ACUTE LETHAL TOXICITY OF PRUDHOE BAY CRUDE OIL AND COREXIT 9527 TO ARCTIC MARINE INVERTEBRATES AND FISH FROM FROBISHER BAY, N.W.T.

by

Malcolm G. Foy

LGL Limited
environmental research associates
44 Eglinton Ave. W.
Toronto, Ontario

for

Environmental Protection Service
Department of Fisheries and Environment
Hull, Quebec

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EXECUTIVE SUMMARY

Introduction

In the summer of 1978, a study was performed to determine the acute toxicity of Prudhoe Bay crude oil and the dispersant, Corexit 9527, alone and in combination, to several species of arctic marine invertebrates and one species of fish. The research was carried out in the Ikaluit Research Laboratory in Frobisher Bay, N.W.T., with locally collected test species. This study was conducted as part of the Arctic Marine Oilspill Program (AMOP) and was intended to verify and expand on results obtained in an earlier study (Foy 1978).

It is emphasized that studies of this nature have limitations and that great care must be taken in using 96 h LC50 values to predict the effects of contamination in a natural situation. The main values of such studies are in establishing the relative sensitivities of different species and life stages, in determining relative toxicities of different contaminants and in defining concentrations of toxicants to be used in subsequent studies of sublethal effects.

Materials and Methods

The toxicities of Prudhoe Bay crude oil, Corexit 9527 and the two in combination were investigated using 96 h semi-static acute bioassays to determine the median lethal concentrations (96 h LC50). In bioassays using oil as a toxicant, either alone or in combination with Corexit, the 96 h LC50 was determined on the basis of *measured* (using fluorescence spectroscopy) concentrations of oil in the water column. Methods were basically the same as those described by Foy (1978).

Oil-water or oil-Corexit-water mixtures were prepared by adding the toxicant(s) to filtered seawater (salinity from 24.1 °/₀₀ to 32.2 °/₀₀), shaking on a reciprocating shaker (0.5 h) and allowing to stand undisturbed in a separatory funnel for 3.5 h. At the end of this time, the lower, aqueous phase was withdrawn and evenly distributed into three vessels (polyethylene food bags supported in jars) which served as replicates.

Species and sizes of test organisms are listed in Table 1. The amphipod species *Anonyx laticoxae* and *Gammarus oceanicus* were found, upon positive identification of test organisms, as contaminant species in bioassays using *A. nugax* and *G. setosus*, respectively. Separate data analyses were performed for these 'contaminant' species even though the numbers of animals were small. Two size classes of *O. litoralis* were used in the bioassays; the smaller animals were referred to as juveniles, the larger as adults.

TABLE 1.
Animals Used in Toxicity Tests.

Species	Range in Length (mm)
Amphipods	
Anonyx laticoxae Gurjanova	21-35
Anonyx nugax (Phipps)	15-45
Boeckosimus sp.	9-24
Gammarus oceanicus Segerstrale	21-37
Gammarus setosus Dementieva	16-40
Onisimus litoralis (Kroyer)	6-9 and 13-19
Fish	
Myoxocephalus quadricornis quadricornis (Linnaeus)	14-23

From 5 to 10 animals were normally used in each replicate test mixture. Most bioassays consisted of

- three replicates of each of four toxicant concentrations,
- five control replicates of filtered seawater and
- three replicates of one concentration of a reference toxicant, sodium lauryl sulphate (SLS).

Every 24 h, dead animals were counted, removed and preserved for subsequent measurement and verification of identification; the remaining live animals were transferred to freshly prepared toxicant mixtures. Animals were not fed during the bioassays.

An attempt was made to maintain an experimental temperature of 4.5°C by circulating cold water around the bioassay vessels. Due to on-off cycling of the cooling unit, temperatures regularly varied by ± 0.5°C. The maximum range of temperature variation recorded in any single experiment (with two exceptions) was 2.9°C; this temperature instability was caused by adding or removing bioassay vessels. Toxicant mixtures were not aerated during the bioassays but dissolved oxygen levels were monitored and were always greater than 4.0 ppm.

Oil-water and oil-Corexit-water mixtures were sampled immediately after toxicant mixture preparation (0 h) and at the end of each 24 h period within the 96 h bioassays. Oil in these samples was extracted with spectrophotometric-grade hexane and the fluorescence of the extract was measured

using a spectrofluorometer. Concentration was determined by applying the relative fluorescence readings to a calibration equation determined by measuring the fluorescence of known concentrations of oil in hexane. Efficiency of extraction was checked by repeatedly extracting the same samples of oil-water mixtures with hexane. All hydrocarbon concentration determinations were corrected for efficiency of extraction.

In oil or oil-Corexit toxicity bioassays, the exposure concentration of oil used in the calculation of LC50 values was determined by averaging the mean 0 h and 24 h fluorometrically measured concentrations. The 96 h LC50 levels of sodium lauryl sulphate and Corexit 9527 were determined on the basis of their nominal concentrations.

Mortality in toxicant mixtures was corrected for control mortality by using Abbot's formula (A.P.H.A. 1976). When possible, 96 h LC50 values were determined using a computerized probit analysis (Davies 1971). Otherwise, a graphical probit analysis (Litchfield and Wilcoxon 1949) or a 10% trimmed Spearman-Karber calculational method (Hamilton *et al.* 1977) was used to determine median lethal concentrations. If all of the above methods failed due to limitations of the data, the 96 h LC50 was interpolated from a graph of mortality versus concentration on semi-log paper.

Two additional procedures were used to gain more information from the toxicity bioassays. In most bioassays, animals that were still alive after 96 h in the toxicant mixtures were transferred to clean seawater for a period of 24 h to observe post-exposure mortality. To gain more information on the nature of the oil-water and oil-Corexit-water emulsions, gas chromatography was performed on samples taken at both 0 h and 24 h.

Results and Discussion

Results of all bioassays are summarized in Table 2.

Sodium Lauryl Sulphate

Concentrations of the synthetic detergent, sodium lauryl sulphate, lethal to 50% of the animals in 96 h ranged from 1-5 ppm in tests with young-of-the-year *Myoxocephalus quadricornis* to 89 ppm in tests with *Gammarus setosus*. It was impossible to determine a 96 h LC50 for *Boeckosimus* sp. because a precipitate formed in concentrations high enough to produce mortality, and the actual exposure concentrations were therefore uncertain. The 96 h LC50 values of SLS for adult *Onisimus litoralis* (28 ppm) and *Anonyx nugax* (16 ppm) were similar to those of 4 to 40 ppm and 24 ppm, respectively, found for the same species in a previous study (Foy 1978). The sensitivity of fourhorn sculpin (*M. quadricornis*) young-of-the-year was similar to the responses that have been reported for several species of fish from other latitudes.

TABLE 2.
Median Lethal Concentrations (96 h LC50) of Four Toxicant Mixtures for the Test Species. Ninety-six h LC50 values of oil in oil-water and oil-Corexit-water mixtures are based on measured oil concentrations in the water column. Unless otherwise indicated, 96 h LC50 values were calculated using a computerized probit analysis (Davies 1971). Values within round brackets after the 96 h LC50 are 95% confidence limits. All values are in ppm.

Species	Toxicant			
	Sodium Lauryl Sulphate	Corexit 9527	Prudhoe Bay Crude Oil	Prudhoe Bay Crude Oil-Corexit 9527
Amphipods				
Anonyx laticoxae	41[35- 45][1]	>140	>51	112 [73-169][1]
Anonyx nugax	16[15- 25][1]	104(97-111)	32(27-37)	45 (34- 61)
Gammarus oceanicus	30[25- 35][1]	>80	>55	105 (75-153)[3]
Gammarus setosus	89(42-186)[2] 42(39- 46)	175(38-803)	56(51-62) >53	138(114-168) 83 (70- 98)
Onisimus litoralis (adult)	28(26- 30) 28(26- 29)	115[80-160][1]	>47	138(118-161)
Onisimus litoralis (juvenile)	22(19- 26)	-	68(62-75)[2]	-
Boeckosimus sp.	>50	>175	>59	162(135-195)
Fish				
Myoxocephalus quadricornis	1-5[4]	<40	43(37-49) 42(39-46)	59 (40- 87)

[1] Interpolated from data plotted on semi-log paper; figures in square brackets give the range of concentrations within which 50% mortality would occur.

[2] Graphical probit analysis estimate (Litchfield and Wilcoxon 1949).

[3] 10% trimmed Spearman-Karber estimate (Hamilton *et al.* 1977).

[4] 50% mortality most likely to occur within this range on basis of mortality observed in concentrations of 1 and 5 ppm used as controls in several experiments.

Corexit 9527

Median lethal concentrations of Corexit 9527 in 96 h for the amphipod species tested were all greater than 80 ppm. Of the amphipod species for which a 96 h LC50 could be determined, *Anonyx nugax* was the most sensitive (96 h LC50 = 104 ppm). *Boeckosimus* sp. appeared to be the most resistant amphipod species tested (96 h LC50 > 175 ppm). The fourhorn sculpin was much more sensitive to this dispersant than were the amphipods; the 96 h LC50 of Corexit 9527 for this species was less than 40 ppm.

Oil-Water Mixtures

With the methods used to prepare oil-water mixtures, measured oil concentrations approached a maximum at about 150 ppm added oil (Figure 1). Increases in added oil above this concentration resulted in only a very slight increase in measured oil concentration in the water column. With several of the test species, this maximum measured oil concentration produced little or no mortality. As a result, 96 h LC50 values of Prudhoe Bay crude oil in oil-water mixtures could not be determined for these species.

Of the animals used as test organisms, *Anonyx nugax* appeared to be most sensitive to Prudhoe Bay crude oil (96 h LC50 = 32 ppm). This is similar to the 96 h LC50 of 32 to 43 ppm found in a previous study (Foy 1978). The 96 h LC50 of Prudhoe Bay crude oil for juvenile *Onisimus litoralis* was 68 ppm; this is a lesser sensitivity than was exhibited by *O. litoralis* (96 h LC50 = 49 ppm) in a previous study (Foy 1978).

Oil-Corexit-Water Mixtures

Measured oil concentrations in the water column of oil-Corexit-water mixtures, unlike oil-water mixtures, increased throughout the range of concentrations of added oil (Figure 1). This resulted in measured hydrocarbon concentrations as much as 7 times greater (at 640 ppm added oil) than those in oil-water mixtures of the same nominal oil concentration. Thus, the higher mortality observed in oil-Corexit-water mixtures than in oil-water mixtures of the same nominal oil concentration was probably due to higher actual oil concentrations in the water column of oil-Corexit-water mixtures.

The 96 h LC50 values of Prudhoe Bay crude oil dispersed by Corexit 9527 ranged from 45 ppm for *Anonyx nugax* to 162 ppm for *Boeckosimus* sp. For at least three species (*A. nugax*, *Gammarus setosus* and *Myoxocephalus quadricornis*), the 96 h LC50 values of oil in oil-Corexit-water mixtures were greater than those in oil-water mixtures. Results for the other species were less well defined since mortalities (other than 100%) did not occur in enough concentrations of oil in oil-water mixtures to determine 96 h LC50 values. However, mortalities in oil-water mixtures

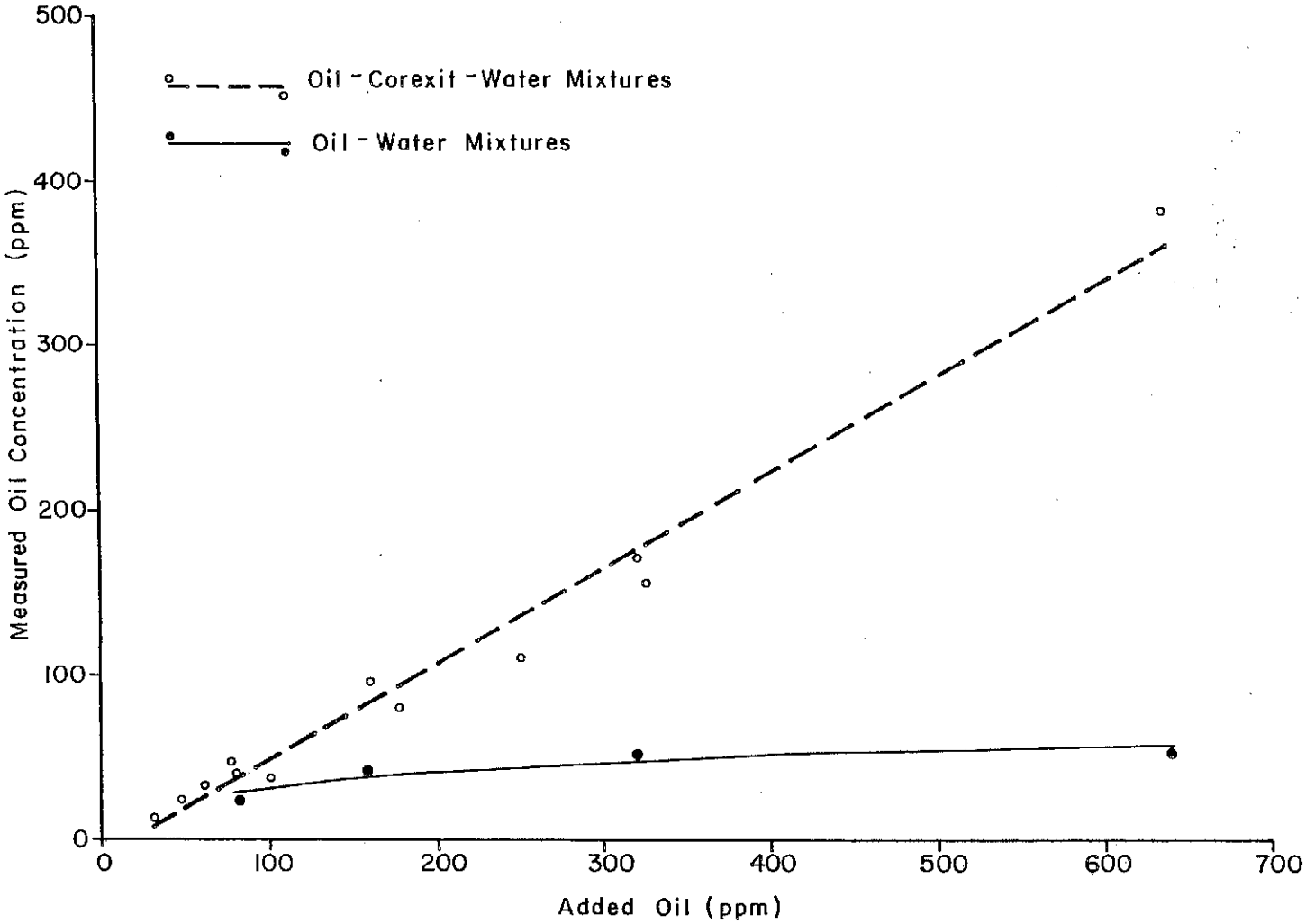

FIGURE 1. Relationship Between Added Oil Concentration and Measured Oil Concentration (average of mean 0 h and 24 h concentrations) in the Water Column for Prudhoe Bay Crude Oil in Oil-Water and Oil-Corexit-Water Mixtures. Each point represents the average of the means of all 0 h and 24 h oil concentration determinations.

were generally greater than those in oil-Corexit-water mixtures of similar measured hydrocarbon concentrations. Foy (1978) reported that oil-Corexit water mixtures were less toxic, based on measured concentrations of oil in the water column, than oil-water mixtures to the amphipod *Anonyx nugax* and the copepod *Calanus hyperboreus* and concluded that 'more of the less soluble and less toxic oil components were entrained in the water column by using a dispersant, thus decreasing toxicity on a *measured* oil basis'.

The results of analysis by gas chromatography indicated that the ratio of dissolved to total hydrocarbons was greater in the oil-water mixtures than in the oil-Corexit-water mixtures. It is assumed that aromatic compounds, dissolved in the water phase of such oil-in-water mixtures, are the primary lethal components of crude oils, at least in short-term toxicity tests. Thus, a higher ratio of dissolved to total hydrocarbons in oil-water mixtures than in oil-Corexit-water mixtures indicates a greater proportion of toxic components. This difference is probably the reason oil-water mixtures appear to be more toxic than oil-Corexit-water mixtures with the same *total measured* hydrocarbons in the water column.

Relative Sensitivity

Anonyx nugax and young-of-the-year *Myoxocephalus quadricornis* were the most sensitive of the test species to the four toxicant mixtures. *Myoxocephalus quadricornis* appeared to be particularly susceptible to mortality caused by detergents (sodium lauryl sulphate and Corexit 9527), whereas *Anonyx nugax* was more affected by oil in both the oil-water and oil-Corexit-water mixtures. While not as well defined as the least resistant species, *Boeckosimus* sp. appeared to be the species most resistant to the toxicant mixtures. The intertidal amphipods *Gammarus oceanicus, G. setosus* and *Onisimus litoralis* and the benthic amphipod *Anonyx laticoxae* were intermediate in their sensitivities to the toxicants used in this study.

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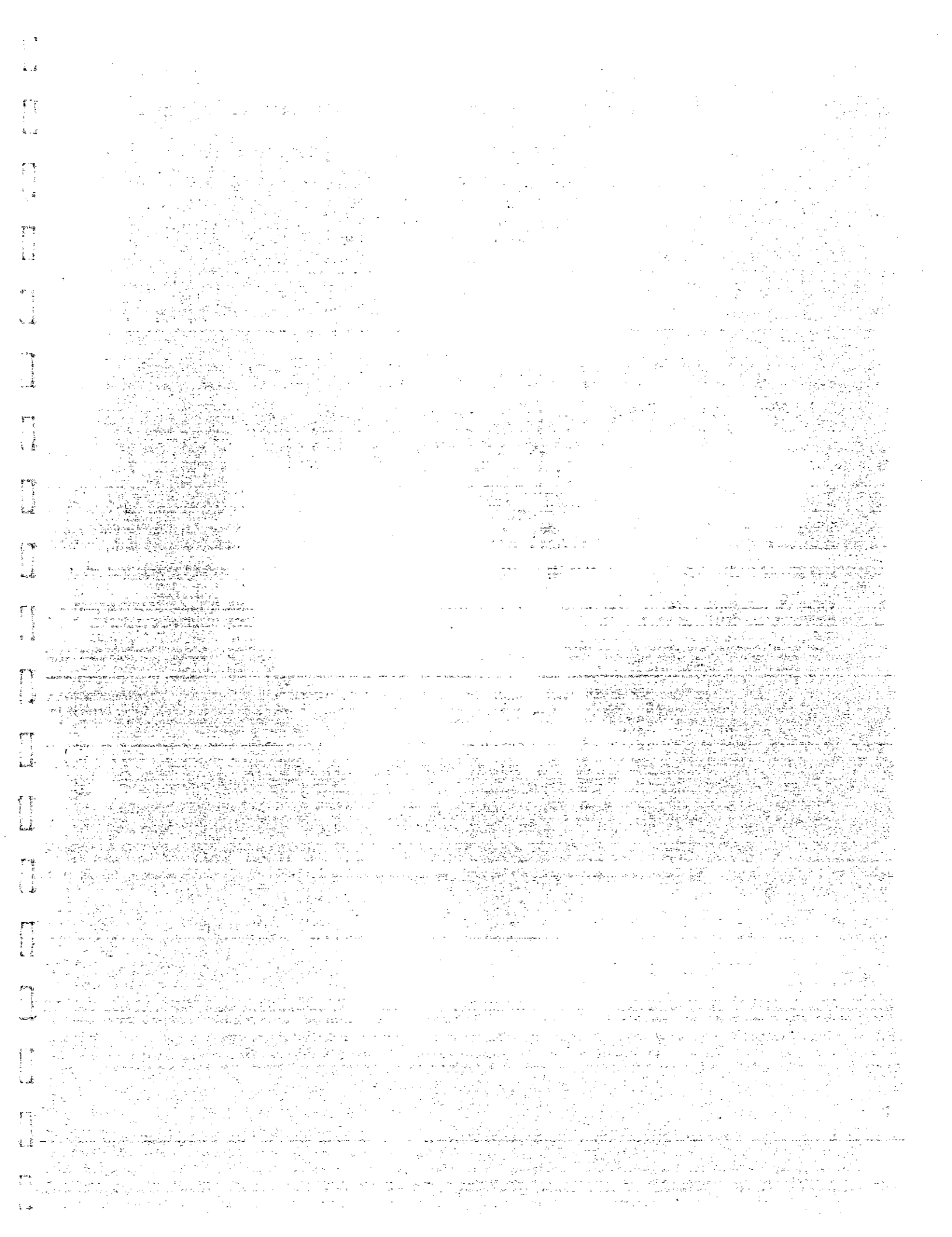

ABSTRACT

The toxicity of Prudhoe Bay crude oil and the dispersant, Corexit 9527, separately and in combination, to several arctic marine amphipods and one arctic marine fish was investigated. Toxicity was evaluated in semi-static 96 h bioassays in which exposure concentrations of hydrocarbons were measured by fluorescence spectroscopy. Mortality results were analyzed by probit analysis to determine the concentration which would be expected to cause 50 percent mortality in 96 h (96 h LC50). In addition, the toxicity of a reference toxicant, sodium lauryl sulphate, was determined.

Mortality in oil-Corexit-water mixtures was much higher than in oil-water mixtures of the same nominal oil concentration. However, measured oil concentrations in the water column were much higher in mixtures dispersed with Corexit than in mechanically dispersed mixtures when the same amounts of oil were added initially. Therefore, the higher mortality observed in the oil-Corexit-water mixtures than in the oil-water mixtures is thought to reflect the higher concentrations of oil to which the organisms were exposed.

When based on actual hydrocarbon concentrations in the water column (as determined by fluorescence spectroscopy), the toxicity of the oil-Corexit-water mixtures was *less* than that found for the oil-water mixtures. This is thought to be a result of the smaller ratio of dissolved hydrocarbons (including toxic water-soluble aromatics) to total measured hydrocarbons in the oil-Corexit-water mixtures than in the oil-water mixtures.

FOREWORD

In the fall of 1977, LGL Limited was contracted by the Environmental Protection Service to conduct a study, as part of the Arctic Marine Oilspill Program (AMOP), on the acute toxicity of crude oil and dispersants to arctic marine organisms. Research was carried out in Resolute Bay, N.W.T., during the winter of 1977-78 and the results were reported in the spring of 1978 (Foy 1978).

LGL Limited was subsequently contracted to continue the aforementioned research with the purpose of verifying results, expanding the list of test organisms and determining seasonal or regional variations in sensitivity. Research was carried out in Frobisher Bay, N.W.T., during August and September 1978. The results of that research are detailed in this report.

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1 INTRODUCTION

Development and transportation of petroleum resources in the Canadian Arctic will almost certainly result in accidental spillages of petroleum hydrocarbons into the marine environment. High priority must be given to the development of technology to minimize such accidents. However, we must also be prepared to deal with large-scale hydrocarbon contamination resulting from imperfections in technology or from human error.

The costs of oilspill cleanup in temperate latitudes are enormous. Because of remoteness and inhospitable climatic conditions, costs of cleanup in arctic regions can be expected to be even greater. In all likelihood, the question will not be one of how to completely remove the contaminant, but one of which geographical and ecological areas have priority in cleanup and protection. The identification of priority ecological areas or communities must be based on the sensitivity and vulnerability of those communities to hydrocarbon contamination.

To identify sensitive ecological areas, one must have a sound knowledge of the individual components of that community (e.g. their life histories, physiology, distribution, etc.) and of the interactions among individual components (e.g. trophic relationships) that make up the community. In addition, it is important to know how and to what degree individuals and, ultimately, the community react to the presence of hydrocarbons. This study, in determining concentrations of crude oil that are lethally toxic to individual species and in contributing some information on life histories, is one small step in that direction.

It must be emphasized, however, that acute toxicity tests of the type reported herein are of value only if their limitations are recognized. Their main values lie in establishing the relative sensitivities of different species and life stages, and in determining relative toxicities of different contaminants. They can also be used to define concentrations of contaminants to be used in subsequent studies of sublethal effects. It is not desirable to use the results of these studies to predict the effects of contamination in a natural situation or to use the 96 h LC50 values obtained to derive meaningful water quality criteria.

2 MATERIALS AND METHODS

2.1 Study Area

This study was performed in Frobisher Bay, N.W.T., from 2 August to 25 September, 1978. Collections of test animals were made in upper Frobisher Bay and toxicity bioassays were carried out in the Ikaluit Laboratory, which is managed by the Department of Indian Affairs and Northern Development.

Many sites in upper Frobisher Bay were sampled in an attempt to collect a wide variety of organisms in numbers sufficient for bioassay purposes. The locations of the sites at which successful collections were made are indicated in Figure 1.

2.2 Test Species

Experiments were performed with six species of benthic amphipods and one species of fish. The amphipod species were *Anonyx laticoxae* Gurjanova, *Anonyx nugax* (Phipps), *Boeckosimus* sp., *Gammarus oceanicus* Segerstrale, *Gammarus setosus* Dementieva, and *Onisimus litoralis* (Kroyer). The fish species was the fourhorn sculpin, *Myoxocephalus quadricornis quadricornis* (Linnaeus). Animals were identified using standard taxonomic reference material and all identifications were verified by the Canadian Aquatic Identification Centre. Locations and dates of capture of the test animals are summarized in Table 1.

TABLE 1.
Test Species Collection Information.

Site	Depth	Species Collected	Date Collected
1	Intertidal	*Gammarus* spp.	3 to 23 Aug.
	Intertidal	*Onisimus litoralis*	3 Aug. to 19 Sept.
2	Bottom (10 m)	*Anonyx* spp.	15 Aug. to 2 Sept.
3	Bottom (10 m)	*Anonyx* spp.	2 to 11 Sept.
	Bottom (10 m)	*Boeckosimus* sp.	5 Sept.
	Surface (0 m)	*Myoxocephalus quadricornis*	2 to 17 Sept.
4	Bottom (10 m)	*Anonyx* spp.	11 to 20 Sept.
		Boeckosimus sp.	11 Sept.
5	Intertidal	*Onisimus litoralis*	15 Sept.

