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FEDERAL/STATE NATURAL RESOURCE DAMAGE ASSESSMENT

DRAFT STATUS REPORT

November 1990

Pre-spill and post-spill concentrations of hydrocarbons in sediments and mussels at intertidal sites within Prince William Sound and the Gulf of Alaska.

Coastal Habitat Study Number 1

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STATUS REPORT - November 1990

STUDY TITLE AND I.D. NUMBER

Pre-spill and post-spill concentrations of hydrocarbons in sediments and mussels at intertidal sites within Prince William Sound and the Gulf of Alaska. Coastal Habitat Study Number 1

EXECUTIVE SUMMARY

Only 24 selected pre-spill and post-spill sediment samples collected in 1989 have been analyzed and we report here the preliminary results of those analyses compared with the earlier baseline study. The 1989 pre-spill data from historical sites and sites established ahead of spill impact indicate values less than 1 ppm total aromatic hydrocarbons (AH) suggesting that hydrocarbon concentrations in Prince William Sound (PWS) at the time of the spill were not greatly elevated above historical baseline levels. Barnes Cove sediments, on the west side of Knight Island, showed AH concentrations on April 7 similar to Naked Island and Bay of Isles - 1 to 2 orders of magnitude less than the oil-contaminated samples collected the 0 ft tide level at several sites by Rice and O'Clair for Air/Water Study No. 2.

The limited samples (post EVOS impact) that have been analyzed and data returned indicate increases above pre-spill and historic levels. Two sites had AHs in sediments above historical levels. Aromatic hydrocarbons levels at Sleepy Bay in May were about 15 times historical levels. Our site at Elrington Island, which is near the southwest exit to the Sound and received weathered oil, showed mean AH in the sediment in May about 4 times greater than the historical levels at Naked Island.

Patterns of selected aromatic hydrocarbons (phenanthrenes, dibenzothiophenes, fluorenes, and chrysenes) in sediments appear to be similar for all sites and may be indicative of Prudhoe Bay crude. Patterns at Naked Island prior to the spill were very different; dibenzothiophenes, fluorenes, and chrysenes were absent and only a trace amount of phenanthrenes were present.

Odd/even ratios of alkanes are also indicative that petroleum was added to the sediments. Mean ratios were about 6 at Naked Island from 1977-79, but ratios ranged from 1 to 3 in 1989.

Abundance of mussels and other epifauna along sediment and mussel transects were photographically recorded during each sampling period. Analysis of these data show decreases in live mussels at one oiled site, Elrington Island. We are expecting results of tissue hydrocarbon analyses soon. These data will provide a basis for determining the cause of the observed differences.

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OBJECTIVES

A. Sample and estimate hydrocarbon concentrations in mussels and sediment from 20 sites within 10% of the actual concentration 95% of the time, when total aromatic concentrations are greater than 200 ng/g dry wt.

B. Test the null hypotheses that hydrocarbon contamination of sediments and mussels is the same for the pre-spill and post-spill period.

C. Document changes in abundance and distribution of intertidal epifauna and test the null hypothesis that no differences occur at oiled and non-oiled sites.

INTRODUCTION

On 26 March 1989, we began resampling 10 historically established intertidal hydrocarbon baseline sites in Prince William Sound in response to the *EXXON VALDEZ* oil spill. We also established 10 additional sites (in PWS and the Kenai Peninsula) along the spill trajectory before oiling, and sampled after oiling to measure changes in hydrocarbon levels in sediments and mussels resulting from the spill. Baseline levels of hydrocarbons at 8 historic sites are very low; about 0.2 ppm or less. No significant increase in aromatic hydrocarbons in intertidal sediments at the 8 sites was apparent from 1977 to 1980.

The present study will eventually compare hydrocarbon levels in sediments and mussels at the historically established sites plus 6 additional sites established in advance of *EXXON VALDEZ* crude oil impact.

STUDY METHODS

Historically established baseline sites were resampled in March 1989 immediately before several of them were impacted by the *EXXON VALDEZ* oil spill, and additional sites were established to cover areas of special concern. Sediment and mussel samples were taken. Photos documented biota in quadrats every 4 m along both mussel and sediment transects. Selected sites were resampled post-spill in April, May, June and August 1989 and in April, June and August in 1990. Details of methodology are described in the study plan dated 27 September 1989.

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STUDY RESULTS

Site Locations and Field Sampling. The locations of 20 sites sampled in the summer of 1989 and 1990 are given in Table 1. Site name, general location, latitude, longitude and the data base abbreviation for each intertidal sample location are listed. Ten of these sites were established as hydrocarbon baseline sites in 1977-81 in a pre-spill study to monitor possible changes in hydrocarbon contamination following the initiation of tanker traffic. The ten sites, four in Port Valdez and six in Prince William Sound, were chosen to bracket the tanker traffic lanes. Sites at Siwash Bay and Olsen Bay were control sites as little incidental introduction of hydrocarbons were expected at these sites. The remaining sites were Dayville, Mineral Creek, Gold Creek, and Sawmill Creek in Port Valdez; and West Bay, Outside Bay, Rocky Bay, and Constantine Harbor in PWS. Six additional sites were established in PWS (see Figure 1) and 4 along the Kenai Peninsula.

Three trips to Prince William Sound and two trips to the Kenai Peninsula were made in the summer of 1990 to collect samples; (1) April 23-28 (Kenai and PWS), (2) June 20-26 (Kenai and PWS) and (3) August 4-10 (PWS). A total of 285 samples were collected; 54 blanks, 165 sediments and 166 mussels.

Historical Baseline Results, 1977-1982. Sediments, mussels, water and fish samples were collected from 8-10 intertidal sites in the summers of 1977-81 and analyzed for aliphatic and aromatic hydrocarbons. Selected sites were sampled in 1982. These data are in a manuscript in preparation (Karinen et al.).

Mean concentrations for selected aromatic hydrocarbons in sediments from samples collected at 8 sites in 1977-79 are compared with aromatic hydrocarbon levels measured in 1980 (Table 2). Concentrations of total selected aromatic hydrocarbons in sediments were very low at all 8 sites; usually less than 0.2 ppm. Highest concentrations in Prince William Sound sites (Constantine Harbor and Rocky Bay) were about 68 times less than concentrations reported for the Auke Bay Marina and 600 times less than moderately polluted harbors in Puget Sound (Karinen 1988). Control sites (Olsen Bay and Siwash Bay) had 1,360 to 12,000 less total aromatic hydrocarbons than the indicated marina sites. The higher concentrations of hydrocarbons at Constantine Harbor and Rocky Bay are probably the result of the large numbers of boats which use these bays for anchorages. Rocky Bay was also the site of one or more boat groundings from 1977 to 1982 as it was used as an anchorage for pilot boats accompanying the tankers from Hinchinbrook Entrance to Port Valdez in the early days of oil shipment from Port Valdez. Although several of the locations show increases in total aromatic hydrocarbons from mean levels (1977-79) compared to 1980; the concentrations are so low and near the

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detection limit of the method that these changes cannot be regarded as significant. Statistical comparisons will be applied to these data and data for later years where possible to determine if a significant change of aromatic hydrocarbons concentrations occurred at these locations prior to the *EXXON VALDEZ* oil spill.

Composition of the aromatic hydrocarbons at Constantine Harbor and Rocky Bay (Table 2) does not match that reported for the ballast effluent, suspended particulates, or sediments in Port Valdez (Karinen 1988) indicating that these hydrocarbons are probably not the result of the ballast effluent introduced to Port Valdez and Prince William Sound. Comparisons with the composition of Prudhoe Bay crude oil suggest some similarity with patterns of aromatics at Rocky Bay.

<u>Analysis of 1989 Sediment Samples</u>. Results of hydrocarbon analyses (aromatics and aliphatics) were received late last week for only 24 sediment samples collected just prior to oil impact from the spill and at various times after the spill. The small number of samples analyzed precludes a statistical analysis of these data and allows us to make only preliminary conclusions. Sediments from five sites (Naked Island, Bay of Isles, Barnes Cove, Sleepy Bay, and Elrington Island) and four time periods (late March ,early April, early May, and mid-August) were analyzed: Naked Island- 2 samples- 3/28/89, 3 samples- 4/08/89, 2 samples- 5/08/89, and 3 samples- 8/15/89 ; Bay of Isles- 2 samples- 3/30/89, and 3 samples- 4/08/89; Barnes Cove- 2 samples- 4/07/89; Sleepy Bay-2 samples- 5/07/89, and 1 sample - 8/17/89; and Elrington Island - 2 samples -5/10/89, and 2 samples -8/17/89.

Mean total aromatic hydrocarbons in sediments from most sites were very low (<0.2-0.3 ppm/dry wt.); only about two to three times historical levels. Lack of data from reference sites (Siwash Bay and Olsen Bay) makes it impossible to say with certainty that this small increase above historical levels is the result of oil from the *Exxon Valdez* or from a gradual input of hydrocarbons over the last nine years.

Two sites (Sleepy Bay and Elrington Island) had mean aromatic concentrations in sediments that were about 15 and 4 times historical levels (1.5 and 0.4 ppm). These two sites were impacted by oil from the spill and had fresh oil layered over much of the upper half of the intertidal zone (Sleepy Bay) or scattered patches of weathered black tarry oil on rocks in the high intertidal zone at the time of sampling.

The few number of samples analyzed to date and the absence of an analysis from a control site far removed from the spill area (Siwash Bay or Olsen Bay) makes it difficult to ascertain the source of the increased aromatic content in the sediments. Two observations seem to implicate the *Exxon Valdez* spill as the source. The pattern of selected aromatic hydrocarbons (phenanthrenes, dibenzothiophenes, fluorenes, and chrysenes) in the sediments and oil from the Exxon Valdez shows some similarity. Oil from the tanker has the following composition for these groups of compounds; phenanthrenes - 16.1%, dibenzothiophenes - 9.2%, fluorenes - 3.5%, and chrysenes - 0.9%. Sediments at Naked Island on May 8, 1989 had 19.8% phenanthrenes, 5.9% dibenzothiophenes, 9.0 % fluorenes, and 12.0% chrysenes. Differences from the parent oil may reflect differences in rates of movement to the sediment by the various groups of compounds. The pre-spill distribution of these aromatic compounds in sediments at Naked Island (1977-79) was very different. No dibenzothiophenes, fluorenes, or chrysenes were present, and phenanthrenes constituted only about 1% of the total aromatic compounds. The second observation that implicates oil from the tanker as the source are the odd/even ratios of alkanes in the tanker oil and that found in the sediments. The tanker oil has an odd/even ratio of .82. The mean ratio in sediment at Naked Island on May 8 was 1.19 - much different than the mean value of 6.09 in sediments at this site from 1977-79. Addition of alkanes from the tanker oil may be responsible for this change. Statistical analyses of these and additional data, hopefully, will determine the source of these hydrocarbon compositional changes.

Based on baseline analyses we expect that even lightly oiled and some beaches with no visible oil will show the presence oil from the spill when samples are analyzed. The early baseline data will provide a firm basis for evaluating injury from the spill.

Photographs of Transect Quadrats. Quadrat slides from mussel transects were analyzed, for May and August 1989, for six sites - Bligh Island, Bay of Isles, Olsen Bay, Elrington Island, Barnes Cove, and Naked Island. Barnacles and mussels and the presence of dead mussels were counted using the 100-random dot method as outlined in the detailed study plan. Differences in abundance of biota were compared among May and August estimates.

The only site which showed significant differences ($P<.05$, Tukey comparison) in live (decrease) and dead (increase) mussels was Elrington Island, an oiled site. This needs to be confirmed with further statistical review and analyses of 1990 photos. There were no significant differences in abundance of barnacles between May and August at any of the sites analyzed.

STATUS OF INJURY ASSESSMENT

Sediments

Only a few of the pre- and post-spill samples from 1989 have been analyzed.

Mussels

None of the 1989 and 1990 samples have been analyzed.

Photographic Quadrats

While significant differences in abundance in live and dead mussels were found at Elrington Island (between May and August 1989), this needs to be confirmed with further statistical review and analyses of 1990 quadrat photos.

CITATIONS

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Table 1. Site Locations and abbreviated names for intertidal baseline sites sampled in 1989 and 1990.

Site	General Location	Latitude	Longitude	DatabaseAbbr.
		Port Valdez		
Dayville		61°05'13"	146°16'40"	DAYVI
Mineral Creek		61°07'40"	146°24'55"	MINEC
Gold Creek		61°07'59"	146°27'47"	GOLDC
Sawmill Creek		61°05'05"	146°26'12"	SAWMC
		PRINCE WILLIAM SOUND		
Siwash Bay	Unakwik Inlet	60°57'15"	147°40'50"	SIWAB
West Bay	Bligh Island	60°52'02"	146°45'20"	BLIGI
Olsen Bay	Port Gravina	60°44'22"	146°11'53"	OLSEN
Outside Bay	Naked Island	60°39'03"	147°26'14"	NAKEI
South Bay	Perry Island	60°41'00"	147°55'55"	PERRI
		60°40'43"	147°55'00"	PERRI
Bay of Isles	Knight Island	60°21'48"	147°41'30"	BOISL
Rocky Bay	Montague Isl.	60°20'06"	147°07'43"	ROCKB
Constantine Hbr.	Hinchinbrook	60°21'06"	146°39'38"	CONST
Barnes Cove	Drier, Knight	60°18'31"	147°45'43"	BARNC
Sleepy Bay	Latouche Isl.	60°04'00"	147°50'02"	SLEEB
Crab Bay	Sawmill, Evans	60°04'20"	147°59'48"	CRABB
Fox Farm	Elrington I.	59°58'15"	148°08'31"	ELRII
		KENAI PENINSULA		
Quicksand Cove	Aialik Bay	59°47'10"	149°47'12"	QUICC
Verdant Cove 1	Aialik Bay	59°41'48"	149°44'20"	VERDC
Verdant Cove 2		59°41'49"	149*44'19"	VERDC
Harris Bay		59°44'12"	149°53'30"	HARRB
Petrof Point	Nuka Passage	59°22'25"	150°60'00"	PETRP

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Table 2. Mean concentrations (ng/g dry weight) for selected aromatic hydrocarbons found in intertidal sediments from 8 Prince William Sound Locations, 1977-1979 and 1980 (). * indicate values <0.1 ng/g (<0.1 ppb).

