TABLE 15.

Toxicant: Dredge Spoil Leachates, Sample E

Species: Crangon sp.

Project #: 371

Temperature: 15 °C

Salinity: 24 ‰ S

E.V.S. CONSULTANTS LTD.

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Sample #	Conc. (% v/v)	Test Date	# of Organisms *	HOURS TO % SURVIVAL										Initial		Final
				1	2	4	18	24	48	72	96			pH	D.O.	D.O.
CONTROL	0	07-12	10	100	100	100	100	90	90	90	90			7.85	11.5	10.8
1	1	07-12	10	100	100	100	100	100	100	100	100			7.95	10.3	10.3
2	18	07-12	10	100	100	100	100	100	100	90	80			7.95	10.0	10.2
3	32	07-12	10	100	100	100	100	100	100	100	100			7.90	9.6	10.5
4	56	07-12	10	100	100	100	100	100	100	90	80			7.90	10.4	10.0
5	100	07-12	10	100	100	100	100	100	100	100	100			7.80	9.8	10.0

*15 liter volume

TABLE 16.

Toxicant: Dredge Spoil Leachates

Species: *Crangon* sp.

Project #: 371

Temperature: 15 °C

Salinity: 22.1 ‰ S

E.V.S. CONSULTANTS LTD.

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Sample #	Conc. (% v/v)	Test Date	# of Organ-isms	HOURS TO % SURVIVAL										Initial		Final
				1	2	4	18	24	48	72	96			pH	D.O.	D.O.
A	100	20-12	5	100	100	100	80	80	80	80	60			7.40	10.3	10.8
B	100	20-12	5	80	20	20	20	20	0	-				7.55	7.8	9.2
CONTROL	0	20-12	5	100	100	100	100	100	100	100	100			7.90	11.1	11.0

Toxicant: Dredge Spoil Leachates

Species: Stickleback   Temperature: 10 °C   E.V.S. CONSULTANTS LTD.

Project #: 371   Salinity: 23 ‰ S   page 1 of 1

Sample #	Conc. (% v/v)	Test Date	# of Organ- isms *	HOURS TO % SURVIVAL										Initial		Final
				1	2	4	18	24	48	72	96			pH	D.O.	D.O.
CONTROL	0	09-02	10	100	100	100	100	100	100	100	100			8.04	11.4	10.6
10	100	09-02	10	100	100	100	100	100	100	100	100			7.95	11.5	9.6
12	100	09-02	10	100	100	100	100	100	100	100	100			7.80	11.0	8.5
A	100	09-02	10	100	100	100	100	100	100	100	100			7.25	9.3	7.8
B	100	09-02	10	100	100	100	100	100	100	100	100			7.40	6.7	8.8
C	100	09-02	10	100	100	100	100	100	100	100	100			7.20	6.2	10.2
D	100	09-02	10	100	100	100	100	100	100	100	100			7.20	10.3	9.8
E	100	09-02	10	100	100	100	100	100	100	100	100			7.50	9.4	10.4

*15 liter volume

mean fish wt. = 1.0 g

Toxicant: Dredge Spoil Leachates - Sample 10

Species: Crangon sp.

Project #: 371

Temperature: 10 °C

Salinity: 23 ‰ S

E.V.S. CONSULTANTS LTD.

Sample #	Conc. (% v/v)	Test Date	# of Organisms *	HOURS TO % SURVIVAL										Initial		Final
				1	2	4	18	24	48	72	96			pH	D.O.	D.O.
CONTROL	0	09-02	10	100	100	100	100	100	100	100	100			8.10	11.1	10.2
1	1	09-02	10	100	100	100	100	100	100	100	100			8.00	11.2	9.9
2	18	09-02	10	100	100	100	100	100	100	100	100			8.00	11.2	10.2
3	32	09-02	10	100	100	100	100	100	100	100	100			8.05	11.2	10.0
4	56	09-02	10	100	100	100	100	100	100	100	100			8.00	11.2	9.8
5	100	09-02	10	100	100	100	100	100	100	90	80			7.95	11.5	9.6

*15 liter volume

Toxicant: Dredge Spoil Leachates - Sample 12

Species: Crangon sp.

Project #: 371

Temperature: 10 °C

Salinity: 23 o/oo S

E.V.S. CONSULTANTS LTD.

Sample #	Conc. (% v/v)	Test Date	# of Organisms *	HOURS TO % SURVIVAL										Initial		Final
				1	2	4	18	24	48	72	96			pH	D.O.	D.O.
CONTROL	0	09-02	10	100	100	100	100	100	100	100	100			8.10	11.1	10.2
1	1	09-02	10	100	100	100	100	100	100	100	100			7.70	11.2	10.8
2	18	09-02	10	100	100	100	100	100	90	90	90			7.60	11.0	10.4
3	32	09-02	10	100	100	100	100	100	90	80	80			7.55	11.0	9.8
4	56	09-02	10	100	100	100	100	100	100	100	100			7.60	11.0	10.2
5	100	09-02	8	100	100	100	100	100	100	100	100			7.80	11.0	8.5

*15 liter volume

TABLE 20.

Toxicant: Dredge Spoil Leachates - Sample A

Species: Crangon sp.

Project #: 371

Temperature: 10 °C

Salinity: 23 °/oo S

E.V.S. CONSULTANTS LTD.

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Sample #	Conc. (% v/v)	Test Date	# of Organisms *	HOURS TO % SURVIVAL										Initial		Final
				1	2	4	18	24	48	72	96			pH	D.O.	D.O.
CONTROL	0	09-02	10	100	100	100	100	100	100	100	100			8.1	11.1	10.2
1	1	09-02	10	100	100	100	100	100	100	100	100			7.95	11.1	10.1
2	18	09-02	10	100	100	100	100	100	100	100	100			7.90	11.3	10.3
3	32	09-02	10	100	100	100	90	90	90	90	90			7.90	11.2	9.8
4	56	09-02	10	100	100	100	100	100	100	100	100			7.80	11.2	9.5
5	100	09-02	10	100	100	100	100	100	100	100	100			7.80	11.0	8.3

*15 liter volume

TABLE 21.

Toxicant: Dredge Spoil Leachates - Sample B

Species: Crangon sp.

Project #: 371

Temperature: 10 °C

Salinity: 23 ‰ S

E.V.S. CONSULTANTS LTD.

Sample #	Conc. (% v/v)	Test Date	# of Organisms*	HOURS TO % SURVIVAL										Initial		Final
				1	2	4	18	24	48	72	96			pH	D.O.	D.O.
CONTROL	0	09-02	10	100	100	100	100	100	100	100	100			8.10	11.1	10.2
1	1	09-02	10	100	100	100	100	100	100	100	100			7.55	9.8	10.4
2	18	09-02	10	100	100	100	100	100	100	100	100			7.50	9.2	10.5
3	32	09-02	10	100	100	100	100	100	100	100	100			7.50	8.5	10.3
4	56	09-02	10	100	100	100	100	100	100	100	100			7.50	8.3	10.2
5	100	09-02	10	100	100	100	80	80	80	70	70			7.40	6.7	8.8

*15 liter volume

TABLE 22.