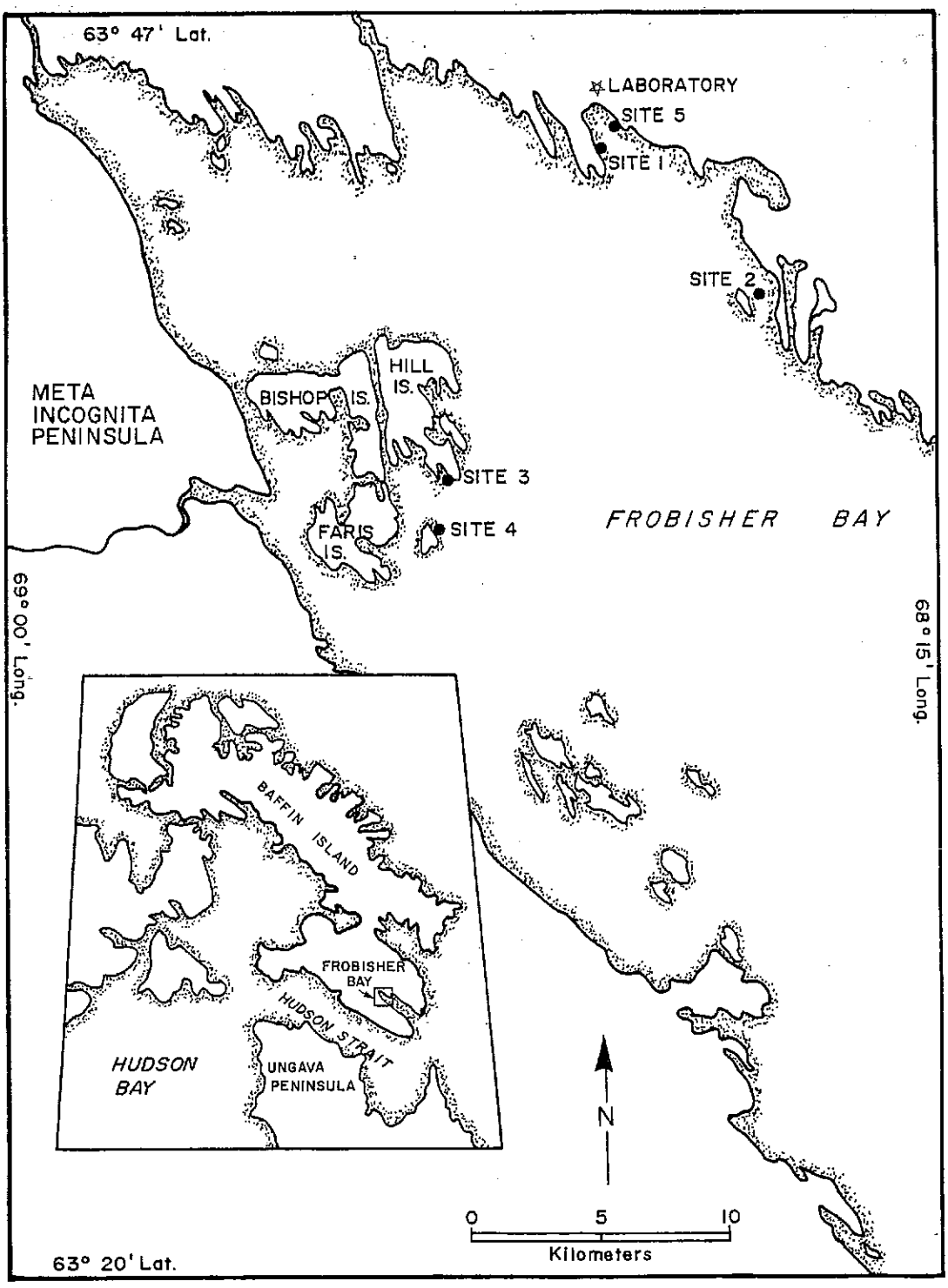

FIGURE 1. Study Area.

2.3 Animal Collection, Maintenance and Acclimation

Amphipods were collected by a variety of methods. *Gammarus* spp. were collected from under rocks and from shallow tidal pools. *Onisimus litoralis* were collected in basically the same way, but small pieces of bait (sardines, seal meat, char, etc.) were sometimes thrown into the pools to attract and concentrate this species. *Anonyx* spp. and *Boeckosimus* sp. were collected in standard cylindrical wire minnow traps which were covered with 1 mm mesh netting. These traps were baited with seal meat or char and left for at least 24 h in 10 m of water.

Fourhorn sculpins, *Myoxocephalus quadricornis*, were collected with dip nets when observed in large numbers in surface waters.

Animals were transported, in water collected from the location of their capture, using insulated containers. If animals were needed immediately for toxicity bioassays, they were transported to the laboratory where they were separated by species and held for acclimation. If a longer time between collection and use in bioassays was anticipated, animals were held in submerged minnow buckets at Site 1 and were fed periodically with sardines, seal meat and char. Amphipods were maintained in this manner for periods of up to 7 days. It was not necessary to hold sculpins in this way.

After test organisms were brought into the laboratory, they were separated by species and placed in freshly collected seawater in polystyrene animal cages which were kept in the cold-water bioassay baths (see p. 11). Water in the cages was changed every 1 to 2 days and aerated continuously using an aquarium air pump (Silent Giant). The length of the acclimation period varied among bioassays and these times are reported with the experimental results (Tables 13 to 48, Appendix A). Animals were not fed during the acclimation period.

2.4 Toxicants

The toxicants used in the present study are the same as those used by Foy (1978) and are described in detail in that report. Prudhoe Bay crude oil (Atlantic Richfield Co., Ferndale, Washington), from the same batch used by Foy (1978), was employed in nominal concentrations from 30 to 640 ppm (µl/l). Corexit 9527 (ESSO Chemicals, Sarnia, Ontario) was used in concentrations from 10 to 640 ppm (µl/l) and, when used to disperse the oil, was used in an amount equal to 1/10 the volume of oil. All concentrations of Corexit referred to in this study are µl of Corexit *concentrate* per liter of water and not concentrations of a diluted formulation. A reference toxicant, sodium lauryl sulphate (BDH chemicals, specially pure), was used in concentrations from 0.5 to 50 ppm (mg/l).

2.5 Test Mixture Preparation

Methods for the preparation of the toxicant mixtures are modified from those of Percy and Mullin (1975) and are described in detail by Foy (1978). Only a brief description of the methods, including modifications, is presented here.

Water used in the preparation of all test mixtures was taken from the surface of nearshore sampling Site 1. Its salinity was measured periodically using an Endeco hand-held refractometer/salinometer accurate to ±0.5°/₀₀. Salinity varied from 24.1 to 32.2°/₀₀ (n=26).

'Semi-stable dispersions' of oil in water or of oil and Corexit in water were prepared by adding the oil or oil and Corexit to 1.5 l of filtered seawater which had been previously cooled to experimental temperature, shaking on a reciprocating shaker for 0.5 h and 'settling' in a stoppered separatory funnel. At the end of the settling period (3.5 h), the lower oil-water or oil-Corexit-water phase was sampled for determination of initial oil concentration and placed into plastic bags (polyethylene food bags, Rapid Packaging Systems Ltd., Scarborough, Ontario) supported in glass jars. The mixture was distributed evenly among three containers to provide replicates. Control water, SLS solutions and Corexit mixtures were prepared as described by Foy (1978), but in plastic bags supported in glass jars. The above preparations took place at room temperature (∿20°C). Jars containing the test solutions were then placed in a water bath (see p. 11) at the experimental temperature and allowed to reach this temperature (about 2 h) before test animals were added.

Glassware used in the preparation of the toxicant mixtures was washed as described by Foy (1978). Polyethylene bags used in the bioassays were replaced when a fresh toxicant mixture was prepared (every 24 h).

2.6 Hydrocarbon Analysis

2.6.1 Fluorescence Spectroscopy

As in Foy (1978), hydrocarbon concentrations in experimental mixtures were monitored by fluorescence spectroscopy using a Turner Model 430 spectrofluorometer. Optimum excitation and emission wavelengths for assay of Prudhoe Bay crude oil were determined as described by Foy (1978) and found to be 355 nm and 410 nm, respectively. All hydrocarbon determinations were made using these excitation and emission wavelengths.

During the study period, several calibration curves were prepared by determining relative fluorescence of known concentrations of Prudhoe Bay crude oil in spectrophotometric grade hexane (J.T. Baker Chemical Co.). A summary of these results is presented in Table 2. Calibration data were combined for calculation of a linear regression equation. Since the relationship between oil concentration and relative fluorescence becomes non-linear (due to quenching of fluorescence) at high concentrations, only determinations at concentrations of 0.01 µl/ml and less were used to calculate the regression line.

TABLE 2.
Relative Fluorescence of Various Concentrations of Oil Used in Producing Calibration Curve.*

Oil Concentration µl oil/ml hexane	Relative Fluorescence			
	n	Range	Mean	s.d.
0.00002	4	0.0034- 0.0103	0.0068	0.0029
0.00005	4	0.0049- 0.0360	0.0169	0.0135
0.00008	3	0.0070- 0.0182	0.0140	0.0061
0.00010	7	0.0120- 0.0264	0.0175	0.0061
0.00020	8	0.0142- 0.0422	0.0263	0.0079
0.00050	8	0.0580- 0.1190	0.0737	0.0200
0.00080	8	0.0910- 0.1670	0.1259	0.0272
0.00100	8	0.1300- 0.2020	0.1505	0.0233
0.00200	8	0.2600- 0.3860	0.3095	0.0451
0.00500	8	0.6220- 0.9420	0.7566	0.1104
0.00800	8	0.9790- 1.3600	1.1286	0.1542
0.01000	8	1.1700- 1.7100	1.3988	0.2016
0.02000	8	2.1900- 3.2000	3.7025	0.3761
0.04000	8	3.8000- 5.7000	4.7950	0.6963
0.06000	8	5.1100- 7.7000	6.4788	0.8997
0.08000	8	6.1700- 9.1600	7.8125	1.0658
0.10000	8	6.8900-10.0000	8.7500	1.1320
0.20000	3	11.2000-13.1000	11.8667	1.0693
0.40000	3	10.9000-12.2000	11.4333	0.6807
0.60000	3	8.9000- 9.8000	9.3333	0.4509
0.80000	3	7.0000- 7.3000	7.2000	0.1732
1.00000	3	5.2000- 5.4700	5.2900	0.1559

* Calibration equation (based on concentrations up to 0.01 µl/ml) was $y = -0.00008 + 0.00711x$ where y = oil concentration (µl/ml hexane) and x = relative fluorescence.

Samples of all oil-water and oil-Corexit-water mixtures used in bioassays were taken immediately after mixture preparation and after a 24 h exposure period. Hydrocarbons in these samples were extracted once with spectrophotometric grade hexane as described by Foy (1978) and the fluorescence of the hexane extracts determined. Samples were diluted with hexane, if necessary, to produce fluorescence readings that would fall within the linear portion of the calibration curve and not in the area of quenching. All hydrocarbon concentrations in bioassay mixtures were calculated from relative fluorescence readings using the regression equation determined as described above.

To determine the efficiency of oil extraction when a single hexane extraction of each sample is used, a minimum of five tests was run at each nominal oil concentration for both oil-water and oil-Corexit-water mixtures. Samples were taken immediately after preparation of the mixture (0 h) and after 24 h exposure, before animals were transferred. These tests were performed as described by Foy (1978) except that hexane extractions were repeated on the same sample until the hydrocarbon concentration in the final extract approximated 10% of the hydrocarbon concentration in the extract with the highest concentration. The resulting concentrations of hydrocarbons were summed and the concentration in the first extract expressed as a percentage of the total.

The efficiency of the first hexane extraction of oil from the oil-water mixtures varied from 85.4% to 97.6% in the samples taken at 0 h (n=27) and from 82.1% to 100.0% in the samples taken at 24 h (n=24). Efficiencies for samples taken at either 0 h or 24 h showed no significant relationship to added oil concentration when the data were analyzed by either linear or exponential regression (Table 3).

TABLE 3.
Regression Coefficients for the Regression of Efficiency of Extraction on Added Oil Concentration in Oil-Water Mixtures at 0 h and 24 h. Significance was determined using a two-tailed t-test.

Exposure Time	d.f.	Linear Regression			Exponential Regression		
		b	t	P	b	t	P
0 h	2	2.78×10^{-3}	0.874	>0.4	3.13×10^{-5}	0.893	>0.4
24 h	2	9.59×10^{-2}	1.809	>0.2	1.05×10^{-4}	1.802	>0.2

Abbreviations: d.f. = degrees of freedom; b = regression coefficient; t = t-statistic; P = probability.

A two-sided Mann-Whitney U-test detected no significant difference between the values from 0 h and 24 h samples ($P>0.2$). Therefore, extraction efficiencies from all added oil concentrations and from both 0 h and 24 h determinations were combined and averaged (mean = 91.2%, s.d.=4.8%) and a single correction factor (1.096) determined; this factor was applied to all oil concentrations measured in the extracts of oil-water mixtures to determine more realistic exposure concentrations.

Extractions of hydrocarbons from oil-Corexit-water mixtures were less efficient and the efficiencies more variable than those of the oil-water mixtures. In order to determine factors to correct for extraction efficiencies, exponential curves were fit by regression analysis to the data from samples taken at 0 h (Figure 2) and 24 h (Figure 3). Correction factors for each nominal oil concentration were determined from these curves (Table 4).

All hydrocarbon measurements made on samples of oil-water and oil-Corexit-water mixtures were multiplied by the appropriate correction factors to determine oil concentration. Because of the great variability in efficiencies of first extractions, this resulted in a few individual measured concentrations that were greater than the nominal concentration (e.g. Table 45, Appendix A). However, it was felt that even with these inconsistencies, the effect of averaging to determine exposure concentration for each experiment would reduce these errors and that the resultant 96 h LC50 values would be more accurate than if no correction factor were used. All measured concentrations of oil from oil-water and oil-Corexit-water mixtures reported herein have been corrected for extraction efficiency.

2.6.2 Gas Chromatography

In order to gain additional information on the nature of the toxicant mixtures, samples of oil-water and oil-Corexit-water mixtures with a nominal (added) concentration of 200 ppm Prudhoe Bay crude oil were analyzed by gas chromatography. These analyses were performed by the Oil and Gas Working Group, Institute for Environmental Studies, University of Toronto. Oil-water and oil-Corexit-water mixtures were prepared as described for bioassay mixtures, and sampled at 0 h and after 24 h (without test animals) under bioassay conditions. Artificial seawater (35°/₀₀) was used to make up the mixtures. In addition, a sample of the oil was analyzed by gas chromatography to determine if it had been weathered to any extent prior to use in bioassays.

Hydrocarbons were extracted from the oil-water or oil-Corexit-water mixtures using the gas stripping technique described by Mackay and Shiu (1976). This method extracts efficiently only those hydrocarbons of volatility greater than naphthalene, which are generally low and medium molecular weight hydrocarbons (Mackay and Shiu 1976).

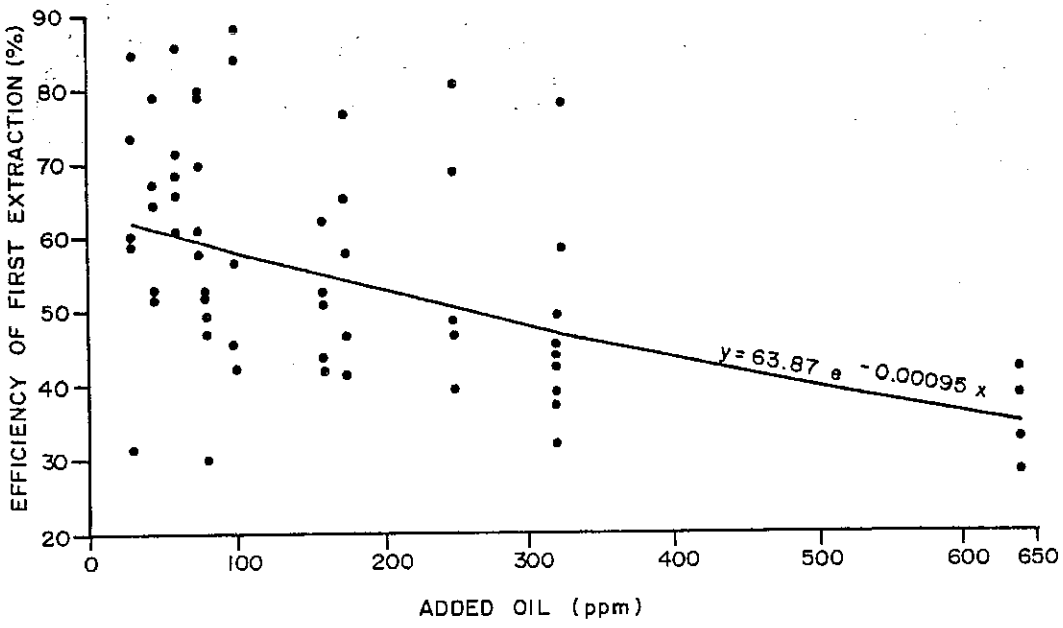

FIGURE 2. Efficiency of Initial Oil Extraction from Oil-Corexit-Water Mixtures at 0 h. Regression coefficient = -9.52×10^{-4}, $P<0.001$ (two-tailed t-test).

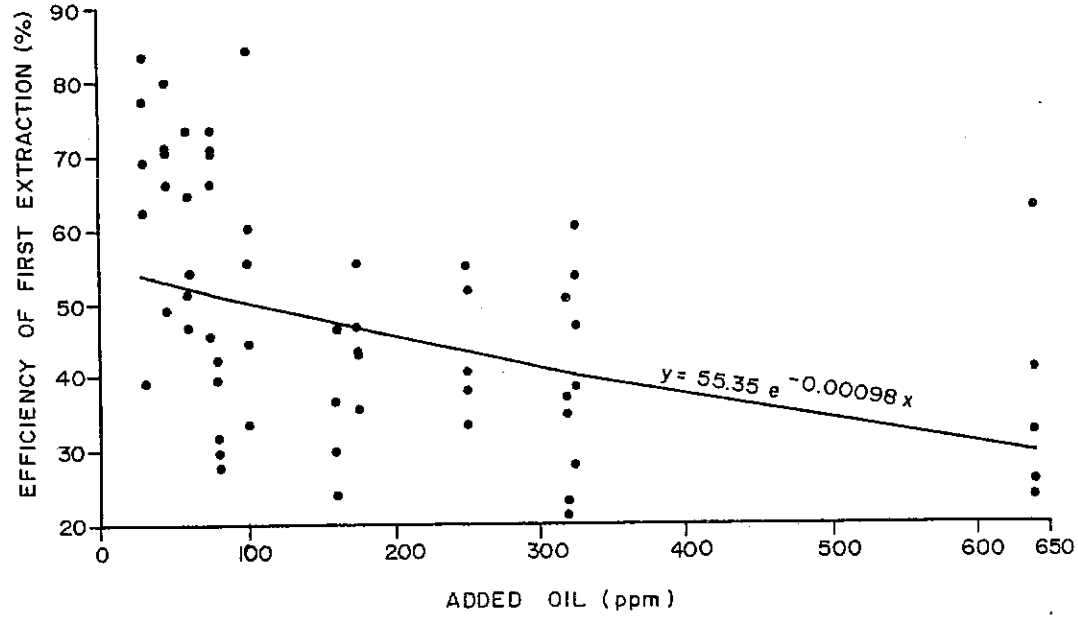

FIGURE 3. Efficiency of Initial Oil Extraction from Oil-Corexit-Water Mixtures after 24 h. Regression coefficient = -9.76×10^{-4}, $P<0.01$ (two-tailed t-test).

TABLE 4. Efficiencies of Initial Oil Extraction and Resultant Correction Factors for Oil-Corexit-Water Mixtures at Exposure Times of 0 h and 24 h.

Added Oil (ppm)	Exposure Time			
	0 h		24 h	
	Efficiency(%)*	Correction Factor	Efficiency(%)*	Correction Factor
30	62.1	1.6103	53.8	1.8587
45	61.2	1.6340	53.0	1.8868
60	60.3	1.6584	52.2	1.9157
75	59.5	1.6807	51.4	1.9455
80	59.2	1.6892	51.2	1.9531
100	58.1	1.7212	50.2	1.9920
160	54.9	1.8215	47.3	2.1142
175	54.1	1.8484	46.7	2.1413
250	50.4	1.9841	43.4	2.3041
320	47.1	2.1231	40.5	2.4691
325	46.9	2.1322	40.3	2.4814
640	34.7	2.8818	29.6	3.3784

* Based on curves in Figures 2 and 3.

Chromatography was performed using a Hewlett-Packard Model 5750 gas chromatograph as described by Mackay and Shiu (1976). The temperature of the column was increased from 50°C to 280°C at 15°C/min and held at 280°C for 20 min. Concentrations were determined by measuring peak areas using a Hewlett-Packard Model 3371 integrator. The error in these quantities is probably on the order of ±50% (D. Mackay, University of Toronto, pers. comm.).

In order to differentiate between dissolved and particulate hydrocarbons, oil-water or oil-Corexit-water mixtures were filtered through a 5 µm pore size filter. Hydrocarbon concentrations in the filtrate (determined by gas chromatography) were considered to be concentrations of dissolved hydrocarbons. The concentration of the particulate (dispersed) hydrocarbon fraction was calculated as the difference between total hydocarbon concentration (determined in an unfiltered sample) and dissolved hydrocarbon concentration.

2.7 Bioassays

Bioassays were conducted as semi-static 96 h acute bioassays, basically as described by Foy (1978). Each experiment consisted of three replicates at each of four toxicant concentrations, in addition to five control replicates. Normally, each replicate contained 5 to 10 animals in a 440 ml volume of test mixture. Animals were not fed during the bioassays. At the end of every 24 h period during the tests, dead animals were counted, removed and preserved, and the living organisms transferred to freshly prepared toxicant mixtures. Animals were considered dead if they displayed no movement of appendages in response to touch. In most experiments, living animals were transferred to toxicant-free seawater at the end of 96 h for a post-exposure period of 24 h to observe delayed mortality. At the end of this period, all animals were preserved for measurement of length and verification of identification. Lengths of amphipods were measured from the tip of the rostrum to the end of the telson. Fish lengths were measured from the tip of the snout to the end of the caudal fin.

In most tests of toxicity of oil, oil-Corexit and Corexit, three replicates of a single concentration of SLS were included as a second control. The concentration was chosen to produce a partial mortality of the test species. It was hoped that by comparing the mortality in this control with that in other experiments or with that expected from the results of the SLS bioassays, gross differences in the condition or 'healthiness' of the test animals during different experiments would be detected if present.

Experimental temperatures were maintained by placing bioassay vessels in water baths. Water was cooled using a water chilling unit

(Model D-100, Frigidunits Inc., Toledo, Ohio) and circulated through the tanks with a Model 3E-12NR Little Giant submersible water pump. Water temperatures were continuously monitored in the water baths using recording thermometers (United Electric Co.) with an accuracy of ±0.7°C. Differences between water bath temperatures and bioassay mixture temperatures were checked with hand-held laboratory thermometers having an accuracy of ±0.5°C.

The temperature at which bioassays were conducted was intended to be 4.5°C. Temperature fluctuation attributable to on-off cycling of the cooling unit was approximately ±0.5°C. Further temperature variation occurred when bioassay vessels were added to or removed from the cooling tanks. The range of temperature fluctuation in a single experiment varied from 1.0°C to 2.9°C, except in two experiments. In the two exceptions (experiments 23 and 24), conducted at the beginning of the study when the temperature control system was still being stabilized, temperatures rose to approximately 13°C on two occasions for periods of 2 to 3 hours. Experimental temperatures of individual toxicity bioassays are reported in tables summarizing the bioassay results in Section 3.3 of this report.

The water temperature at a depth of 0.5 m at Site 1 was 3.5°C on 11 August. Grainger (1971) recorded temperatures as high as 5.7°C in surface waters close to the present study area. Surface water immediately adjacent to shore, and particularly in tidal pools, probably reaches temperatures higher than these. All test animals used in this study, except *Anonyx* spp. and *Boeckosimus* sp., were collected from either nearshore surface waters or from intertidal pools. Therefore, the temperatures at which bioassays were conducted are within the range of temperatures normally encountered by these species in their natural environment. *Anonyx nugax, A. laticoxae* and *Boeckosimus* sp. were collected only from depths of about 10 m. Temperatures at these depths would not be expected to be as high or as variable as those in the intertidal region. In stations close to the present study area, Grainger (1971) recorded a maximum temperature of 1.2°C at a depth of 10 m, during the summer months. Bioassays using these animals were probably conducted at temperatures above those which they would normally encounter.

Test mixtures were not aerated during the bioassays and dissolved oxygen concentration was checked periodically using a HACH oxygen kit (accuracy of ±1 ppm). In all experiments, dissolved oxygen levels remained above 4.0 ppm, the minimum level recommended by LaRoche *et al.* (1970) for oil-dispersant bioassays. In some cases, oxygen concentration increased during the 24 h exposure periods. Only in bioassays using *Anonyx* spp. did dissolved oxygen levels decrease significantly during the 24 h period.

2.8 Calculation of 96 h LC50 Values

In determining median lethal concentrations, mortality data from all replicates at each concentration were combined and averaged.

Corrections for mortality in control vessels were made using Abbot's formula (A.P.H.A. 1976). Exposure concentrations in oil-water and oil-Corexit-water mixtures were calculated as the average of the mean 0 h and mean 24 h oil concentration determinations for each experiment.

For comparative purposes, estimates of 96 h LC50 values were calculated by three methods when possible: a computerized probit analysis (Davies 1971), a graphical probit analysis (Litchfield and Wilcoxon 1949), and a 10% trimmed Spearman-Karber calculational method (Hamilton *et al.* 1977). In most experiments one or more of the three methods could not be used because of methodological limitations of the various analysis techniques. Only in one instance did the 96 h LC50 estimated by graphical probit analysis differ from the estimate obtained using computerized probit analysis by more than 10%. This occurred in experiment 42, in which the toxicity of SLS to young-of-the-year sculpins was tested. In this instance, the 96 h LC50 values were low (8.5 and 4.8 ppm using computerized probit analysis and graphical probit analysis, respectively) and the highest mortality observed was 30.3%. This required that the 96 h LC50 be estimated by extrapolation. In thirteen other comparisons of 96 h LC50 estimates obtained by computerized and graphical probit analyses, percent differences ranged from 0.4 to 9.7%. Seven 96 h LC50 values were estimated using both the computerized probit analysis and the 10% trimmed Spearman-Karber method. In these comparisons, the percent differences between LC50 estimates ranged from 0.0 to 5.9%.

Because the 96 h LC50 estimates obtained by all three methods were similar and because more estimates could be calculated using the computerized probit analysis, all estimates of 96 h LC50 values and their 95% confidence limits reported herein are those determined by the computerized probit analysis unless otherwise indicated. In some instances, 96 h LC50 values could not be calculated by the computerized probit analysis but could be estimated by one of the other two methods. In other cases, too few partial mortalities occurred to use any of the above methods. In these cases, whenever possible, estimates of the median mortality were interpolated from a graph of percent mortality and oil concentration on semi-log paper. However, this method does not allow the calculation of confidence limits.

Some bioassays were inadvertently conducted with mixtures of two species (i.e. *Anonyx nugax* and *Anonyx laticoxae; Gammarus setosus* and *Gammarus oceanicus*). In analyzing results from these tests, percent mortalities and median lethal concentrations were calculated separately for each species. As a result, numbers of test organisms for each species were sometimes small, and the statistical reliability of the results questionable. However, since consistent patterns of relative species sensitivity were observed in these results, it was felt worthwhile to include them.

3 RESULTS AND DISCUSSION

3.1 Test Species

Toxicity bioassays were conducted using six species of benthic or intertidal amphipods and one species of fish as test organisms.

3.1.1 *Anonyx laticoxae*

Anonyx laticoxae was caught with *Anonyx nugax* in baited minnow traps set at depths of approximately 10 m. During the bioassays, it was not recognized as being a separate species and therefore occurred as a 'contaminant' in the toxicity tests with *A. nugax*. Separate data analyses were conducted using *A. laticoxae*, but the numbers of animals were too small to yield reliable results from individual bioassays.

Body lengths of *Anonyx laticoxae* used in these experiments ranged from 21 to 35 mm with 89% falling between 26 and 35 mm (Figure 4). Very little is known about the life history of this amphipod. Steele and Brunel (1968) state that this species apparently matures when greater than 30 mm in length and D. Thomson (LGL Ltd., pers. comm.) found a brooding female, 32 mm in length, near Cape Warrender, Devon Island. No ovigerous or brooding females were found in the present collection although several exceeded 32 mm in length.

There do not appear to be any published reports identifying *Anonyx laticoxae* as a food item for other marine organisms in eastern arctic waters. However, some food organisms identified as *A. nugax* before the genus revision of Steele and Brunel (1968) could have been *A. laticoxae* (see below).