COMPOUND/ SITE	Constan-tine	Rocky Bay	Naked Isl.	Olsen Bay	Bligh Isl.	Siwash Bay	Dayville	Mineral Cr
i-Propylbenzene	0.3(*)	0.5(.2)	.2(*)	.2(*)	.2(*)	.2(*)	.2(*)	.1(*)
n-Propylbenzene	0.7(*)	0.8(.4)	.1(*)	.4(*)	.1(*)	1.0(*)	.2(*)	*(*)
Indane	0.1(*)	0.5(*)	*(*)	*(*)	*(*)	.1(*)	*(*)	.1(*)
Naphthalene	5.0(3)	4.0(6)	.5(*)	.4(*)	.2(.3)	.6(2)	1.0(2)	2(4)
Benzothiophene	0.1(*)	0.1(*)	*(*)	*(*)	*(*)	*(*)	*(*)	*(*)
2-Methylnaphthalene	15.0(14)	7.0(13)	.3(*)	.3(*)	.3(*)	.1(.7)	1.0(3)	2(4)
1-Methylnaphthalene	12.0(12)	2.0(6)	.1(*)	.3(*)	.1(*)	.1(*)	.4(1)	1(2)
Biphenyl	9.0(9)	3.0(6)	*(*)	*(*)	*(*)	.2(*)	*(*)	*(*)
2-6-Dimethylnaph-thalene	9.0(10)	4.0(7)	.3(*)	*(*)	.1(*)	.1(*)	.1(.8)	.6(2)
2,3,5-Trimethyl-naphthalene	7.0(7)	*(*)	*(*)	*(*)	*(*)	*(*)	*(*)	*(*)
Fluorene	3.0(4)	10(10)	*(*)	.1(*)	*(*)	*(*)	*(.5)	1(3)
Dibenzothiophene	3.0(*)	2(*)	*(*)	*(*)	*(*)	*(*)	*(.1)	.6(.7)
Phenanthrene	34.0(34)	35(60)	.9(*)	.4(*)	.5(2)	.4(4)	.8(5)	7(15)
Anthracene	0.1(*)	2(4)	*(.7)	*(*)	*(*)	.4(*)	*(*)	*(.4)
Fluoranthene	4.0(*)	9(17)	.4(3)	*(*)	*(*)	.1(*)	*(*)	6(12)
Pyrene	7.0(7)	11(21)	82(2)	*(*)	*(*)	.2(*)	*(*)	2(6)
Benz(a)anthracene	2.0(3)	1(.3)	*(*)	*(*)	*(*)	*(*)	*(*)	*(*)
Chrysene	8.0(13)	12(19)	*(*)	*(*)	*(*)	*(*)	*(*)	*(*)
Benzo(e)pyrene	3.0(4)	5(13)	*(*)	*(*)	*(*)	*(*)	*(*)	*(*)
Benzo(a)pyrene	3.0(*)	4(*)	*(*)	*(*)	*(*)	1(*)	*(*)	*(*)
Perylene	81.0(69)	31(56)	14(24)	8(*)	5(10)	4(7)	*(*)	*(*)
TOTAL AROMATICS	206(189)	144(248)	99(35)	10(*)	6(12)	9(19)	4(12)	22(49)

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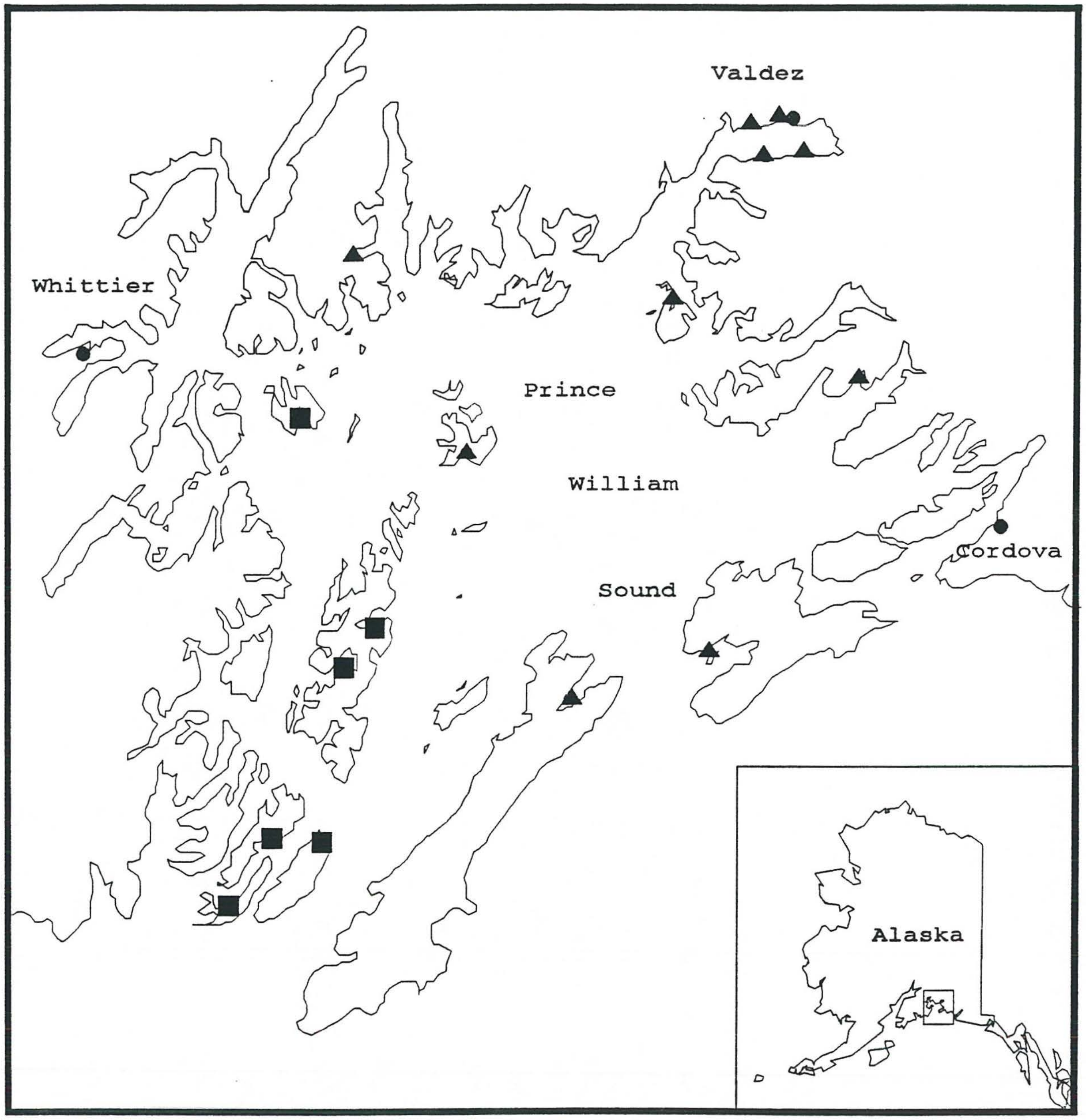
Figure 1. Intertidal baseline sampling sites.

▲ = historical sites ■ = established in 1989.



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1. EXECUTIVE SUMMARY

The purpose of the Coastal Habitat Study is to document and quantify injuries to biological resources found in the shallow subtidal, intertidal, and supratidal zones throughout the shoreline areas affected by the *Exxon Valdez* oil spill.

This is a preliminary report intended to provide information on progress of the study and to indicate possible trends revealed by initial analyses. The Coastal Habitat Study is being conducted by several principal investigators, each responsible for a major component of the work. This report is composed of sections prepared by the various investigators. The summary for each section is given below.

SITE SELECTION

Ninety-seven study sites comprised of 59 sites retained from 1989 and 38 sites added in 1990 were selected for the intertidal component of the Coastal Habitat Injury Assessment (CHIA). These study sites are representative the broad range of coastal habitat types, oiling characteristics, and clean-up techniques found in the spill area.

Control sites were carefully paired with oiled sites to closely match physical and biological characteristics while maintaining a statistically valid site selection strategy. The current site selection scheme will strengthen the ability of the CHIA to detect EVOS injuries while maintaining the ability to extrapolate these results to the universe of other oiled shorelines. However, the current suite of study sites remains at the minimum necessary to perform this extrapolation.

SUPRATIDAL

In general, total production of plant material was lower at oiled sites in some zones of the supratidal than at corresponding control sites. The trend of lower production on oiled sites with respect to matched controls was observed for *Elymus*, the dominant plant in some zones of the supratidal, and also for forb vegetation, in zones 4-6 of fine textured beaches. Two matched estuary pairs also exhibited lower production on the oiled sites with respect to corresponding control sites. The consistent pattern of

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higher production at control sites relative to oiled sites suggests the possibility of oil related impact.

INTERTIDAL

Invertebrates

Preliminary analysis of 1989 quadrat data for sheltered rocky beaches indicates that densities of barnacles, limpets, amphipods, isopods, oligochaetes and nematodes may have been higher in the first meter drop of the control sites than on the corresponding oiled sites. Densities of limpets during 1990, as measured by the semicircle technique, were significantly higher on the first meter drop of the sheltered rocky and coarse textured control sites than on the corresponding oiled sites. Mussels appeared to be more concentrated in the second and third meter drops on the control sites as compared with the oiled sites. *Fucus* densities may also be reduced in the upper portions of sheltered rocky beaches that were oiled. As a great deal of material remains to be analyzed, final conclusions cannot be drawn at this time.

Invertebrate Experiments in Herring Bay

As a part of the Coastal Habitat Injury Assessment program, an experimental field station was established in Herring Bay, Knight Island, Prince William Sound. The station was established as a result of a NRDA Management Team recommendation, to provide a research platform for intertidal damage assessment through field experimentation.

During the summer of 1990, five separate studies were implemented on 15 pairs of oiled and non-oiled sites in Herring Bay. Careful attention was given to matching pairs of sites, which included similarity in substrate composition, slope, directional and solar aspect, wave exposure, and common biological communities.

One study examined presence/absence differences between common intertidal species on impacted and reference sites. A second study examined differences in the population dynamics of several species of invertebrates between impacted and reference sites. Two separate studies examined settlement between oiled and non-oiled surfaces, and a fifth study examined differences in algal grazing by limpets.

Results from some of the studies conducted this summer are incomplete, pending certain analyses. Nevertheless, portions of the data presented in this report demonstrate that differences exist among components of intertidal communities between the selected oiled and reference sites in Herring Bay, and that some of these differences can be attributed to oil. For example, populations of one limpet species were significantly lower at all oiled sites compared to the non-oiled controls. Also, oiled surfaces appear to retard initial settlement by juvenile barnacles, compared to non-oiled surfaces.

Mussel Histology

The purpose of the histological work on mussel tissues is to determine if the oil had an impact on the reproductive activities of the mussels or on the ability of the mussels to accumulate high-energy storage materials for future reproduction. Preliminary analyses of various tissues from mussels collected in all three study regions indicate that the reproductive cycle of mussels at oiled sites in the Lower Cook Inlet/Kenai Peninsula and Kodiak/Alaska Peninsula regions may have been delayed by a few months.

Fishes

The intertidal fish study is divided into field and laboratory components. Objectives of field study were to determine abundance, biomass, recruitment, size distribution, and age of fish from oiled and unoiled sites. Objectives of laboratory studies were to determine changes in histopathology in gill tissues, gill parasite load, and respiration with exposure to oil. A general review of methods are presented with more in depth explanations for those methods that were generalized in the SOP or were modified.

Identification, counting, and measuring length and weight of the fish collected for the field study have just been completed and the data are currently being entered into the data base. Because of this, little can be said about field results. A hasty analysis of total abundance of all species combined was done for both sampling cycles; the Wilcoxon matched pairs signed-rank test detected a significant ($P<0.025$) difference between oiled and unoiled sites but the sign test did not. Within three of five quadrats tested, the sign test detected no difference between oiled and unoiled sites but the Wilcoxon test detected a significant ($P<0.02$) difference for quadrat 3 in sampling cycle 1 but not for quadrats 2 and 4. No significant difference between oiled and unoiled sites within quadrats for the second sampling cycle was found using the sign or Wilcoxon tests. Length frequency of the high cockscomb does not appear to be different for three pairs of sampling sites. From these cursory analyses it would appear that recovery is taking place. It should be stressed, however, that this analysis includes all species together and the effect of cover has not been considered.

Gill tissues have been embedded and the initial stages of examination have begun. No results, however, are available at this time. Gill parasite load was highest in fish collected from a heavily oiled site, intermediate for fish collected at an unoiled site and reared in an aquarium containing rocks coated with oil. Fish from an unoiled site had the fewest gill parasites. Respiration was highest for fish collected from an unoiled site reared in an aquarium with oiled rocks, intermediate for fish collected from an oiled site, and lowest for fish collected from an unoiled site.