Toxicant: Dredge Spoil Leachates - Sample C

Species: Crangon sp.

Project #: 371

Temperature: 10 °C

Salinity: 23 ‰ S

E.V.S. CONSULTANTS LTD.

Sample #	Conc. (% v/v)	Test Date	# of Organisms *	HOURS TO % SURVIVAL										Initial		Final
				1	2	4	18	24	48	72	96			pH	D.O.	D.O.
CONTROL	0	09-02	10	100	100	100	100	100	100	100	100			8.10	11.1	10.2
1	1	09-02	11	100	100	100	83	83	83	83	83			7.55	10.1	10.3
2	18	09-02	10	100	100	100	100	100	100	100	100			7.40	9.0	10.4
3	32	09-02	10	100	100	100	100	100	100	100	100			7.40	8.6	10.6
4	56	09-02	10	100	100	100	90	90	90	90	90			7.25	6.7	10.3
5	100	09-02	10	100	100	100	80	70	70	70	70			7.20	6.2	10.2

*15 liter volume

TABLE 23.

Toxicant: Dredge Spoil Leachates - Sample D

Species: Crangon sp.

Project #: 371

Temperature: 10 °C

Salinity: 23 o/oo S

E.V.S. CONSULTANTS LTD.

Sample #	Conc. (% v/v)	Test Date	# of Organisms *	HOURS TO % SURVIVAL										Initial		Final
				1	2	4	18	24	48	72	96			pH	D.O.	D.O.
CONTROL	0	09-02	10	100	100	100	100	100	100	100	100			8.10	11.1	10.2
1	1	09-02	10	100	100	100	100	100	90	90	90			7.60	10.0	10.4
2	18	09-02	10	100	100	100	100	100	100	100	100			7.50	10.1	10.5
3	32	09-02	10	100	100	100	100	100	100	100	100			7.45	9.9	10.3
4	56	09-02	10	100	100	100	100	100	100	100	100			7.30	9.8	10.2
5	100	09-02	10	100	100	100	100	100	100	100	100			7.20	10.3	9.8

*15 liter volume

TABLE 24.

Toxicant: Dredge Spoil Leachates - Sample E

Species: Crangon sp.

Project #: 371

Temperature: 10 °C

Salinity: 23 0/oo S

E.V.S. CONSULTANTS LTD.

Sample #	Conc. (% v/v)	Test Date	# of Organisms *	HOURS TO % SURVIVAL										Initial		Final
				1	2	4	18	24	48	72	96			pH	D.O.	D.O.
CONTROL	0	09-02	10	100	100	100	100	100	100	100	100			8.10	11.1	10.2
1	1	09-02	10	100	100	100	100	100	100	100	100			7.65	9.90	10.3
2	18	09-02	10	100	100	100	100	100	100	100	100			7.60	9.70	10.3
3	32	09-02	10	100	100	100	100	100	100	90	80			7.50	9.50	10.1
4	56	09-02	10	100	100	100	100	100	100	100	100			7.50	9.40	9.6
5	100	09-02	9	100	100	100	78	78	67	67	56			7.50	9.40	10.4

*15 liter volume

TABLE 25.

Toxicant: NaPCP

Species: Stickleback — Temperature: 15 °C — E.V.S. CONSULTANTS LTD.

Project #: 371 — Salinity: 25 ‰ S —

Sample #	Conc. (ppb)	Test Date	# of Organisms*	HOURS TO % SURVIVAL							
				1	2	4	18	24	48	72	96
CONTROL	0	01-11	10	100	100	100	100	100	100	100	100
1	5	01-11	10	100	100	100	100	100	100	100	100
2	20	01-11	10	100	100	100	100	100	100	100	90
3	40	01-11	10	100	100	100	100	100	100	80	60
4	60	01-11	10	100	100	100	100	100	100	90	50
5	80	01-11	10	100	100	100	100	100	90	80	0

*15 liter volume

mean fish wt. = 0.64 g.

[redacted]

Toxicant: NaPCP

Species: Stickleback

Project #: 371

Temperature: 10 °C

Salinity: 25 ‰ S

E.V.S. CONSULTANTS LTD.

Sample #	Conc. (ppb)	Test Date	# of Organisms *	HOURS TO % SURVIVAL							
				1	2	4	18	24	48	72	96
CONTROL	0	14-02	10	100	100	100	100	100	100	100	100
1	5	14-02	10	100	100	100	100	100	100	100	100
2	20	14-02	10	100	100	100	100	100	100	100	100
3	40	14-02	10	100	100	100	100	100	100	100	100
4	60	14-02	10	100	100	100	100	100	90	70	60
5	80	14-02	10	100	100	100	100	100	70	50	40

*15 liter volume

Mean fish wt. = 0.78 g/l

TABLE 27.

Toxicant: NaPCP

Species: Crangon sp.

Project #: 371

Temperature: 15 ^{o}C

Salinity: 24 o/oo S

E.V.S. CONSULTANTS LTD.

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Sample #	Conc. (ppb)	Test Date	# of Organisms *	HOURS TO % SURVIVAL										
				1	2	4	16	24	48	51	67	76	90	96
CONTROL	0	29-11	15	100	100	100	100	100	100	7	7	7	7	7
1	20	29-11	15	100	100	93.3	93.3	53.3	53.3	33.3	7	7	7	7
2	40	29-11	15	100	100	93.3	93.3	93.3	53.3	26.6	0	-		
3	60	29-11	15	100	100	100	100	100	86.6	53.3	7	0	-	
4	80	29-11	15	100	100	100	100	100	86.6	66.7	0	-		
5	100	29-11	15	100	100	100	100	100	93.3	93.3	66.7	40	13.3	13.3
6	120	29-11	15	100	100	100	100	100	100	100	80	73.3	66.7	53.5
7	200	29-11	8	100	100	100	100	100	100	100	62.5	25	25	25

*30 liter volume

TABLE 28.

Toxicant: NaPCP

Species: Crangon sp.

Project #: 371

Temperature: 15 °C

Salinity: 21.2 ‰ S

E.V.S. CONSULTANTS LTD.

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Sample #	Conc. (ppb)	Test Date	# of Organisms *	HOURS TO % SURVIVAL								Initial		Final
				1	2	4	18	24	48	72	96	pH	D.O.	D.O.
CONTROL	0	14-12	10	100	100	100	100	100	100	100	90	8.10	11.1	>10.0
1	50	14-12	9	100	100	100	100	100	100	100	100			>10.0
2	100	14-12	10	100	100	100	100	100	100	100	80			>10.0
3	200	14-12	10	100	100	100	100	80	60	60	60			>10.0
4	400	14-12	10	100	100	90	50	50	30	10	10			>10.0
5	600	14-12	10	100	100	100	0	-				7.85	11.7	>10.0

*20 liter volume

TABLE 29.