3.1.2 *Anonyx nugax*

Large numbers of *Anonyx nugax* were caught throughout the study period using baited minnow traps set in about 10 m of water at Sites 2, 3 and 4. Test animals appeared to include individuals of two size classes: 15 to 34 mm and 36 to 45 mm (Figure 5). The wide size range of animals collected over a relatively short period (15 August to 20 September) is thought to be indicative of a lengthy breeding period (Steele 1961). This is corroborated by reports of ovigerous females (40 to 41 mm long) taken near Resolute, Cornwallis Island, in December (Foy 1978), mature males taken from Barrow Strait in May (D. Thomson, LGL Ltd., pers. comm.) and brooding females captured in Brentford Bay, Boothia Peninsula, in August (LGL Ltd., unpubl. data). *Anonyx nugax* is generally regarded as a benthic scavenger. However, it has been collected in the plankton (Green and Steele 1975) and on the undersurface of ice (Thomson *et al.* 1975), and has been reported to consume diatoms (Thomson *et al.* 1975).

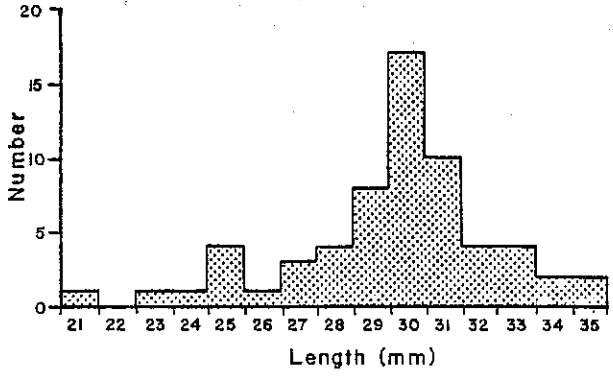

FIGURE 4. Length Frequency of *Anonyx laticoxae* Used in 96 h Bioassays.

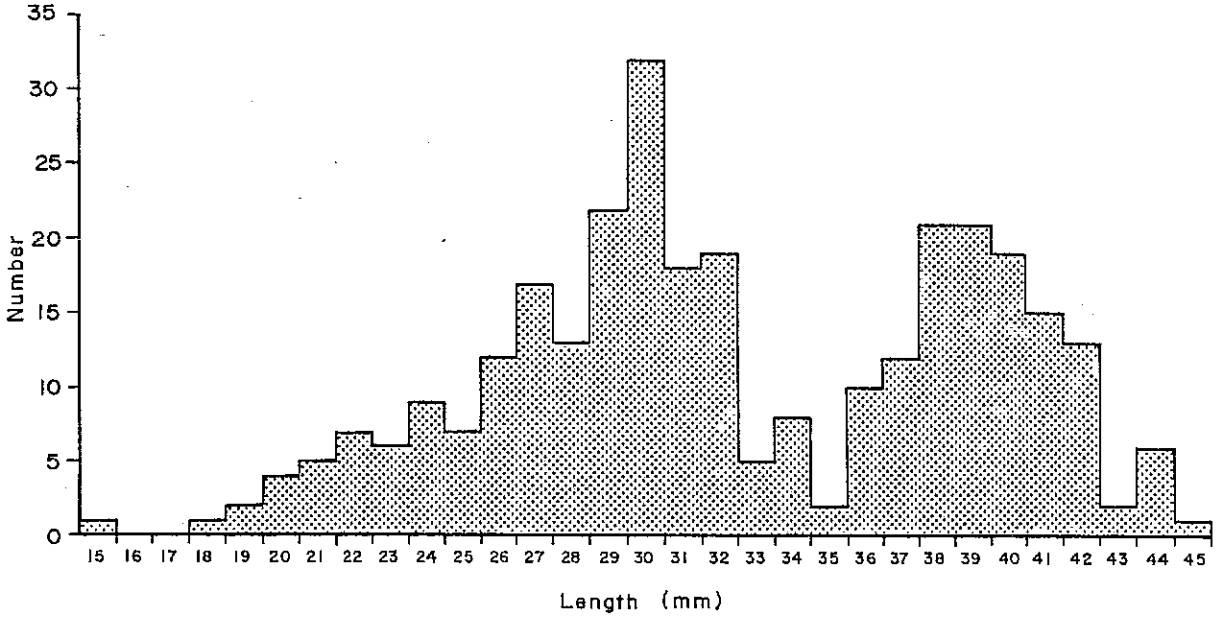

FIGURE 5. Length Frequency of *Anonyx nugax* Used in 96 h Bioassays.

Anonyx nugax has been recorded, generally in small numbers, from stomachs of eider ducks, cod, bearded seals (Dunbar 1954), ringed seals (McLaren 1958) and arctic char (Grainger 1953). However, these reports preceded the genus revision of Steele and Brunel (1968) and it is possible that some amphipods identified as *A. nugax* were actually other, less common, species known to occur in arctic waters. There are some more recent reports of *A. nugax* being utilized as food. Bain and Sekerak (1978) found small numbers of this species in the stomach contents of arctic cod, and Sekerak *et al.* (1976) found that fourhorn and arctic sculpins had consumed small numbers of *A. nugax*.

3.1.3 *Boeckosimus* sp.

On the basis of the shape of the telson, the lateral head lobes and epimeron 3, and on the basis of the current distribution records, these specimens most clearly resembled *Boeckosimus affinis* (Hansen). However, they also resembled *Boeckosimus derjugini* (Gurjanova) and *Boeckosimus dubius* (Schellenberg) in some characteristics. Until the taxonomic problems of this group of lysianassids are solved, it is impossible to assign a specific name to this organism (D. Laubitz, Canadian Aquatic Identification Centre, pers. comm.).

Individuals of this species ranged in length from 9 to 24 mm (Figure 6). A few mature brooding females were found in the 22 to 24 mm size range. This species appeared to favour the same habitat as *Anonyx* spp. and was collected only in traps set at about 10 m depth.

3.1.4 *Gammarus oceanicus*

Gammarus oceanicus is a euryhaline intertidal amphipod which is confined to the Atlantic Ocean and adjacent seas. It is the most numerous *Gammarus* species from Newfoundland south but is less abundant than *G. setosus* in the northern region of its range (Steele and Steele 1972). In this study, *G. oceanicus* was collected, along with *G. setosus*, in the intertidal region from under small rocks and algae.

Like *Anonyx laticoxae*, this species appeared as a 'contaminant' species; it was found upon positive identification of the test organisms used in the toxicity tests on *Gammarus setosus*. Interestingly, it only appeared in the early stages of the study. Although separate analyses of the data on *G. oceanicus* have been performed, it is emphasized that the number of organisms was small and that the reliability of the results is therefore questionable.

Individuals of *G. oceanicus* varied from 21 to 37 mm in length (Figure 7). Steele and Steele (1972) speculate that in its northern range, *G. oceanicus* may take 4 years to reach lengths of 30 mm for females and 35 mm for males.

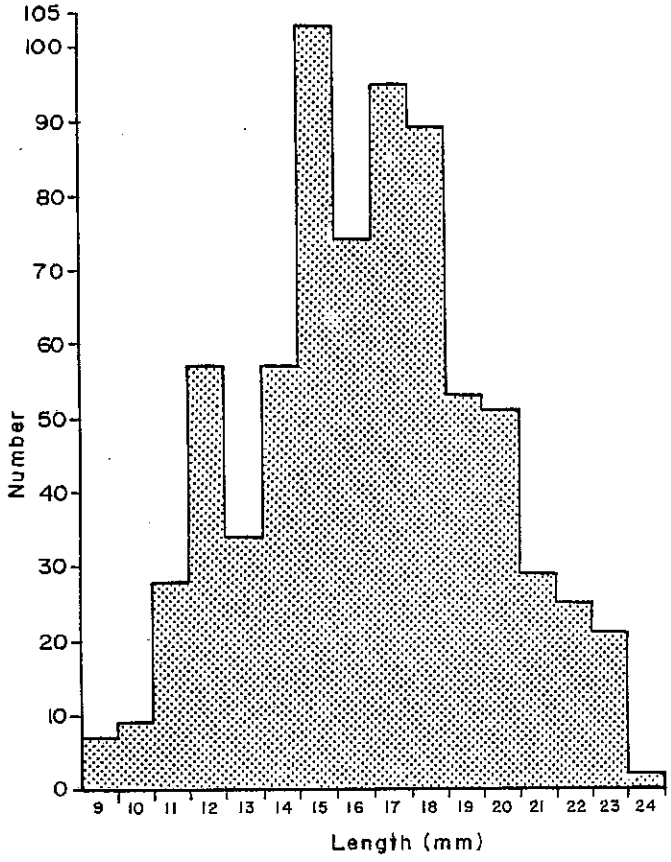

FIGURE 6. Length Frequency of *Boeckosimus* sp. Used in 96 h Bioassays.

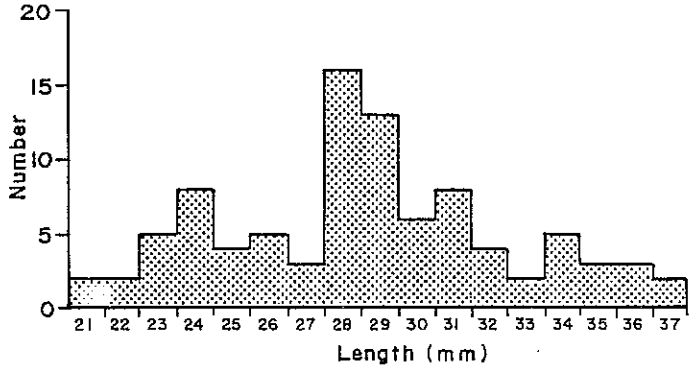

FIGURE 7. Length Frequency of *Gammarus oceanicus* Used in 96 h Bioassays.

Because the habitat of *Gammarus oceanicus* is similar to that of *G. setosus*, it is probably utilized as food by inshore feeding birds, fish and mammals, as is *G. setosus*. McLaren (1958) found this species in the stomach of one ringed seal taken off southwest Baffin Island and recorded unidentified gammarids in stomachs of ringed seals from Ungava Bay and Northern Labrador. Grainger (1953) reported relatively large numbers of *Gammarus* sp. in the stomach contents of arctic char taken in Frobisher Bay. It is possible that some of these unidentified gammarids were *G. oceanicus*. However, it is expected that *G. setosus*, because of its greater numbers, is a more important food item in these regions.

3.1.5 *Gammarus setosus*

The amphipod *Gammarus setosus* has a circumpolar distribution and is the most common species of *Gammarus* from Labrador north (Steele and Steele 1974). It is found primarily in intertidal and shallow water regions (Ellis and Wilce 1961; Steele and Steele 1970).

Body lengths of *G. setosus* used in the toxicity bioassays varied from 16 to 40 mm (Figure 8). Steele and Steele (1970) reported that at 3°C, in the laboratory, *G. setosus* reached maturity at mean body lengths of 14 mm for males and 12 mm for females. It is likely that the individuals used in this study were adults, some of which would breed in the fall and winter.

Gammarus setosus is an important food item for many species of vertebrates. Fish which have been found to consume this amphipod include arctic cod (Bain and Sekerak 1978), arctic char (Sekerak *et al.* 1976), arctic cisco (Craig and Griffiths 1978) and several species of sculpins (Sekerak *et al.* 1976). *Gammarus setosus* is also consumed by several bird species, including the Oldsquaw (Alliston *et al.* 1976; Johnson 1978), Red Phalarope (Alliston *et al.* 1976), Northern Fulmar, Thick-billed Murre and Black Guillemot (Bradstreet 1976, 1977). Ringed seals have also been known to consume this species (McLaren 1958).

3.1.6 *Onisimus litoralis*

Onisimus litoralis is a common arctic littoral and intertidal amphipod, generally restricted to nearshore shallow waters 30 m or less in depth (Stephensen 1935; Dunbar 1954; MacGinitie 1955; Sekerak *et al.* 1976). It has generally been regarded as a scavenger (Steele 1961) but has been observed to feed on ice algae (Foy 1978).

Foy (1978) reported catching *O. litoralis* in baited traps. In the present study, this species did not seem to be attracted to such traps and was therefore collected from tidal pools. Frequently, individuals were buried in the sand, as has been noted by Steele (1961), and would sometimes move from the sand into the open after small pieces of raw fish or seal were placed in the pools.

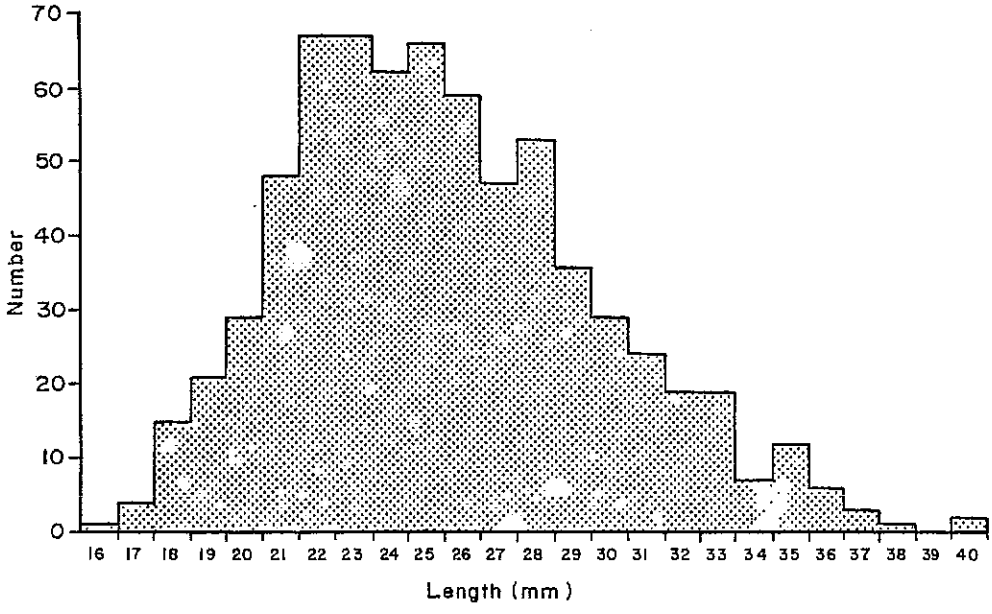

FIGURE 8. Length Frequency of *Gammarus setosus* Used in 96 h Bioassays.

Body lengths of individuals used in the toxicity tests fell into two distinct size classes; 6 to 9 mm and 13 to 19 mm (Figure 9). Based on life history information on this species compiled by Foy (1978) and Steele (1961), the smaller animals were immature young that had been spawned in the winter or spring. The larger individuals would likely mate in the coming autumn or early spring. The smaller animals are referred to as juveniles, the larger ones as adults.

Like *Gammarus setosus*, *Onisimus litoralis* appears to be an important food item for several species of vertebrates. It has been found to be a major food item of arctic char (Grainger 1953, Sekerak *et al.* 1976), arctic cod (Bain and Sekerak 1978), arctic cisco (Craig and Griffiths 1978) and several species of sculpins (Sekerak *et al.* 1976). Alliston *et al.* (1976) found that in Creswell Bay, Somerset Island, several species of shorebirds fed on this amphipod. It has also been found to be a food item of the Thick-billed Murre, Black Guillemot, Northern Fulmar and Black-legged Kittiwake (Bradstreet 1976, 1977). Johnson (1978) found it to be an important food item of the Oldsquaw. The ringed seal also has been found to consume this amphipod species (McLaren 1958).

3.1.7 *Myoxocephalus quadricornis*

The sculpin *Myoxocephalus quadricornis* is considered to have two forms, one marine and the other freshwater (Scott and Crossman 1973). The marine form is called the fourhorn sculpin (*M. quadricornis quadricornis*) and the freshwater form is called the deepwater sculpin (*M. quadricornis thompsonii*). It is the marine form that has been used as a test organism in this study.

The fourhorn sculpin has a circumpolar distribution, commonly inhabiting cold brackish coastal waters (Kendel *et al.* 1975; Percy 1975). Adults are generally bottom feeders while fry may be pelagic as well as bottom feeders (Kendel *et al.* 1975).

Total lengths of *M. quadricornis* used in the toxicity bioassays varied from 14 to 23 mm (Figure 10). Fish of this size class would be young-of-the-year that had probably been spawned during late winter or early spring (Khan and Faber 1974; Kendel *et al.* 1975).

Kendel *et al.* (1975) found that fry of 12 to 20 mm in length, taken off the Yukon coast in late July, had not commenced feeding. Since individuals used in the toxicity tests reported here were only slightly longer, it is reasonable to assume that they had not, or had only recently, started to feed. Fish used in the present study may have been at a stage of greatest sensitivity to pollutants. Rice *et al.* (1975) found that alevins of pink salmon were most sensitive to crude oil at completion of yolk absorption. In studies on the effects of dispersants, larvae of several marine fish reached their greatest sensitivity at, and immediately subsequent to, their first feeding (Wilson 1977). Sensitivity declined once successful feeding had been established.

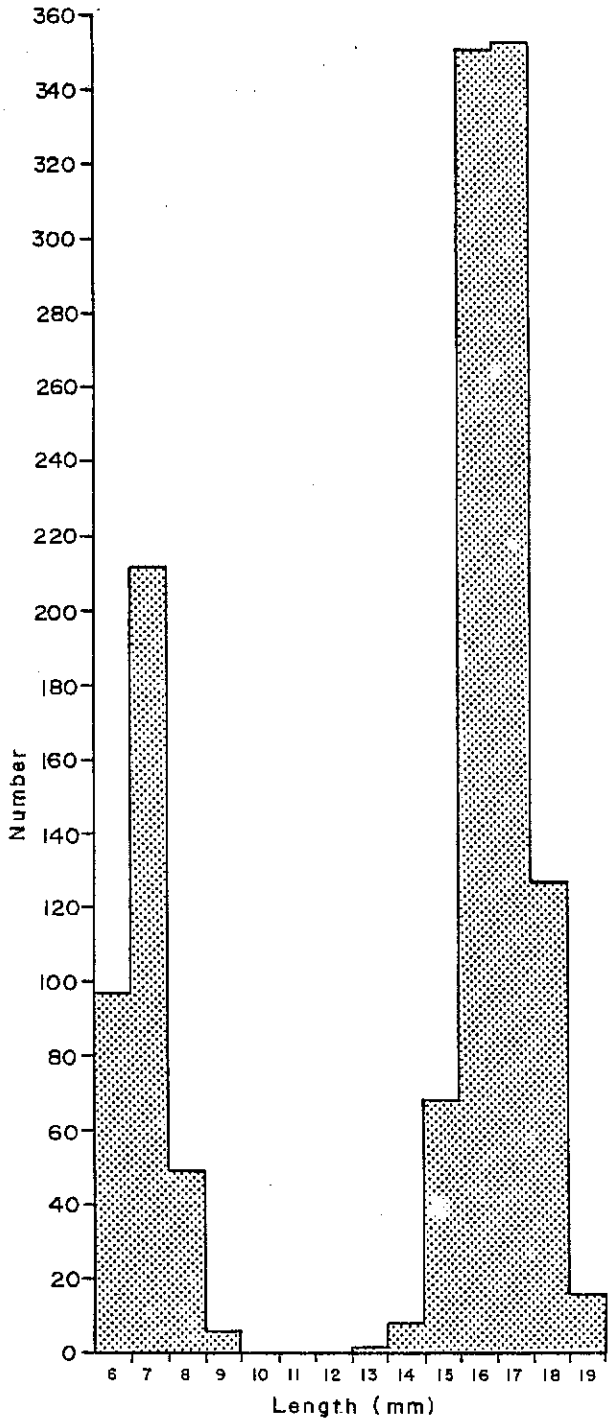

FIGURE 9. Length Frequency of *Onisimus litoralis* Used in 96 h Bioassays.

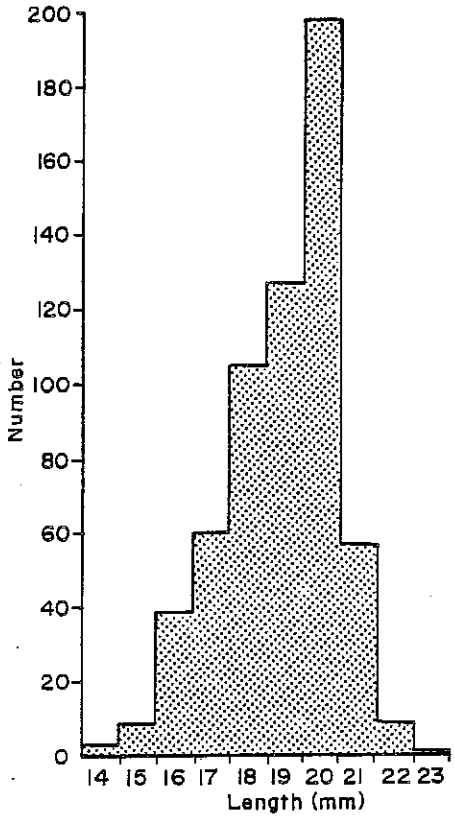

FIGURE 10. Length Frequency of *Myoxocephalus quadricornis* Used in 96 h Bioassays.

At some times, fourhorn sculpins may be important as food for other vertebrate species. Griffiths *et al.* (1975) found that this species was an important food item of arctic char in Nunaluk Lagoon, Yukon Territory. Kendel *et al.* (1975) describe it as being an important forage food for other species of fish along the Yukon coast. In the central and eastern arctic regions of Canada, unidentified sculpins have been reported, generally in small numbers, in the stomach contents of the Black-legged Kittiwake, Thick-billed Murre and Black Guillemot (Bradstreet 1977), arctic char (Grainger 1953), arctic cod (Bain and Sekerak 1978) and ringed seal (McLaren 1958).

3.2 Bioassays

The raw data from all bioassays are presented in Tables 13 to 48, Appendix A. It is emphasized that total numbers of some test species (i.e. *Anonyx laticoxae* and *Gammarus oceanicus*) used in the bioassays were extremely small and that the 96 h LC50 values given for these species can only be considered gross estimates.

3.2.1 Sodium Lauryl Sulphate

The use of a reference toxicant has been recommended as a basis for comparing results of different investigations and for checking the relative 'healthiness' of test organisms (Tarzwell 1969; LaRoche *et al.* 1970; Wilson *et al.* 1973). Sodium lauryl sulphate (dodecyl sodium sulphate), a synthetic anionic detergent of the linear alkylate sulphonate type (Tatem *et al.* 1976), has been suggested for use as a reference toxicant in oil and oil-dispersant toxicity bioassays (Tarzwell 1969; LaRoche *et al.* 1970).

Results of the 96 h bioassays with sodium lauryl sulphate (SLS) are shown in Table 5. The fourhorn sculpin, *Myoxocephalus quadricornis*, was more sensitive to SLS than were the amphipod species tested. From the results of two bioassays, it appeared that the 96 h LC50 of SLS for *M. quadricornis* was between 3 and 9 ppm. However, SLS concentrations of 4 and 5 ppm used as controls in other experiments caused 100% mortality (Tables 39 and 48, Appendix A). For the most sensitive amphipod tested, *Anonyx nugax*, the 96 h median lethal concentration of SLS was between 15 and 25 ppm. Juvenile *Onisimus litoralis* appeared to be slightly more sensitive to SLS than the adults (96 h LC50 values of 22 and 28 ppm, respectively). In two separate bioassays (experiments 21 and 34), *Gammarus setosus* exhibited different sensitivities to SLS, with calculated 96 h LC50 estimates of 89 and 42 ppm. It is possible that in experiment 34 the relatively long acclimation period of 120 h contributed to a greater sensitivity and thus a lower 96 h LC50. Of the species tested, *Boeckosimus* sp. and *Gammarus setosus* appeared to be most resistant to SLS.

The acute response of *Myoxocephalus quadricornis* to SLS was similar to that which has been reported for fish species from other latitudes.

TABLE 5.
Median Lethal Concentrations (96 h LC50) of Sodium Lauryl Sulphate for Test Species, and Conditions Under Which They Were Determined. Unless otherwise indicated, 96 h LC50 values were calculated using a computerized probit analysis (Davies 1971). Values within round brackets after the 96 h LC50 are 95% confidence limits.

Species	Exp.#	N	96 h LC50 (ppm)	Animal Length (mm)			Temperature Range (°C)	A.P. (h)
				Mean	s.d.	Range		
Amphipods								
Anonyx laticoxae	26	19	41[35-45][1]	28.0	3.1	21-34	4.1-7.0	70
Anonyx nugax	26	38	16[15-25][1]	32.6	5.7	22-44	4.1-7.0	70
Boeckosimus sp.	50	30	>50	17.4	2.7	12-23	4.5-5.5	196
Gammarus oceanicus	21	19	30[25-35][1]	29.4	3.8	23-36	3.0-5.0	16
Gammarus setosus	21	40	89(42-186)[2]	26.2	2.9	20-33	3.0-5.0	16
	34	83	42(39-46)	22.7	3.5	16-33	4.5-6.5	120
Onisimus litoralis (adult)	25	120	28(26-30)	16.8	1.0	13-19	3.9-6.0	52
	29	120	28(26-29)	16.6	0.9	15-19	3.8-5.3	44
Onisimus litoralis (juvenile)	33	134	22(19-26)	6.9	0.7	6-9	4.0-5.5	32
Fish								
Myoxocephalus quadricornis	39	72	<5	17.1	1.3	14-20	4.5-5.5	36
	42	60	5(3-9)[2]	19.6	1.1	17-22	3.5-5.7	24

Abbreviations: N=number of animals; s.d.=standard deviation; A.P.=acclimation period.

[1]Interpolated from data plotted on semi-log paper; figures in square brackets give the range of concentrations within which 50% mortality would occur.

[2]Estimate from graphical probit analysis (Litchfield and Wilcoxon 1949).

Doe and Harris (1976) reported 96 h LC50 values of SLS for *Salmo gairdneri* fingerlings of 3.2 to 5.0 mg/l. For this same species and toxicant, Fogels and Sprague (1977) calculated a 96 h LC50 of 4.6 mg/l. LaRoche *et al.* (1970) found the 96 h LC50 of SLS for the estuarine fish *Fundulus heteroclitus* to be between 4.5 and 5.6 mg/l. Wells and Doe (1976) reported a 96 h LC50 of 6.2 mg/l for the same species. *Menidia beryllina, Fundulus similus* and *Cyprinodon variegatus* exhibit similar sensitivities to this chemical; reported 96 h LC50 determinations are 3, 5 and 10 ppm, respectively (Anderson 1975). Fogels and Sprague (1977) reported the 96 h LC50 levels of SLS to be 8.0 and 8.1 mg/l for zebrafish (*Brachydanio rerio*) and flagfish (*Jordanella floridae*), respectively. In the list given by Abel (1974), determinations of the 96 h median lethal concentrations of linear alkylate sulphonate detergents for seven species of fish vary from 0.6 to 6.4 mg/l.

There is little information on the effects of SLS on marine amphipods. Foy (1978) reported 96 h LC50 levels of SLS for *Onisimus litoralis, Boeckosimus edwardsi* and *Anonyx nugax* of 4 to 40 ppm, greater than 40 ppm, and 24 ppm, respectively. These are very similar to values of the 96 h LC50 of SLS determined for amphipods in the present study.