Algae - Site Surveys

Several types of data were taken on the intertidal algae in the PWS, CIK, and KAP areas as part of the stratified, random sampling program. Measurements were taken on the percent algal cover, the density of fertile *Fucus* plants, the number of *Fucus* plants and receptacles, the average lengths of *Fucus* plants, the total *Fucus* biomass, *Fucus* egg viability, and the growth of *Fucus* germlings in the field. Preliminary results indicate that oiling and/or post oiling treatment caused damage to the *Fucus* populations in both the PWS and KAP areas. In general, the numbers, biomass, condition, and reproductivity of the dominant intertidal plant, *Fucus* gardneri were adversely affected by oiling. The extent of the damage and the estimated time for populations to recover await the completion of further data collection and analysis.

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Algal Experiments - Herring Bay

By examining *Fucus* plants at oiled and control sites within Herring Bay on Knight Island this study has shown that the intertidal dominant alga *Fucus gardneri* was severely affected by the oil spill and subsequent clean-up activities. A major finding was that the percent cover of *Fucus* was reduced by the oil spill. In response to this reduction, algae other than *Fucus* increased in abundance. Most of these other algae consisted of "weedy" annual species indicative of disturbed areas. The average size of *Fucus* plants in oiled areas tended to be smaller than the plants in control areas, suggesting a reduction of large plants at oiled sites. The number of reproductive *Fucus*, which are all at least 10 cm in length, was greatly reduced at oiled sites, and those plants which were still reproductive at oiled sites tended to have fewer receptacles per plant. Combined with the information on density of reproductive plants and the number of receptacles per plant, egg release data showed dramatic reductions in the number of eggs released per beach from local plants. Experiments inoculating control and oiled beaches indicate reduced recruitment in oiled areas relative to similarly inoculated control beaches. Transplanted newly settled *Fucus* plants, especially the larger plants, showed longer survival in oiled areas due to decreased herbivore pressure in oil impacted areas.

SUBTIDAL

The effects of oil on subtidal habitats in Prince William Sound is being assessed through comparisons of pairs of oiled and control study sites in five habitat types: silled fjords, eelgrass areas, *Laminaria/Agarum* bays, *Laminaria/Agarum* points, and *Nereocystis* areas. Silled fjords were sampled three times to date: Fall 1989, Spring and Fall 1990. Remaining habitats were sampled in Spring 1990 only. This report provides preliminary results from the first three of these habitats in 1990. Results for the silled fjords are based on samples collected in the Fall 1989 and Spring 1990.

In Fall 1989, numerous dead organisms, including highly mobile forms such as squid and fishes, were observed at depths >13 m in an oiled silled fjord (Herring Bay). In Spring 1990 this site was revisited, as were three other similar habitats. Few dead organisms were observed in the Spring survey, suggesting that the mortalities observed in 1989 could have been oil-related or oxygen-related. Examination of the

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1990 samples revealed greater disturbance than observed in 1989. Low values for diversity, richness, evenness and biomass, with a corresponding high dominance value reflected gross disturbance. A more extensive survey of silled fjord habitats was completed in Fall 1990, and will provide additional data to assess the possible role of seasonal anoxia as a cause of disturbance. Therefore, until we obtain and integrate results of oxygen data and hydrocarbon analysis, we are unable to determine the exact sources of disturbance.

In eelgrass habitats, there was a consistent trend to lower density of eelgrass at oiled sites, although individual paired comparisons were not significant. There also was a similar, but weaker, trend to lower density of flowering turions and spathes at oiled sites. Among large epibenthic invertebrates, there were no patterns associated with oiled sites, with the exception of the crab *Telmessus*, which showed depressed densities. No data on infauna are yet available. Fishes tended to be less abundant at the control sites. This difference was due almost entirely to a non-significant, but persistent, trend to higher densities of young-of-the-year Pacific cod at oiled eelgrass sites. Densities of other fishes were similar between oiled and control paired sites.

In *Laminaria/Agarum* bay habitats, there was little difference in density or percent cover of algae, including the dominant *Agarum* and *Laminaria* species. Large epibenthic invertebrates were also similar between oiled and control paired sites; however, the crab *Telmessus* again displayed a consistent trend to lower density in oiled sites. No data on infauna are yet available. Fishes tended to occur at higher density at oiled sites. In the deep stratum (9-20 m) the trend was due principally to a group of small sculpin species; whereas in the shallow stratum, the pattern was due to significantly higher densities of arctic shanny at two or three oil/control site pairs.

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2. GENERAL INTRODUCTION

The purpose of the Coastal Habitat Injury Assessment Study is to document and quantify injuries to biological resources found in the shallow subtidal, intertidal, and supratidal zones throughout the shoreline areas affected by the *Exxon Valdez* oil spill.

Study sites were selected and ground-truthed during Phase I. Work conducted in Phase I is discussed in Chapter 3 of this report. Phase II of the project is an intensive evaluation of the study sites to determine the extent of injury to natural resources. The objective of this study is to estimate the effects of oiling on the quantity (abundance and biomass), quality (reproductive condition and growth rate), and composition (diversity and proportions of populations) of key species in the critical trophic levels of coastal biological communities. The study was carried out in three major coastal regions, Prince William Sound, Lower Cook Inlet/Kenai Peninsula, and Kodiak/Alaska Peninsula. The subtidal work (to 20 m depth) was only conducted in Prince William Sound and, in 1990, the supratidal work (above MHHW) was limited to locations in the Kodiak/Alaska Peninsula region. In addition to the broad examination of intertidal habitats impacted by the oil spill, a field station was established in Herring Bay, Knight Island (PWS), to allow focused studies on the impact of oil on various components of the intertidal flora and fauna. To conduct this work, a barge with living quarters and laboratory space was chartered. One of the studies to be conducted was a comparison of oiled, untreated (set-asides) sheltered rocky sites with oiled, treated sites. Unfortunately, the set-asides in Herring Bay were not correctly categorized (by Exxon or Exxon contractors) and the sites were not heavily oiled, so this aspect of the plan could not be carried out. The other experimental studies in Herring Bay have been successful and preliminary results are provided in the Intertidal Section of this report.

It should be clearly noted that this is a preliminary report intended to provide information on the progress of the study and to indicate possible trends revealed by initial sample processing and data analyses. As the field season ended just two months before submission of this report, a large majority of the samples and data remain to be analyzed. In particular, it should be noted that a great deal of information on recruitment remains to be extracted from photographs of numerous cleared plots at all of the study sites. These data will contribute to our understanding of recovery rates and processes.

The report is organized according to the major elements of the study: site selection, supratidal, intertidal and subtidal. Each section was written by the principal investigator(s) primarily responsible for that portion of the work which, given the brief time available for editing, has resulted in some variability in writing style between sections. Finally, a report (Borstad, Kerr and Hill) on the potential use of airborne spectrographic imaging to determine algal cover on beaches is included as Appendix V.

3.0 SITE SELECTION

Summary

Ninety-seven study sites comprised of 59 sites retained from 1989 and 38 sites added in 1990 were selected for the intertidal component of the Coastal Habitat Injury Assessment (CHIA). These study sites are representative the broad range of coastal habitat types, oiling characteristics, and clean-up techniques found in the spill area.

Control sites were carefully paired with oiled sites to closely match physical and biological characteristics while maintaining a statistically valid site selection strategy. The current site selection scheme will strengthen the ability of the CHIA to detect EVOS injuries while maintaining the ability to extrapolate these results to the universe of other oiled shorelines. However, the current suite of study sites remains at the minimum necessary to perform this extrapolation.

Objectives

1. To maintain a statistically valid study site selection strategy and identify additional study sites using existing map-based coastal habitat and oil impact classification schemes.

2. To ground-truth potential study sites to evaluate map-based habitat and oil impact classifications.

3. To describe and mark approximately 45 study sites in addition to the 57 sites that have been identified for comprehensive sampling in 1990.

Introduction

The purpose of the Coastal Habitat Injury Assessment (CHIA) is to document and quantify injuries to biological resources found in the shallow subtidal, intertidal, and supratidal zones throughout the shoreline areas affected by the *Exxon Valdez* Oil Spill (EVOS). In 1989, the selection of basic experimental units (study sites) for the CHIA was accomplished using a stratified random sample with probability proportional to size. Following ground truthing surveys, 111 study sites consisting of 74 oiled sites in the very light/light and moderate/heavy oiling categories and 37 non-oiled control sites were selected. The study sites were distributed among five coastal habitat categories[1] in three geographical regions[2].

Sampling of these study sites in 1989 by the CHIA investigators revealed several problems. First, the method of randomly selecting controls had included some sites in the study (mostly located on the mainland) which had dissimilar physical and biological characteristics to the oiled sites (mostly located on islands). This made it difficult to detect injuries caused by EVOS because the natural variance between oiled sites and control sites would mask differences in biomass and species diversity that could otherwise be attributed to the spill. Additionally, it was found that sampling methods could not detect significant injuries on very light or lightly oiled sites. Based on this and other information, the Management Team recommended several changes to the site selection process in 1990:

1. Control sites should be paired with oiled sites to more closely match their physical and biological characteristics.

2. Additional deductively selected oiled sites should be added to provide information in habitat categories where there was a deficit of inductively selected study sites.

3. Sites in the very light/light oiled category should be dropped from the study to allow resources and effort to be devoted to moderate/heavy oiled and control sites.

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[1]The five habitat categories are: 1) exposed rocky shores, 2) fine textured beaches, 3) coarse textured beaches, 4) sheltered rocky shores, and 5) sheltered estuarine shores.

[2]The three geographical regions are: 1) Prince William Sound (PWS), 2) Cook Inlet and Kenai Peninsula (CIK), and 3) Kodiak and Alaska Peninsula (KAP).

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Additionally, it was agreed that the supratidal and subtidal assessment components of the CHIA should adopt their own site selection process in 1990. This report summarizes the site selection process for the intertidal component of the CHIA.

Site Selection Team

The 1990 CHIA site selection team consisted of Kimbal Sundberg, Alaska Department of Fish and Game; Lawrence Deysher, Coastal Resources Associates; and Peter Ribbons, University of Alaska - Fairbanks. Assistance with locating and surveying National Park Service study sites was provided by Kathy Ann Miller, University of California - Berkeley and Douglas Houston, National Park Service - Olympic National Park. Lyman McDonald and Dale Strickland, University of Wyoming and Raymond Highsmith, University of Alaska - Fairbanks assisted with pairing 1989 oiled and control sites and with reviewing the site selection methodology. In addition, Dr. McDonald participated in the initial site selection surveys.

Methods

The methodology for study site selection in 1990 included procedures for pairing control sites with existing randomly selected oiled sites and procedures for selecting additional oiled and paired control sites. Each randomly selected oiled site was first characterized with respect to its physical characteristics and secondarily with respect to its biological characteristics. The physical characters of most concern were: 1) substrate composition, 2) wave exposure, 3) beach slope, 4) proximity to sources of fresh water, and 5) nearshore bathymetry. Biological characters included general indicators of community composition such as presence of mussel beds, algal beds, gastropods, and barnacles. Oiled sites were characterized using site photographs, diagrams, and field notes from the 1989 Phase I surveys, U.S Geological Survey (USGS) topographic maps, NOAA charts, and the Environmental Sensitivity Index (ESI) maps.

Control Sites

The first sites to be considered for potential controls were the group of control sites sampled during the 1989 CHIA Phase II program. The next group of potential controls were sites surveyed and marked during the 1989 Phase I program but not sampled during Phase II. When suitable controls could not be found from these two groups, we consulted the Damage Assessment Geoprocessing Group (GEO) combined ESI and oiling maps produced in July, 1989. From these maps we selected approximately five potential controls in closest proximity to the oiled site that had been classified as non-oiled or very lightly oiled. Reference was made to the September, 1989 ADEC Post-Treatment Shoreline Oiling Assessment ("walkathon") and other available shoreline oiling assessment information to determine the oiling history of potential sites. If the site had been classified at any time with oiling greater than very light, it was rejected from further consideration as a control. In most cases, sites classified as very light oiling have received only a few small spots of oil or occasional tar balls.

The list of potential sites was then prioritized according to distance from the oiled site with the closest site receiving the highest priority.

During the site selection surveys, which were conducted at low tide, we first visited the oiled site for which a control site needed to be chosen. During this initial visit we inventoried the site characteristics and checked that these parameters matched those described from previous surveys. We then began the survey of the potential control sites produced from the mapped data, working down the priority list of potential controls until a suitable site was chosen.

Each potential control was surveyed from a helicopter to determine its suitability with regard to the physical characteristics. Sites that appeared to be suitable from the air, were subjected to a more detailed ground survey. This ground survey involved evaluating the physical and biological characteristics and searching for signs of oiling. A determination of accessibility for intertidal sampling was also made following the criteria used in 1989. Sites that could not be safely accessed were rejected. Suitable sites were measured, photographed, and marked following the methods used in 1989. An attempt was made to measure control site lengths equal to the paired oiled site, but in all cases, a minimum of 100 meters of comparable habitat was marked.

Oiled Sites

Additional moderate/heavy oiled sites and respective controls were sought for habitat categories which had less than four replicate pairs of study sites per region. A list of potential oiled sites was created by reviewing the walkathon surveys, ESI maps, 1989 field notes and photographs, ADEC segment inspection records, and discussions with agency spill response and monitoring personnel. In the CIK region, particular attention was given to including oiled study sites that were occupied by University of Washington (UW) and University of California - Berkeley (UC-B) intertidal biologists under contract to the NPS in 1989. In the KAP region, particular attention was given to including sites occupied in 1989 by NPS intertidal biologists. These sites were included because of the opportunities to incorporate additional 1989 data into the CHIA and to ensure that these sites would continue to be studied in 1990.