Toxicant: NaPCP

Species: Crangon sp.   Temperature: 25 °C   E.V.S. CONSULTANTS LTD.

Project #: 371   Salinity: 10 ‰ S   page 1 of 3

Sample #	Conc. (ppb)	Test Date	# of Organisms*	HOURS TO % SURVIVAL							
				1	2	4	18	24	48	72	96
CONTROL	0	14-02	10	100	100	100	80	80	60	50	10
1	50	14-02	10	100	100	100	100	100	80	60	20
2	100	14-02	10	100	100	100	100	100	80	80	40
3	200	14-02	10	100	100	100	100	100	90	80	70
4	400	14-02	10	100	100	100	80	70	30	10	10
5	600	14-02	10	100	100	80	40	20	0	-	

*15 liter volume

TABLE [redacted]

Toxicant: NaPCP

Species: Crangon sp. Temperature: 25 °C E.V.S. CONSULTANTS LTD.

Project #: 371 Salinity: 10 o/oo S page 2 of 3

Sample #	Conc. (ppb)	Test Date	# of Organ-isms *	HOURS TO % SURVIVAL											
				1	2	4	18	24	48	72	96				
CONTROL	0	24-02	10	100	100	100	80	80	50	30	0				
1	50	24-02	10	100	100	100	100	100	40	30	10				
2	100	24-02	10	100	100	100	90	90	30	0	-				
3	200	24-02	10	100	100	100	90	90	60	30	10				
4	400	24-02	10	100	100	90	50	50	0	-					
5	600	24-02	10	100	100	100	20	20	0	-					

*15 liter volume

TABLE 31.

Toxicant: NaPCP

Species: Crangon sp.

Project #: 371

Temperature: 25 °C

Salinity: 10 ‰ S

E.V.S. CONSULTANTS LTD.

Sample #	Conc. (ppb)	Test Date	# of Organ-isms*	HOURS TO % SURVIVAL							
				1	2	4	18	24	48	72	96
CONTROL	0	24-02	10	100	100	100	80	80	50	30	0
1	50	24-02	10	100	100	100	90	90	80	30	10
2	100	24-02	10	100	100	100	90	90	80	50	0
3	200	24-02	10	100	100	100	70	70	40	10	0
4	400	24-02	10	100	100	100	30	30	10	0	-
5	600	24-02	10	100	100	90	20	20	0	-	

*15 liter volume

TABLE 32.

Toxicant: NaPCP - Loading Densities

Species: Crangon sp.

Project #: 371

Temperature: 15 °C

Salinity: 24 ‰ S

E.V.S. CONSULTANTS LTD.

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Sample #	Conc. ppb	Test Date	# of Organisms	HOURS TO % SURVIVAL												Loading Density
				1	2	4	18	24	48	72	96					(g/l)
1	245	21-12	5	100	100	100	100	100	60	60	60					0.2
2	245	21-12	10	100	100	100	100	90	90	70	60					0.5
3	245	21-12	10	100	100	100	90	80	60	50	50					1.0
4	245	21-12	10	100	100	100	90	90	70	70	70					2.0
5	245	21-12	10	100	100	100	90	90	90	90	80					5.0
6	245	21-12	10	100	100	100	90	90	90	90	90					10.0

APPENDIX II

POPULATION CHARACTERISTICS OF *Crangon* sp. DREDGE SPOIL LEACHATE AND REFERENCE TOXICANT BIOASSAYS

TABLE 33. DECEMBER LEACHATE - SAMPLE 10

Concentration (% v/v)	Time (h)	Species	Weight (g)	Sex	Parasite Location	Degree of Gill Clogging
100	> 96	*C. communis*	1.35		-	**
		C. communis	1.30		-	**
		C. communis	1.15		-	**
		C. communis	1.05		abd	**
		C. communis	0.70		abd	**
56	> 96	*C. communis*	2.05		abd	**
		C. communis	1.50		-	**
		C. communis	1.35		-	**
		C. communis	2.20		-	**
		C. communis	1.50		-	**
		C. communis	1.75		-	**
		C. communis	3.10		-	**
		C. communis	1.15		-	**
		C. communis	0.95		-	**
		C. communis	1.05		-	**
32	> 96	*C. communis*	1.45		-	*
		C. communis	1.95		-	*
		C. communis	4.05	F	-	*
		C. communis	2.00		-	*
		C. communis	2.00		-	*
		C. communis	1.45		-	*
		C. communis	1.40		-	*
		C. communis	1.60		-	*
		C. communis	2.05		-	*
		C. communis	1.70		-	*
18	96	*C. communis*	1.55		-	*
	> 96	*C. communis*	0.60		-	*
		C. communis	3.00		-	*
		C. communis	1.95		-	*
		C. communis	1.90		-	*
		C. communis	1.75		abd	*
		C. communis	1.60		-	*
		C. communis	0.35		-	*
		C. communis	2.00		-	*
1	> 96	*C. communis*	0.45		-	
		C. communis	2.20	F	-	
		C. communis	1.30		-	
		C. communis	0.35		-	
		C. communis	2.40	F	-	
		C. communis	1.95		abd	
		C. communis	1.55		-	
		C. communis	1.10		abd	
		C. communis	1.45		-	
		C. communis	2.00		-	

TABLE 34. DECEMBER LEACHATE - SAMPLE 12

Concentration (% v/v)	Time (h)	Species	Weight (g)	Sex	Parasite Location	Degree of Gill Clogging
100	> 96	*C. communis*	1.70		abd	
		C. communis	1.90		-	
		C. communis	1.70		-	
		C. communis	2.00	F	-	
		C. communis	1.50		-	
		C. communis	0.30		-	
		C. communis	1.70		-	
		C. communis	3.45	F	-	
		C. communis	0.45		-	
		C. communis	1.30		-	
56	> 96	*C. communis*	1.55		-	
		C. communis	2.15		-	
		C. communis	1.55		-	
		C. communis	1.70		-	
		C. communis	1.85		abd	
		C. communis	1.90		-	
		C. communis	1.70		-	
		C. communis	1.75		-	
		C. communis	1.80		-	
		C. communis	1.45		-	
		C. communis	1.75		-	
32	> 96	*C. communis*	2.95	F	-	
		C. communis	1.70		-	
		C. communis	1.80		-	
		C. communis	3.85		-	
		C. communis	1.90		-	
		C. communis	3.15		-	
		C. communis	1.70		-	
		C. communis	1.20		-	
		C. communis	1.15		abd	
		C. communis	1.55		-	
18	> 96	*C. communis*	1.35		car	
		C. communis	2.30		-	
		C. communis	1.75		-	
		C. communis	1.90		abd	
		C. communis	2.20		-	
		C. communis	2.75	F	-	
		C. communis	2.05		-	
		C. communis	1.95		-	
		C. communis	1.25		-	
		C. communis	1.15		-	
1	> 96	*C. communis*	1.90		-	
		C. communis	2.85		-	
		C. communis	1.60		-	
		C. communis	1.35		abd	
		C. communis	2.05		abd	
		C. communis	1.90		-	
		C. communis	1.65		-	
		C. communis	1.55		-	
		C. communis	1.60		-	
		C. communis	1.85		-	