Sensitivities of other aquatic invertebrates to SLS vary considerably. Tatem *et al.* (1976) reported 96 h TLm[1] values for the grass shrimp, *Palaemonetes pugio,* of 69 to 162 ppm. For the sandworm, *Nereis virens,* LaRoche *et al.* (1970) reported a 96 h median lethal concentration of 13.5 ppm. Wells and Sprague (1976) found that first stage larvae of the American lobster (*Homarus americanus*) were comparatively sensitive to SLS (96 h LC50 of 0.72 ppm), whereas Wells and Doe (1976) found that fourth stage larvae were much less sensitive (96 h LC50 of 18.7 ppm). Tatem *et al.* (1976) cited Zillioux *et al.* (1973) as finding a 48 h TLm of 3.4 ppm SLS for the brine shrimp, *Artemia* sp., and Anderson (1975) reported a 24 h TLm of 2 ppm SLS for the opossum shrimp, *Mysidopsis almyra.*

Because of time and space limitations, it was not possible to perform a complete SLS bioassay with each Corexit, oil, or oil and Corexit bioassay. Therefore, SLS bioassays were carried out separately on each species, and three replicates of a single concentration of SLS were used concurrently with most bioassays of other toxicants. Expected mortality for the single concentration was estimated from the SLS bioassay results for each species and compared to the mortality observed in each test with a single concentration. Results are shown in Table 6.

Because *Anonyx laticoxae* and *Gammarus oceanicus* were found as 'contaminant' species, the concentrations of SLS used as controls in oil, Corexit and oil-Corexit bioassays were those chosen for *A. nugax* and *G. setosus,* respectively. Therefore, *A. laticoxae*, on the basis of SLS

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[1] TLm = median tolerance limit and has the same numerical value as LC50.

TABLE 6.
Differences between Expected and Observed Mortality in Sodium Lauryl Sulphate Controls.

SLS Concentration for each Species	Exp.#	N	Expected Mortality[1] (%)	Observed Mortality[2] (%)	Difference
Amphipods					
Anonyx laticoxae					
25 ppm	51	3	0	0	0
25 ppm	40	3	0	0	0
Anonyx nugax					
25 ppm	51	12	100	67	-33
25 ppm	40	12	100	100	0
25 ppm	48	15	100	49	-51
Boeckosimus sp.					
50 ppm	46	30	3	3	0
50 ppm	45	30	3	3	0
Gammarus oceanicus					
35 ppm	23	5	100	60	-40
35 ppm	22	4	100	100	0
35 ppm	24	3	100	22	-78
Gammarus setosus					
35 ppm	23	16	22	42	+20
35 ppm	31	15	22	40	+18
35 ppm	22	11	22	27	+ 5
35 ppm	24	12	22	48	+26
35 ppm	35	21	22	14	- 8
Onisimus litoralis (adult)					
35 ppm	27	30	88	90	+ 2
25 ppm	32	30	29	63	+34
25 ppm	30	30	29	40	+11
Onisimus litoralis (juvenile)					
25 ppm	36	21	59	80	+21
Fish					
Myoxocephalus quadricornis					
5 ppm	38	18	100	100	0
1 ppm	43	15	0	0	0
1 ppm	44	15	0	0	0
4 ppm	55	18	100	100	0

Abbreviations: N = number of animals.

[1] Expected mortality calculated from equation of probit line, when possible. Otherwise, expected mortality was that observed for the same concentration in the SLS bioassay.

[2] Observed mortality calculated from combined replicate data, including adjustment for mortality in seawater controls.

bioassay results, was not expected to exhibit any mortality in 25 ppm SLS and, indeed, did not. *Gammarus oceanicus*, on the basis of SLS bioassay results, was expected to exhibit 100% mortality in control SLS concentrations of 35 ppm. Observed mortality, however, was up to 78% less than expected. It is not possible to determine whether these differences between observed and expected mortality reflected differences in condition of test animals, because the number of animals used in the control SLS mixtures was small, and the death of a single animal, therefore, made a large difference in percent mortality.

Gammarus setosus and *Onisimus litoralis* appeared to be of relatively uniform condition in different experiments. In the SLS controls of all toxicity tests with these organisms, the maximum difference in mortality was 34% of that which was expected on the basis of the SLS bioassays. The condition of *Boeckosimus* sp. appeared to be even less variable; this species demonstrated 3% mortality in 50 ppm SLS in three experiments, including the SLS bioassay.

The SLS concentrations used as controls in bioassays using *Myoxocephalus quadricornis* were all either above or below the range of concentrations which produced partial effects. Therefore, the difference of 0% between observed and expected effects does not indicate a uniform sensitivity of the test animals in these cases.

Recently, there has been some question as to the suitability of sodium lauryl sulphate as a reference toxicant. Fogels and Sprague (1977) cite Pessah *et al.* (1975) as reporting that SLS in solution decreased in toxicity with time and that SLS bioassays failed to detect differences in sensitivity between healthy and diseased fish. Five-year-old SLS, stored as a powder, has been reported to be approximately one-third as toxic as 1-year-old SLS to zebrafish, flagfish and rainbow trout (Fogels and Sprague 1977). In solution, SLS may not have a homogeneous distribution; detergents tend to concentrate at the sides of vessels, at the air-water interface, and perhaps on the surfaces of test organisms (Abel 1974). In the present study, the formation of a precipitate was noted in SLS concentrations of 50 ppm and higher. Such precipitate formation has also been reported by Rice *et al.* (1977) and Foy (1978). When precipitate formation occurs, the concentration of SLS is not known with certainty. It is evident from the foregoing that the actual concentrations of SLS to which test animals are exposed in a bioassay will be somewhat uncertain and variable.

3.2.2 Corexit 9527

Results of bioassays conducted to determine the acute effects of Corext 9527 on the test species are summarized in Table 7. The one fish species tested, *Myoxocephalus quadricornis*, was far more sensitive

TABLE 7.
Median Lethal Concentrations (96 h LC50) of Corexit 9527 for Test Species and Conditions Under Which They Were Determined. Unless otherwise indicated, 96 h LC50 values were calculated using a computerized probit analysis (Davies 1971). Values within round brackets after the 96 h LC50 are 95% confidence limits.

Species	Exp.#	N	96 h LC50 (ppm)	SLS Control		Animal Length(mm)			Temperature Range (°C)	A.P. (h)
				Conc.(ppm)	%D	Mean	s.d.	Range		
Amphipods										
Anonyx laticoxae	40	13	>140	25	0.0	30.1	2.0	25-34	4.0-5.5	18
Anonyx nugax	40	47	104(97-111)	25	100.0	35.1	5.2	25-44	4.0-5.5	18
Boeckosimus sp.	53	96	>175	-	-	13.9	3.2	9-23	4.4-5.5	120
Gammarus oceanicus	22	15	>80	35	100.0	29.8	3.2	22-36	3.0-5.2	16
Gammarus setosus	22	44	175(38-803)	35	27.3	26.9	3.8	20-35	3.0-5.2	16
Onisimus litoralis (adult)	32	119	115[80-160][1]	25	63.3	16.6	0.9	14-19	3.8-6.3	36
Fish										
Myoxocephalus quadricornis	44	60	<40	1.0	0.0	19.8	1.0	17-22	3.5-5.7	16

Abbreviations: N = number of animals; Conc. = concentration; %D = percent mortality; s.d. = standard deviation; A.P. = acclimation period.

[1] Interpolated from data plotted on semi-log paper; figures in square brackets give the range of concentrations within which 50% mortality would occur.

to this dispersant than were the amphipod species tested; the calculated 96 h LC50 was less than 40 ppm (µl/l), or less than 39.8 mg/l based on a density of 0.996 g/cm^3 (ESSO Chemicals 1976). This is a greater sensitivity than that found by Doe and Harris (1976) for *Salmo gairdneri* fingerlings (96 h LC50 of 140 to 233 mg/l) and probably greater than that found for the fresh water zebrafish (*Brachydanio rerio*), for which a 48 h LC50 was calculated as 550 ppm (ESSO Chemicals 1976). Amphipods were more resistant to Corexit 9527. The 96 h LC50 determinations for the species tested were all greater than 80 ppm. *Boeckosimus* sp. exhibited no mortality during 96 h at a concentration of 175 ppm.

Little information on the acute toxicity of Corexit 9527 to marine invertebrates can be found in the literature. Foy (1978) reported 96 h LC50 levels of Corexit for two species of amphipods, *Onisimus litoralis* and *Boeckosimus edwardsi*, as greater than 70 and greater than 80 ppm, respectively. A 48 h LC50 of 6600 ppm of Corexit 9527 was reported by ESSO Chemicals (1976) for the brown shrimp, *Crangon crangon*, but it is not clear whether this was calculated as ppm of Corexit 9527 concentrate or as ppm of a diluted formulation.

3.2.3 Prudhoe Bay Crude Oil

Analysis by gas chromatography confirmed the presence of volatile aromatics in the Prudhoe Bay crude oil used in the toxicity bioassays and indicated that the oil had not been 'weathered' significantly prior to use (Figure 11).

3.2.3.a Hydrocarbon Analysis of the Test Mixtures

The relationship between nominal (added) oil concentration and measured exposure oil concentration (average of mean 0 h and mean 24 h concentration determinations for each experiment) in the oil-water and oil-Corexit-water mixtures is illustrated in Figure 12. Measured hydrocarbons in oil-Corexit-water mixtures increased in a linear fashion, as nominal oil concentration increased, throughout the range of nominal oil concentrations used in the toxicity bioassays. In contrast, measured hydrocarbons in the oil-water mixtures increased only slightly with increasing nominal oil concentrations. It is evident that the addition of Corexit to oil-water mixtures substantially increased the concentrations of hydrocarbons in the water column over those in oil-water mixtures that had been dispersed solely by mechanical means. At a nominal oil concentration of 640 ppm, the measured oil concentration in the water column was approximately 7 times greater in oil-Corexit-water mixtures than in oil-water mixtures. This is similar to the factor of approximately 6 times reported by Foy (1978) for the same nominal oil concentration.

One oil-water mixture and one oil-Corexit-water mixture (both with a nominal oil concentration of 200 µl/l) were analyzed by gas chromatography. The results indicate that concentrations of particulate

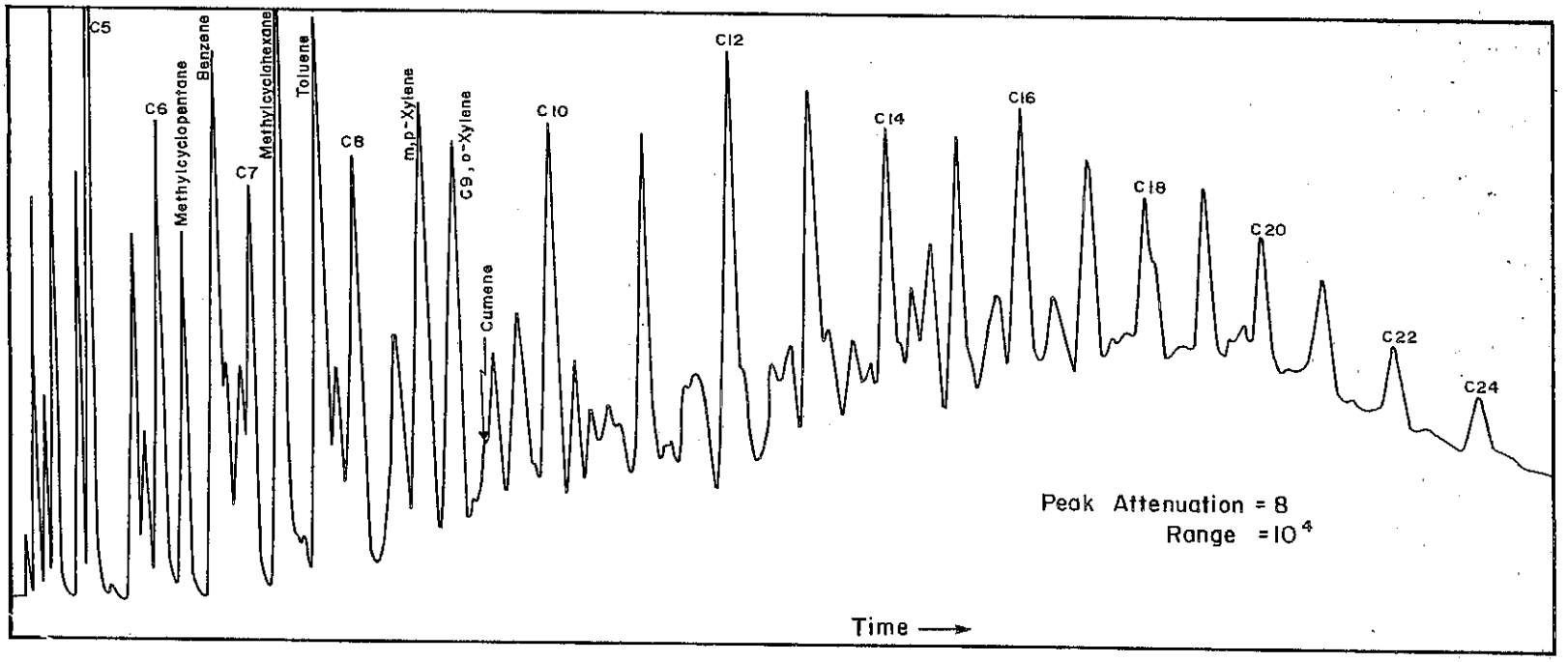
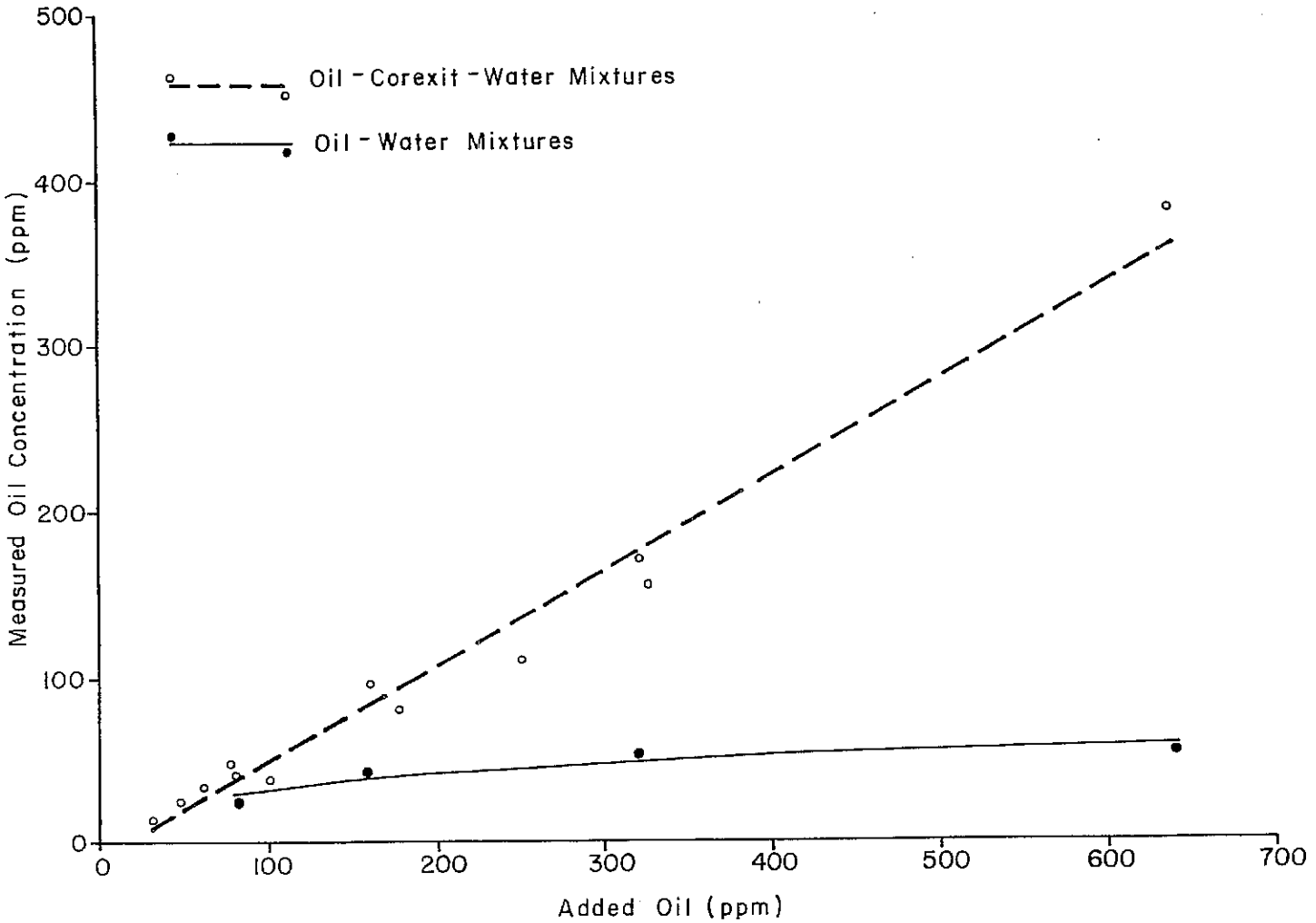


FIGURE 11. Gas Chromatogram of Prudhoe Bay Crude Oil Used in Toxicity Tests.



FIGUR 12. Relationship Between Added Oil Concentration and Measured Oil Concentration (average of mean 0 h and 24 h concentrations) in the Water Column for Prudhoe Bay Crude Oil in Oil-Water and Oil-Corexit-Water Mixtures. Each point represents the average of the means of all 0 h and 24 h oil concentration determinations.

(dispersed) hydrocarbons were much higher in the oil-Corexit-water mixture than in the oil-water mixture (Table 8). Concentrations of 'dissolved' hydrocarbons were also higher in the oil-Corexit-water mixture. However, 'dissolved' hydrocarbons were defined as those hydrocarbons that passed through a filter which had a 5 µm diameter pore size, and dispersed oil droplets can be smaller than 5 µm. Stokes and Harvey (1973) found that the addition of detergents to oil-water mixtures increased the number of oil droplets in the small-diameter size range (as small as 2 to 3 µm). It is thought, therefore, that the apparently higher 'dissolved' hydrocarbon concentration in the oil-Corexit-water mixture was due, at least in part, to particulate oil less than 5 µm in diameter that passed through the filter.

TABLE 8.
Concentration of Gas-Strippable Hydrocarbons (mg/l), as Determined by Gas Chromatography, in Oil-Water and Oil-Corexit-Water Mixtures at 0 h and after 24 h. Nominal oil concentration was 200 µl/l.

Sample	Concentration of 'Dissolved' Hydrocarbons	Concentration of Particulate Hydrocarbons	Total
Oil-Water, 0 h	1.20	4.20	5.40
Oil-Water, 24 h	0.32	2.80	3.10
Oil-Corexit-Water, 0 h	3.50	17.90	21.40
Oil-Corexit-Water, 24 h	0.81	12.30	13.10

The much higher concentration of total hydrocarbons, as measured by gas chromatography, in the oil-Corexit-water mixture than in the oil-water mixture was due primarily to the higher concentration of particulate hydrocarbons in the oil-Corexit-water mixture. Total hydrocarbon concentration was approximately 4 times greater in the oil-Corexit-water mixture than in the oil-water mixture, and approximately 90% of the total hydrocarbons in the oil-Corexit-water mixture were of a particulate nature (Table 8). The ratio of dissolved to particulate hydrocarbons was greater in the oil-water mixture (1:3.5 at 0 h and 1:8.8 at 24 h) than in the oil-Corexit-water mixture (1:5.1 at 0 h and 1:15.2 at 24 h).

Aromatic compounds were the predominant gas-strippable hydrocarbons in both the oil-water and oil-Corexit-water mixtures (Figures 13 and 14) and were found in the following approximate proportions:

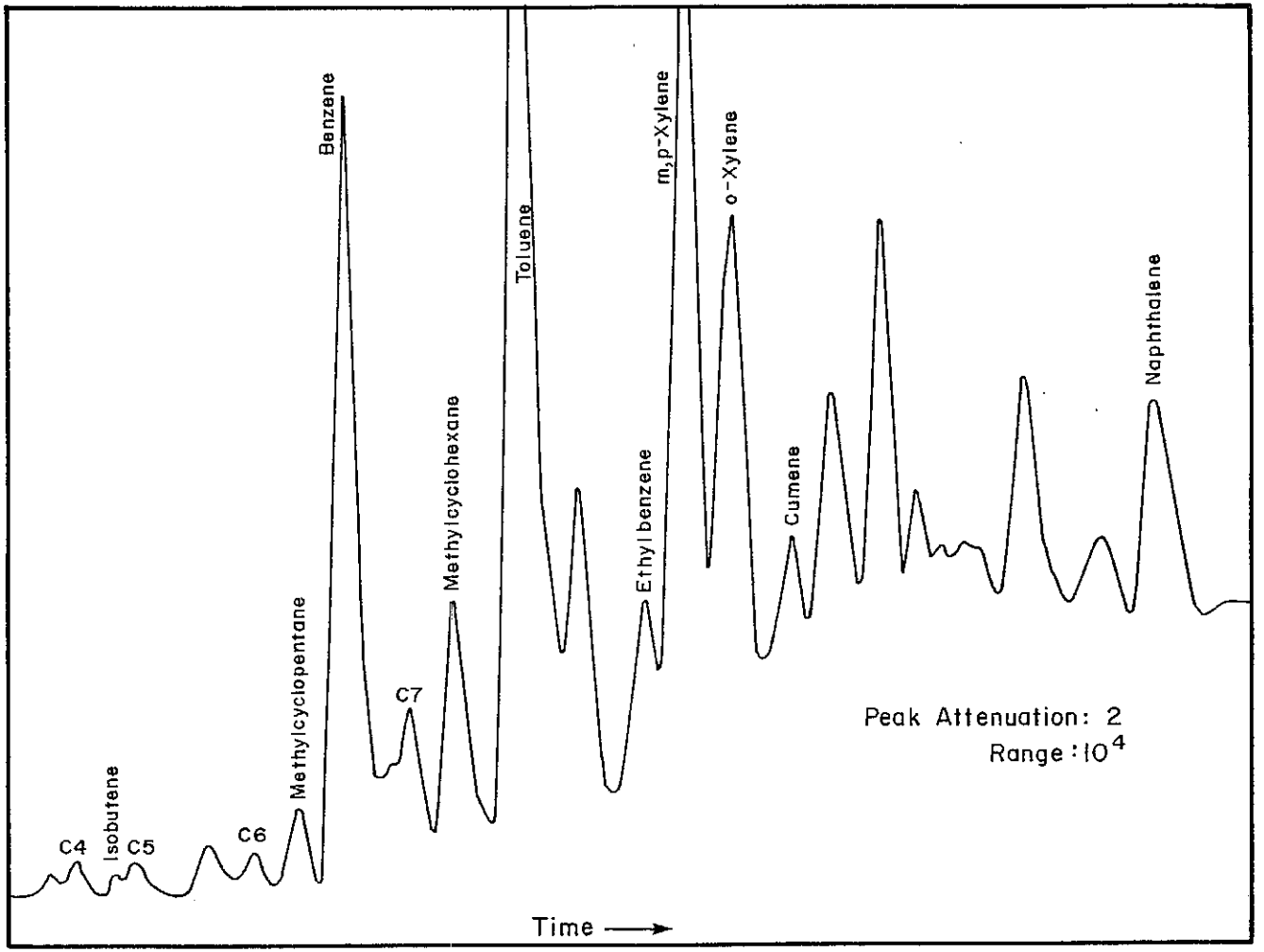


FIGURE 13. Gas Chromatogram of an Unfiltered Sample of a Mixture of Prudhoe Bay Crude Oil and Water. The sample was taken at 0 h.

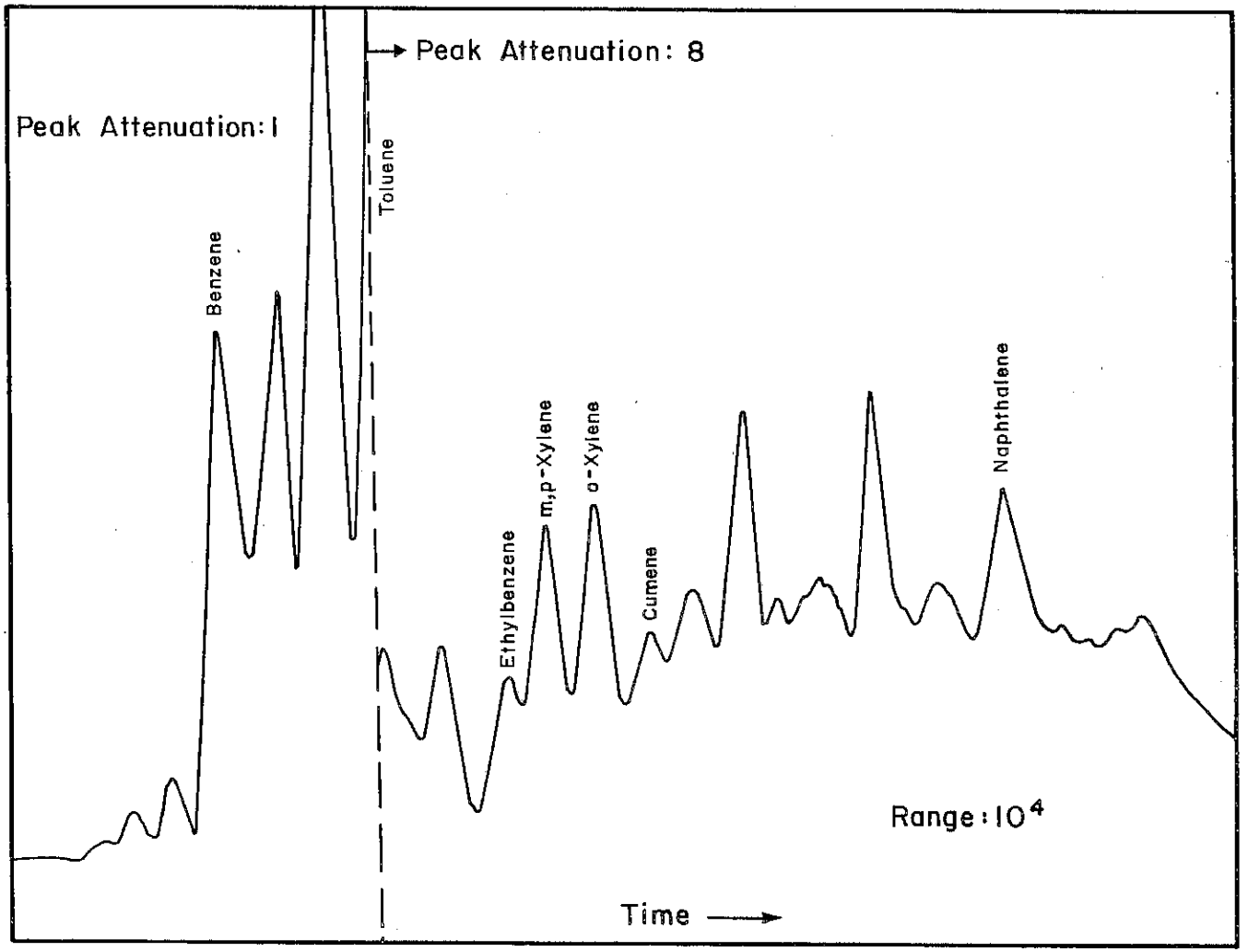


FIGURE 14. Gas Chromatogram of an Unfiltered Sample of a Mixture of Prudhoe Bay Crude Oil, Corexit 9527 and Water. The sample was taken at 0 h.

benzene	4
toluene	4
m- and *p*-xylenes	2
o-xylene	1
naphthalene	1

The oil-Corexit-water mixture contained a higher concentration of alkanes than did the oil-water mixture. These alkanes, because of their low aqueous solubility, would presumably be present in the particulate fraction.

Water soluble aromatics are generally considered to be the compounds that cause toxicity in oil-water mixtures. Their toxicity, in the short-term at least, is greatest when they are dissolved in the aqueous phase, from which they can be readily incorporated by aquatic organisms. Therefore, oil-water emulsions with a high dissolved to particulate hydrocarbon ratio would be expected to be more toxic than emulsions with the same actual measured hydrocarbon concentration but with a lower dissolved to particulate hydrocarbon ratio.