Aerial and ground surveys were conducted at potential oiled sites to confirm the habitat and oiling classifications and to inventory site characteristics. Sites that did not fit the required habitat and oiling classifications were dropped from consideration. Sites that fit were measured and marked to include a minimum of 100 meters of suitable habitat. Controls were selected using the same methods described previously for control sites.

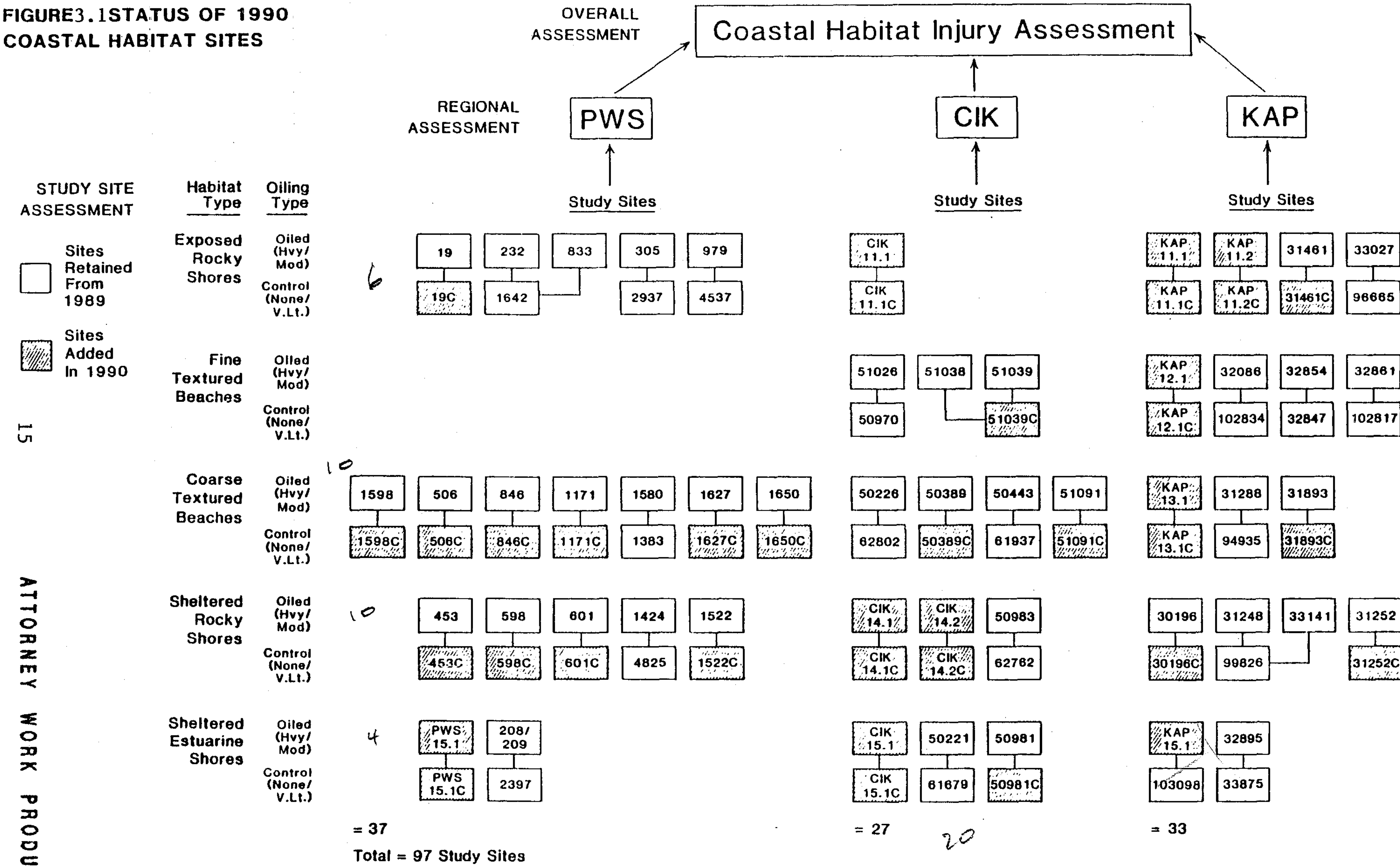
Results

Table 3.1 and Figure 3.1 summarize the results of the 1990 CHIA site selection. Following the pairing of previously selected oiled and control sites using information obtained during 1989 CHIA Phase I and Phase II surveys, 20 additional oiled sites and 40 additional control sites were determined to be needed to meet the goals of the study design. After characterizing and mapping 151 potential oiled and control sites, field surveys were begun in PWS on 23 April during a spring tide series. Surveys proceeded from east to west, pausing during the neap tide periods, and were completed on 11 June in the KAP region. Upland land owners were contacted and

Table 3.1 Summary of 1990 Coastal Habitat Site Selection

REGION	SITES NEEDED		POTENTIAL SITES		SITES SURVEYED		SITES SELECTED		SITES REMOVED	
	OIL	CONTROL	OIL	CONTROL	OIL	CONTROL	OIL	CONTROL	OIL	CONTROL
PWS	3	14	3	69	3	47	1	12	9	7
CIK	10	14	5	27	5	19	4	8	7	5
KAP	7	12	6	41	5	22	5	9	18	7
SUBTOTAL	20	40	14	137	13	88	10	29	34	19
TOTAL	60		151		101		39		53	

FIGURE3.1STATUS OF 1990 COASTAL HABITAT SITES



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land use permits were obtained for authorization to land helicopters or to place site markings. The following are highlights of these site selection surveys:

Prince William Sound

Controls were selected for one exposed rocky site, six coarse textured sites, four sheltered rocky sites, and one sheltered estuary site. Control site 1642 was found to be a suitable pair for both oiled sites 232 and 833.

Three potential oiled estuary sites were identified and surveyed. Of these, two estuary sites were rejected because they were found to be very-lightly oiled. The one estuary site that was selected (Site PWS15.1, Bay of Isles) was found to be heavily oiled from the supratidal fringe through the lower intertidal zone.

Cook Inlet and Kenai Peninsula

Controls were selected for one exposed rocky site, two fine textured sites, two coarse textured sites, two sheltered rocky sites, and two sheltered estuary sites. Control site 51039C was found to be a suitable pair for both oiled sites 51038 and 51039.

One potential oiled exposed rocky site was identified and surveyed. This site was selected after being found to be heavily oiled in the upper to mid-intertidal zone.

Four potential oiled sheltered rocky sites, which were occupied by UC-B and UW biologists in 1989, were identified and surveyed. Of these, two sites were rejected because they were found to be lightly oiled. The two remaining sites were selected after being found to be heavily oiled in the upper to mid-intertidal zone.

One potential oiled sheltered estuary site was identified and surveyed. This site was selected after being found to be moderately oiled in the upper intertidal zone.

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Kodiak and Alaska Peninsula

Controls were selected for three exposed rocky sites, one fine textured site, two coarse textured sites, two sheltered rocky sites, and one sheltered estuary site. Control site 99826 was found to be a suitable pair for both oiled sites 31248 and 33141.

Two potential oiled exposed rocky sites, which were occupied by NPS biologists in 1989, were identified and surveyed. These sites were selected after both were found to be moderately oiled with weathered tar and mousse in the upper to mid-intertidal zone.

One potential oiled fine textured site, which was occupied by NPS biologists in 1989, was identified and surveyed. Although no oil was observed during the survey, the site was selected based on NPS information that the site had been heavily oiled in 1989.

Two potential oiled coarse textured sites, which were occupied by NPS biologists in 1989, were identified and surveyed. One site was rejected because we were unable to obtain an NPS permit to survey the site because of concerns about disturbing an adjacent seabird colony. The other site was selected after finding moderate to heavy oiling in the upper to mid-intertidal zone.

One potential oiled sheltered estuary was identified and surveyed. The site was selected after finding moderate oiling in the upper intertidal zone and oily sheens in the soft sediments on the tidal flats.

Site Marker Removal

Site markers were removed from 53 very light/light oiled and control sites that were selected in 1989 but were dropped from the CHIA in 1990. Paint markings on rocks were removed using a propane torch and wire brush.

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Status of Injury Assessment

Substantial progress was made in meeting the objectives of the study plan. Appendix I contains additional information on the 97 study sites that were selected. These study sites are representative of the broad range of intertidal habitat types, oiling characteristics, and clean-up techniques found in the spill area.

The process of pairing of control sites with oiled sites was substantially completed. Preliminary indications from the 1990 CHIA sampling data suggests that good matches were obtained for most pairs. The current site selection scheme should strengthen the ability of the CHIA to detect EVOS injuries while maintaining the ability to extrapolate these results to the universe of other oiled shorelines. However, the current suite of study sites remains at the minimum necessary to perform this extrapolation.

The addition of 10 deductively selected oiled sites and their associated paired controls should provide important additional information on EVOS injuries in habitat categories that were previously deficient in inductively (randomly) selected sites. However, this information cannot be used in the extrapolation. Considerable effort was made this year to identify and field survey all possible oiled sites in deficient habitat categories. Despite these efforts, study site deficiencies remain in PWS (sheltered estuaries), CIK (exposed rocky, fine textured, sheltered rocky, and sheltered estuaries), and KAP (coarse textured, and sheltered estuaries).

Eleven more moderate/heavy oiled sites in the deficient habitat categories would need to be identified, surveyed, and selected to eliminate this deficit; a goal that is probably not achievable. Certain habitat categories are naturally scarce in the spill area (e.g., sheltered estuaries and fine textured beaches) and heavy/moderate oiled sites in scarce habitats are more scarce. In addition, some oiled sites cannot be accessed for sampling because they are unsafe (e.g., most exposed rocky shores in CIK) or access has been determined by land managers to be incompatible with other resource values (e.g., seabird colonies). Unless it can be clearly demonstrated that additional sites will benefit the objectives of the CHIA, we do not recommend adding new sites in 1991. However, several adjustments in the pairing of control sites may be still be needed after reviewing the 1990 sampling data.

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4.0 SUPRATIDAL

Summary

In general, total production of plant material was lower at oiled sites in some zones of the supratidal than at corresponding control sites. The trend of lower production on oiled sites with respect to matched controls was observed for *Elymus*, the dominant plant in some zones of the supratidal, and also for forb vegetation, in zones 4-6 of fine textured beaches. Two matched estuary pairs also exhibited lower production on the oiled sites with respect to corresponding control sites. The consistent pattern of higher production at control sites relative to oiled sites suggests the possibility of oil related impact.

Objectives

1. To determine changes in vegetation production in the supratidal zone of oiled and unoiled beaches in the Kodiak-Alaska Peninsula region.
2. To determine changes in forage quality of vegetation, as measured by nutrient content and *in vitro* digestibility.
3. To measure an microbial activity in the soils of oiled and unoiled beaches.
4. To measure hydrocarbon concentrations in the soils of oiled and unoiled beaches.

Sampling Effort

In 1990, supratidal sampling was limited to the Kodiak-Alaska Peninsula (KAP) region. The IAB field crew sampled paired sites in three habitat types: fine-textured, coarse-textured and estuarine (Table 4.1). Fine-textured and estuarine sites were sampled twice for biomass, at dates corresponding to mid and late season for vegetation growth. The first harvest was done at a time when many of the plants were just beginning to senesce, and the data from this time is therefore the best available estimate of seasonal productivity. The second harvest was done late in the

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Table 4.1. Sites visited in 1990 for supratidal sampling.

Oiled Site	Control Site	Habitat	Sampling Periods
32961	102817	Fine	Both
32086	102834	Fine	Both*
32854	32847	Fine	Both
KAP12.1	KAP12.1C	Fine	Both
31288	94935	Coarse	Peak only
31893	31893C	Coarse	Peak only
KAP13.1	KAP13.1C	Coarse	Peak only
32895	33875	Estuarine	Both
KAP15.1	KAP15.1C	Estuarine	Both

*(Site 102834 visited Peak only)

season to provide a comparison with the 1989 field sampling. Coarse-textured sites were sampled only during peak season. Soil cores were collected from each vegetation zone for analyses of soil microbial activity and of hydrocarbon concentrations.

At each site visited, the intertidal transects described in the preceding section were extended into the supratidal stratum. Vegetation zones were identified using a classification system of 14 categories based on 1989 field observations (Table 4.2). Quadrats were placed in a zone whenever vascular vegetation was present along the transect. 70% of the quadrats collected at peak season and 80% of the quadrats collected late in the season contained vascular plant tissue. Supratidal vegetation sampling activity is summarized in Table 4.3.

Plant samples from each quadrat were sorted into the species and tissue categories illustrated in Figure 4.1. Each sample provided 2-6 subsamples for further analysis. These subsamples were subsequently dried and weighed to determine biomass per meter^2. Seven vegetation zones were identified for cross-site comparison of biomass categories (Table 4.4). Zones 4 and 6 were the most commonly encountered, representing 31.8 and 23.4% of the total number of quadrats respectively.