TABLE 35. DECEMBER LEACHATE - SAMPLE A

Concentration (% v/v)	Time (h)	Species	Weight (g)	Sex	Parasite Location	Degree of Gill Clogging
100	96	*C. communis*	1.90		-	*
	> 96	*C. communis*	3.45	F	-	*
		C. communis	2.85		-	*
56	96	*C. communis*	2.80	F	-	*
	> 96	*C. communis*	2.65		-	*
		C. communis	3.00		-	*
32	72	*C. communis*	1.75		-	
	96	*C. communis*	2.60		-	
	>96	*C. communis*	1.50	F	-	
		C. communis	2.40		-	
		C. communis	3.15		-	
		C. communis	1.75		-	
		C. communis	1.80		-	
		C. communis	2.30		-	
		C. communis	1.65		-	
		C. communis	1.35		-	
18	72	*C. communis*	2.80		-	
	96	*C. communis*	1.30		-	
	> 96	*C. communis*	2.10		-	
		C. communis	1.55		-	
		C. communis	1.55		-	
		C. communis	1.75		-	
		C. communis	2.05		-	
1	96	*C. communis*	1.90		abd	
	96	*C. communis*	1.95		-	
	> 96	*C. communis*	3.15		-	
		C. communis	1.30		-	
		C. communis	1.65		-	
		C. communis	1.60		abd	
		C. communis	1.80		-	
		C. communis	2.15		-	
		C. communis	2.85		-	
		C. communis	1.35		-	

TABLE 36. DECEMBER LEACHATE - SAMPLE B

Concentration (% v/v)	Time (h)	Species	Weight (g)	Sex	Parasite Location	Degree of Gill Clogging
18	> 96	*C. communis*	1.20		-	
		C. communis	1.20		-	
1	> 96	*C. communis*	1.90		-	
		C. communis	1.80		-	
		C. communis	1.70		-	
		C. communis	0.75		abd	
		C. communis	1.90		-	
		C. communis	1.15		-	
		C. communis	2.15		abd	
		C. communis	1.20		-	
		C. communis	1.20		-	

TABLE 37. DECEMBER LEACHATE - SAMPLE C

Concentration (% v/v)	Time (h)	Species	Weight (g)	Sex	Parasite Location	Degree of Gill Clogging
56	96	*C. communis*	1.95		-	*
	96	*C. communis*	1.20		-	*
	>96	*C. communis*	2.30		-	*
		C. communis	2.25		abd	*
		C. communis	2.40		-	*
		C. communis	0.95		-	*
		C. communis	1.20		-	*
32	96	*C. communis*	1.65		-	*
	> 96	*C. communis*	1.85		-	*
		C. communis	1.20		-	*
		C. communis	2.50		-	*
		C. communis	1.40		-	*
		C. communis	1.95	F	-	*
		C. communis	1.30		-	*
		C. communis	1.70		-	*
18	> 96	*C. communis*	2.10		-	
		C. communis	1.85		-	
		C. communis	1.70		-	
		C. communis	1.70		-	
		C. communis	1.30		-	
		C. communis	1.20		-	
		C. communis	2.15		-	
		C. communis	1.75		-	
		C. communis	1.45		-	
		C. communis	1.45		-	
1	96	*C. communis*	1.60		-	
		C. communis	1.35		-	
		C. communis	3.20		-	
		C. communis	3.40		-	
		C. communis	1.70		-	
		C. communis	1.30		-	
		C. communis	2.10		-	
		C. communis	1.50		-	
		C. communis	2.40		-	

TABLE 38. DECEMBER LEACHATE - SAMPLE D

Concentration (% v/v)	Time (h)	Species	Weight (g)	Sex	Parasite Location	Degree of Gill Clogging
100	> 96	*C. communis*	2.10		-	
		C. communis	1.80		-	
		C. communis	3.20		-	
		C. communis	2.45		-	
		C. communis	1.95		-	
		C. communis	1.65		-	
56	72	*C. communis*	2.40		-	
	72	*C. communis*	0.65		-	
	> 96	*C. communis*	0.45		-	
		C. communis	2.15		-	
		C. communis	1.20		abd	
		C. communis	2.05		-	
		C. communis	1.50		-	
		C. communis	1.55		-	
		C. communis	1.05		-	
		C. communis	1.90		abd	
32	> 96	*C. communis*	1.70		-	
		C. communis	0.95		-	
		C. communis	0.45		-	
		C. communis	2.25		-	
		C. communis	2.90	F	-	
		C. communis	1.50		-	
		C. communis	1.25		-	
		C. communis	1.10		-	
		C. communis	1.45	F	-	
		C. communis	1.10		abd	
18	> 96	*C. communis*	1.70		-	
		C. communis	1.05		-	
		C. communis	2.25		-	
		C. communis	1.25		-	
		C. communis	1.20		-	
		C. communis	1.50		-	
		C. communis	1.60		-	
		C. communis	1.60		-	
		C. communis	1.65		-	
		C. communis	1.30		-	
1	> 96	*C. communis*	0.35		-	
		C. communis	2.05		-	
		C. communis	3.80		-	
		C. communis	3.10	F	-	
		C. communis	1.00		-	
		C. communis	1.30		-	
		C. communis	0.65		-	
		C. communis	1.85		-	
		C. communis	2.05		-	
		C. communis	1.75		-	

TABLE 39. DECEMBER LEACHATE - SAMPLE E

Concentration (% v/v)	Time (h)	Species	Weight (g)	Sex	Parasite Location	Degree of Gill Clogging
100	> 96	*C. communis*	1.45		-	**
		C. communis	2.10		-	**
		C. communis	1.60		-	**
		C. communis	2.10		-	**
		C. communis	1.35		-	**
		C. communis	1.30		-	**
		C. communis	1.95	F	-	**
		C. communis	2.00		-	**
		C. communis	1.55		-	**
		C. communis	1.65		abd	**
56	72	*C. communis*	1.55		abd	
	96	*C. communis*	2.05		-	
	> 96	*C. communis*	1.65		abd	
		C. communis	1.45	F	-	
		C. communis	1.35		abd	
		C. communis	1.90	F	-	
		C. communis	1.50		-	
		C. communis	1.50		-	
		C. communis	1.15		abd	
		C. communis	1.20		-	
32	> 96	*C. communis*	2.60	F	-	
		C. communis	3.15		-	
		C. communis	1.70		-	
		C. communis	2.85		-	
		C. communis	2.10		-	
		C. communis	2.00		-	
		C. communis	1.70		-	
		C. communis	1.20		-	
		C. communis	1.55		-	
		C. communis	1.75		-	
18	72	*C. communis*	1.45		-	
	96	*C. communis*	2.95		abd	
	> 96	*C. communis*	3.10		-	
		C. communis	1.90		-	
		C. communis	2.55		-	
		C. communis	2.00		-	
		C. communis	2.85		-	
		C. communis	1.60		-	
		C. communis	1.45		-	
		C. communis	0.95		abd	
1	> 96	*C. communis*	2.05		-	
		C. communis	1.55		-	
		C. communis	1.45		-	
		C. communis	1.10		-	
		C. communis	1.25		-	
		C. communis	1.35		-	
		C. communis	1.90		-	
		C. communis	1.60		-	
		C. communis	2.60	F	-	
		C. communis	0.95		-	