3.2.3.b Median Lethal Concentrations

Results of the bioassays using Prudhoe Bay crude oil in oil-water mixtures are summarized in Table 9. In several cases, the highest hydrocarbon concentrations attained in the water column, in oil-water mixtures, were not high enough to produce mortality. In these instances 96 h LC50 values could not be determined.

Of the species tested, *Anonyx nugax* appeared to be the most sensitive to measured hydrocarbons in oil-water mixtures. The 96 h LC50 was calculated as 32 ppm, with 95% confidence limits of 27-37 ppm. This appears to be similar to the 96 h LC50 of between 32 and 43 ppm reported for this species by Foy (1978). The fourhorn sculpin was the next most sensitive test species; 96 h LC50 levels of measured hydrocarbons were 43 and 42 ppm in two separate bioassays. *Gammarus setosus* and *Onisimus litoralis* juveniles were more resistant, with 96 h LC50 levels of 56 and 68 ppm, respectively. The 96 h LC50 of Prudhoe Bay crude oil (in oil-water mixtures) for *O. litoralis* was reported by Foy (1978) to be 49 ppm. The difference between the 96 h LC50 for *O. litoralis* determined in the present study and that given by Foy (1978) can be accounted for by the fact that measured hydrocarbon concentrations reported by Foy (1978) were not corrected for extraction efficiency.

It was not possible to calculate reliable 96 h LC50 estimates for the remaining test organisms since, generally, mortality was observed in only the highest oil concentrations used.

As discussed by Foy (1978), comparison of these results with

TABLE 9.
Median Lethal Concentrations (96 h LC50) of Prudhoe Bay Crude Oil in Oil-Water Mixtures for Test Species, and Conditions Under Which They Were Determined. Unless otherwise indicated, 96 h LC50 values were calculated using a computerized probit analysis (Davies 1971). Values within round brackets after the 96 h LC50 are 95% confidence limits.

Species	Exp.#	N	96 h LC50 (ppm)	SLS Control		Animal Length(mm)			Temperature Range (°C)	A.P. (h)
				Conc.(ppm)	%D	Mean	s.d.	Range		
Amphipods										
Anonyx laticoxae	51	6	>51	25	0.0	31.3	2.1	28-35	4.5- 6.5	72
Anonyx nugax	51	54	32(27-37)	25	66.7	26.8	4.6	15-40	4.5- 6.5	72
Boeckosimus sp.	46	119	>59	50	3.3	16.4	2.9	11-24	4.2- 5.5	100
Gammarus oceanicus	23	10	>55	35	60.0	28.3	3.0	23-36	5.0-13.0	37
Gammarus setosus	23	47	56(51-62)	35	41.6	29.1	3.6	22-38	5.0-13.0	37
	31	84	>53	35	26.5	23.9	3.3	18-36	3.8- 5.2	24
Onisimus litoralis (adult)	27	108	>47	35	90.0	16.6	0.8	14-19	3.9- 5.5	85
Onisimus litoralis (juvenile)	36	124	68(62-75)[1]	25	80.0	6.9	0.7	6-9	4.2- 5.5	70
Fish										
Myoxocephalus quadricornis	38	72	43(37-49)	5	100.0	18.0	1.3	14-21	4.5- 6.0	72
	43	60	42(39-46)	1	0.0	19.8	1.1	16-23	3.5- 5.7	64

Abbreviations: N = number of animals; Conc. = concentration; %D = percent mortality; s.d. = standard deviation; A.P. = acclimation period.

[1] Estimate from graphical probit analysis (Litchfield and Wilcoxon 1949).

those of other workers is difficult because of varying methods and analytical procedures. Percy and Mullin (1975), using methods and analytical techniques similar to those used in the present study, investigated the effects of crude oils on arctic marine invertebrates. Using their data, Foy (1978) calculated a 96 h LC50 of 32 ppm of Norman Wells crude oil for the amphipod *Boeckosimus affinis*. Linden (1976) found that the 96 h median lethal concentration of a Venezuelan crude oil, in the form of an oil-water mixture, for adult *Gammarus oceanicus* was 550 µl/l (calculated on the basis of nominal oil concentration). This appears to be similar to the 96 h LC50 of Prudhoe Bay crude oil determined in the present study for *Gammarus setosus;* a measured concentration of 56 ppm (Table 9) represents a nominal concentration of approximately 575 ppm (see Figure 12).

Results of bioassays determining the toxic effects of Prudhoe Bay crude oil dispersed in oil-Corexit-water mixtures are summarized in Table 10. Again, *Anonyx nugax* was the most sensitive species tested (96 h LC50 = 45 ppm) and *Myoxocephalus quadricornis* was the next most sensitive (96 h LC50 = 59 ppm). Of the species tested, *Boeckosimus* sp. seemed to be the most resistant to the oil-Corexit-water mixtures; the 96 h LC50 of measured hydrocarbons for this species was 162 ppm.

The 96 h LC50 determinations, when based on hydrocarbon concentrations measured by fluorescence spectroscopy, were lower, for at least three species (*Anonyx nugax, Gammarus setosus,* and *Myoxocephalus quadricornis*), in oil-water mixtures than in oil-Corexit-water mixtures (Tables 9 and 10). Although results for the other species tested are less well defined, they are generally consistent with the conclusion that the toxicity of Prudhoe Bay crude oil hydrocarbons (as measured by fluorescence spectroscopy) is somewhat greater in oil-water mixtures than in oil-Corexit-water mixtures (see Tables 31 to 48, Appendix A). These results confirm the preliminary findings of Foy (1978).

The higher toxicity of hydrocarbons (based on *measured exposure concentration*) in the oil-water mixtures, compared to the oil-Corexit-water mixtures, may have resulted from a higher proportion of water-soluble aromatic compounds in the oil-water mixtures (see p. 32). It is generally thought that the water soluble aromatics in crude oils are the agents causing mortality in oil-water mixtures.

In the present study, mortalities observed in oil-Corexit-water mixtures were higher than those in oil-water mixtures of the same *nominal* oil concentration. Similar results have been obtained in other studies (e.g., Swedmark *et al.* 1973; Linden 1975; Percy and Mullin 1975; Foy 1978). This higher mortality observed in oil-dispersant mixtures is thought to be merely a result of much higher oil concentrations in the water column of chemically dispersed mixtures. The results of some other studies support this interpretation. Trudel (1978) found that Lago Medio crude oil was equally toxic, based on measured concentrations, to natural phytoplankton populations (based on inhibition of carbon-14 uptake) whether chemically dispersed using Corexit 9527, or mechanically dispersed. Vaughan (1973) found that, when based on nominal concentration, South Louisiana

TABLE 10.
Median Lethal Concentrations (96 h LC50) of Prudhoe Bay Crude Oil in Oil-Corexit-Water Mixtures for Test Species and Conditions Under Which They Were Determined. Unless otherwise indicated, 96 h LC50 values were calculated using a computerized probit analysis (Davies 1971). Values within round brackets after the 96 h LC50 are 95% confidence limits.

Species	Exp. #	N	96 h LC50 (ppm)	SLS Control		Animal Length (mm)			Temperature Range (°C)	A.P. (h)
				Conc. (ppm)	%D	Mean	s.d.	Range		
Amphipods										
Anonyx laticoxae	48	5	112[73-169][1]	-	-	30.7	1.8	28-33	4.4-6.5	20
Anonyx nugax	48	55	45(34-61)	25	48.9	35.9	5.3	25-45	4.4-6.5	20
Boeckosimus sp.	45	120	162(135-195)	50	3.3	17.8	2.4	13-23	4.0-5.5	52
Gammarus oceanicus	24	20	105(73-153)[2]	35	33.3	27.9	4.7	21-37	5.0-13.0	41
Gammarus setosus	24	55	138(114-168)	35	48.2	28.3	4.0	21-40	5.0-13.0	41
	35	84	83(70-98)	35	14.3	24.5	4.1	17-37	4.8-6.5	120
Onisimus litoralis (adult)	30	118	138(118-161)	25	40.0	16.5	0.9	14-18	3.7-5.2	72
Fish										
Myoxocephalus quadricornis	55	71	59(40-87)	4.0	100.0	19.6	0.9	16-21	4.4-5.5	96

Abbreviations: N=number of animals; Conc.=concentration; %D=percent mortality; s.d.=standard deviation; A.P.= acclimation period.

[1] Interpolated from data plotted on semi-log paper; figures in square brackets give the range of concentrations within which 50% mortality would occur.

[2] Estimate from 10% trimmed Spearman-Karber analysis (Hamilton *et al.* 1977).

crude oil had a 96 h TLm for shiner perch (*Cymatogaster aggregata*) juveniles of 100 ppm when chemically dispersed and 840 ppm when mechanically dispersed. However, when based on estimated exposure concentrations of oil, chemically and mechanically dispersed oil had 96 h TLm levels of 14 ppm and 15 ppm, respectively. Venezia and Fossato (1977) concluded from a study of the effects of Kuwait crude oil and Corexit 7664 on the harpacticoid copepod *Tisbe bulbisetosa* that 'the reinforcement of the toxic effect of oil plus Corexit is due...to the higher actual hydrocarbon concentration in a suspension resulting from such a mixture'.

3.3 Post-Exposure Period

In many of the bioassays, animals remaining alive after the 96 h exposure period were transferred to fresh seawater for a 24 h observation period. Mortality data recorded during this period are given in Tables 13 to 48, Appendix A, and summarized by combining the replicate data, in Table 11.

The sole purpose of such a post-exposure period was to determine if mortality of animals continued after they were returned to clean water, following the 96 h exposure period. In many cases, mortality exceeding that in seawater controls was observed during the post-exposure period, indicating that irreversible damage had been caused by exposure to the toxicants for 96 h. The absence of mortality during the 24 h post-exposure period does not necessarily indicate that the effects of the toxicant had been mitigated; mortality might have occurred if the animals had been kept for longer than 24 h after exposure to the toxicants.

3.4 Relative Species Sensitivity

It must be emphasized that the sensitivity of an organism to a given toxicant is not constant. Fogels and Sprague (1977) cited Brown (1968) as finding that 48 h LC50 values of various toxicants varied by a factor of 2.5 over a period of 9 months. Tatem *et al.* (1976) found that grass shrimp (*Palaemonetes pugio*), collected at various times of year, varied in their sensitivity to SLS by as much as a factor of 2.3. Sensitivity to a given toxicant may even vary at different times of day (Spieler *et al.* 1977). Fogels and Sprague (1977) state that 'results of short-term bioassays should...be regarded only as estimates, within approximately one order of magnitude, of the acute toxicity of a substance'.

With this variability in mind, the sensitivities, to a particular toxicant, of all species tested in this study were remarkably similar (Table 12). Only the sensitivity of the fourhorn sculpin to the detergent SLS and possibly to Corexit 9527 was markedly different from the reactions of the amphipod species.

TABLE 11.
Percent Mortality (Calculated from Combined Replicate Data) During the Post-Exposure Period after 96 h Exposure to Various Toxicant Concentrations for Each Species-Toxicant Combination. Each block of numbers represents results of one experiment.

Species	Toxicants											
	Sodium Lauryl Sulphate			Corexit 9527			Prudhoe Bay Crude Oil			Prudhoe Bay Crude Oil and Corexit		
	Conc. (ppm)	N	%D	Conc. (ppm)	N	%D	Conc. (ppm)[1]	N	%D	Conc. (ppm)[1]	N	%D
Amphipods												
Anonyx laticoxae	0[2]	4	0	0	3	0	No Post-Exposure Period			No Post-Exposure Period		
	15	8	0	80	4	0						
	25	4	0	100	1	0						
	35	3	0	120	2	0						
	45	1	0	140	5	80						
Anonyx nugax	0	21	0	0	22	0						
	15	4	0	80	11	9	No Post-Exposure Period			No Post-Exposure Period		
	25	0	-	100	7	0						
	35	0	-	120	3	33						
	45	0	-	140	0	-						
Gammarus oceanicus	0	3	0	0	3	0	0	9	0	0	7	14
	15	4	25	10	4	0	25	2	0	61	6	0
	25	7	29	20	2	0	40	2	0	134	1	0
	35	0	-	40	3	0	53	1	0	264	0	-
	45	1	100	80	4	0	55	3	0	621	0	-
Gammarus setosus	0	21	0	0	21	0	0	26	0	0	27	0
	15	10	0	10	10	0	25	13	0	61	14	0
	25	7	29	20	11	0	40	4	0	134	6	33
	35	8	0	40	11	9	53	11	0	232	1	0
	45	8	50	80	9	0	55	10	0	621	0	-

TABLE 11. (Cont'd)

Species	Toxicants											
	Sodium Lauryl Sulphate			Corexit 9527			Prudhoe Bay Crude Oil			Prudhoe Bay Crude Oil and Corexit		
	Conc. (ppm)	N	%D	Conc. (ppm)	N	%D	Conc. (ppm)[1]	N	%D	Conc. (ppm)[1]	N	%D
	0	34	0				0	34	0	0	35	0
	20	21	0	No			24	21	0	39	19	5
	30	18	0	Experiment			44	21	0	87	11	18
	40	14	0				53	20	10	113	7	14
	50	4	25				56	21	0	147	1	0
Onisimus litoralis (adult)	0	47	0	0	49	0	0	49	0	0	49	0
	15	29	0	80	30	7	28	30	0	36	28	0
	25	27	4	160	1	0	40	28	4	94	25	0
	35	2	0	320	0	-	46	30	0	162	12	25
	45	0	-	640	0	-	47	29	0	293	1	100
	0	49	2									
	20	27	4	No			No			No		
	24	25	4	Experiment			Experiment			Experiment		
	28	15	13									
	32	5	20									
Onisimus litoralis (juvenile)	0	52	0				0	42	0			
	20	20	10	No			28	31	0	No		
	24	14	7	Experiment			43	29	0	Experiment		
	28	10	10				57	23	13			
	32	10	40				60	23	9			

TABLE 11. (Cont'd)

Species	Toxicants								
	Sodium Lauryl Sulphate			Corexit 9527			Prudhoe Bay Crude Oil			Prudhoe Bay Crude Oil and Corexit		
	Conc. (ppm)	N	%D	Conc. (ppm)	N	%D	Conc. (ppm)[1]	N	%D	Conc. (ppm)[1]	N	%D
Fish												
Myoxocephalus quadricornis	0	22	5				0	30	0			
	0.5	13	8	No Post-			23	16	0	No Post-		
	0.8	13	0	Exposure			38	12	0	Exposure		
	1.0	11	9	Period			56	9	11	Period		
	3.0	10	10				58	0	-			

Abbreviations: Conc. = Concentration; N = number of animals alive after 96 h exposure to toxicant; %D = percent mortality during 24 h post-exposure period.

[1] Concentration in oil-water and oil-Corexit-water mixtures represents measured exposure concentration.

[2] Concentration of 0 ppm represents control seawater solution.

TABLE 12.
Median Lethal Concentrations (96 h LC50) of Four Toxicant Mixtures for the Test Species. Unless otherwise indicated, 96 h LC50 values were calculated using a computerized probit analysis (Davies 1971). Values within round brackets after the 96 h LC50 are 95% confidence limits. All values are in ppm.

Species	Toxicant			
	Sodium Lauryl Sulphate	Corexit 9527	Prudhoe Bay Crude Oil	Prudhoe Bay Crude Oil-Corexit 9527
Amphipods				
Anonyx laticoxae	41[35- 45][1]	>140	>51	112 [73-169][1]
Anonyx nugax	16[15- 25][1]	104(97-111)	32(27-37)	45 (34- 61)
Gammarus oceanicus	30[25- 35][1]	>80	>55	105 (75-153)[3]
Gammarus setosus	89(42-186)[2] 42(39- 46)	175(38-803)	56(51-62) >53	138(114-168) 83 (70- 98)
Onisimus litoralis (adult)	28(26- 30) 28(26- 29)	115[80-160][1]	>47	138(118-161)
Onisimus litoralis (juvenile)	22(19- 26)	-	68(62-75)[2]	-
Boeckosimus sp.	>50	>175	>59	162(135-195)
Fish				
Myoxocephalus quadricornis	1-5[4]	<40	43(37-49) 42(39-46)	59 (40- 87)

[1] Interpolated from data plotted on semi-log paper; figures in square brackets give the range of concentrations within which 50% mortality would occur.

[2] Graphical probit analysis estimate (Litchfield and Wilcoxon 1949).

[3] 10% trimmed Spearman-Karber estimate (Hamilton *et al.* 1977).

[4] 50% mortality most likely to occur within this range on basis of mortality observed in concentrations of 1 and 5 ppm used as controls in several experiments.

Some consistent patterns in relative sensitivity can be discerned, however. Of the organisms tested, fourhorn sculpin (*Myoxocephalus quadricornis*) young-of-the-year and the large amphipod *Anonyx nugax* appeared to be the most sensitive to all four toxicant mixtures (Table 12). *Myoxocephalus quadricornis* was more sensitive to sodium lauryl sulphate and Corexit 9527, while *Anonyx nugax* appeared to be slightly more sensitive to the Prudhoe Bay crude oil in both oil-water and oil-Corexit-water mixtures. This reversal in order of sensitivity may be a result of different modes of toxic action for the detergents and oil mixtures. There is no reason to expect that invertebrates and fish will react in the same way to a given toxicant (Sprague 1970).

Other amphipods tested were slightly more resistant to the toxicant mixtures. *Boeckosimus* sp. appeared to be one of the most resistant species tested and *Anonyx laticoxae* also appeared to be relatively resistant, compared to *A. nugax*. It is interesting to note that, while these three species were all collected from approximately the same depth in the sublittoral zone, their sensitivities to the toxicant mixtures were different. This seems to contradict the theory that sublittoral species are generally more sensitive to pollution than littoral species because of their adaptation to a less variable environment (Swedmark *et al.* 1973). However, the biology of *Boeckosimus* sp. and *Anonyx laticoxae* is not well known and it may be that these species do inhabit some areas of more variable nature. The three intertidal amphipods tested, *Onisimus litoralis, Gammarus oceanicus* and *G. setosus,* appeared to be relatively similar in sensitivity to the toxicant mixtures. None of these species were the most or least sensitive to any of the toxicants.

3.5 Relative Life Stage Sensitivity

Many workers have indicated that juvenile or larval stages of many marine organisms are more sensitive to pollutants than the adults (e.g. Moore and Dwyer 1974; Rice *et al.* 1975; Linden 1976; Wilson 1977). In the present study, the 96 h LC50 of SLS for juvenile *Onisimus litoralis* was only slightly, but significantly (test of significant difference, A.P.H.A. 1976, p. 737) lower than that for adult *O. litoralis*. Linden (1976) found that 4 to 6 day old *Gammarus oceanicus* (~1 mm in length) were about 700 times more sensitive to crude oil, based on added oil concentrations, than adult *G. oceanicus*. It is probable that the juvenile *O. litoralis* (6-9 mm) used in this study were well past the stage of greatest sensitivity.

3.6 Chemical Dispersion of Oil in Arctic Waters

Cleanup of oil in temperate latitudes has proved to be an expensive undertaking. Cleanup under arctic conditions, because of the

logistic difficulties, can be expected to be even more expensive. Coupled with this is an inadequate technology for dealing with spilled oil in an ice-infested cold-water environment. It is anticipated that only a partial cleanup of oil or protection of some priority ecological or geographical areas would be attempted. The characteristics of such areas will determine, to some extent, the cleanup methods used in the event of a spill.

One method used in dealing with oil spills is the application of oil dispersants before the slick reaches nearshore regions. Ever since the 'Torrey Canyon' spill, the use of dispersants has been a controversial subject; much of the mortality observed after that spill was attributable to the highly toxic dispersants used in cleanup operations (Smith 1968). Since that time, 'second generation' dispersants, which are much lower in inherent toxicity, have been developed. The toxicity of the dispersants themselves may no longer be a strong argument against using them.

The use of dispersants on oil spilled in arctic waters might be indicated in some instances. Birds have been the most obvious and immediate victims of surface oil spills in waters of other latitudes. Holmes and Cronshow (1977) state that between 1955 and 1972, one million bird deaths were recorded following oil spills. Nettleship (1977) states that 'pollution of the seas by oil poses the largest single threat to seabirds'. The large populations of seabirds that inhabit some areas of the arctic archipelago, such as Lancaster Sound (Johnson *et al.* 1976), could be severely affected by a large spill of oil. Rapid use of dispersants to break up and emulsify the surface slick would help to minimize bird mortality in such a case.

Dispersal of oil in offshore areas may, in some cases, seem preferable to contamination of the shoreline and nearshore waters. In arctic regions, littoral areas and shallow water regions are sometimes important as feeding areas for vertebrates. Several of the amphipod species used in the present study are found in large numbers in the intertidal zone and have been identified as important food items for a number of fish, birds and marine mammals. The greatest damage to these communities may not be caused by direct lethal toxicity of the petroleum hydrocarbons. In many cases, oil slicks that reach the shoreline will have been weathered and will have lost a large proportion of their most toxic components as a result of several processes, including dissolution and evaporation (Clark and MacLeod 1977). However, oil that reaches the shoreline in arctic areas may be persistent. Owens (1978) states that a heavy oil, stranded on a low-energy shoreline in arctic regions, may be expected to last for decades with little loss of volume. The alteration of habitat may result in desertion of the area

by its residents or in a gradual decline in numbers of the inhabitant populations as a result of damage caused by chronic exposure to sublethal levels of hydrocarbons. The ultimate consequence is a disruption of the food chain.

The use of chemicals to disperse petroleum hydrocarbons in offshore waters does present some hazards, however. The results detailed in the present report, and the results of other toxicity studies in which exposure concentrations of hydrocarbons were measured, indicate that the use of a 'second generation' dispersant does not increase the toxicity of a crude oil. The use of a dispersant does, however, greatly increase the amount of oil entrained in the water column, thereby increasing the availability to aquatic organisms. If left as a slick on the water surface, a significant proportion of the volatile and most toxic components would normally be lost in a short time as a result of evaporation. Virtually all hydrocarbons smaller than C_{15} can evaporate from a sea surface within 10 days and the lightest compounds can completely volatilize within hours (Clark and MacLeod 1977). The rate of evaporation varies with conditions such as the type of petroleum, wave state, wind speed and water temperature (Clark and MacLeod 1977). If the oil is dispersed, a greater quantity of the more toxic compounds becomes dissolved in the water column. In the dissolved form, these compounds are easily incorporated by aquatic organisms.

After a large spill of petroleum hydrocarbons, one would expect some initial and localized mortality of planktonic organisms in the area of the spill. However, because of natural variability in planktonic populations and the dynamic nature of the aquatic environment, in which concentrations of pollutants and populations of planktonic organisms are constantly changing in time and space, it is extremely difficult to quantify the impact.

Some proportion of petroleum hydrocarbons dispersed in offshore waters will eventually reach the bottom sediments. As the lighter fractions of the petroleum dissolve or evaporate, the specific gravity of the oil increases. Dispersed particles may agglomerate, and absorption or adsorption of oil by particulate matter may occur. The result is a net downard movement of the oil (Clark and MacLeod 1977; Karrick 1977). The effect of such contamination on the sublittoral benthos is not well known. Possible effects are mortality due to toxicity, sublethal damage and mechanical injury caused by coating. Sanborn (1977) has speculated that anoxia may result in some areas because of the high biochemical oxygen demand of oil. In any case, the ultimate consequences of such pollution are not likely to be immediately obvious but may be significant, none the less.

Thus, despite the low toxicity of recently developed dispersants, the consequences of using them are still uncertain. In arctic regions, for which an understanding of basic biological relationships is often inadequate, the problem is compounded.

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6 APPENDIX A

TABLE 13.
Toxic Effects of Sodium Lauryl Sulphate on *Anonyx laticoxae*, Experiment #26.

SLS Concentration and Day	Mortality					
	R1		R2		R3	
	D/N	%D	D/N	%D	D/N	%D
15 ppm						
1	0/3	0.0	0/2	0.0	0/3	0.0
2	0/3	0.0	0/2	0.0	0/3	0.0
3	0/3	0.0	0/2	0.0	0/3	0.0
4	0/3	0.0	0/2	0.0	0/3	0.0
5 (PE)	0/3	0.0	0/2	0.0	0/3	0.0
25 ppm						
1	0/1	0.0	0/2	0.0	0/1	0.0
2	0/1	0.0	0/2	0.0	0/1	0.0
3	0/1	0.0	0/2	0.0	0/1	0.0
4	0/1	0.0	0/2	0.0	0/1	0.0
5 (PE)	0/1	0.0	0/2	0.0	0/1	0.0
35 ppm						
1	0/1	0.0	0/1	0.0	0/1	0.0
2	0/1	0.0	0/1	0.0	0/1	0.0
3	0/1	0.0	0/1	0.0	0/1	0.0
4	0/1	0.0	0/1	0.0	0/1	0.0
5 (PE)	0/1	0.0	0/1	0.0	0/1	0.0
45 ppm						
1	0/1	0.0	0/2	0.0	0/1	0.0
2	0/1	0.0	0/2	0.0	0/1	0.0
3	1/1	100.0	0/2	0.0	1/1	100.0
4	1/1	100.0	1/2	50.0	1/1	100.0
5 (PE)	1/1	100.0	1/2	50.0	1/1	100.0

Control mortality was 0/4 (0.0%) after 4 days and 0/4 (0.0%) after the post-exposure period.

Acclimated for 70 h; bioassay temperature = 4.1°C to 7.0°C.

Abbreviations: R1 = replicate 1; D/N = number of animals dead vs total number of animals exposed; %D = percent mortality; PE = post-exposure period; SLS = Sodium Lauryl Sulphate.

TABLE 14.
Toxic Effects of Sodium Lauryl Sulphate on *Anonyx nugax*, Experiment #26.

SLS Concentration and Day	Mortality					
	R1		R2		R3	
	D/N	%D	D/N	%D	D/N	%D
15 ppm						
1	0/2	0.0	0/3	0.0	0/2	0.0
2	0/2	0.0	0/3	0.0	0/2	0.0
3	0/2	0.0	0/3	0.0	0/2	0.0
4	1/2	50.0	1/3	33.3	1/2	50.0
5 (PE)	1/2	50.0	1/3	33.3	1/2	50.0
25 ppm						
1	0/4	0.0	0/2	0.0	0/4	0.0
2	1/4	25.0	0/2	0.0	1/4	25.0
3	4/4	100.0	2/2	100.0	2/4	50.0
4	4/4	100.0	2/2	100.0	4/4	100.0
5 (PE)	4/4	100.0	2/2	100.0	4/4	100.0
35 ppm						
1	0/3	0.0	0/4	0.0	1/3	33.3
2	0/3	0.0	1/4	25.0	3/3	100.0
3	2/3	66.6	3/4	75.0	3/3	100.0
4	3/3	100.0	4/4	100.0	3/3	100.0
5 (PE)	3/3	100.0	4/4	100.0	3/3	100.0
45 ppm						
1	2/4	50.0	1/3	33.3	3/4	75.0
2	3/4	75.0	3/3	100.0	4/4	100.0
3	4/4	100.0	3/3	100.0	4/4	100.0
4	4/4	100.0	3/3	100.0	4/4	100.0
5 (PE)	4/4	100.0	3/3	100.0	4/4	100.0

Control mortality was 0/21 (0.0%) after 4 days and 0/21 (0.0%) after the post-exposure period.

Acclimated for 70 h; bioassay temperature = 4.1°C to 7.0°C.

Abbreviations: R1 = replicate 1; D/N = number of animals dead vs total number of animals exposed; %D = percent mortality; PE = post-exposure period; SLS = Sodium Lauryl Sulphate.