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TABLE 4.2 SUPRATIDAL VEGETATION ZONE CLASSIFICATION 1990

ZONE #	VEGETATION TYPE
0	Bare Sediment (entire zone). Includes sand/gravel bars in sites cut by streams.
1	Pioneer - scattered seedlings (usually *Honckenya*) near mean high water, that may or may not survive winter storms or highest tides.
2	*Honckenya peploides* in clumps or solid band.
3	Dominated by mixed forbs other than Honckenya, e.g. *Lathyrus* (beach pea) or *Senecio*.
4	Driftwood intermixed with *Elymus* and/or forbs.
5	*Elymus* (with little or no other type of vegetation present).
6	*Elymus* intermixed with considerable amounts (>33%) of other types of vegetation.
* 7	Other graminoides (grasses) such as *Deschampia* sp. and *Calamagrostis* sp. Found at back of beach, upper reaches of estuaries or on storm berms.
* 8	*Puccinellia*, *Triglochin* (arrowgrass) and/or *Plantago* (goosetongue). These species often occur together near MHW on beaches with considerable freshwater influence or on rocky ledges in the splash zone.
* 9	*Carex* species (pure or nearly pure stands).
10	*Carex* mixed with other graminoides or forbs.
*11	Other halophytic vegetation, e.g. *Cochlearia, Glaux or Spergularia*.
*12	Other. Site described in field notes.
*13	Intertidal vegetation. List species on logsheet.

* = Zones not encountered on 1990 supratidal transects

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Table 4.3. Summary of supratidal vegetation sample collection KAP region.

	Sites	Transects	Quadrats	Vegetation Samples
FIRST HARVEST				
Fine	8	48	321	197
Coarse	6	32	32	31
Estuarine	4	24	91	81
SECOND HARVEST				
Fine	7	42	407	308
Estuarine	4	24	140	133

In this report we present only biomass data from the first harvest. Analyses still to be completed include analyzing the plant samples for nutrient content and forage quality (*in vitro* digestibility). Because these are the analyses required to examine sub-lethal effects of oiling, we are presently only able to examine lethal effects. The soil and hydrocarbon analyses are also not yet complete.

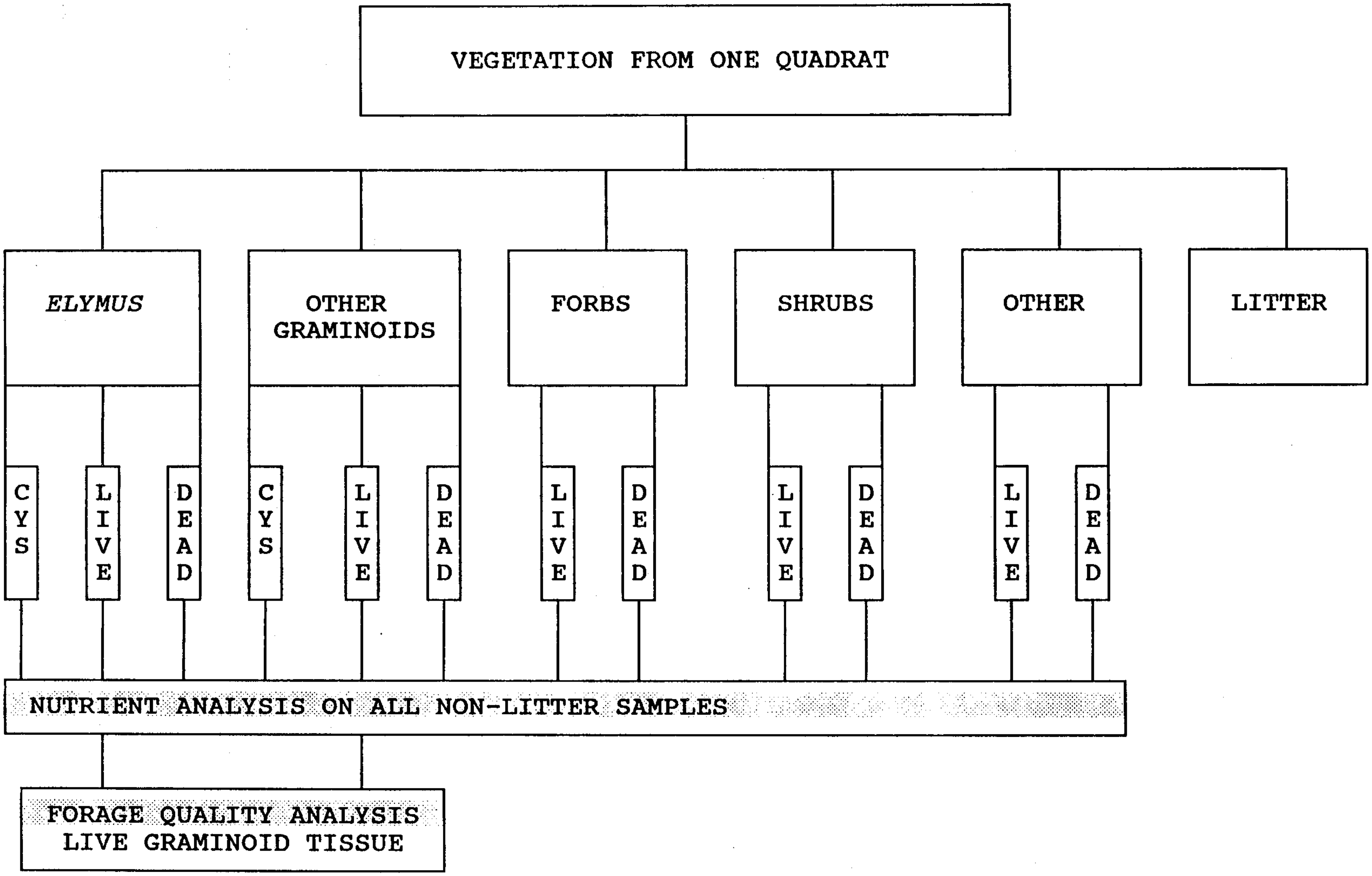
Results

The matched site pairs were selected based on their intertidal characteristics. As a result the supratidal vegetation zones do not always match well; there are many cases where vegetation zones found on one site of a pair are not found on the other pair. This reduces the number of useful pairs for statistical analyses.

Data are presented for the total estimated production of several specific species or plant groups, and for the total plant production per meter^2 within each vegetation zone. Production was estimated by adding live, current year senescence, and current year dead material.

On fine textured beaches the general pattern suggests that oiling reduced plant productivity. Figures 4.2 and 4.3 show total estimated production and *Elymus* production in zones 4-6 (the dominant zones) of fine textured beaches. The great majority of the biomass in zones 4-6 is comprised of *Elymus*, except on site 32847 in zone 4, where there was a large biomass of forbs. In zones 4-6 there were seven cases

FIGURE 4.1 SUPRATIDAL BIOMASS SAMPLE PROCESSING



CYS = Current Year Senescence

Table 4.4. Vegetation zones chosen for cross-site comparisons.

Vegetation Zone	No. Quadrats	% of Total
1	64	14.4
2	25	5.6
3	6	1.4
4	141	31.8
5	52	11.7
6	104	23.4
10	52	11.7

Sample Processing and Data Analysis to date

where we had matching data from the oiled and control sites. In six of these cases the control sites showed higher productivity than the oiled sites.

Examining forb production in vegetation zones 4-6 (Fig. 4.4), the same pattern is apparent; production is consistently lower on the oiled site than in its paired control.

In the *Honckenya* zone (zone 2) on fine textured beaches, there was only one matched pair (site KAP12.1), and it showed much lower total plant production on the oiled beach (Fig. 4.5). Such a large apparent reduction raises the possibility that on site 32854 (site C on Fig. 4.4), plants were completely eliminated from vegetation zone 2, converting it to barren ground and making comparison impossible.

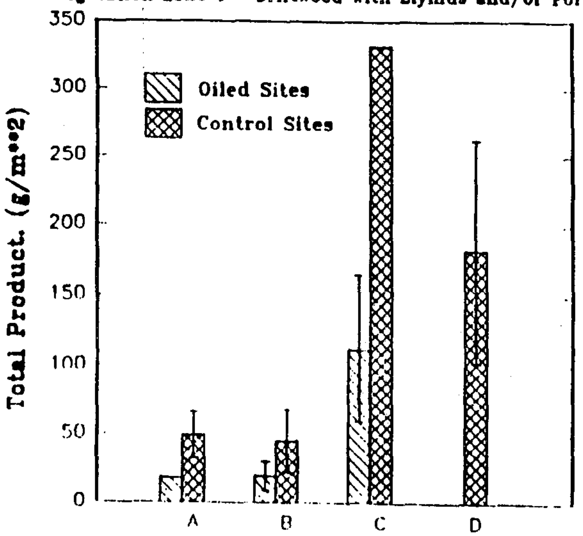
The consistent pattern of greater production on control vs. oiled sites suggests that oiling reduced plant productivity on fine textured beaches. However, the limited number of sites with adequate matching of oiled and control vegetation zones makes it hard to draw strong conclusions from these data without more sophisticated statistical analyses.

On Estuarine sites, there were only two pairs of sites studied. There were few vegetation zone matches on these sites to allow comparison of vegetative production. In the two cases where control and oiled sites had matching vegetation zones, the control site had greater estimated production (Fig. 4.6), supporting the pattern observed on fine textured beaches, but the data are inadequate to draw meaningful conclusions from them.

Fig. 4.2

Kodiak – AK Peninsula
Habitat Type 2 (Fine – Textured)

Vegetation Zone 4 – Driftwood with Elymus and/or Forbs

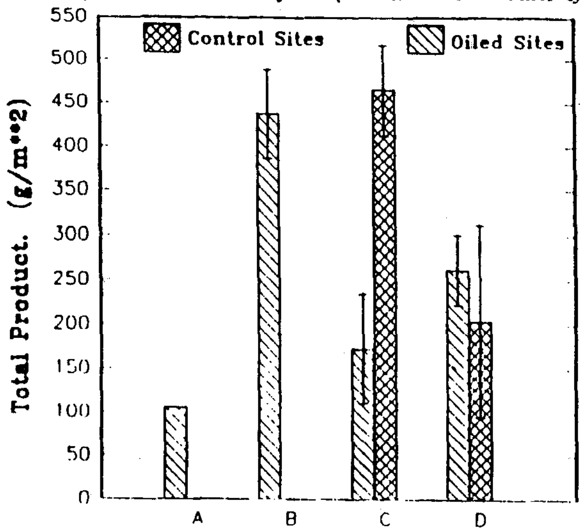


Paired Sites

Pair	Type	Site	Location
A.	Oil	32861	N. Puale Bay
A.	Cont	102817	N. of Yantarni Bay
B.	Oil	32086	Katmai Bay
B	Cont	102834	N. of Yantarni Bay
C.	Oil	32854	N. Puale Bay
C.	Cont	32847	N. Puale Bay
D	Oil	KAP12.1	Kaguyak **
D	Cont	KAP12.1C	N. Dakavak Bay

* No live vegetation collected in Zone
** Vegetation Zone not present at site

Vegetation Zone 5 – Elymus (with little or no other type)

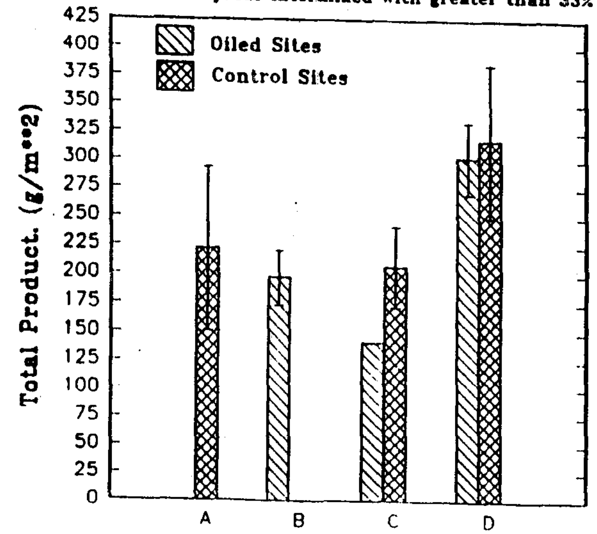


Paired Sites

Pair	Type	Site	Location
A.	Oil	32861	N. Puale Bay
A	Cont	102817	N of Yantarni Bay*
B.	Oil	32086	Katmai Bay
B.	Cont	102834	N of Yantarni Bay*
C.	Oil	32854	N. Puale Bay
C.	Cont	32847	N. Puale Bay
D.	Oil	KAP12.1	Kaguyak
D	Cont	KAP12.1C	N. Dakavak Bay

* No vegetationcollected in Zone
** Vegetation Zone not present at site

Vegetation Zone 6 – Elymus intermixed with greater than 33% other type



Paired Sites

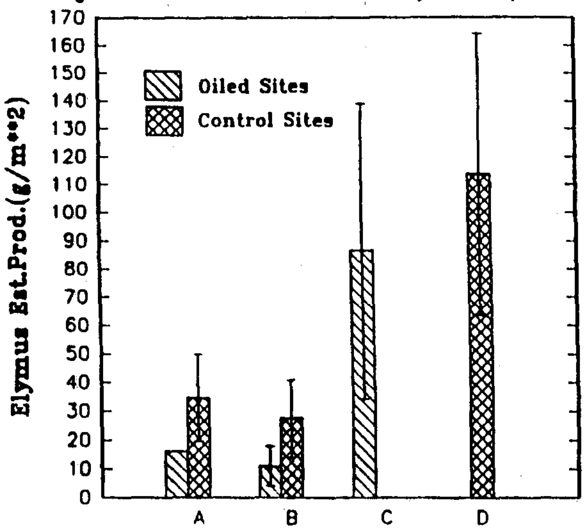
Pair	Type	Site	Location
A.	Oil	32861	N. Puale Bay **
A.	Cont	102817	N of Yantarni Bay
B.	Oil	32086	Katmai Bay
B.	Cont	102834	N of Yantarni Bay*
C.	Oil	32854	N. Puale Bay
C.	Cont	32847	N. Puale Bay
D.	Oil	KAP12.1	Kaguyak
D.	Cont	KAP12.1C	N. Dakavak Bay