TABLE 40. FEBRUARY LEACHATE - SAMPLE 10

Concentration (% v/v)	Time (h)	Species	Weight (g)	Sex	Parasite Location	Degree of Gill Clogging
100	72	*C. communis*	1.09		-	**
	96	*C. communis*	1.00		-	**
	> 96	*C. communis*	0.45		-	**
		C. communis	0.55		-	**
		C. communis	0.42		-	**
		C. communis	0.40		-	**
		C. communis	1.98		abd	**
		C. communis	2.62	F	-	**
		C. communis	2.10	F	-	**
56	> 96	*C. communis*	0.33		-	*
		C. communis	0.32		-	*
		C. communis	0.35		-	*
		C. communis	0.50		-	*
		C. communis	1.39		-	*
		C. communis	2.25		abd	*
		C. communis	1.21	F	-	*
		C. communis	1.99		abd	*
		C. communis	3.21	F	-	*
		C. communis	2.40	F	-	*
32	> 96	*C. communis*	0.41		-	
		C. communis	0.45		-	
		C. communis	0.39		-	
		C. communis	0.44		-	
		C. communis	1.49	F	-	
		C. communis	2.19	F	-	
		C. communis	1.90		abd	
		C. communis	1.75		abd	
		C. communis	1.39		abd	
		C. communis	1.88		-	
		C. communis	1.69		-	
18	> 96	*C. communis*	0.49		-	
		C. communis	0.56		-	
		C. communis	0.21		-	
		C. communis	0.33		-	
		C. communis	1.19	F	-	
		C. communis	1.62	F	-	
		C. communis	1.75		-	
		C. communis	1.27	F	-	
		C. communis	2.82	F	-	
1	> 96	*C. communis*	0.36		-	
		C. communis	0.49		-	
		C. communis	0.30		-	
		C. communis	0.60		-	
		C. communis	0.35		-	
		C. communis	0.42		-	
		C. communis	0.50		-	
		C. communis	1.42	F	-	
		C. communis	1.82		abd	
		C. communis	1.80		abd	
		C. communis	3.50	F	-	

TABLE 41. FEBRUARY LEACHATE - SAMPLE 12

Concentration (% v/v)	Time (h)	Species	Weight (g)	Sex	Parasite Location	Degree of Gill Clogging
100	> 96	*C. communis*	0.41		-	**
		C. communis	0.35		-	**
		C. communis	0.29		-	**
		C. communis	0.81		-	**
		C. communis	1.55	F	-	**
		C. communis	2.38		-	**
		C. communis	3.66	F	-	**
		C. communis	1.70		-	**
56	> 96	*C. communis*	0.81		-	*
		C. communis	0.42		-	*
		C. communis	0.30		-	*
		C. communis	0.81		-	*
		C. communis	1.42		-	*
		C. communis	1.15		-	*
		C. communis	1.92		abd	*
		C. communis	1.75	F	-	*
		C. communis	1.85	F	-	*
32	48	*C. communis*	1.90		abd	*
	72	*C. communis*	1.25		abd	*
	> 96	*C. communis*	0.35		-	
		C. communis	0.51		-	
		C. communis	0.42		-	
		C. communis	1.12		car	
		C. communis	2.93	F	-	
		C. communis	1.40		-	
		C. communis	1.61		-	
		C. communis	1.80	F	-	
18	48	*C. communis*	2.27		abd,regr	
	> 96	*C. communis*	2.03		abd	
		C. communis	1.52		abd	
		C. communis	2.52		-	
		C. communis	2.06		abd	
		C. communis	3.29	F	-	
		C. communis	3.69	F	-	
		C. communis	2.21		-	
		C. communis	2.83		-	
1	> 96	*C. communis*	2.25		-	
		C. communis	1.72		-	
		C. communis	1.91		-	
		C. communis	1.95		abd	
		C. communis	3.25	F	-	
		C. communis	1.99	F	-	
		C. communis	1.60	F	-	
		C. communis	1.21	F	-	
		C. communis	1.70	F	-	
		C. communis	0.45		-	
		C. communis	0.88		-	

TABLE 42. FEBRUARY LEACHATE - SAMPLE A

Concentration (% v/v)	Time (h)	Species	Weight (g)	Sex	Parasite Location	Degree of Gill Clogging
100	> 96	*C. communis*	1.18		-	**
		C. communis	2.01	F	-	**
		C. communis	1.55	F	-	**
		C. communis	2.05		-	**
		C. communis	0.92		abd	**
		C. communis	1.60		abd	**
		C. communis	2.15		abd	**
		C. communis	1.18		abd	**
		C. communis	1.70	F	-	**
		C. communis	3.31	F	-	**
56	> 96	*C. communis*	1.40		-	*
		C. communis	1.58		-	*
		C. communis	0.60		-	*
		C. communis	2.02		-	*
		C. communis	2.49		-	*
		C. communis	1.61		-	*
		C. communis	3.42	F	-	*
		C. communis	1.51	F	-	*
		C. communis	1.59	F	-	*
		C. communis	1.92	F	-	*
32	18	*C. communis*	1.38		abd	
	> 96	*C. communis*	0.83		-	
		C. communis	1.00		-	
		C. communis	1.41		-	
		C. communis	2.82	F	-	
		C. communis	2.51	F	-	
		C. communis	2.62	F	-	
		C. communis	1.20	F	-	
		C. communis	1.51	F	-	
		C. communis	1.59	F	-	
18	> 96	*C. communis*	1.86		-	
		C. communis	1.73		-	
		C. communis	0.36		-	
		C. communis	0.46		-	
		C. communis	1.72		-	
		C. communis	1.69		-	
		C. communis	1.71	F	-	
		C. communis	3.65	F	-	
		C. communis	2.71	F	-	
		C. communis	3.40	F	-	
1	> 96	*C. communis*	1.62		-	
		C. communis	1.28		-	
		C. communis	1.68		abd	
		C. communis	1.22		car	
		C. communis	1.85	F	-	
		C. communis	2.00	F	-	
		C. communis	1.91	F	-	
		C. communis	3.70	F	-	
		C. communis	1.75	F	-	
		C. communis	2.20	F	-	