TABLE 15.
Toxic Effects of Sodium Lauryl Sulphate on *Boeckosimus* sp., Experiment #50.

SLS Concentration and Day	Mortality					
	R1		R2		R3	
	D/N	%D	D/N	%D	D/N	%D
50 ppm						
1	0/10	0.0	0/10	0.0	0/10	0.0
2	0/10	0.0	0/10	0.0	0/10	0.0
3	0/10	0.0	1/10	10.0	0/10	0.0
4	0/10	0.0	1/10	10.0	1/10	10.0
5 (PE)	-	-	-	-	-	-

Higher concentrations used in this experiment produced precipitate in experimental solutions. Because the true concentration of SLS in solution is not known, results are not reported.

Control mortality was 0/50 (0.0%) after 4 days.

Acclimated for 196 h; bioassay temperature = 4.5°C to 5.5°C.

Abbreviations: R1 = replicate 1; D/N = number of animals dead vs total number of animals exposed; %D = percent mortality. PE = post-exposure period; SLS = Sodium Lauryl Sulphate.

TABLE 16.
Toxic Effects of Sodium Lauryl Sulphate on *Gammarus oceanicus*, Experiment #21.

SLS Concentration and Day	Mortality					
	R1		R2		R3	
	D/N	%D	D/N	%D	D/N	%D
15 ppm						
1	0/1	0.0	0/1	0.0	0/2	0.0
2	0/1	0.0	0/1	0.0	0/2	0.0
3	0/1	0.0	0/1	0.0	0/2	0.0
4	0/1	0.0	0/1	0.0	0/2	0.0
5 (PE)	0/1	0.0	0/1	0.0	1/2	50.0
25 ppm						
1	0/3	0.0	0/2	0.0	0/2	0.0
2	0/3	0.0	0/2	0.0	0/2	0.0
3	0/3	0.0	0/2	0.0	0/2	0.0
4	0/3	0.0	0/2	0.0	0/2	0.0
5 (PE)	1/3	33.3	0/2	0.0	1/2	50.0
35 ppm						
1	0/2	0.0	0/1	0.0	0/1	0.0
2	0/2	0.0	0/1	0.0	1/1	100.0
3	1/2	50.0	1/1	100.0	1/1	100.0
4	2/2	100.0	1/1	100.0	1/1	100.0
5 (PE)	2/2	100.0	1/1	100.0	1/1	100.0
45 ppm						
1	1/2	50.0	0/2	0.0	-	-
2	1/2	50.0	0/2	0.0	-	-
3	1/2	50.0	1/2	50.0	-	-
4	1/2	50.0	2/2	100.0	-	-
5 (PE)	2/2	100.0	2/2	100.0	-	-

Control mortality was 0/3 (0.0%) after 4 days and 0/3 (0.0%) after the post-exposure period.

Acclimated for 16 h; bioassay temperature = 3.0°C to 5.0°C.

Abbreviations: R1 = replicate 1; D/N = number of animals dead vs total number of animals exposed; %D = percent mortality; PE = post-exposure period; SLS = Sodium Lauryl Sulphate.

TABLE 17.
Toxic Effects of Sodium Lauryl Sulphate on *Gammarus setosus*, Experiment #21.

SLS Concentration and Day	Mortality					
	R1		R2		R3	
	D/N	%D	D/N	%D	D/N	%D
15 ppm						
1	0/4	0.0	0/4	0.0	0/3	0.0
2	1/4	25.0	0/4	0.0	0/3	0.0
3	1/4	25.0	0/4	0.0	0/3	0.0
4	1/4	25.0	0/4	0.0	0/3	0.0
5 (PE)	1/4	25.0	0/4	0.0	0/3	0.0
25 ppm						
1	1/2	50.0	0/3	0.0	0/3	0.0
2	1/2	50.0	0/3	0.0	0/3	0.0
3	1/2	50.0	0/3	0.0	0/3	0.0
4	1/2	50.0	0/3	0.0	0/3	0.0
5 (PE)	2/2	100.0	0/3	0.0	1/3	33.0
35 ppm						
1	0/3	0.0	0/4	0.0	0/4	0.0
2	1/3	33.3	1/4	25.0	1/4	25.0
3	1/3	33.3	1/4	25.0	1/4	25.0
4	1/3	33.3	1/4	25.0	1/4	25.0
5 (PE)	1/3	33.3	1/4	25.0	1/4	25.0
45 ppm						
1	0/3	0.0	0/2	0.0	0/5	0.0
2	0/3	0.0	0/2	0.0	0/5	0.0
3	0/3	0.0	0/2	0.0	1/5	20.0
4	0/3	0.0	1/2	50.0	1/5	20.0
5 (PE)	2/3	66.7	1/2	50.0	3/5	60.0

Control mortality was 0/21 (0.0%) after 4 days and 0/21 (0.0%) after the post-exposure period.

Acclimated for 16 h; bioassay temperature = 3.0°C to 5.0°C.

Abbreviations: R1 = replicate 1; D/N = number of animals dead vs total number of animals exposed; %D = percent mortality; PE = post-exposure period; SLS = Sodium Lauryl Sulphate.

TABLE 18.
Toxic Effects of Sodium Lauryl Sulphate on *Gammarus setosus*, Experiment #34.

SLS Concentration and Day	Mortality					
	R1		R2		R3	
	D/N	%D	D/N	%D	D/N	%D
20 ppm						
1	0/7	0.0	0/7	0.0	0/7	0.0
2	0/7	0.0	0/7	0.0	0/7	0.0
3	0/7	0.0	0/7	0.0	0/7	0.0
4	0/7	0.0	0/7	0.0	0/7	0.0
5 (PE)	0/7	0.0	0/7	0.0	0/7	0.0
30 ppm						
1	0/7	0.0	0/7	0.0	0/6	0.0
2	0/7	0.0	1/7	14.3	0/6	0.0
3	0/7	0.0	1/7	14.3	0/6	0.0
4	0/7	0.0	2/7	28.6	0/6	0.0
5 (PE)	0/7	0.0	2/7	28.6	0/6	0.0
40 ppm						
1	0/7	0.0	0/7	0.0	0/7	0.0
2	0/7	0.0	0/7	0.0	0/7	0.0
3	1/7	14.3	2/7	28.6	0/7	0.0
4	3/7	42.9	3/7	42.9	1/7	14.3
5 (PE)	3/7	42.9	3/7	42.9	1/7	14.3
50 ppm						
1	0/7	0.0	0/7	0.0	1/7	14.3
2	1/7	14.3	2/7	28.6	3/7	42.9
3	1/7	14.3	3/7	42.9	4/7	57.1
4	5/7	71.4	6/7	85.7	6/7	85.7
5 (PE)	6/7	85.7	6/7	85.7	6/7	85.7

Control mortality was 0/34 (0.0%) after 4 days and 0/34 (0.0%) after the post-exposure period.

Acclimated for 120 h; bioassay temperature = 4.5°C to 6.5°C.

Abbreviations: R1 = replicate 1; D/N = number of animals dead vs total number of animals exposed; %D = percent mortality; PE = post-exposure period; SLS = Sodium Lauryl Sulphate.

TABLE 19.
Toxic Effects of Sodium Lauryl Sulphate on *Onisimus litoralis*, Experiment #25.

SLS Concentration and Day	Mortality					
	R1		R2		R3	
	D/N	%D	D/N	%D	D/N	%D
15 ppm						
1	0/10	0.0	0/10	0.0	0/10	0.0
2	0/10	0.0	0/10	0.0	0/10	0.0
3	0/10	0.0	0/10	0.0	1/10	10.0
4	0/10	0.0	0/10	0.0	1/10	10.0
5 (PE)	0/10	0.0	0/10	0.0	1/10	10.0
25 ppm						
1	0/10	0.0	0/10	0.0	0/10	0.0
2	0/10	0.0	0/10	0.0	0/10	0.0
3	0/10	0.0	0/10	0.0	0/10	0.0
4	2/10	20.0	0/10	0.0	1/10	10.0
5 (PE)	3/10	30.0	0/10	0.0	1/10	10.0
35 ppm						
1	0/10	0.0	0/10	0.0	0/10	0.0
2	0/10	0.0	3/10	30.0	5/10	50.0
3	2/10	20.0	6/10	60.0	7/10	70.0
4	9/10	90.0	9/10	90.0	10/10	100.0
5 (PE)	9/10	90.0	9/10	90.0	10/10	100.0
45 ppm						
1	2/10	20.0	1/10	10.0	3/10	30.0
2	6/10	60.0	9/10	90.0	10/10	100.0
3	9/10	90.0	10/10	100.0	10/10	100.0
4	10/10	100.0	10/10	100.0	10/10	100.0
5 (PE)	10/10	100.0	10/10	100.0	10/10	100.0

Control mortality was 0/47 (0.0%) after 4 days and 0/47 (0.0%) after the post-exposure period.

Acclimated for 52 h; bioassay temperature = 3.9°C to 6.0°C.

Abbreviations: R1 = replicate 1; D/N = number of animals dead vs total number of animals exposed; %D = percent mortality; PE = post-exposure period; SLS = Sodium Lauryl Sulphate.

TABLE 20.
Toxic Effects of Sodium Lauryl Sulphate on *Onisimus litoralis*, Experiment #29.

SLS Concentration and Day	Mortality					
	R1		R2		R3	
	D/N	%D	D/N	%D	D/N	%D
20 ppm						
1	0/10	0.0	0/10	0.0	0/10	0.0
2	0/10	0.0	0/10	0.0	1/10	10.0
3	1/10	10.0	0/10	0.0	1/10	10.0
4	1/10	10.0	0/10	0.0	2/10	20.0
5 (PE)	2/10	20.0	0/10	0.0	2/10	20.0
24 ppm						
1	0/10	0.0	0/10	0.0	0/10	0.0
2	0/10	0.0	1/10	10.0	0/10	0.0
3	0/10	0.0	1/10	10.0	1/10	10.0
4	1/10	10.0	2/10	20.0	2/10	20.0
5 (PE)	2/10	20.0	2/10	20.0	2/10	20.0
28 ppm						
1	0/10	0.0	0/10	0.0	0/10	0.0
2	0/10	0.0	1/10	10.0	1/10	10.0
3	2/10	20.0	3/10	30.0	2/10	20.0
4	6/10	60.0	5/10	50.0	4/10	40.0
5 (PE)	6/10	60.0	6/10	60.0	5/10	50.0
32 ppm						
1	0/10	0.0	0/10	0.0	1/10	10.0
2	2/10	20.0	2/10	20.0	6/10	60.0
3	4/10	40.0	4/10	40.0	6/10	60.0
4	8/10	80.0	9/10	90.0	8/10	80.0
5 (PE)	9/10	90.0	9/10	90.0	8/10	80.0

Control mortality was 0/49 (0.0%) after 4 days and 1/49 (2.0%) after the post-exposure period.

Acclimated for 44 h; bioassay temperature = 3.8°C to 5.3°C.

Abbreviations: R1 = replicate 1; D/N = number of animals dead vs total number of animals exposed; %D = percent mortality; PE = post-exposure period; SLS = Sodium Lauryl Sulphate.

TABLE 21.
Toxic Effects of Sodium Lauryl Sulphate on *Onisimus litoralis* juveniles, Experiment #33.

SLS Concentration and Day	Mortality					
	R1		R2		R3	
	D/N	%D	D/N	%D	D/N	%D
20 ppm						
1	0/11	0.0	0/12	0.0	0/11	0.0
2	0/11	0.0	0/12	0.0	0/11	0.0
3	0/11	0.0	1/12	8.3	0/11	0.0
4	4/11	36.4	5/12	41.7	5/11	45.5
5 (PE)	4/11	36.4	6/12	50.0	6/11	54.6
24 ppm						
1	0/10	0.0	0/13	0.0	0/11	0.0
2	1/10	10.0	0/13	0.0	0/11	0.0
3	3/10	30.0	4/13	30.8	3/11	27.3
4	5/10	50.0	9/13	69.2	6/11	54.6
5 (PE)	6/10	60.0	9/13	69.2	6/11	54.6
28 ppm						
1	0/11	0.0	0/11	0.0	0/11	0.0
2	0/11	0.0	0/11	0.0	0/11	0.0
3	3/11	27.3	3/11	27.3	2/11	18.2
4	8/11	72.7	7/11	63.6	8/11	72.7
5 (PE)	8/11	72.7	8/11	72.7	8/11	72.7
32 ppm						
1	0/11	0.0	1/11	9.1	0/11	0.0
2	1/11	9.1	1/11	9.1	0/11	0.0
3	5/11	45.5	2/11	18.2	3/11	27.3
4	8/11	72.7	7/11	63.6	8/11	72.7
5 (PE)	9/11	81.8	8/11	72.7	10/11	90.9

Control mortality was 0/52 (0.0%) after 4 days and 0/52 (0.0%) after the post-exposure period.

Acclimated for 32 h; bioassay temperature = 4.0°C to 5.5°C.

Abbreviations: R1 = replicate 1; D/N = number of animals dead vs total number of animals exposed; %D = percent mortality; PE = post-exposure period; SLS = Sodium Lauryl Sulphate.

TABLE 22.
Toxic Effects of Sodium Lauryl Sulphate on *Myoxocephalus quadricornis* young-of-the-year, Experiment #39.

SLS Concentration and Day	Mortality					
	R1		R2		R3	
	D/N	%D	D/N	%D	D/N	%D
5 ppm						
1	6/6	100.0	6/6	100.0	6/6	100.0
2	6/6	100.0	6/6	100.0	6/6	100.0
3	6/6	100.0	6/6	100.0	6/6	100.0
4	6/6	100.0	6/6	100.0	6/6	100.0
5 (PE)	6/6	100.0	6/6	100.0	6/6	100.0
10 ppm						
1	6/6	100.0	6/6	100.0	6/6	100.0
2	6/6	100.0	6/6	100.0	6/6	100.0
3	6/6	100.0	6/6	100.0	6/6	100.0
4	6/6	100.0	6/6	100.0	6/6	100.0
5 (PE)	6/6	100.0	6/6	100.0	6/6	100.0
20 ppm						
1	6/6	100.0	6/6	100.0	6/6	100.0
2	6/6	100.0	6/6	100.0	6/6	100.0
3	6/6	100.0	6/6	100.0	6/6	100.0
4	6/6	100.0	6/6	100.0	6/6	100.0
5 (PE)	6/6	100.0	6/6	100.0	6/6	100.0
40 ppm						
1	6/6	100.0	6/6	100.0	6/6	100.0
2	6/6	100.0	6/6	100.0	6/6	100.0
3	6/6	100.0	6/6	100.0	6/6	100.0
4	6/6	100.0	6/6	100.0	6/6	100.0
5 (PE)	6/6	100.0	6/6	100.0	6/6	100.0

Control mortality was 0/30 (0.0%) after 1 day.

Acclimated for 36 h; bioassay temperature = 4.5°C to 5.5°C.

Abbreviations: R1 = replicate 1; D/N = number of animals dead vs total number of animals exposed; %D = percent mortality; PE = post-exposure period; SLS = Sodium Lauryl Sulphate.

TABLE 23.
Toxic Effects of Sodium Lauryl Sulphate on *Myoxocephalus quadricornis* young-of-the-year, Experiment #42.

SLS Concentration and Day	Mortality					
	R1		R2		R3	
	D/N	%D	D/N	%D	D/N	%D
0.5 ppm						
1	1/5	20.0	1/5	20.0	0/5	0.0
2	1/5	20.0	1/5	20.0	0/5	0.0
3	1/5	20.0	1/5	20.0	0/5	0.0
4	1/5	20.0	1/5	20.0	0/5	0.0
5 (PE)	1/5	20.0	1/5	20.0	1/5	20.0
0.8 ppm						
1	0/5	0.0	0/5	0.0	1/5	20.0
2	0/5	0.0	0/5	0.0	1/5	20.0
3	0/5	0.0	0/5	0.0	1/5	20.0
4	0/5	0.0	1/5	20.0	1/5	20.0
5 (PE)	0/5	0.0	1/5	20.0	1/5	20.0
1.0 ppm						
1	1/5	20.0	1/5	20.0	1/5	20.0
2	1/5	20.0	1/5	20.0	1/5	20.0
3	1/5	20.0	1/5	20.0	1/5	20.0
4	1/5	20.0	1/5	20.0	2/5	40.0
5 (PE)	2/5	40.0	1/5	20.0	2/5	40.0
3.0 ppm						
1	1/5	20.0	0/5	0.0	0/5	0.0
2	1/5	20.0	0/5	0.0	1/5	20.0
3	1/5	20.0	0/5	0.0	1/5	20.0
4	1/5	20.0	0/5	0.0	4/5	80.0
5 (PE)	1/5	20.0	1/5	20.0	4/5	80.0

Control mortality was 3/25 (12.0%) after 4 days and 4/25 (16.0%) after the post-exposure period.

Acclimated for 24 h; bioassay temperature = 3.5°C to 5.7°C.

Abbreviations: R1 = replicate 1; D/N = number of animals dead vs total number of animals exposed; %D = percent mortality; PE = post-exposure period; SLS = Sodium Lauryl Sulphate.

TABLE 24.
Toxic Effects of Corexit 9527 on *Anonyx laticoxae*, Experiment #40.

Corexit Concentration and Day	Mortality					
	R1		R2		R3	
	D/N	%D	D/N	%D	D/N	%D
80 ppm						
1	0/2	0.0	0/2	0.0	-	-
2	0/2	0.0	0/2	0.0	-	-
3	0/2	0.0	0/2	0.0	-	-
4	0/2	0.0	0/2	0.0	-	-
5 (PE)	0/2	0.0	0/2	0.0	-	-
100 ppm						
1	0/1	0.0	-	-	-	-
2	0/1	0.0	-	-	-	-
3	0/1	0.0	-	-	-	-
4	0/1	0.0	-	-	-	-
5 (PE)	0/1	0.0	-	-	-	-
120 ppm						
1	-	-	0/1	0.0	0/1	0.0
2	-	-	0/1	0.0	0/1	0.0
3	-	-	0/1	0.0	0/1	0.0
4	-	-	0/1	0.0	0/1	0.0
5 (PE)	-	-	0/1	0.0	0/1	0.0
140 ppm						
1	0/3	0.0	0/2	0.0	0/1	0.0
2	0/3	0.0	0/2	0.0	0/1	0.0
3	1/3	33.3	0/2	0.0	0/1	0.0
4	1/3	33.3	0/2	0.0	0/1	0.0
5 (PE)	3/3	100.0	1/2	50.0	0/1	0.0

Control mortality was 0/3 (0.0%) after 4 days and 0/3 (0.0%) after the post-exposure period. Mortality in SLS (25 ppm) was 0/3 (0.0%) after 4 days and 0/3 (0.0%) after the post-exposure period.

Acclimated for 18 h; bioassay temperature = 4.0°C to 5.5°C.

Abbreviations: R1 = replicate 1; D/N = number of animals dead vs total number of animals exposed; %D = percent mortality; PE = post-exposure period; SLS = Sodium Lauryl Sulphate.

TABLE 25.
Toxic Effects of Corexit 9527 on *Anonyx nugax*, Experiment #40.

Corexit Concentration and Day	Mortality					
	R1		R2		R3	
	D/N	%D	D/N	%D	D/N	%D
80 ppm						
1	0/3	0.0	0/3	0.0	0/5	0.0
2	0/3	0.0	0/3	0.0	0/5	0.0
3	0/3	0.0	0/3	0.0	0/5	0.0
4	0/3	0.0	0/3	0.0	0/5	0.0
5 (PE)	0/3	0.0	0/3	0.0	1/5	20.0
100 ppm						
1	0/4	0.0	0/5	0.0	0/5	0.0
2	1/4	25.0	1/5	20.0	0/5	0.0
3	3/4	75.0	1/5	20.0	2/5	40.0
4	3/4	75.0	2/5	40.0	2/5	40.0
5 (PE)	3/4	75.0	2/5	40.0	2/5	40.0
120 ppm						
1	0/5	0.0	0/4	0.0	0/4	0.0
2	1/5	20.0	0/4	0.0	2/4	50.0
3	3/5	60.0	3/4	75.0	3/4	75.0
4	4/5	80.0	3/4	75.0	3/4	75.0
5 (PE)	4/5	80.0	4/4	100.0	3/4	75.0
140 ppm						
1	0/2	0.0	0/3	0.0	0/4	0.0
2	0/2	0.0	2/3	66.7	3/4	75.0
3	2/2	100.0	3/3	100.0	4/4	100.0
4	2/2	100.0	3/3	100.0	4/4	100.0
5 (PE)	2/2	100.0	3/3	100.0	4/4	100.0

Control mortality was 0/22 (0.0%) after 4 days and 0/22 (0.0%) after the post-exposure period. Mortality in SLS (25 ppm) was 12/12 (100%) after 4 days.

Acclimated for 18 h; bioassay temperature = 4.0°C to 5.5°C.

Abbreviations: R1 = replicate 1; D/N = number of animals dead vs total number of animals exposed; %D = percent mortality; PE = post-exposure period; SLS = Sodium Lauryl Sulphate.

TABLE 26.
Toxic Effects of Corexit 9527 on *Boeckosimus* sp, Experiment #53.

Corexit Concentration and Day	Mortality					
	R1		R2		R3	
	D/N	%D	D/N	%D	D/N	%D
100 ppm						
1	0/8	0.0	0/8	0.0	0/8	0.0
2	0/8	0.0	0/8	0.0	0/8	0.0
3	0/8	0.0	0/8	0.0	0/8	0.0
4	0/8	0.0	0/8	0.0	0/8	0.0
5 (PE)	-	-	-	-	-	-
125 ppm						
1	0/8	0.0	0/8	0.0	0/8	0.0
2	0/8	0.0	0/8	0.0	0/8	0.0
3	0/8	0.0	0/8	0.0	0/8	0.0
4	0/8	0.0	0/8	0.0	0/8	0.0
5 (PE)	-	-	-	-	-	-
150 ppm						
1	0/8	0.0	0/8	0.0	0/8	0.0
2	0/8	0.0	0/8	0.0	0/8	0.0
3	0/8	0.0	0/8	0.0	0/8	0.0
4	0/8	0.0	0/8	0.0	0/8	0.0
5 (PE)	-	-	-	-	-	-
175 ppm						
1	0/8	0.0	0/8	0.0	0/8	0.0
2	0/8	0.0	0/8	0.0	0/8	0.0
3	0/8	0.0	0/8	0.0	0/8	0.0
4	0/8	0.0	0/8	0.0	0/8	0.0
5 (PE)	-	-	-	-	-	-

Control mortality was 0/40 (0.0%) after 4 days. Animals were not exposed to a SLS control.

Acclimated for 120 h; bioassay temperature = 4.4°C to 5.5°C.

Abbreviations: R1 = replicate 1; D/N = number of animals dead vs total number of animals exposed; %D = percent mortality; PE = post-exposure period; SLS = Sodium Lauryl Sulphate.

TABLE 27.
Toxic Effects of Corexit 9527 on *Gammarus oceanicus*, Experiment #22.

Corexit Concentration and Day	Mortality					
	R1		R2		R3	
	D/N	%D	D/N	%D	D/N	%D
10 ppm						
1	0/2	0.0	0/2	0.0	0/1	0.0
2	0/2	0.0	0/2	0.0	0/1	0.0
3	0/2	0.0	0/2	0.0	0/1	0.0
4	1/2	50.0	0/2	0.0	0/1	0.0
5 (PE)	1/2	50.0	0/2	0.0	0/1	0.0
20 ppm						
1	0/1	0.0	0/1	0.0	0/1	0.0
2	0/1	0.0	1/1	100.0	0/1	0.0
3	0/1	0.0	1/1	100.0	0/1	0.0
4	0/1	0.0	1/1	100.0	0/1	0.0
5 (PE)	0/1	0.0	1/1	100.0	0/1	0.0
40 ppm						
1	0/1	0.0	0/2	0.0	-	-
2	0/1	0.0	0/2	0.0	-	-
3	0/1	0.0	0/2	0.0	-	-
4	0/1	0.0	0/2	0.0	-	-
5 (PE)	0/1	0.0	0/2	0.0	-	-
80 ppm						
1	0/1	0.0	-	-	0/3	0.0
2	0/1	0.0	-	-	0/3	0.0
3	0/1	0.0	-	-	0/3	0.0
4	0/1	0.0	-	-	0/3	0.0
5 (PE)	0/1	0.0	-	-	0/3	0.0

Control mortality was 0/3 (0.0%) after 4 days and 0/3 (0.0%) after the post-exposure period. Mortality in SLS (35 ppm) was 4/4 (100.0%) after 4 days.

Acclimated for 16 h; bioassay temperature = 3.0°C to 5.2°C.

Abbreviations: R1 = replicate 1; D/N = number of animals dead vs total number of animals exposed; %D = percent mortality; PE = post-exposure period; SLS = Sodium Lauryl Sulphate.

TABLE 28.
Toxic Effects of Corexit 9527 on *Gammarus setosus*, Experiment #22.

Corexit Concentration and Day	Mortality					
	R1		R2		R3	
	D/N	%D	D/N	%D	D/N	%D
10 ppm						
1	0/3	0.0	0/3	0.0	0/4	0.0
2	0/3	0.0	0/3	0.0	0/4	0.0
3	0/3	0.0	0/3	0.0	0/4	0.0
4	0/3	0.0	0/3	0.0	0/4	0.0
5 (PE)	0/3	0.0	0/3	0.0	0/4	0.0
20 ppm						
1	0/4	0.0	0/4	0.0	0/3	0.0
2	0/4	0.0	0/4	0.0	0/3	0.0
3	0/4	0.0	0/4	0.0	0/3	0.0
4	0/4	0.0	0/4	0.0	0/3	0.0
5 (PE)	0/4	0.0	0/4	0.0	0/3	0.0
40 ppm						
1	0/4	0.0	0/3	0.0	0/5	0.0
2	0/4	0.0	0/3	0.0	1/5	20.0
3	0/4	0.0	0/3	0.0	1/5	20.0
4	0/4	0.0	0/3	0.0	1/5	20.0
5 (PE)	1/4	25.0	0/3	0.0	1/5	20.0
80 ppm						
1	0/4	0.0	0/5	0.0	1/2	50.0
2	0/4	0.0	1/5	20.0	1/2	50.0
3	0/4	0.0	1/5	20.0	1/2	50.0
4	0/4	0.0	1/5	20.0	1/2	50.0
5 (PE)	0/4	0.0	1/5	20.0	1/2	50.0

Control mortality was 0/21 (0.0%) after 4 days and 0/21 (0.0%) after the post-exposure period. Mortality in SLS (35 ppm) was 3/11 (27.3%) after 4 days and 3/11 (27.3%) after the post-exposure period.

Acclimated for 16 h; bioassay temperature = 3.0°C to 5.2°C.

Abbreviations: R1 = replicate 1; D/N = number of animals dead vs total number of animals exposed; %D = percent mortality; PE = post-exposure period; SLS = Sodium Lauryl Sulphate.

TABLE 29.
Toxic Effects of Corexit 9527 on *Onisimus litoralis*, Experiment #32.