* No live vegetation collected in Zone
** Vegetation Zone not present at site

Fig. 4.3

Kodiak - AK Peninsula
Habitat Type 2 (Fine - Textured)

Vegetation Zone 4 - Driftwood with Elymus and/or Forbs

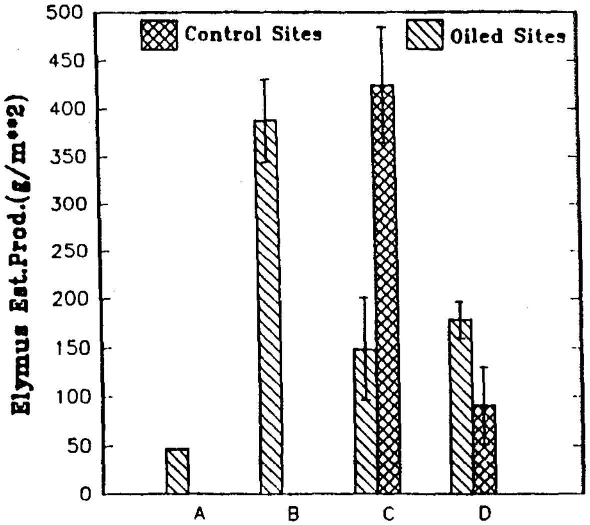


Paired Sites

Pair	Type	Site	Location
A.	Oil	32861	N. Puale Bay
A.	Cont	102817	N. of Yantarni Bay
B.	Oil	32086	Katmai Bay
B.	Cont	102834	N. of Yantarni Bay
C.	Oil	32854	N. Puale Bay
C.	Cont	32847	N. Puale Bay *
D.	Oil	KAP12.1	Kaguyak **
D.	Cont	KAP12.1C	N. Dakavak Bay

* No Elymus collected in Zone
** Vegetation Zone not present at site

Vegetation Zone 5 - Elymus (with little or no other type)

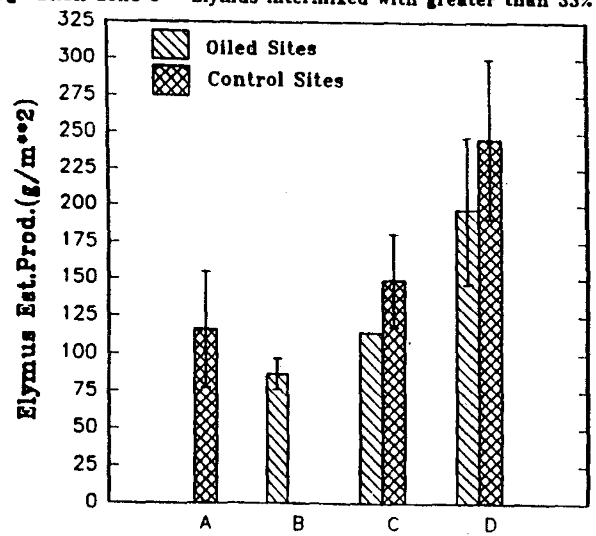


Paired Sites

Pair	Type	Site	Location
A.	Oil	32861	N. Puale Bay
A.	Cont	102817	N of Yantarni Bay*
B.	Oil	32086	Katmai Bay
B.	Cont	102834	N of Yantarni Bay*
C.	Oil	32854	N. Puale Bay
C.	Cont	32847	N. Puale Bay
D.	Oil	KAP12.1	Kaguyak
D.	Cont	KAP12.1C	N. Dakavak Bay

* No Elymus collected in Zone
** Vegetation Zone not present at site

Vegetation Zone 6 - Elymus intermixed with greater than 33% other type



Paired Sites

Pair	Type	Site	Location
A.	Oil	32861	N. Puale Bay **
A.	Cont	102817	N of Yantarni Bay
B.	Oil	32086	Katmai Bay
B.	Cont	102834	N of Yantarni Bay*
C.	Oil	32854	N. Puale Bay
C.	Cont	32847	N. Puale Bay
D.	Oil	KAP12.1	Kaguyak
D	Cont	KAP12.1C	N. Dakavak Bay

* No Elymus collected in Zone
** Vegetation Zone not present at site

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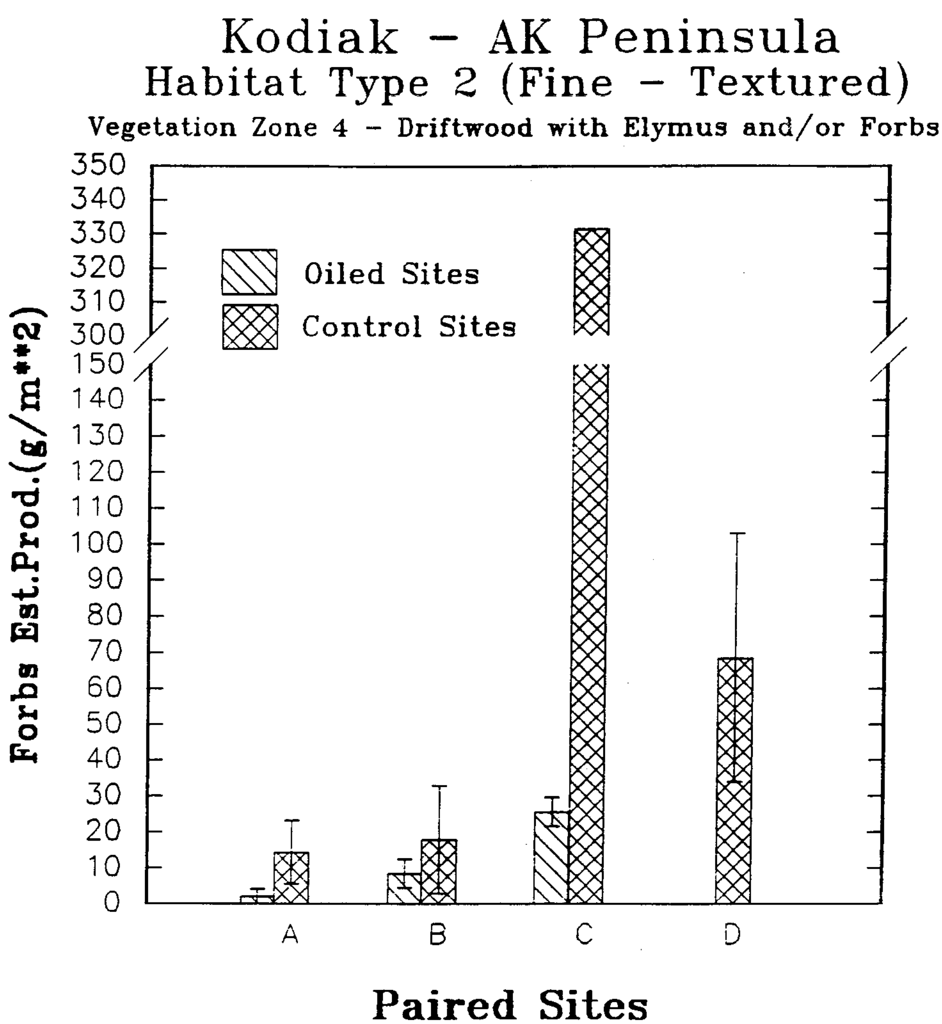
Fig. 4.4



Paired Sites

Pair	Type	Site	Location
A.	Oil	32861	N. Puale Bay
A.	Cont	102817	N. of Yantarni Bay
B.	Oil	32086	Katmai Bay
B.	Cont	102834	N. of Yantarni Bay
C.	Oil	32854	N. Puale Bay
C.	Cont	32847	N. Puale Bay
D.	Oil	KAP12.1	Kaguyak **
D.	Cont	KAP12.1C	N. Dakavak Bay

* No Forbs collected in Zone

** Vegetation Zone not present at site

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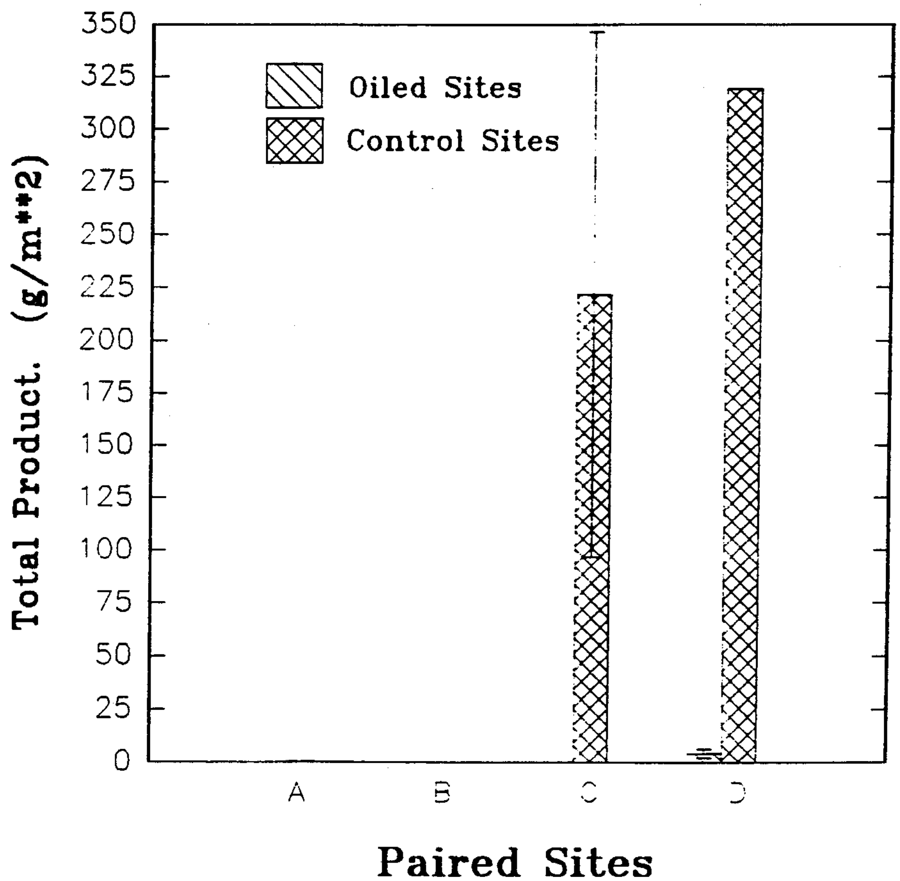
Fig. 4.5

Kodiak – AK Peninsula
Habitat Type 2 (Fine – Textured)
Vegetation Zone 2 – Honckenya Peploides in clumps or solid brand



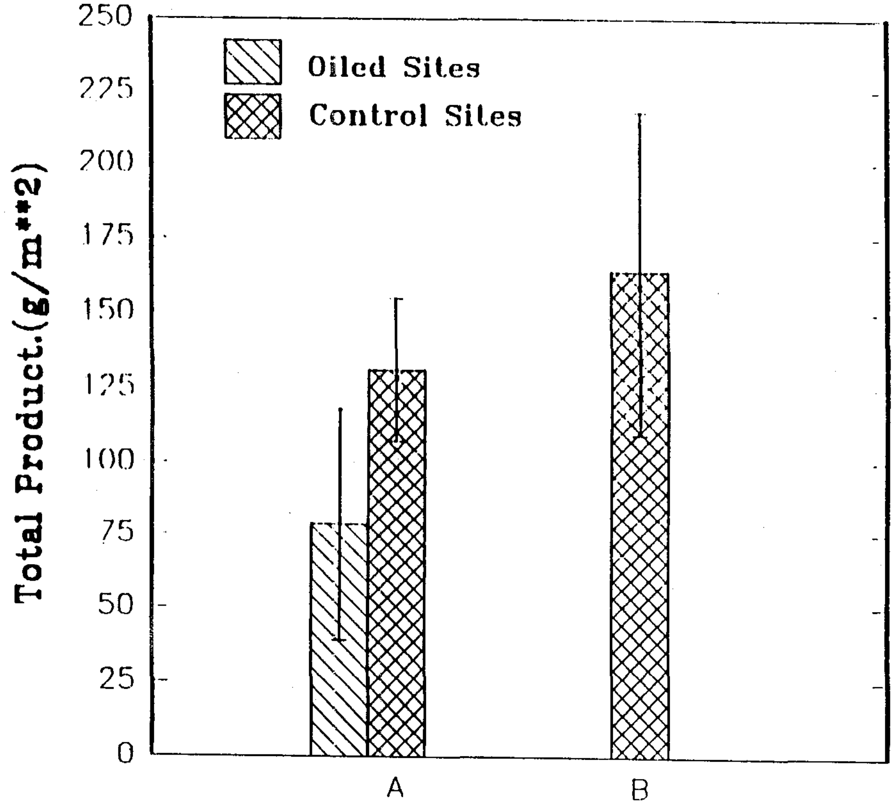
Pair	Type	Site	Location
A.	Oil	32861	N. Puale Bay **
A.	Cont	102817	N. of Yantarni Bay*
B.	Oil	32086	Katmai Bay **
B.	Cont	102834	N. of Yantarni Bay*
C.	Oil	32854	N. Puale Bay **
C.	Cont	32847	N. Puale Bay
D.	Oil	KAP12.1	Kaguyak
D.	Cont	KAP12.1C	N. Dakavak Bay