TABLE 43. FEBRUARY LEACHATE - SAMPLE B

Concentration (% v/v)	Time (h)	Species	Weight (g)	Sex	Parasite Location	Degree of Gill Clogging
100	18	*C. communis*	1.50		-	**
	18	*C. communis*	1.05		abd	**
	72	*C. communis*	0.40		abd	**
	> 96	*C. communis*	2.32		-	**
		C. communis	1.90		abd	**
		C. communis	1.40	F	-	**
		C. communis	2.40	F	-	**
		C. communis	2.11	F	-	**
		C. communis	0.50		-	**
		C. communis	0.55		-	**
56	> 96	*C. communis*	1.10		-	*
		C. communis	0.31		-	*
		C. communis	0.41		-	*
		C. communis	0.40		-	*
		C. communis	1.50		car	*
		C. communis	1.70	F	-	*
		C. communis	1.92	F	-	*
		C. communis	2.49	F	-	*
		C. communis	2.85	F	-	*
32	> 96	*C. communis*	1.80		-	*
		C. communis	0.40		-	*
		C. communis	1.50		-	*
		C. communis	1.96		-	*
		C. communis	1.88		-	*
		C. communis	1.95		-	*
		C. communis	2.05	F	-	*
		C. communis	3.45	F	-	*
		C. communis	1.30	F	-	*
		C. communis	1.46	F	-	*
18	> 96	*C. communis*	3.02	F	-	
		C. communis	2.05	F	-	
		C. communis	1.75	F	-	
		C. communis	0.82		-	
		C. communis	2.11		-	
		C. communis	0.71		-	
		C. communis	0.39		-	
		C. communis	0.43		-	
		C. alaskensis	0.51		-	
		C. alaskensis	0.51		-	
1	> 96	*C. communis*	0.39		-	
		C. communis	0.51		-	
		C. communis	0.45		-	
		C. communis	2.22		-	
		C. communis	3.29	F	-	
		C. communis	2.50	F	-	
		C. communis	1.40	F	-	
		C. communis	2.09	F	-	
		C. communis	2.05	F	-	
		C. communis	1.75	F	-	

TABLE 44. FEBRUARY LEACHATE - SAMPLE C

Concentration (% v/v)	Time (h)	Species	Weight (g)	Sex	Parasite Location	Degree of Gill Clogging
100	18	*C. communis*	2.60		-	**
	18	*C. communis*	0.49		-	**
	24	*C. communis*	2.05		car & abd	**
	> 96	*C. communis*	1.40		-	**
		C. communis	0.50		-	**
		C. communis	0.45		-	**
		C. communis	1.38		-	**
		C. communis	1.68	F	-	**
		C. communis	2.35	F	-	**
		C. communis	2.15	F	-	**
56	18	*C. communis*	1.73		-	*
	> 96	*C. communis*	0.10		-	*
		C. communis	0.55		-	*
		C. communis	2.10	F	-	*
		C. communis	3.24		-	*
		C. communis	2.06		-	*
		C. communis	2.45		abd	*
		C. communis	0.50		-	*
		C. communis	0.32		-	*
		C. communis	1.83		abd	*
32	> 96	*C. communis*	2.00		-	*
		C. communis	2.25		-	*
		C. communis	2.25		-	*
		C. communis	0.65		-	*
		C. communis	0.51		-	*
		C. communis	1.68	F	-	*
		C. communis	1.60	F	-	*
		C. communis	3.65	F	-	*
		C. communis	3.32	F	-	*
		C. communis	1.80	F	-	*
18	> 96	*C. alaskensis*	0.50		-	*
		C. communis	0.40		-	
		C. communis	0.61		-	
		C. communis	0.52		-	
		C. communis	1.90		-	
		C. communis	1.45		-	
		C. communis	1.66	F	-	
		C. communis	1.52	F	-	
		C. communis	1.80	F	-	
		C. communis	2.03	F	-	
1	> 96	*C. communis*	0.50		-	
		C. communis	1.45		-	
		C. communis	0.51		-	
		C. communis	0.59		-	
		C. communis	0.70		-	
		C. communis	1.72		-	
		C. communis	1.31		abd	
		C. communis	2.16		abd	
		C. communis	3.05	F	-	
		C. communis	1.91	F	-	

TABLE 45. FEBRUARY LEACHATE - SAMPLE D

Concentration (% v/v)	Time (h)	Species	Weight (g)	Sex	Parasite Location	Degree of Gill Clogging
100	> 96	*C. communis*	0.81		-	**
		C. communis	0.62		-	**
		C. communis	0.45		-	**
		C. communis	1.70		-	**
		C. communis	0.51		-	**
		C. communis	1.48	F	-	**
		C. communis	2.49	F	-	**
		C. communis	1.70	F	-	**
		C. communis	1.65	F	-	**
		C. communis	1.89	F	-	**
56	> 96	*C. communis*	1.58		-	*
		C. communis	1.68		abd	*
		C. communis	0.70		-	*
		C. communis	0.18		-	*
		C. communis	0.48		-	*
		C. communis	0.18		-	*
		C. communis	0.41		-	*
		C. communis	1.75	F	-	*
		C. communis	2.14	F	-	*
32	> 96	*C. communis*	2.01	F	-	
		C. communis	1.28		-	
		C. communis	2.29		abd	
		C. communis	0.58		-	
		C. communis	0.41		-	
		C. communis	0.51		-	
		C. communis	0.30		-	
		C. communis	1.62	F	-	
		C. communis	1.85	F	-	
18	> 96	*C. communis*	0.50		-	
		C. communis	0.67		-	
		C. communis	1.25		car	
		C. communis	2.02		-	
		C. communis	0.58		-	
		C. communis	1.51		abd	
		C. communis	1.70		abd	
		C. communis	3.36	F	-	
		C. communis	2.23	F	-	
		C. communis	2.75	F	-	
1	48	?	-	?	?	cannabilized
	> 96	*C. communis*	0.32		-	
		C. communis	0.80		-	
		C. communis	0.42		-	
		C. communis	0.31		-	
		C. communis	0.25		-	
		C. communis	2.00		abd	
		C. communis	2.19	F	-	
		C. communis	1.85	F	-	
		C. communis	1.47	F	-	