Corexit Concentration and Day	Mortality					
	R1		R2		R3	
	D/N	%D	D/N	%D	D/N	%D
80 ppm						
1	0/10	0.0	0/10	0.0	0/10	0.0
2	0/10	0.0	0/10	0.0	0/10	0.0
3	0/10	0.0	0/10	0.0	0/10	0.0
4	0/10	0.0	0/10	0.0	0/10	0.0
5 (PE)	0/10	0.0	0/10	0.0	2/10	20.0
160 ppm						
1	0/10	0.0	0/10	0.0	0/10	0.0
2	5/10	50.0	5/10	50.0	4/10	40.0
3	7/10	70.0	8/10	80.0	9/10	90.0
4	9/10	90.0	10/10	100.0	10/10	100.0
5 (PE)	9/10	90.0	10/10	100.0	10/10	100.0
320 ppm						
1	6/10	60.0	8/10	80.0	5/10	50.0
2	10/10	100.0	10/10	100.0	10/10	100.0
3	10/10	100.0	10/10	100.0	10/10	100.0
4	10/10	100.0	10/10	100.0	10/10	100.0
5 (PE)	10/10	100.0	10/10	100.0	10/10	100.0
640 ppm						
1	9/10	90.0	9/9	100.0	9/10	90.0
2	10/10	100.0	9/9	100.0	10/10	100.0
3	10/10	100.0	9/9	100.0	10/10	100.0
4	10/10	100.0	9/9	100.0	10/10	100.0
5 (PE)	10/10	100.0	9/9	100.0	10/10	100.0

Control mortality was 0/49 (0.0%) after 4 days and 0/49 (0.0%) after the post-exposure period. Mortality in SLS (25 ppm) was 19/30 (63.3%) after 4 days and 20/30 (66.7%) after the post-exposure period.

Acclimated for 36 h; bioassay temperature = 3.8°C to 6.3°C.

Abbreviations: R1 = replicate 1; D/N = number of animals dead vs total number of animals exposed; %D = percent mortality; PE = post-exposure period; SLS = Sodium Lauryl Sulphate.

TABLE 30.
Toxic Effects of Corexit 9527 on *Myoxocephalus quadricornis* young-of-the-year. Experiment #44.

Corexit Concentration and Day	Mortality					
	R1		R2		R3	
	D/N	%D	D/N	%D	D/N	%D
40 ppm						
1	0/5	0.0	0/5	0.0	0/5	0.0
2	4/5	80.0	4/5	80.0	3/5	60.0
3	4/5	80.0	4/5	80.0	3/5	60.0
4	5/5	100.0	4/5	80.0	4/5	80.0
5 (PE)	-	-	-	-	-	-
60 ppm						
1	0/5	0.0	0/5	0.0	1/5	20.0
2	4/5	80.0	3/5	60.0	5/5	100.0
3	5/5	100.0	5/5	100.0	5/5	100.0
4	5/5	100.0	5/5	100.0	5/5	100.0
5 (PE)	-	-	-	-	-	-
80 ppm						
1	3/5	60.0	0/5	0.0	1/5	20.0
2	5/5	100.0	5/5	100.0	5/5	100.0
3	5/5	100.0	5/5	100.0	5/5	100.0
4	5/5	100.0	5/5	100.0	5/5	100.0
5 (PE)	-	-	-	-	-	-
100 ppm						
1	1/5	20.0	2/5	40.0	2/5	40.0
2	5/5	100.0	4/5	80.0	5/5	100.0
3	5/5	100.0	5/5	100.0	5/5	100.0
4	5/5	100.0	5/5	100.0	5/5	100.0
5 (PE)	-	-	-	-	-	-

Control mortality was 0/25 (0.0%) after 4 days. Mortality in SLS (1.0 ppm) was 0/15 (0.0%) after 4 days.

Acclimated for 16 h; bioassay temperature = 3.5°C to 5.7°C.

Abbreviations: R1 = replicate 1; D/N = number of animals dead vs total number of animals exposed; %D = percent mortality; PE = post-exposure period; SLS = Sodium Lauryl Sulphate.

TABLE 31.
Toxic Effects of Prudhoe Bay Crude Oil on *Anonyx laticoxae*, Experiment #51.

Added Oil and Day	Mortality R1 D/N	R1 %D	R2 D/N	R2 %D	R3 D/N	R3 %D	Measured Hydrocarbon Concentration MC°	MC^{24}	$\overline{MC}$
80 ppm									20.7
1	0/2	0.0	-	-	-	-	34.0	6.8	
2	0/2	0.0	-	-	-	-	34.0	7.1	
3	0/2	0.0	-	-	-	-	34.9	6.6	
4	0/2	0.0	-	-	-	-	35.5	6.8	
5 (PE)	-	-	-	-	-	-	$\overline{x}$=34.6	6.8	
160 ppm									36.4
1	-	-	-	-	0/1	0.0	66.7	12.9	
2	-	-	-	-	0/1	0.0	63.5	6.4	
3	-	-	-	-	0/1	0.0	67.3	6.2	
4	-	-	-	-	0/1	0.0	61.7	6.2	
5 (PE)	-	-	-	-	-	-	$\overline{x}$=64.8	7.9	
320 ppm									45.5
1	0/1	0.0	-	-	-	-	86.6	15.6	
2	0/1	0.0	-	-	-	-	79.8	15.8	
3	0/1	0.0	-	-	-	-	75.4	7.3	
4	0/1	0.0	-	-	-	-	73.5	9.8	
5 (PE)	-	-	-	-	-	-	$\overline{x}$=78.8	12.1	
640 ppm									50.8
1	0/1	0.0	0/1	0.0	-	-	92.2	13.0	
2	0/1	0.0	0/1	0.0	-	-	94.1	29.1	
3	0/1	0.0	0/1	0.0	-	-	81.6	13.8	
4	0/1	0.0	0/1	0.0	-	-	76.0	6.1	
5 (PE)	-	-	-	-	-	-	$\overline{x}$=86.0	15.5	

Control mortality was 0/4 (0.0%) after 4 days. Mortality in SLS (25 ppm) was 0/3 (0.0%) after 4 days.

Acclimated for 72 h; bioassay temperature = 4.5°C to 6.5°C.

Abbreviations: R1 = replicate 1; D/N = number of animals dead vs total number of animals exposed; %D = percent mortality; MC° = measured concentration of hydrocarbons at time of addition of animals (0 h); MC^{24} = measured concentration of hydrocarbons 24 h after animals were added; $\overline{MC}$ = mean measured concentration of hydrocarbons over the 96 h exposure period; PE = post-exposure period; SLS = Sodium Lauryl Sulphate.

TABLE 32.
Toxic Effects of Prudhoe Bay Crude Oil on *Anonyx nugax*, Experiment #51.

Added Oil and Day	Mortality R1 D/N	R1 %D	R2 D/N	R2 %D	R3 D/N	R3 %D	Measured Hydrocarbon Concentration MC°	MC^{24}	$\overline{MC}$
80 ppm									20.7
1	0/3	0.0	0/5	0.0	0/5	0.0	34.0	6.8	
2	0/3	0.0	0/5	0.0	0/5	0.0	34.0	7.1	
3	0/3	0.0	0/5	0.0	0/5	0.0	34.9	6.6	
4	0/3	0.0	1/5	20.0	1/5	20.0	35.5	6.8	
5 (PE)	-	-	-	-	-	-	$\bar{x}$=34.6	6.8	
160 ppm									36.4
1	0/5	0.0	0/5	0.0	0/4	0.0	66.7	12.9	
2	0/5	0.0	0/5	0.0	0/4	0.0	63.5	6.4	
3	1/5	20.0	3/5	60.0	0/4	0.0	67.3	6.2	
4	3/5	60.0	3/5	60.0	1/4	25.5	61.7	6.2	
5 (PE)	-	-	-	-	-	-	$\bar{x}$=64.8	7.9	
320 ppm									45.5
1	0/4	0.0	0/5	0.0	2/5	40.0	86.6	15.6	
2	1/4	25.5	1/5	20.0	3/5	60.0	79.8	15.8	
3	2/4	50.0	1/5	20.0	4/5	80.0	75.4	7.3	
4	4/4	100.0	4/5	80.0	4/5	80.0	73.5	9.8	
5 (PE)	-	-	-	-	-	-	$\bar{x}$=78.8	12.1	
640 ppm									50.8
1	0/4	0.0	3/4	75.5	0/5	0.0	92.2	13.0	
2	2/4	50.0	3/4	75.5	4/5	80.0	94.1	29.1	
3	3/4	75.5	3/4	75.5	5/5	100.0	81.6	13.8	
4	4/4	100.0	4/4	100.0	5/5	100.0	76.0	6.1	
5 (PE)	-	-	-	-	-	-	$\bar{x}$=86.0	15.5	

Control mortality was 0/21 (0.0%) after 4 days. Mortality in SLS (25 ppm) was 8/12 (66.7%) after 4 days.

Acclimated for 72 h; bioassay temperature = 4.5°C to 6.5°C.

Abbreviations: R1 = replicate 1; D/N = number of animals dead vs total number of animals exposed; %D = percent mortality; MC° = measured concentration of hydrocarbons at time of addition of animals (0 h); $\overline{MC}^{24}$ = measured concentration of hydrocarbons 24 h after animals were added; $\overline{MC}$ = mean measured concentration of hydrocarbons over the 96 h exposure period; PE = post-exposure period; SLS = Sodium Lauryl Sulphate.

TABLE 33.
Toxic Effects of Prudhoe Bay Crude Oil on *Boeckosimus* sp., Experiment #46.

Added Oil and Day	Mortality R1 D/N	R1 %D	R2 D/N	R2 %D	R3 D/N	R3 %D	Measured Hydrocarbon Concentration MC°	MC^{24}	$\overline{MC}$
80 ppm									21.8
1	0/10	0.0	0/9	0.0	0/10	0.0	34.9	11.5	
2	0/10	0.0	0/9	0.0	0/10	0.0	15.6	10.3	
3	0/10	0.0	0/9	0.0	0/10	0.0	34.0	11.8	
4	0/10	0.0	0/9	0.0	0/10	0.0	38.6	17.6	
5 (PE)	-	-	-	-	-	-	$\bar{x}$=30.8	12.8	
160 ppm									44.9
1	0/10	0.0	0/10	0.0	0/10	0.0	63.5	19.2	
2	0/10	0.0	0/10	0.0	0/10	0.0	67.9	28.0	
3	0/10	0.0	0/10	0.0	0/10	0.0	61.7	28.9	
4	0/10	0.0	0/10	0.0	0/10	0.0	67.3	22.5	
5 (PE)	-	-	-	-	-	-	$\bar{x}$=65.1	24.7	
320 ppm									55.1
1	0/9	0.0	0/10	0.0	0/11	0.0	76.0	34.2	
2	0/9	0.0	0/10	0.0	0/11	0.0	72.9	34.9	
3	0/9	0.0	0/10	0.0	0/11	0.0	88.5	27.4	
4	0/9	0.0	0/10	0.0	0/11	0.0	75.4	31.3	
5 (PE)	-	-	-	-	-	-	$\bar{x}$=78.2	32.0	
640 ppm									59.0
1	0/10	0.0	0/10	0.0	0/10	0.0	94.7	32.2	
2	0/10	0.0	0/10	0.0	0/10	0.0	86.0	40.4	
3	0/10	0.0	0/10	0.0	0/10	0.0	88.5	18.3	
4	0/10	0.0	0/10	0.0	1/10	10.0	91.6	19.8	
5 (PE)	-	-	-	-	-	-	$\bar{x}$=90.2	27.7	

Control mortality was 0/50 (0.0%) after 4 days. Mortality in SLS (50 ppm) was 1/30 (3.3%) after 4 days.

Acclimated for 100 h; bioassay temperature = 4.2°C to 5.5°C.

Abbreviations: R1 = replicate 1; D/N = number of animals dead vs total number of animals exposed; %D = percent mortality; MC° = measured concentration of hydrocarbons at time of addition of animals (0 h); MC^{24} = measured concentration of hydrocarbons 24 h after animals were added; $\overline{MC}$ = mean measured concentration of hydrocarbons over the 96 h exposure period; PE = post-exposure period; SLS = Sodium Lauryl Sulphate.

TABLE 34.
Toxic Effects of Prudhoe Bay Crude Oil on *Gammarus oceanicus*. Experiment #23.

Added Oil and Day	Mortality R1 D/N	R1 %D	R2 D/N	R2 %D	R3 D/N	R3 %D	Measured Hydrocarbon Concentration MC°	MC^{24}	$\overline{MC}$
80 ppm									24.8
1	0/1	0.0	0/1	0.0	-	-	39.9	18.1	
2	0/1	0.0	0/1	0.0	-	-	41.1	-	
3	0/1	0.0	0/1	0.0	-	-	36.8	12.1	
4	0/1	0.0	0/1	0.0	-	-	32.7	5.6	
5 (PE)	0/1	0.0	0/1	0.0	-	-	$\overline{x}$=37.6	11.9	
160 ppm									39.7
1	-	-	-	-	0/2	0.0	56.7	34.9	
2	-	-	-	-	0/2	0.0	62.9	-	
3	-	-	-	-	0/2	0.0	62.3	29.9	
4	-	-	-	-	0/2	0.0	34.9	10.5	
5 (PE)	-	-	-	-	0/2	0.0	$\overline{x}$=54.2	25.1	
320 ppm									52.7
1	-	-	0/1	0.0	-	-	61.7	35.5	
2	-	-	0/1	0.0	-	-	88.5	-	
3	-	-	0/1	0.0	-	-	76.6	26.1	
4	-	-	0/1	0.0	-	-	81.0	23.6	
5 (PE)	-	-	0/1	0.0	-	-	$\overline{x}$=77.0	28.4	
640 ppm									54.6
1	0/2	0.0	0/1	0.0	0/2	0.0	63.5	36.1	
2	0/2	0.0	0/1	0.0	0/2	0.0	87.9	-	
3	0/2	0.0	0/1	0.0	0/2	0.0	72.3	32.4	
4	0/2	0.0	1/1	100.0	1/2	50.0	86.6	26.2	
5 (PE)	0/2	0.0	1/1	100.0	1/2	50.0	$\overline{x}$=77.6	31.6	

Control mortality was 0/9 (0.0%) after 4 days and 0/9 (0.0%) after the post-exposure period. Mortality in SLS (35 ppm) was 3/5 (60.0%) after 4 days and 3/5 (60.0%) after the post-exposure period.

Acclimated for 37 h; bioassay temperature = 5.0°C to 13.0°C.

Abbreviations: R1 = replicate 1; D/N = number of animals dead vs total number of animals exposed; %D = percent mortality; MC° = measured concentration of hydrocarbons at time of addition of animals (0 h); $\overline{MC^{24}}$ = measured concentration of hydrocarbons 24 h after animals were added; $\overline{MC}$ = mean measured concentration of hydrocarbons over the 96 h exposure period; PE = post-exposure period; SLS = Sodium Lauryl Sulphate.

TABLE 35.
Toxic Effects of Prudhoe Bay Crude Oil on *Gammarus setosus*, Experiment #23.

Added Oil and Day	Mortality R1 D/N	R1 %D	R2 D/N	R2 %D	R3 D/N	R3 %D	Measured Hydrocarbon Concentration MC°	MC^{24}	$\overline{MC}$
80 ppm									24.8
1	0/6	0.0	0/7	0.0	-	-	39.9	18.1	
2	0/6	0.0	0/7	0.0	-	-	41.1	-	
3	0/6	0.0	0/7	0.0	-	-	36.8	12.1	
4	0/6	0.0	0/7	0.0	-	-	32.7	5.6	
5 (PE)	0/6	0.0	0/7	0.0	-	-	$\bar{x}$=37.6	11.9	
160 ppm									39.7
1	-	-	-	-	0/4	0.0	56.7	34.9	
2	-	-	-	-	0/4	0.0	62.9	-	
3	-	-	-	-	0/4	0.0	62.3	29.9	
4	-	-	-	-	0/4	0.0	34.9	10.5	
5 (PE)	-	-	-	-	0/4	0.0	$\bar{x}$=54.2	25.1	
320 ppm									52.7
1	-	-	0/7	0.0	0/7	0.0	61.7	35.5	
2	-	-	0/7	0.0	1/7	14.3	88.5	-	
3	-	-	0/7	0.0	2/7	28.6	76.6	26.1	
4	-	-	0/7	0.0	3/7	42.9	81.0	23.6	
5 (PE)	-	-	0/7	0.0	3/7	42.9	$\bar{x}$=77.0	28.4	
640 ppm									54.6
1	0/5	0.0	0/6	0.0	0/5	0.0	63.5	36.1	
2	0/5	0.0	0/6	0.0	0/5	0.0	87.9	-	
3	0/5	0.0	0/6	0.0	2/5	40.0	72.3	32.4	
4	2/5	40.0	2/6	33.3	2/5	40.0	86.6	26.2	
5 (PE)	2/5	40.0	2/6	33.3	2/5	40.0	$\bar{x}$=77.6	31.6	

Control mortality was 1/27 (3.7%) after 4 days and 1/27 (3.7%) after the post-exposure period. Mortality in SLS (35 ppm) was 7/16 (43.8%) after 4 days and 7/16 (43.8%) after the post-exposure period.

Acclimated for 37 h; bioassay temperature = 5.0°C to 13.0°C.

Abbreviations: R1 = replicate 1; D/N = number of animals dead vs total number of animals exposed; %D = percent mortality; MC° = measured concentration of hydrocarbons at time of addition of animals (0 h); MC^{24} = measured concentration of hydrocarbons 24 h after animals were added; $\overline{MC}$ = mean measured concentration of hydrocarbons over the 96 h exposure period; PE = post-exposure period; SLS = Sodium Lauryl Sulphate.

TABLE 36.
Toxic Effects of Prudhoe Bay Crude Oil on *Gammarus setosus*, Experiment #31.

Added Oil and Day	Mortality R1 D/N	R1 %D	R2 D/N	R2 %D	R3 D/N	R3 %D	Measured Hydrocarbon Concentration MC°	MC^{24}	$\overline{MC}$
80 ppm									24.3
1	0/7	0.0	0/7	0.0	0/7	0.0	40.8	9.9	
2	0/7	0.0	0/7	0.0	0/7	0.0	38.3	12.4	
3	0/7	0.0	0/7	0.0	0/7	0.0	49.2	16.2	
4	0/7	0.0	0/7	0.0	0/7	0.0	19.6	7.4	
5 (PE)	0/7	0.0	0/7	0.0	0/7	0.0	$\overline{x}$=37.0	11.5	
160 ppm									44.2
1	0/7	0.0	0/7	0.0	0/7	0.0	69.2	14.9	
2	0/7	0.0	0/7	0.0	0/7	0.0	64.8	19.9	
3	0/7	0.0	0/7	0.0	0/7	0.0	76.6	21.1	
4	0/7	0.0	0/7	0.0	0/7	0.0	68.5	18.6	
5 (PE)	0/7	0.0	0/7	0.0	0/7	0.0	$\overline{x}$=69.8	18.6	
320 ppm									55.7
1	0/7	0.0	0/7	0.0	0/7	0.0	99.7	18.0	
2	0/7	0.0	0/7	0.0	0/7	0.0	88.5	13.6	
3	0/7	0.0	0/7	0.0	0/7	0.0	81.6	24.9	
4	0/7	0.0	0/7	0.0	0/7	0.0	96.0	23.0	
5 (PE)	0/7	0.0	0/7	0.0	0/7	0.0	$\overline{x}$=91.5	19.9	
640 ppm									53.1
1	0/7	0.0	0/7	0.0	0/7	0.0	93.5	12.4	
2	0/7	0.0	0/7	0.0	0/7	0.0	82.3	22.4	
3	0/7	0.0	1/7	14.3	0/7	0.0	80.4	16.1	
4	0/7	0.0	1/7	14.3	0/7	0.0	97.9	19.3	
5 (PE)	0/7	0.0	2/7	28.6	1/7	14.3	$\overline{x}$=88.5	17.6	

Control mortality was 1/35 (2.9%) after 4 days and 1/35 (2.9%) after the post-exposure period. Mortality in SLS (35 ppm) was 6/15 (40.0%) after 4 days and 9/15 (60.0%) after the post-exposure period.

Acclimated for 24 h; bioassay temperature = 3.8°C to 5.2°C.

Abbreviations: R1 = replicate 1; D/N = number of animals dead vs total number of animals exposed; %D = percent mortality; MC° = measured concentration of hydrocarbons at time of addition of animals (0 h); MC^{24} = measured concentration of hydrocarbons 24 h after animals were added; $\overline{MC}$ = mean measured concentration of hydrocarbons over the 96 h exposure period; PE = post-expsoure period; SLS = Sodium Lauryl Sulphate.

TABLE 37.
Toxic Effects of Prudhoe Bay Crude Oil on *Onisimus litoralis*, Experiment #27.

Added Oil and Day	Mortality R1 D/N	R1 %D	R2 D/N	R2 %D	R3 D/N	R3 %D	Measured Hydrocarbon Concentration MC°	MC^{24}	$\overline{MC}$
80 ppm									28.4
1	0/10	0.0	0/10	0.0	0/10	0.0	24.0	12.4	
2	0/10	0.0	0/10	0.0	0/10	0.0	34.0	24.0	
3	0/10	0.0	0/10	0.0	0/10	0.0	33.0	22.4	
4	0/10	0.0	0/10	0.0	0/10	0.0	50.2	26.8	
5 (PE)	0/10	0.0	0/10	0.0	0/10	0.0	$\bar{x}$=35.3	21.4	
160 ppm									39.7
1	0/9	0.0	0/9	0.0	0/10	0.0	35.5	14.9	
2	0/9	0.0	0/9	0.0	0/10	0.0	48.0	24.9	
3	0/9	0.0	0/9	0.0	0/10	0.0	60.4	31.7	
4	0/9	0.0	0/9	0.0	0/10	0.0	77.3	24.9	
5 (PE)	0/9	0.0	1/9	11.1	0/10	0.0	$\bar{x}$=55.3	24.1	
320 ppm									46.5
1	0/10	0.0	0/10	0.0	0/10	0.0	34.2	18.0	
2	0/10	0.0	0/10	0.0	0/10	0.0	55.4	30.5	
3	0/10	0.0	0/10	0.0	0/10	0.0	66.7	43.6	
4	0/10	0.0	0/10	0.0	0/10	0.0	97.9	25.5	
5 (PE)	0/10	0.0	0/10	0.0	0/10	0.0	$\bar{x}$=63.6	29.4	
640 ppm									45.6
1	0/10	0.0	0/10	0.0	0/10	0.0	36.7	19.3	
2	0/10	0.0	0/10	0.0	0/10	0.0	49.8	24.9	
3	0/10	0.0	0/10	0.0	0/10	0.0	68.5	36.7	
4	1/10	10.0	0/10	0.0	0/10	0.0	105.3	23.6	
5 (PE)	1/10	10.0	0/10	0.0	0/10	0.0	$\bar{x}$=65.1	26.1	

Control mortality was 0/49 (0.0%) after 4 days and 0/49 (0.0%) after the post-exposure period. Mortality in SLS (35 ppm) was 27/30 (90.0%) after 4 days and 29/30 (96.7%) after the post-exposure period.

Acclimated for 85 h; bioassay temperature = 3.9°C to 5.5°C.

Abbreviations: R1 = replicate 1; D/N = number of animals dead vs total number of animals exposed; %D = percent mortality; MC° = measured concentration of hydrocarbons at time of addition of animals (0 h); MC^{24} = measured concentration of hydrocarbons 24 h after animals were added; $\overline{MC}$ = mean measured concentration of hydrocarbons over the 96 h exposure period; PE = post-exposure period; SLS = Sodium Lauryl Sulphate.

TABLE 38.
Toxic Effects of Prudhoe Bay Crude Oil on *Onisimus litoralis* juveniles, Experiment #36.

Added Oil and Day	Mortality R1 D/N	R1 %D	R2 D/N	R2 %D	R3 D/N	R3 %D	Measured Hydrocarbon Concentration MC°	MC^{24}	$\overline{MC}$
80 ppm									28.3
1	0/10	0.0	0/11	0.0	0/10	0.0	37.1	14.6	
2	0/10	0.0	0/11	0.0	0/10	0.0	40.5	22.9	
3	0/10	0.0	0/11	0.0	0/10	0.0	40.8	19.0	
4	0/10	0.0	0/11	0.0	0/10	0.0	33.6	17.7	
5 (PE)	0/10	0.0	0/11	0.0	0/10	0.0	$\bar{x}$=38.0	18.6	
160 ppm									42.6
1	0/11	0.0	0/9	0.0	0/10	0.0	71.0	23.1	
2	0/11	0.0	0/9	0.0	0/10	0.0	59.8	24.3	
3	0/11	0.0	0/9	0.0	0/10	0.0	56.1	19.4	
4	0/11	0.0	1/9	11.1	0/10	0.0	66.0	21.1	
5 (PE)	0/11	0.0	1/9	11.1	0/10	0.0	$\bar{x}$=63.2	22.0	
320 ppm									56.5
1	0/10	0.0	0/11	0.0	0/11	0.0	83.5	14.8	
2	2/10	20.0	1/11	9.1	0/11	0.0	92.2	26.8	
3	3/10	30.0	1/11	9.1	4/11	36.4	92.2	27.9	
4	3/10	30.0	2/11	18.2	4/11	36.4	91.6	22.8	
5 (PE)	4/10	40.0	3/11	27.3	5/11	45.5	$\bar{x}$=89.9	23.1	
640 ppm									59.5
1	0/11	0.0	0/10	0.0	0/10	0.0	106.6	16.7	
2	0/11	0.0	0/10	0.0	1/10	10.0	101.0	27.9	
3	2/11	18.2	2/10	20.0	2/10	20.0	98.5	20.5	
4	3/11	27.3	3/10	30.0	2/10	20.0	89.1	15.5	
5 (PE)	4/11	36.4	3/10	30.0	3/10	30.0	$\bar{x}$=98.8	20.2	

Control mortality was 0/42 (0.0%) after 4 days and 0/42 (0.0%) after the post-exposure period. Mortality in SLS (25 ppm) was 17/21 (81.0%) after 4 days and 18/21 (85.7%) after the post-exposure period.

Acclimated for 70 h; bioassay temperature = 4.2°C to 5.5°C.

Abbreviations: R1 = replicate 1; D/N = number of animals dead vs total number of animals exposed; %D = percent mortality; MC° = measured concentration of hydrocarbons at time of addition of animals (0 h); MC^{24} = measured concentration of hydrocarbons 24 h after animals were added; $\overline{MC}$ = mean measured concentration of hydrocarbons over the 96 h exposure period; PE = post-exposure period; SLS = Sodium Lauryl Sulphate.

TABLE 39.
Toxic Effects of Prudhoe Bay Crude Oil on *Myoxocephalus quadricornis* young-of-the-year, Experiment #38.

Added Oil and Day	Mortality R1 D/N	R1 %D	R2 D/N	R2 %D	R3 D/N	R3 %D	Measured Hydrocarbon Concentration MC°	MC^{24}	$\overline{MC}$
80 ppm									23.0
1	0/6	0.0	0/6	0.0	0/6	0.0	35.8	12.3	
2	0/6	0.0	0/6	0.0	0/6	0.0	37.4	12.6	
3	0/6	0.0	0/6	0.0	0/6	0.0	36.5	13.7	
4	2/6	33.3	0/6	0.0	0/6	0.0	25.3	9.9	
5 (PE)	2/6	33.3	0/6	0.0	0/6	0.0	$\overline{x}$=33.8	12.1	
160 ppm									37.6
1	0/6	0.0	0/6	0.0	0/6	0.0	56.0	19.0	
2	0/6	0.0	0/6	0.0	0/6	0.0	63.5	18.9	
3	0/6	0.0	1/6	16.7	0/6	0.0	62.3	18.1	
4	1/6	16.7	3/6	50.0	2/6	33.3	47.5	15.0	
5 (PE)	1/6	16.7	3/6	50.0	2/6	33.3	$\overline{x}$=57.3	17.8	
320 ppm									55.5
1	0/6	0.0	0/6	0.0	0/6	0.0	79.8	22.4	
2	1/6	16.7	0/6	0.0	0/6	0.0	81.6	28.0	
3	2/6	33.3	0/6	0.0	1/6	16.7	82.9	17.3	
4	3/6	50.0	3/6	50.0	3/6	50.0	104.7	26.7	
5 (PE)	3/6	50.0	4/6	66.7	3/6	50.0	$\overline{x}$=87.3	23.6	
640 ppm									57.5
1	3/6	50.0	1/6	16.7	1/6	16.7	90.4	22.9	
2	4/6	66.7	5/6	83.3	2/6	33.3	93.5	18.6	
3	5/6	83.3	5/6	83.3	6/6	100.0	92.9	19.2	
4	6/6	100.0	6/6	100.0	6/6	100.0	99.1	22.9	
5 (PE)	6/6	100.0	6/6	100.0	6/6	100.0	$\overline{x}$=94.0	20.9	

Control mortality was 0/30 (0.0%) after 4 days and 0/30 (0.0%) after the post-exposure period. Mortality in SLS (5.0 ppm) was 18/18 (100.0%) after 2 days.