* No vegetation collected in Zone
** Vegetation Zone not present at site

Fig. 4.6

Kodiak – AK Peninsula
Habitat Type 5 – Estuarine

Vegetation Zone 4 – Driftwood with Elymus and/or Forbs

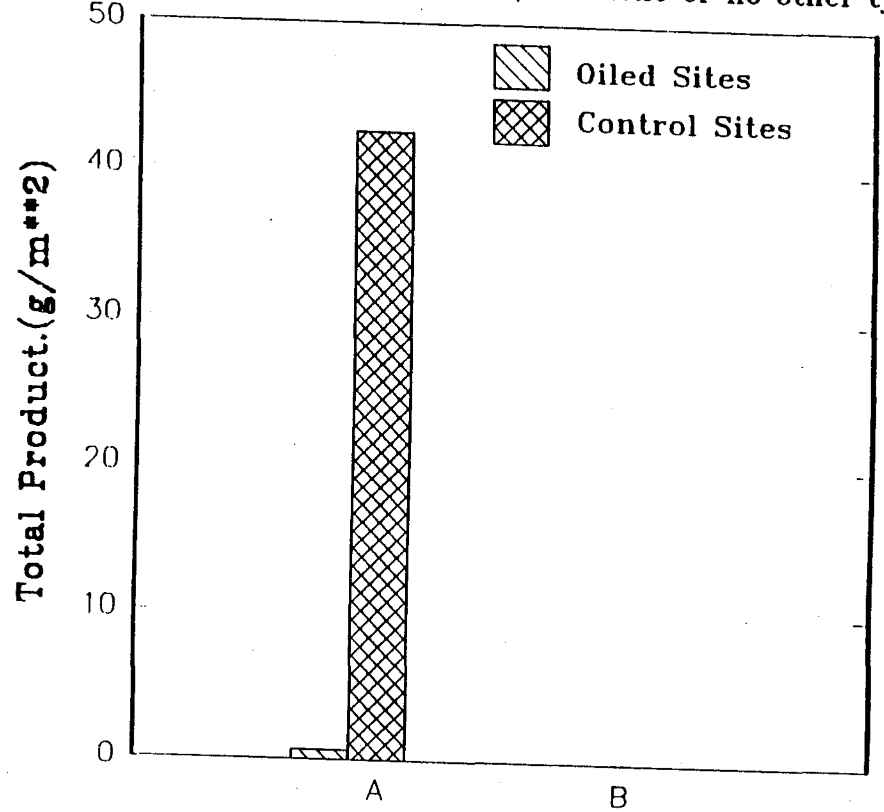


Paired Sites

Pair	Type	Site	Location
A.	Oil	32895	N. Puale Bay
A.	Cont	33875	W. Yantarni Bay
B.	Oil	KAP15.1	Chiniak Lagoon **
B.	Cont	KAP15.1C	Tugidak Lagoon

* No vegetation collected in Zone
** Vegetation Zone not present at site

Vegetation Zone 5 – Elymus (with little or no other type



Paired Sites

Pair	Type	Site	Location
A.	Oil	32895	N. Puale Bay
A.	Cont	33875	W. Yantarni Bay
B.	Oil	KAP15.1	Chiniak Lagoon **
B.	Cont	KAP15.1C	Tugidak Lagoon**

* No Elymus collected in Zone
** Vegetation Zone not present at site

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These results appear to contradict last years results for Prince William Sound, which suggested that *Elymus* production was higher in oiled than unoiled sites. In retrospect it seems likely that this effect was due to the poor match between oiled and control sites in PWS that was noted in the intertidal studies.

5.0 INTERTIDAL

5.1 INVERTEBRATES

Summary

Preliminary analysis of 1989 quadrat data for sheltered rocky beaches indicates that densities of barnacles, limpets, amphipods, isopods, oligochaetes and nematodes may have been higher in the first meter drop of the control sites than on the corresponding oiled sites. Densities of limpets during 1990, as measured by the semicircle technique, were significantly higher on the first meter drop of the sheltered rocky and coarse textured control sites than on the corresponding oiled sites. Mussels appeared to be more concentrated in the second and third meter drops on the control sites as compared with the oiled sites. *Fucus* densities may also be reduced in the upper portions of sheltered rocky beaches that were oiled. As a great deal of material remains to be analyzed, final conclusions cannot be drawn at this time.

Introduction

Intertidal invertebrate samples were collected from five habitat types in three regions thought to have been impacted by oil. The regions include Prince William Sound, Cook Inlet - Kenai Peninsula and Kodiak Island - Alaska Peninsula. Samples were collected in sheltered rocky, exposed rocky, coarse textured, fine textured and sheltered estuary habitats. The sampling was designed to estimate population densities and biomass of major invertebrate taxa on oiled sites and compare the results with corresponding data from control sites, where oil was absent. The aim of this procedure is to document any damage to invertebrate populations and biomass which may have resulted from the oil and subsequent attempts at cleaning and bioremediation.

Methods

The methods for collection and processing of the data are covered in detail in the approved study plan and the methods were followed throughout the study. Essentially, six 0.1-m^2 quadrat samples were collected at each of four 1-m drops on the beaches. In addition, semicircle data were collected at each quadrat. The semicircle data basically consisted of a distance measure to the nearest mussel, limpet or *Fucus* plant and an index of density was calculated for each taxon in each of the four meter drops. The semicircle data in each meter drop were subjected to sign tests and Wilcoxon matched pairs tests and summarized in tables.

Results

The quadrat data are primarily for sheltered rocky habitat, which was given the highest priority for sorting and analysis. Rocky habitats tend to be a patchwork of numerous microhabitats, resulting from physical variables such as degree of exposure to wind, sunlight, winter icing, substrate relief, presence of cracks and crevices, steepness of slope, presence of flotsam on the beach, and current velocities when the habitat is submerged. In addition, biological factors such as the degree of algal cover and the species composition of the algae can have substantial influences on the invertebrate fauna. Nonetheless, the some specific trends emerged in the preliminary data.

The average number per 0.1 m^{-2}, of major taxa which demonstrated trends in 1989 are listed in Table 5.1.1. Barnacles, limpets, amphipods, isopods, nematodes and oligochaetes had higher average populations in the first meter drop in control sites from sheltered rocky habitats than from corresponding oiled sites. The same pattern emerged from data on the second meter drop, with the exception of nematodes. The pattern was repeated for limpets in the third meter drop. While mussel populations were higher on oiled beaches, the biomass was higher on control beaches, suggesting that higher concentrations of small mussels (1-4 mm long) were occurring on the oiled beaches (7.69 vs. 5.63 g/0.1 m^2). Mussels of 1-4 mm length are not easily detectable in the field and would therefore not be included in the semicircle analyses discussed below. The higher concentration of smaller mussels may be related to the presence on the oiled beaches of increased densities of filamentous algae (possible due to reduced

Table 5.1.1. Mean number of individuals per 0.1 m^2 in sheltered rocky habitat.

Taxon	Control	Oiled
First Meter Below MHHW		
Balanomorpha	513	377
Lottidae	5.39	2.47
Mytilus	45.17	21.26
Amphipoda	1.5	0
Isopoda	0.44	0
Nematoda	41.33	1.52
Oligochaeta	75.44	6.65
Second Meter Below MHHW		
Balanomorpha	1134	704
Lottidae	20.8	13.2
Mytilus	146	200
Amphipoda	107	2.4
Isopoda	4.05	2.48
Nematoda	8.44	11.92
Oligochaeta	463.8	35.92
Third Meter Below MHHW		
Balanomorpha	373	719.2
Lottidae	30.3	22.4
Mytilus	147	523
Amphipoda	26	71.25
Isopoda	12.9	18.9
Nematoda	27.27	308.0
Oligochaeta	70.5	172.3

grazing limpet densities), which form a natural settlement location and refuge for juvenile mussels. Data analysis on the abundance of filamentous algae from the quadrat samples is not yet complete. The unusually high concentration of these small mussels may be an additional indication of a disturbed system. It will be very interesting to see what proportion of these high juvenile densities are able to make the transition to primary substrate occupation in the normal adult zone.

The above trends in limpet densities are repeated in the semicircle data collected during 1990 in Prince William Sound. The results for the sign test and the Wilcoxon matched-pairs test for individual habitat types in Prince William Sound are shown in Tables 5.1.2-5.1.4. The limpet densities on sheltered rocky habitats in the first and second meter drops were higher on control than oiled sites ($p=0.053$ and 0.1875 and 0.03 and 0.0313 for the sign test and Wilcoxon test repectively, Table 5.1.2). Mussel densities appear to have been higher in the second and third meter drops on control sites than on the oiled sites (Table 5.1.2). Note that mussel density estimates from the semicircle data exclude very small individuals, which can only be reliably detected by microscopic examination of the quadrat samples. Therefore, mussel densities determined from semicircle data should not be compared to density estimates from quadrat data, which include microscopic individuals. Trends were not detected in the preliminary data from exposed rocky sites (Table 5.1.3).

Although we are not yet able to detect trends in density in the 1989 quadrat data from coarse textured habitats, the 1990 semicircle data indicate limpet populations in the first meter drop were significantly higher on control than oiled sites (Table 5.1.4). Similar trends may also be indicated for limpets in the second meter drop and mussels in the second and third meter drops. Semicircle data from sheltered rocky and coarse textured beaches in the Kodiak and Cook Inlet regions suggest similar population trends, however, data analysis is not yet complete (Tables 5.1.5-5.1.28). *Fucus* densities were reduced at oiled sites in the first two meters of vertical drop at the second 1990 survey of sheltered rocky sites (Table. 5.1.24).

Large population differences were noted in the 1989 quadrat data set from a matched pair of estuary sites in Prince William Sound. Populations of Balanomorpha, *Littorina* spp., *Mytilus* spp. and Lottidae (limpets) were substantially higher on the control site than on the oiled site (Figs. 5.1.1a-5.1.1d).

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Table 5.1.2. Sign and Wilcoxan matched pairs test for differences between limpet, mussel, and fucus densities for the control sites and matched oiled sites over the pairs from the first round of the 1990 field season in Prince William Sound(PWS) for Habitat 4 (Sheltered Rocky). P1 is significance level for the sign test and P2 is the significance level for the Wilcoxan matched pairs test for the hypothesis H_0: The probability of an oiled site having a higher density than the control site is p=.5. These are one-tailed probabilities.

Species	1st meter	2nd meter	3rd meter	4th meter
LIMPETS	4/5[b]	5/5	3/5	0/0
	P1=.1875	P1=.0313	P1=.5000	P1=*
	P2=.053	P2=.030	P2=.606	P2=*
MUSSELS	1/5	4/5	4/4	0/0
	P1=.9688	P1=.1875	P1=.0625	P1=*
	P2=.947	P2=.295	P2=.050	P2=*
FUCUS	3/5	2/5	4/5	0/1
	P1=.5000	P1=.8125	P1=.1875	P1=*
	P2=.140	P2=.705	P2=.053	P2=.977

[b] the number of positive differences over the total number of pairs excluding ties
P1 = P-value(sig. level) obtained from sign test
P2 = P-value(sig. level) obtained from Wilcoxan matched pairs test
* = not enough data

Table 5.1.3. Sign and Wilcoxan matched pairs test for differences between limpet, mussel, and fucus densities for the control sites and matched oiled sites over the pairs from the first round of the 1990 field season in Prince William Sound(PWS) for Habitat 1 (Exposed Rocky). P1 is significance level for the sign test and P2 is the significance level for the Wilcoxan matched pairs test for the hypothesis H_0: The probability of an oiled site having a higher density than the control site is p=.5. These are one-tailed probabilities.

Species	1st meter	2nd meter	3rd meter	4th meter
LIMPETS	2/4[b]	1/5	2/5	3/5
	P1=.6875	P1=.969	P1=.813	P1=.500
	P2=.500	P2=.947	P2=.911	P2=.295
MUSSELS	2/4	2/5	2/4	2/2
	P1=.6875	P1=.813	P1=.500	P1=*
	P2=.572	P2=.911	P2=.292	P2=.186
FUCUS	3/3	3/5	3/5	2/5
	P1=.1250	P1=.500	P1=.500	P1=.813
	P2=.091	P2=.295	P2=.295	P2=.500

[b] the number of positive differences over the total number of pairs excluding ties
P1 = P-value(sig. level) obtained from sign test
P2 = P-value(sig. level) obtained from Wilcoxan matched pairs test
* = not enough data

Table 5.1.4. Sign and Wilcoxan matched pairs test for differences between limpet, mussel, and fucus densities for the control sites and matched oiled sites over the pairs from the first round of the 1990 field season in Prince William Sound(PWS) for <u>Habitat 3 (Coarse Textured)</u>. P1 is significance level for the sign test and P2 is the significance level for the Wilcoxan matched pairs test for the hypothesis H_0: The probability of an oiled site having a higher density than the control site is p=.5. These are one-tailed probabilities.

Species	1st meter	2nd meter	3rd meter	4th meter
LIMPETS	5/5[b]	4/7	2/7	0/4
	P1=.0313	P1=.5000	P1=.9375	P1=*
	P2=.030	P2=.336	P2=.864	P2=.978
MUSSELS	3/3	4/5	5/6	1/4
	P1=.1250	P1=.1875	P1=.1094	P1=.9375
	P2=.091	P2=.583	P2=.102	P2=.950
FUCUS	0/0	3/4	3/4	1/1
	P1=*	P1=.3125	P1=.3125	P1=*
	P2=*	P2=.101	P2=.101	P2=.500

[b] the number of positive differences over the total number of pairs excluding ties
P1 = P-value(sig. level) obtained from sign test
P2 = P-value(sig. level) obtained from Wilcoxan matched pairs test
* = not enough data

Table 5.1.5. Sign and Wilcoxan matched pairs test for differences between limpet densities for the control sites and matched oiled sites over all Exposed Rocky (Habitat 1) sites from the first round of the 1990 field season. The last two rows give significance levels for both tests in testing the hypothesis H_0: The probability of an oiled site having a higher density than the control site is p=.5. These are one-tailed probabilities.