TABLE 46. FEBRUARY LEACHATE - SAMPLE E

Concentration (% v/v)	Time (h)	Species	Weight (g)	Sex	Parasite Location	Degree of Gill Clogging
100	18	*C. communis*	2.30	F	-	**
		C. communis	1.52	F	-	**
		C. communis	1.39		abd	**
	48	*C. communis*	0.50		-	**
	96	*C. communis*	1.32		-	**
	> 96	*C. communis*	1.66		-	**
		C. communis	1.69	F	-	**
		C. communis	2.80	F	-	**
		C. communis	2.05		abd	**
56	> 96	*C. communis*	2.10		-	*
		C. communis	0.80		-	*
		C. communis	0.59		-	*
		C. communis	0.65		-	*
		C. communis	0.99		-	*
		C. communis	3.65		-	*
		C. communis	1.72		abd	*
		C. communis	1.65		abd	*
		C. communis	1.79	F	-	*
		C. communis	2.35	F	-	*
32	72	*C. communis*	1.90		-	
	96	*C. communis*	0.80		-	
	> 96	*C. alaskensis*	1.40	F	-	
		C. communis	0.60		-	
		C. alaskensis	1.75	F	-	
		C. communis	1.61	F	-	
		C. communis	2.59	F	-	
		C. communis	2.49	F	-	
		C. communis	2.30	F	-	
		C. communis	2.85	F	-	
18	> 96	*C. communis*	0.50		-	
		C. communis	1.45		-	
		C. communis	0.51		-	
		C. communis	0.59		-	
		C. communis	0.70		-	
		C. communis	1.72		-	
		C. communis	1.31		abd	
		C. communis	2.16		abd	
		C. communis	3.05	F	-	
		C. communis	1.91	F	-	
1	> 96	*C. communis*	2.00		abd	
		C. communis	1.52		abd	
		C. communis	0.72		-	
		C. communis	1.40		-	
		C. communis	1.29		-	
		C. communis	0.62		-	
		C. communis	0.48		-	
		C. communis	0.41		-	
		C. communis	1.91	F	-	
		C. communis	4.61	F	-	

TABLE 47. FEBRUARY LEACHATE CONTROLS

Concentration (% v/v)	Time (h)	Species	Weight (g)	Sex	Parasite Location	Degree of Gill Clogging
0 (24-02-77)	> 96	*C. communis*	2.54		-	
		C. communis	2.32	F	-	
		C. communis	2.40		-	
		C. communis	2.76	F	-	
		C. communis	3.27		-	
		C. communis	2.80	F	-	
		C. communis	0.41		-	
		C. communis	0.22		-	
		C. communis	1.92		-	
		C. communis	2.46		abd	
0	> 96	*C. communis*	1.72		abd	
		C. communis	2.73	F	-	
		C. communis	0.80		-	
		C. communis	2.83	F	-	
		C. communis	2.25		-	
		C. communis	1.20		-	
		C. communis	1.35		-	
		C. communis	1.63		-	
		C. communis	0.68		-	
		C. communis	1.48		-	

TABLE 48. SODIUM PENTACHLOROPHENATE - DECEMBER

Concentration (% v/v)	Time (h)	Species	Weight (g)	Sex	Parasite Location	Degree of Gill Clogging
50	>96	*C. communis*	0.41		-	
		C. communis	0.45		-	
		C. communis	1.45	F	-	
		C. communis	0.52		-	
		C. communis	2.31		-	
		C. communis	2.71		abd	
		C. communis	1.70		-	
		C. communis	1.95		-	
		C. communis	1.78		-	
100	>96	*C. communis*	1.00		-	
		C. communis	1.45		abd	
		C. communis	1.50		-	
		C. communis	1.83	F	-	
		C. communis	0.27		-	
		C. communis	0.12		-	
		C. communis	1.18		-	
		C. communis	1.15		-	
		C. communis	2.00		-	
		C. communis	1.08		-	
200	24	*C. communis*	1.12		-	
	24	*C. communis*	1.05		-	
	48	*C. alaskensis*	1.03	F	abd	
	48	*C. communis*	1.50		abd	
	> 96	*C. communis*	1.90		-	
		C. communis	2.51		-	
		C. communis	0.28		-	
		C. communis	0.18		-	
		C. communis	1.77		-	
		C. alaskensis	0.32		-	
400	4	*C. communis*	1.80		-	
	18	*C. communis*	0.81		-	
	18	*C. communis*	1.05		abd	
	18	*C. communis*	1.52		abd	
	18	*C. communis*	0.25		-	
	48	*C. communis*	0.64		-	
	48	*C. communis*	2.11		-	
	72	*C. communis*	3.20		-	
	72	*C. communis*	1.50		-	
	> 96	*C. communis*	1.38		-	
600	18	*C. communis*	1.97		-	
		C. communis	1.97		-	
		C. communis	2.02		-	
		C. communis	0.31		-	
		C. communis	2.06		-	
		C. communis	1.68		-	
		C. communis	0.18		-	
		C. communis	2.07		-	
		C. communis	0.41		-	
		C. communis	0.78		-	

TABLE 49. SODIUM PENTACHLOROPHENATE - CONTROL - DECEMBER

Concentration (% v/v)	Time (h)	Species	Weight (g)	Sex	Parasite Location	Degree of Gill Clogging
0	96	*C. communis*	0.70		-	
	> 96	*C. communis*	1.75		abd	
		C. communis	1.88		-	
		C. communis	2.40		-	
		C. communis	1.30		-	
		C. communis	1.50		-	
		C. communis	1.52		abd	
		C. communis	1.72		-	
		C. communis	1.85		-	
		C. communis	1.77		-	

TABLE 50. SODIUM PENTACHLOROPHENATE - FEBRUARY (14-02-77)

Concentration (% v/v)	Time (h)	Species	Weight (g)	Sex	Parasite Location	Degree of Gill Clogging
50	48	*C. communis*	0.40		-	
	48	*C. communis*	0.99		abd	
	72	*C. communis*	0.61		-	
	72	*C. communis*	1.07		-	
	96	*C. communis*	0.50		-	
	96	*C. communis*	1.73		-	
	96	*C. communis*	0.35		-	
	96	*C. communis*	0.51		-	
	>96	*C. communis*	0.37		-	
	>96	*C. communis*	1.52	F	-	
100	48	*C. communis*	0.73		-	
	48	*C. communis*	0.38		-	
	96	*C. communis*	1.59		-	
	96	*C. communis*	2.00	F	-	
	96	*C. communis*	2.09	F	-	
	96	*C. communis*	0.58		-	
	>96	*C. communis*	0.48		-	
	>96	*C. communis*	0.48		-	
	>96	*C. communis*	0.62		-	
	>96	*C. communis*	2.18	F	-	
200	48	*C. communis*	0.73		-	
	72	*C. communis*	2.18	F	-	
	96	*C. communis*	0.50		-	
	>96	*C. alaskensis*	0.51		-	
	>96	*C. communis*	2.30		abd	
	>96	*C. communis*	0.55		-	
	>96	*C. communis*	0.38		-	
	>96	*C. communis*	2.08	F	-	
	>96	*C. communis*	0.22		-	
400	18	*C. communis*	0.35		-	
	18	*C. communis*	1.80	F	-	
	24	*C. communis*	1.11		-	
	48	*C. communis*	0.63		-	
	48	*C. communis*	1.78		-	
	48	*C. communis*	2.29	F	-	
	48	*C. communis*	1.90	F	-	
	72	*C. communis*	3.17		-	
	72	*C. communis*	0.59		-	
	>96	*C. communis*	0.50		-	
600	18	*C. communis*	3.11	F	-	
	18	*C. communis*	1.45	F	-	
	18	*C. communis*	0.82		-	
	18	*C. communis*	0.60		-	
	18	*C. communis*	0.45		-	
	18	*C. communis*	1.82	F	-	
	24	*C. communis*	2.55		-	
	24	*C. communis*	0.55		-	
	48	*C. communis*	0.62		-	
	48	*C. communis*	0.60		-	