Acclimated for 72 h; bioassay temperature = 4.5°C to 6.0°C.

Abbreviations: R1 = replicate 1; D/N = number of animals dead vs total number of animals exposed; %D = percent mortality; MC° = measured concentration of hydrocarbons at time of addition of animals (0 h); MC^{24} = measured concentration of hydrocarbons 24 h after animals were added; $\overline{MC}$ = mean measured concentration of hydrocarbons over the 96 h exposure period; PE = post-exposure period; SLS = Sodium Lauryl Sulphate.

TABLE 40.
Toxic Effects of Prudhoe Bay Crude Oil on *Myoxocephalus quadricornis* young-of-the-year, Experiment #43.

Added Oil and Day	Mortality R1 D/N	R1 %D	R2 D/N	R2 %D	R3 D/N	R3 %D	Measured Hydrocarbon Concentration MC°	MC^{24}	$\overline{MC}$
80 ppm									27.0
1	0/5	0.0	0/5	0.0	0/5	0.0	37.1	14.3	
2	0/5	0.0	0/5	0.0	0/5	0.0	40.8	15.6	
3	0/5	0.0	1/5	20.0	0/5	0.0	44.9	13.6	
4	0/5	0.0	1/5	20.0	0/5	0.0	37.3	12.0	
5 (PE)	-	-	-	-	-	-	$\bar{x}$=40.0	13.9	
160 ppm									39.5
1	0/5	0.0	0/5	0.0	0/5	0.0	62.0	18.4	
2	0/5	0.0	0/5	0.0	0/5	0.0	68.5	19.2	
3	0/5	0.0	0/5	0.0	0/5	0.0	56.7	12.4	
4	0/5	0.0	1/5	20.0	0/5	0.0	62.3	16.2	
5 (PE)	-	-	-	-	-	-	$\bar{x}$=62.4	16.6	
320 ppm									49.6
1	0/5	0.0	0/5	0.0	0/5	0.0	99.1	14.7	
2	2/5	40.0	0/5	0.0	1/5	20.0	87.3	15.6	
3	4/5	80.0	1/5	20.0	3/5	60.0	75.4	11.3	
4	4/5	80.0	5/5	100.0	4/5	80.0	79.8	13.0	
5 (PE)	-	-	-	-	-	-	$\bar{x}$=85.4	13.7	
640 ppm									52.1
1	1/5	20.0	0/5	0.0	2/5	40.0	94.1	13.6	
2	4/5	80.0	3/5	60.0	5/5	100.0	87.3	16.1	
3	5/5	100.0	5/5	100.0	5/5	100.0	91.6	9.6	
4	5/5	100.0	5/5	100.0	5/5	100.0	-	-	
5 (PE)	-	-	-	-	-	-	$\bar{x}$=91.0	13.1	

Control mortality was 0/25 (0.0%) after 4 days. Mortality in SLS (1.0 ppm) was 0/15 (0.0%) after 4 days.

Acclimated for 64 h; bioassay temperature = 3.5°C to 5.7°C.

Abbreviations: R1 = replicate 1; D/N = number of animals dead vs total number of animals exposed; %D = percent mortality; MC° = measured concentration of hydrocarbons at time of addition of animals (0 h); MC^{24} = measured concentration of hydrocarbons 24 h after animals were added; $\overline{MC}$ = mean measured concentration of hydrocarbons over the 96 h exposure period; PE = post-exposure period; SLS = Sodium Lauryl Sulphate.

TABLE 41.
Toxic Effects of Prudhoe Bay Crude Oil-Corexit 9527 Mixtures on *Anonyx laticoxae*, Experiment #48.

Added Oil/ Corexit and Day	Mortality R1 D/N	R1 %D	R2 D/N	R2 %D	R3 D/N	R3 %D	Measured Hydrocarbon Concentration MC°	MC^{24}	$\overline{MC}$
100/10 ppm									32.8
1	-	-	-	-	0/1	0.0	35.1	29.3	
2	-	-	-	-	0/1	0.0	57.7	37.8	
3	-	-	-	-	0/1	0.0	51.8	14.0	
4	-	-	-	-	0/1	0.0	28.8	7.8	
5 (PE)	-	-	-	-	-	-	$\overline{x}$=43.4	22.2	
175/17.5 ppm									72.6
1	0/3	0.0	-	-	-	-	83.0	83.9	
2	0/3	0.0	-	-	-	-	107.1	63.2	
3	0/3	0.0	-	-	-	-	100.9	24.8	
4	0/3	0.0	-	-	-	-	84.6	33.1	
5 (PE)	-	-	-	-	-	-	$\overline{x}$=93.9	51.3	
250/25 ppm									109.2
1	-	-	-	-	-	-	109.4	77.9	
2	-	-	-	-	-	-	150.6	110.7	
3	-	-	-	-	-	-	113.4	68.7	
4	-	-	-	-	-	-	124.1	118.5	
5 (PE)	-	-	-	-	-	-	$\overline{x}$=124.4	94.0	
325/32.5 ppm									169.1
1	0/1	0.0	-	-	-	-	217.7	133.3	
2	0/1	0.0	-	-	-	-	193.4	127.6	
3	0/1	0.0	-	-	-	-	154.0	181.3	
4	1/1	100.0	-	-	-	-	206.1	138.9	
5 (PE)	-	-	-	-	-	-	$\overline{x}$=192.8	145.3	

Control mortality was 0/2 (0.0%) after 4 days.

Acclimated for 20 h; bioassay temperature = 4.4°C to 6.5°C.

Abbreviations: R1 = replicate 1; D/N = number of animals dead vs total number of animals exposed; %D = percent mortality; MC° = measured concentration of hydrocarbons at time of addition of animals (0 h); MC^{24} = measured concentration of hydrocarbons 24 h after animals were added; $\overline{MC}$ = mean measured concentration of hydrocarbons over the 96 h exposure period; PE = post-exposure period; SLS = Sodium Lauryl Sulphate.

TABLE 42.
Toxic Effects of Prudhoe Bay Crude Oil-Corexit 9527 Mixtures on *Anonyx nugax*, Experiment #48.

Added Oil/ Corexit and Day	Mortality R1 D/N	R1 %D	R2 D/N	R2 %D	R3 D/N	R3 %D	Measured Hydrocarbon Concentration MC°	MC^{24}	$\overline{MC}$
100/10 ppm									32.8
1	0/5	0.0	0/5	0.0	1/4	25.0	35.1	29.3	
2	0/5	0.0	0/5	0.0	1/4	25.0	57.7	37.8	
3	1/5	20.0	1/5	20.0	1/4	25.0	51.8	14.0	
4	1/5	20.0	2/5	40.0	2/4	50.0	28.8	7.8	
5 (PE)	-	-	-	-	-	-	$\bar{x}$=43.4	22.2	
175/17.5 ppm									72.6
1	0/2	0.0	1/5	20.0	0/5	0.0	83.0	83.9	
2	1/2	50.0	2/5	40.0	3/5	60.0	107.1	63.2	
3	1/2	50.0	3/5	60.0	4/5	80.0	100.9	24.8	
4	1/2	50.0	4/5	80.0	4/5	80.0	84.6	33.1	
5 (PE)	-	-	-	-	-	-	$\bar{x}$=93.9	51.3	
250/25 ppm									109.2
1	0/5	0.0	2/5	40.0	2/5	40.0	109.4	77.9	
2	3/5	60.0	2/5	40.0	4/5	80.0	150.6	110.7	
3	4/5	80.0	4/5	80.0	5/5	100.0	113.4	68.7	
4	5/5	100.0	5/5	100.0	5/5	100.0	124.1	118.5	
5 (PE)	-	-	-	-	-	-	$\bar{x}$=124.4	94.0	
325/32.5 ppm									167.9
1	1/4	25.0	3/5	60.0	3/5	60.0	217.7	133.3	
2	4/4	100.0	5/5	100.0	4/5	80.0	193.4	127.6	
3	4/4	100.0	5/5	100.0	5/5	100.0	154.0	181.3	
4	4/4	100.0	5/5	100.0	5/5	100.0	-	-	
5 (PE)	-	-	-	-	-	-	$\bar{x}$=188.4	147.4	

Control mortality was 2/23 (8.7%) after 4 days. Mortality in SLS (25 ppm) was 8/15 (53.3%) after 4 days.

Acclimated for 20 h; bioassay temperature = 4.4°C to 6.5°C.

Abbreviations: R1 = replicate 1; D/N = number of animals dead vs total number of animals exposed; %D = percent mortality; MC° = measured concentration of hydrocarbons at time of addition of animals (0 h); $\overline{MC^{24}}$ = measured concentration of hydrocarbons 24 h after animals were added; $\overline{MC}$ = mean measured concentration of hydrocarbons over the 96 h exposure period; PE = post-exposure period; SLS = Sodium Lauryl Sulphate.

TABLE 43.
Toxic Effects of Prudhoe Bay Crude Oil-Corexit 9527 Mixtures on *Boeckosimus* sp., Experiment #45.

Added Oil/ Corexit and Day	Mortality R1 D/N	R1 %D	R2 D/N	R2 %D	R3 D/N	R3 %D	Measured Hydrocarbon Concentration MC°	MC^{24}	$\overline{MC}$
80/8 ppm									33.4
1	0/10	0.0	0/10	0.0	0/10	0.0	43.7	22.7	
2	0/10	0.0	0/10	0.0	0/10	0.0	47.1	34.0	
3	0/10	0.0	0/10	0.0	0/10	0.0	31.6	17.8	
4	0/10	0.0	0/10	0.0	0/10	0.0	49.0	21.1	
5 (PE)	-	-	-	-	-	-	$\overline{x}$=42.9	23.9	
160/16 ppm									68.4
1	0/10	0.0	0/10	0.0	0/10	0.0	81.3	37.2	
2	0/10	0.0	0/10	0.0	0/10	0.0	110.8	42.0	
3	0/10	0.0	0/10	0.0	0/10	0.0	73.5	58.8	
4	0/10	0.0	1/10	10.0	0/10	0.0	77.1	66.0	
5 (PE)	-	-	-	-	-	-	$\overline{x}$=85.7	51.0	
320/32 ppm									129.3
1	0/10	0.0	0/10	0.0	0/10	0.0	167.8	146.7	
2	3/10	30.0	0/10	0.0	0/10	0.0	137.6	143.9	
3	5/10	50.0	0/10	0.0	1/10	10.0	151.5	69.4	
4	6/10	60.0	5/10	50.0	1/10	10.0	132.8	84.8	
5 (PE)	-	-	-	-	-	-	$\overline{x}$=147.4	111.2	
640/64 ppm									348.5
1	0/10	0.0	0/10	0.0	4/10	40.0	466.4	222.8	
2	5/10	50.0	7/10	70.0	6/10	60.0	310.6	344.9	
3	7/10	70.0	8/10	80.0	8/10	80.0	363.9	250.7	
4	9/10	90.0	10/10	100.0	8/10	80.0	365.5	463.1	
5 (PE)	-	-	-	-	-	-	$\overline{x}$=376.6	320.4	

Control mortality was 0/50 (0.0%) after 4 days. Mortality in SLS (50 ppm) was 1/30 (3.3%) after 4 days.

Acclimated for 52 h; bioassay temperature = 4.0°C to 5.5°C.

Abbreviations: R1 = replicate 1; D/N = number of animals dead vs total number of animals exposed; %D = percent mortality; MC° = measured concentration of hydrocarbons at time of addition of animals (0 h); MC^{24} = measured concentration of hydrocarbons 24 h after animals were added; $\overline{MC}$ = mean measured concentration of hydrocarbons over the 96 h exposure period; PE = post-exposure period; SLS = Sodium Lauryl Sulphate.

TABLE 44.
Toxic Effects of Prudhoe Bay Crude Oil-Corexit 9527 Mixtures on *Gammarus oceanicus*, Experiment #24.

Added Oil/ Corexit and Day	Mortality R1 D/N	R1 %D	R2 D/N	R2 %D	R3 D/N	R3 %D	Measured Hydrocarbon Concentration MC°	MC^{24}	$\overline{MC}$
80/8 ppm									60.8
1	0/3	0.0	0/1	0.0	0/2	0.0	91.3	59.4	
2	0/3	0.0	0/1	0.0	0/2	0.0	51.9	57.2	
3	0/3	0.0	0/1	0.0	0/2	0.0	61.5	74.4	
4	0/3	0.0	0/1	0.0	0/2	0.0	47.5	42.7	
5 (PE)	0/3	0.0	0/1	0.0	0/2	0.0	$\overline{x}$=63.1	58.4	
160/16 ppm									133.5
1	-	-	0/1	0.0	0/3	0.0	165.2	173.7	
2	-	-	0/1	0.0	0/3	0.0	139.3	137.6	
3	-	-	0/1	0.0	0/3	0.0	134.1	71.4	
4	-	-	1/1	100.0	2/3	66.7	144.5	101.5	
5 (PE)	-	-	1/1	100.0	2/3	66.7	$\overline{x}$=145.8	121.1	
320/32 ppm									263.6
1	0/1	0.0	0/2	0.0	0/3	0.0	331.5	273.1	
2	1/1	100.0	2/2	100.0	3/3	100.0	204.7	245.0	
3	1/1	100.0	2/2	100.0	3/3	100.0	-	-	
4	1/1	100.0	2/2	100.0	3/3	100.0	-	-	
5 (PE)	1/1	100.0	2/2	100.0	3/3	100.0	$\overline{x}$=268.1	259.1	
640/64 ppm									620.6
1	2/4	50.0	-	-	-	-	737.0	517.9	
2	4/4	100.0	-	-	-	-	728.8	498.6	
3	4/4	100.0	-	-	-	-	-	-	
4	4/4	100.0	-	-	-	-	-	-	
5 (PE)	4/4	100.0	-	-	-	-	$\overline{x}$=732.9	508.3	

Control mortality was 0/7 (0.0%) after 4 days and 1/7 (14.3%) after the post-exposure period. Mortality in SLS (35 ppm) was 1/3 (33.3%) after 4 days and 2/3 (66.7%) after the post-exposure period.

Acclimated for 41 h; bioassay temperature = 5.0°C to 13.0°C.

Abbreviations: R1 = replicate 1; D/N = number of animals dead vs total number of animals exposed; %D = percent mortality; MC° = measured concentration of hydrocarbons at time of addition of animals (0 h); MC^{24} = measured concentration of hydrocarbons 24 h after animals were added; $\overline{MC}$ = mean measured concentration of hydrocarbons over the 96 h exposure period; PE = post-exposure period; SLS = Sodium Lauryl Sulphate.

TABLE 45.
Toxic Effects of Prudhoe Bay Crude Oil-Corexit 9527 Mixtures on *Gammarus setosus*, Experiment #24.

Added Oil/ Corexit and Day	Mortality R1 D/N	R1 %D	R2 D/N	R2 %D	R3 D/N	R3 %D	Measured Hydrocarbon Concentration MC°	MC^{24}	$\overline{MC}$
80/8 ppm									60.8
1	0/3	0.0	0/6	0.0	0/5	0.0	91.3	59.4	
2	0/3	0.0	0/6	0.0	0/5	0.0	51.9	57.2	
3	0/3	0.0	0/6	0.0	0/5	0.0	61.5	74.4	
4	0/3	0.0	0/6	0.0	0/5	0.0	47.5	42.7	
5 (PE)	0/3	0.0	0/6	0.0	0/5	0.0	$\bar{x}$=63.1	58.4	
160/16 ppm									133.5
1	0/7	0.0	0/6	0.0	0/3	0.0	165.2	173.7	
2	1/7	14.3	0/6	0.0	0/3	0.0	139.3	137.6	
3	2/7	28.6	0/6	0.0	0/3	0.0	134.1	71.4	
4	3/7	42.9	5/6	83.3	0/3	0.0	144.5	101.5	
5 (PE)	4/7	57.1	6/6	100.0	0/3	0.0	$\bar{x}$=145.8	121.1	
320/32 ppm									231.7
1	1/6	16.7	0/5	0.0	0/4	0.0	331.5	273.1	
2	3/6	50.0	2/5	40.0	1/4	25.0	204.7	245.0	
3	6/6	100.0	4/5	80.0	1/4	25.0	228.8	195.9	
4	6/6	100.0	5/5	100.0	3/4	75.0	234.9	139.7	
5 (PE)	6/6	100.0	5/5	100.0	3/4	75.0	$\bar{x}$=250.0	213.4	
640/64 ppm									620.6
1	2/3	66.7	-	-	2/7	28.6	737.0	517.9	
2	3/3	100.0	-	-	7/7	100.0	728.8	498.6	
3	3/3	100.0	-	-	7/7	100.0	-	-	
4	3/3	100.0	-	-	7/7	100.0	-	-	
5 (PE)	3/3	100.0	-	-	7/7	100.0	$\bar{x}$=732.9	508.3	

Control mortality was 1/28 (3.6%) after 4 days and 1/28 (3.6%) after the post-exposure period. Mortality in SLS (35 ppm) was 6/12 (50.0%) after 4 days and 8/12 (66.7%) after the post-exposure period.

Acclimated for 41 h; bioassay temperature = 5.0°C to 13°C.

Abbreviations: R1 = replicate 1; D/N = number of animals dead vs total number of animals exposed; %D = percent mortality; MC° = measured concentration of hydrocarbons at time of addition of animals (0 h); MC^{24} = measured concentration of hydrocarbons 24 h after animals were added; $\overline{MC}$ = mean measured concentration of hydrocarbons over the 96 h exposure period; PE = post-exposure period; SLS = Sodium Lauryl Sulphate.

TABLE 46.
Toxic Effects of Prudhoe Bay Crude Oil-Corexit 9527 Mixtures on *Gammarus setosus*, Experiment #35.

Added Oil/ Corexit and Day	Mortality R1 D/N	R1 %D	R2 D/N	R2 %D	R3 D/N	R3 %D	Measured Hydrocarbon Concentration MC°	MC^{24}	$\overline{MC}$
100/10 ppm									38.7
1	0/7	0.0	1/7	14.3	0/7	0.0	52.3	34.6	
2	0/7	0.0	1/7	14.3	0/7	0.0	43.0	45.5	
3	0/7	0.0	2/7	28.6	0/7	0.0	35.0	36.2	
4	0/7	0.0	2/7	28.6	0/7	0.0	29.8	32.9	
5 (PE)	0/7	0.0	3/7	42.9	0/7	0.0	$\bar{x}$=40.0	37.3	
175/17.5 ppm									86.7
1	1/7	14.3	0/7	0.0	0/7	0.0	120.3	74.2	
2	1/7	14.3	0/7	0.0	1/7	14.3	90.3	78.5	
3	1/7	14.3	2/7	28.6	1/7	14.3	73.5	91.3	
4	4/7	57.1	3/7	42.9	3/7	42.9	79.3	85.8	
5 (PE)	4/7	57.1	5/7	71.4	3/7	42.9	$\bar{x}$=90.9	82.5	
250/25 ppm									112.7
1	1/7	14.3	0/7	0.0	1/7	14.3	123.5	113.9	
2	2/7	28.6	1/7	14.3	1/7	14.3	123.5	112.6	
3	3/7	42.9	1/7	14.3	5/7	71.4	133.1	77.2	
4	3/7	42.9	4/7	57.1	7/7	100.0	102.6	115.2	
5 (PE)	4/7	57.1	4/7	57.1	7/7	100.0	$\bar{x}$=120.7	104.7	
325/32.5 ppm									147.1
1	0/7	0.0	0/7	0.0	3/7	42.9	169.1	130.5	
2	7/7	100.0	4/7	57.1	6/7	85.7	143.7	122.7	
3	7/7	100.0	4/7	57.1	7/7	100.0	175.2	93.0	
4	7/7	100.0	6/7	85.7	7/7	100.0	186.7	155.9	
5 (PE)	7/7	100.0	6/7	85.7	7/7	100.0	$\bar{x}$=168.7	125.5	

Control mortality was 0/35 (0.0%) after 4 days and 0/35 (0.0%) after the post-exposure period. Mortality in SLS (35 ppm) was 3/21 (14.3%) after 4 days and 10/21 (47.6%) after the post-exposure period.

Acclimated for 120 h; bioassay temperature = 4.8°C to 6.5°C.

Abbreviations: R1 = replicate 1; D/N = number of animals dead vs total number of animals exposed; %D = percent mortality; MC° = measured concentration of hydrocarbons at time of addition of animals (0 h); MC^{24} = measured concentration of hydrocarbons 24 h after animals were added; $\overline{MC}$ = mean measured concentration of hydrocarbons over the 96 h exposure period; PE = post-exposure period; SLS = Sodium Lauryl Sulphate.

TABLE 47.
Toxic Effects of Prudhoe Bay Crude Oil-Corexit 9527 Mixtures on *Onisimus litoralis*, Experiment #30.

Added Oil/ Corexit and Day	Mortality R1 D/N	R1 %D	R2 D/N	R2 %D	R3 D/N	R3 %D	Measured Hydrocarbon Concentration MC°	MC^{24}	$\overline{MC}$
80/8 ppm									35.6
1	0/8	0.0	0/10	0.0	0/10	0.0	37.9	31.1	
2	0/8	0.0	0/10	0.0	0/10	0.0	32.1	42.7	
3	0/8	0.0	0/10	0.0	0/10	0.0	49.9	33.8	
4	0/8	0.0	1/10	10.0	0/10	0.0	33.6	23.3	
5 (PE)	0/8	0.0	1/10	10.0	0/10	0.0	$\bar{x}$=38.4	32.7	
160/16 ppm									93.7
1	0/10	0.0	0/9	0.0	0/10	0.0	103.0	107.5	
2	0/10	0.0	0/9	0.0	1/10	10.0	103.0	107.5	
3	0/10	0.0	1/9	11.1	1/10	10.0	87.5	77.5	
4	0/10	0.0	2/9	22.2	2/10	20.0	97.8	65.4	
5 (PE)	0/10	0.0	2/9	22.2	2/10	20.0	$\bar{x}$=97.8	89.5	
320/32 ppm									161.6
1	0/10	0.0	0/11	0.0	0/10	0.0	168.4	202.9	
2	3/10	30.0	1/11	9.1	0/10	0.0	162.4	160.7	
3	5/10	50.0	6/11	54.6	3/10	30.0	156.3	132.6	
4	8/10	80.0	8/11	72.7	3/10	30.0	162.4	146.7	
5 (PE)	8/10	80.0	9/11	81.8	5/10	50.0	$\bar{x}$=162.4	160.7	
640/64 ppm									292.6
1	2/10	20.0	2/10	20.0	3/10	30.0	253.2	373.7	
2	8/10	80.0	10/10	100.0	8/10	80.0	269.6	373.7	
3	8/10	80.0	10/10	100.0	9/10	90.0	228.6	364.1	
4	10/10	100.0	10/10	100.0	9/10	90.0	228.6	248.8	
5 (PE)	10/10	100.0	10/10	100.0	10/10	100.0	$\bar{x}$=245.0	340.1	

Control mortality was 0/49 (0.0%) after 4 days and 0/49 (0.0%) after the post-exposure period. Mortality in SLS (25 ppm) was 12/30 (40.0%) after 4 days and 15/30 (50.0%) after the post-exposure period.

Acclimated for 72 h; bioassay temperature = 3.7°C to 5.2°C.

Abbreviations: R1 = replicate 1; D/N = number of animals dead vs total number of animals exposed; %D = percent mortality; MC° = measured concentration of hydrocarbons at time of addition of animals (0 h); MC^{24} = measured concentration of hydrocarbons 24 h after animals were added; $\overline{MC}$ = mean measured concentration of hydrocarbons over the 96 h exposure period; PE = post-exposure period; SLS = Sodium Lauryl Sulphate.

TABLE 48.
Toxic Effects of Prudhoe Bay Crude Oil-Corexit 9527 Mixtures on *Myoxocephalus quadricornis* young-of-the-year, Experiment #55.

Added Oil/ Corexit and Day	Mortality R1 D/N	R1 %D	R2 D/N	R2 %D	R3 D/N	R3 %D	Measured Hydrocarbon Concentration MC°	MC^{24}	$\overline{MC}$
30/3.0 ppm									15.4
1	0/5	0.0	0/6	0.0	0/6	0.0	10.1	14.1	
2	0/5	0.0	0/6	0.0	0/6	0.0	15.6	19.7	
3	0/5	0.0	0/6	0.0	0/6	0.0	16.0	15.2	
4	0/5	0.0	0/6	0.0	0/6	0.0	15.4	17.0	
5 (PE)	-	-	-	-	-	-	$\bar{x}$=14.3	16.5	
45/4.5 ppm									28.2
1	0/6	0.0	0/6	0.0	0/6	0.0	28.8	24.3	
2	0/6	0.0	0/6	0.0	0/6	0.0	23.9	20.9	
3	0/6	0.0	0/6	0.0	0/6	0.0	32.3	28.7	
4	0/6	0.0	0/6	0.0	0/6	0.0	35.3	30.8	
5 (PE)	-	-	-	-	-	-	$\bar{x}$=30.1	26.2	
60/6.0 ppm									34.7
1	0/6	0.0	0/6	0.0	0/6	0.0	33.9	18.5	
2	1/6	16.7	0/6	0.0	0/6	0.0	39.6	30.5	
3	1/6	16.7	0/6	0.0	0/6	0.0	23.1	50.5	
4	2/6	33.3	0/6	0.0	0/6	0.0	41.9	39.8	
5 (PE)	-	-	-	-	-	-	$\bar{x}$=34.6	34.8	
75/7.5 ppm									48.4
1	0/6	0.0	1/6	16.7	1/6	16.7	47.3	42.6	
2	1/6	16.7	1/6	16.7	1/6	16.7	59.2	44.5	
3	1/6	16.7	1/6	16.7	1/6	16.7	48.7	35.7	
4	1/6	16.7	1/6	16.7	3/6	50.0	62.1	47.0	
5 (PE)	-	-	-	-	-	-	$\bar{x}$=54.3	42.5	

Control mortality was 1/30 (3.3%) after 4 days. Mortality in SLS (4.0 ppm) was 18/18 (100.0%) after 4 days.

Acclimated for 96 h; bioassay temperature = 4.4°C to 5.5°C.

Abbreviations: R1 = replicate 1; D/N = number of animals dead vs total number of animals exposed; %D = percent mortality; MC° = measured concentration of hydrocarbons at time of addition of animals (0 h); MC^{24} = measured concentration of hydrocarbons 24 h after animals were added; $\overline{MC}$ = mean measured concentration of hydrocarbons over the 96 h exposure period; PE = post-exposure period; SLS = Sodium Lauryl Sulphate.