TABLE 51. SODIUM PENTACHLOROPHENATE - FEBRUARY (24-02-77)

Concentration (% v/v)	Time (h)	Species	Weight (g)	Sex	Parasite Location	Degree of Gill Clogging
50	48	*C. communis*	1.40	F	-	
	48	*C. communis*	2.42	F	-	
	48	*C. communis*	2.42		-	
	48	*C. communis*	0.59		-	
	48	*C. communis*	1.43		-	
	48	*C. communis*	0.30		-	
	72	*C. communis*	2.18	F	-	
	96	*C. communis*	1.52		-	
	96	*C. communis*	2.10		-	
	>96	*C. communis*	1.45		-	
100	18	*C. communis*	1.00		-	
	48	*C. communis*	1.49		abd	
	48	*C. communis*	1.45		abd	
	48	*C. communis*	2.35	F	-	
	48	*C. communis*	1.99	F	-	
	48	*C. communis*	1.39		-	
	48	*C. communis*	0.51		-	
	72	*C. communis*	2.29	F	-	
	72	*C. communis*	1.83		-	
200	18	*C. communis*	2.68	F	-	
	48	*C. communis*	3.15	F	-	
	48	*C. communis*	3.85	F	-	
	48	*C. communis*	2.02	F	-	
	72	*C. communis*	2.10		abd	
	72	*C. communis*	1.70	F	-	
	72	*C. communis*	2.57	F	-	
	96	*C. communis*	3.80	F	-	
	96	*C. communis*	0.75		-	
	>96	*C. communis*	0.71		-	
400	4	*C. communis*	1.40	F	-	
	18	*C. communis*	1.61		-	
	18	*C. communis*	3.02	F	-	
	18	*C. communis*	1.60		-	
	18	*C. communis*	0.39		-	
	48	*C. communis*	1.99		abd	
	48	*C. communis*	2.15		-	
	48	*C. communis*	3.06	F	-	
	48	*C. communis*	2.09	F	-	
	48	*C. communis*	2.62	F	-	
600	18	*C. communis*	1.61		-	
	18	*C. communis*	2.19		-	
	18	*C. communis*	1.26		-	
	18	*C. communis*	2.19	F	-	
	18	*C. communis*	1.51	F	-	
	18	*C. communis*	1.50	F	-	
	18	*C. communis*	1.51	F	-	
	18	*C. communis*	1.52	F	-	
	48	*C. communis*	2.93		-	
	48	*C. communis*	1.68		-	

TABLE 52. <u>SODIUM PENTACHLOROPHENATE - FEBRUARY</u> (24-02-77)

Concentration (% v/v)	Time (h)	Species	Weight (g)	Sex	Parasite Location	Degree of Gill Clogging
50	18	*C. communis*	1.55		-	
	48	*C. communis*	1.78		-	
	72	*C. communis*	1.71	F	-	
	72	*C. communis*	1.85	F	-	
	72	*C. communis*	2.13	F	-	
	72	*C. communis*	0.65		-	
	72	*C. communis*	1.80		-	
	96	*C. communis*	1.70		-	
	96	*C. communis*	2.10	F	-	
	>96	*C. communis*	3.20	F	-	
100	18	*C. communis*	2.10		abd	
	48	*C. communis*	1.77		abd	
	72	*C. communis*	3.15	F	-	
	72	*C. communis*	2.90	F	-	
	72	*C. communis*	2.49	F	-	
	72	*C. communis*	2.05	F	-	
	72	*C. communis*	3.31	F	-	
	96	*C. communis*	2.99	F	-	
	96	*C. communis*	3.00	F	-	
	96	*C. communis*	2.12	F	-	
200	18	*C. communis*	2.27		abd	
	18	*C. communis*	1.66		abd	
	18	*C. communis*	2.00	F	-	
	48	*C. communis*	1.72	F	-	
	48	*C. communis*	2.31	F	-	
	48	*C. communis*	1.29		-	
	72	*C. communis*	4.15	F	-	
	72	*C. communis*	2.41	F	-	
	72	*C. communis*	2.52	F	-	
	96	*C. communis*	2.10		-	
400	72	*C. communis*	2.71	F	-	
	18	*C. communis*	2.12	F	-	
	18	*C. communis*	0.51		-	
	18	*C. communis*	0.78		abd	
	18	*C. communis*	1.70		abd	
	18	*C. communis*	1.67		abd	
	18	*C. communis*	0.55		-	
	18	*C. communis*	1.66		-	
	48	*C. communis*	2.20	F	-	
	72	*C. communis*	1.47	F	-	
600	4	*C. communis*	1.60		abd	
	18	*C. communis*	1.45	F	-	
	18	*C. communis*	0.49		-	
	18	*C. communis*	1.95	F	-	
	18	*C. communis*	2.52		abd	
	18	*C. communis*	3.29	F	-	
	18	*C. communis*	1.70	F	-	
	18	*C. communis*	1.93	F	-	
	48	*C. communis*	2.30		abd	
	48	*C. communis*	3.60		-	

TABLE 53. SODIUM PENTACHLOROPHENATE - CONTROLS - FEBRUARY

Concentration (% v/v)	Time (h)	Species	Weight (g)	Sex	Parasite Location	Degree of Gill Clogging
0	18	*C. communis*	0.61		-	
(24-02-77)	18	*C. communis*	0.51		-	
	48	*C. communis*	2.20	F	-	
	48	*C. communis*	2.00	F	-	
	48	*C. communis*	1.60		-	
	72	*C. communis*	1.69		abd	
	72	*C. communis*	1.72	F	-	
	96	*C. communis*	2.05	F	-	
	96	*C. communis*	2.99	F	-	
	96	*C. communis*	2.10		abd	
0	18	*C. communis*	1.34		abd	
(14-02-77)	18	*C. communis*	0.29		-	
	48	*C. communis*	2.91	F	-	
	48	*C. communis*	0.50		-	
	72	*C. communis*	2.41	F	-	
	96	*C. communis*	1.97		-	
	96	*C. communis*	2.01	F	-	
	96	*C. communis*	3.89	F	-	
	96	*C. communis*	2.70	F	-	
	>96	*C. communis*	1.73		-	