REGION	SITE PAIRS	1ST METER[a]	2ND METER[a]	3RD METER[a]	4TH METER[a]
PWS	305/2937	+ 2.185	- 2.644	+ 1.488	- 0.510
	979/4537	+ 1.022	+ 0.399	- 1.731	- 8.141
	19/19C	- 0.251	- 1.768	+ 0.982	+ 3.921
	833/1642	- 1.295	-39.246	- 6.260	+ 6.810
	232/1642	tie	- 0.221	-25.034	+ 8.716
CIK	11.1/11.1C	+ 1.193	- 0.057	+ 1.707	*
KAP	11.1/11.1C	tie	+ 0.994	- 3.268	+ 4.924
	11.2/11.2C	+ 0.410	+ 0.696	- 2.600	- 1.005
	31461/31461C	+ 1.403	- 6.312	- 1.466	+ 7.954
	33027/96665	+ 1.204	+ 9.033	+36.898	*
proportion positive differences[b]		6/8	4/10	4/10	5/8
P-value(sig. level) sign test		P=.145	P=.821	P=.821	P=.363
P-value(sig. level) Wilcoxan test		P=.071	P=.762	P=.846	P=.147

a sign and magnitude of difference between density estimate for control site and density estimate for the matched oiled site (control - oiled).
b the number of positive differences over the total number of pairs excluding ties
* not enough data

Table 5.1.6. Sign and Wilcoxan matched pairs test for differences between <u>mussel densities</u> for the control sites and matched oiled sites over all <u>Exposed Rocky (Habitat 1) sites from the first round</u> of the 1990 field season. The last two rows give significance levels for both tests in testing the hypothesis H_0: The probability of an oiled site having a higher density than the control site is p=.5. These are one-tailed probabilities.

REGION	SITE PAIRS	1ST METER[a]	2ND METER[a]	3RD METER[a]	4TH METER[a]
PWS	305/2937	+ 0.578	- 1.700	- 0.683	tie
	979/4537	- 0.041	+ 0.043	- 0.207	tie
	19/19C	+ 0.401	+ 0.925	tie	tie
	833/1642	- 1.215	- 1.881	+ 1.174	+ 2.416
	232/1642	tie	-32.615	+ 1.174	+ 2.416
CIK	11.1/11.1C	+ 0.660	+ 0.227	- 0.128	*
KAP	11.1/11.1C	- 0.177	+ 0.992	+ 0.273	- 0.534
	11.2/11.2C	tie	tie	tie	tie
	31461/31461C	- 0.187	- 4.461	+ 0.321	tie
	33027/96665	+ 0.122	+ 0.956	+ 1.344	*
proportion positive differences[b]		4/8	5/9	5/8	2/3
P-value(sig. level) sign test		P=.637	P=.500	P=.363	P=.500
P-value(sig. level) Wilcoxan test		P=.417	P=.828	P=.221	P=.211

[a] sign and magnitude of difference between density estimate for control site and density estimate for the matched oiled site (control - oiled).

[b] the number of positive differences over the total number of pairs excluding ties

* not enough data

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Table 5.1.7. Sign and Wilcoxan matched pairs test for differences between fucus densities for the control sites and matched oiled sites over all Exposed Rocky (Habitat 1) sites from the first round of the 1990 field season. The last two rows give significance levels for both tests in testing the hypothesis H_0: The probability of an oiled site having a higher density than the control site is p=.5. These are one-tailed probabilities.

REGION	SITE PAIRS	1ST METER[a]	2ND METER[a]	3RD METER[a]	4TH METER[a]
PWS	305/2937	+ 0.014	- 1.207	+ 0.247	- 0.138
	979/4537	+ 0.277	+ 2.491	- 0.634	- 0.382
	19/19C	+ 0.200	- 0.301	- 0.510	- 0.158
	833/1642	tie	+ 1.078	+ 3.023	+ 0.265
	232/1642	tie	+ 1.078	+ 3.023	+ 0.506
CIK	11.1/11.1C	tie	tie	tie	*
KAP	11.1/11.1C	tie	tie	tie	+ 0.391
	11.2/11.2C	tie	tie	tie	tie
	31461/31461C	tie	- 0.497	+ 0.567	+ 1.530
	33027/96665	tie	+ 0.196	tie	*
proportion positive differences[b]		3/3	4/7	4/6	4/7
P-value(sig. level) sign test		P=.125	P=.500	P=.344	P=.500
P-value(sig. level) Wilcoxan test		P=.091	P=.500	P=.394	P=.735

a sign and magnitude of difference between density estimate for control site and density estimate for the matched oiled site (control - oiled).

b the number of positive differences over the total number of pairs excluding ties

* not enough data

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Table 5.1.8. Sign and Wilcoxan matched pairs test for differences between limpet densities for the control sites and matched oiled sites over all Coarse Textured (Habitat 3) sites from the first round of the 1990 field season. The last two rows give significance levels for both tests in testing the hypothesis H_0: The probability of an oiled site having a higher density than the control site is p=.5. These are one-tailed probabilities.

REGION	SITE PAIRS	1ST METER[a]	2ND METER[a]	3RD METER[a]	4TH METER[a]
PWS	846/846C	+ 0.136	-11.728	+ 1.717	*
	506/506C	+ 1.106	+46.261	- 5.242	tie
	1650/1650C	+ 0.306	+ 7.124	+11.712	- 3.429
	1627/1627C	tie	+ 0.401	- 5.109	- 6.146
	1598/1598C	+ 2.403	+ 0.364	-36.031	*
	1580/1383	tie	- 0.871	- 2.004	- 3.359
	1171/1171C	+ 0.194	- 0.282	- 0.700	-11.607
CIK	50226/62802	- 0.149	- 0.885	- 1.590	- 1.176
	50389/50389C	- 0.145	- 0.010	- 0.268	+ 0.488
	50443/61937	tie	tie	tie	- 0.411
	51091/51091C	tie	tie	tie	tie
KAP	13.1/13.1C	tie	- 0.028	- 0.387	+19.706
	31288/94935	+ 0.294	tie	tie	- 5.313
	31893/31893C	tie	tie	+ 0.288	+ 0.554
proportion positive differences[b]		6/8	4/10	3/11	3/10
P-value(sig. level) sign test		P=.145	P=.828	P=.967	P=.945
P-value(sig. level) Wilcoxan test		P=.040	P=.541	P=.916	P=.907

a sign and magnitude of difference between density estimate for control site and density estimate for the matched oiled site (control - oiled).

b the number of positive differences over the total number of pairs excluding ties

* not enough data

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Table 5.1.9. Sign and Wilcoxan matched pairs test for differences between mussels densities for the control sites and matched oiled sites over all Coarse Textured (Habitat 3) sites from the first round of the 1990 field season. The last two rows give significance levels for both tests in testing the hypothesis H_0: The probability of an oiled site having a higher density than the control site is p=.5. These are one-tailed probabilities.

REGION	SITE PAIRS	1ST METER[a]	2ND METER[a]	3RD METER[a]	4TH METER[a]
PWS	846/846C	tie	- 3.388	+ 1.821	*
	506/506C	+ 1.934	+ 1.890	+75.631	- 9.809
	1650/1650C	+ 0.152	+ 0.562	+ 1.801	- 0.367
	1627/1627C	tie	+ 1.886	+ 0.681	- 2.621
	1598/1598C	+ 0.171	-10.188	-35.961	*
	1580/1383	tie	tie	+ 0.144	+ 0.152
	1171/1171C	tie	+ 0.453	+ 0.713	tie
CIK	50226/62802	tie	- 0.419	- 2.250	- 1.238
	50389/50389C	tie	- 0.713	- 0.260	+ 0.130
	50443/61937	tie	tie	tie	tie
	51091/51091C	tie	tie	+0.127	+ 0.681
KAP	13.1/13.1C	tie	tie	- 0.915	+ 0.779
	31288/94935	tie	+ 0.315	+ 0.315	+ 2.819
	31893/31893C	tie	tie	tie	tie
proportion positive differences[b]		3/3	5/9	8/12	5/9
P-value(sig. level) sign test		P=.125	P=.500	P=.194	P=.500
P-value(sig. level) Wilcoxan test		P=.091	P=.594	P=.278	P=.639

a sign and magnitude of difference between density estimate for control site and density estimate for the matched oiled site (control - oiled).

b the number of positive differences over the total number of pairs excluding ties

* not enough data

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Table 5.1.10. Sign and Wilcoxan matched pairs test for differences between fucus densities for the control sites and matched oiled sites over all Coarse Textured (Habitat 3) sites from the first round of the 1990 field season. The last two rows give significance levels for both tests in testing the hypothesis H_0: The probability of an oiled site having a higher density than the control site is p=.5. These are one-tailed probabilities.

REGION	SITE PAIRS	1ST METER[a]	2ND METER[a]	3RD METER[a]	4TH METER[a]
PWS	846/846C	tie	- 0.183	tie	*
	506/506C	tie	+ 3.220	+ 0.846	tie
	1650/1650C	tie	+ 0.977	+ 0.419	tie
	1627/1627C	tie	tie	tie	tie
	1598/1598C	tie	tie	- 0.250	*
	1580/1383	tie	tie	tie	tie
	1171/1171C	tie	+ 0.308	+ 3.547	+ 1.162
CIK	50226/62802	tie	tie	- 0.403	- 0.469
	50389/50389C	tie	tie	- 0.119	tie
	50443/61937	tie	tie	tie	tie
	51091/51091C	tie	tie	tie	tie
KAP	13.1/13.1C	tie	tie	tie	tie
	31288/94935	tie	+ 0.680	+ 0.291	tie
	31893/31893C	tie	tie	tie	tie
proportion positive differences[b]		0/0	4/5	4/7	1/2
P-value(sig. level) sign test		P=*	P=.188	P=.500	P=.750
P-value(sig. level) Wilcoxan test		P=*	P=.053	P=.136	P=.500

a sign and magnitude of difference between density estimate for control site and density estimate for the matched oiled site (control - oiled).

b the number of positive differences over the total number of pairs excluding ties

* not enough data

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Table 5.1.11. Sign and Wilcoxan matched pairs test for differences between limpet densities for the control sites and matched oiled sites over all Sheltered Rocky (Habitat 4) sites from the first round of the 1990 field season. The last two rows give significance levels for both tests in testing the hypothesis H_0: The probability of an oiled site having a higher density than the control site is p=.5. These are one-tailed probabilities.

REGION	SITE PAIRS	1ST METER[a]	2ND METER[a]	3RD METER[a]	4TH METER[a]
PWS	601/601C	+ 0.449	+14.054	+29.219	*
	598/598C	+ 0.525	+ 5.660	-28.941	tie
	453/453C	- 0.366	+ 0.975	-41.714	*
	1522/1522C	+ 0.664	+ 1.720	+ 1.796	*
	1424/4825	+19.758	+ 1.538	+ 0.027	*
CIK	14-1/14-1C	+ 4.381	-182.26	+ 5.234	-10.117
	14-2/14-2C	+ 3.295	+31.952	- 0.621	tie
	50983/62762	+ 0.314	+22.579	+ 0.439	*
KAP	30196/30196C	+ 4.005	- 0.394	- 1.110	- 0.307
	31248/99826	- 8.633	- 4.187	-11.077	*
	33141/99826	+ 1.967	+ 1.863	tie	*
	31252/31252C	-16.464	+ 3.843	-15.352	-14.919
proportion positive differences[b]		9/12	9/12	5/11	0/3
P-value(sig. level) sign test		P=.073	P=.073	P=.726	P=1.0
P-value(sig. level) Wilcoxan test		P=.112	P=.073	P=.801	P=.969

[a] sign and magnitude of difference between density estimate for control site and density estimate for the matched oiled site (control - oiled).

[b] the number of positive differences over the total number of pairs excluding ties

* not enough data

able 5.1.12. Sign and Wilcoxan matched pairs test for differences between mussel densities for the control sites and matched oiled sites over all Sheltered Rocky (Habitat 4) sites from the first round of the 1990 field season. The last two rows give significance levels for both tests in testing the hypothesis H_0: The probability of an oiled site having a higher density than the control site is p=.5. These are one-tailed probabilities.

REGION	SITE PAIRS	1ST METER[a]	2ND METER[a]	3RD METER[a]	4TH METER[a]
PWS	601/601C	- 0.176	-15.257	+ 0.265	*
	598/598C	- 0.564	+ 4.743	+ 1.131	*
	453/453C	- 0.387	+ 0.198	+ 0.415	*
	1522/1522C	- 3.252	+ 1.389	*	*
	1424/4825	+ 0.243	+ 0.196	+ 0.210	*
CIK	14-1/14-1C	- 1.673	tie	+ 0.152	tie
	14-2/14-2C	+ 0.459	+ 0.637	tie	tie
	50893/62762	+ 1.295	-33.394	-25.015	*
KAP	30196/30196C	+ 0.263	- 0.339	tie	tie
	31248/99826	+ 0.311	+17.507	- 0.579	*
	33141/99826	- 0.366	+18.951	- 3.015	*
	31252/31252C	+ 0.262	+ 2.641	+ 2.911	+ 8.385
proportion positive differences[b]		6/12	8/11	6/9	1/1
P-value(sig. level) sign test		P=.613	P=.113	P=.254	P=.500
P-value(sig. level) Wilcoxan test		P=.722	P=.175	P=.500	P=.500

a sign and magnitude of difference between density estimate for control site and density estimate for the matched oiled site (control - oiled).

b the number of positive differences over the total number of pairs excluding ties

* not enough data

Table 5.1.13. Sign and Wilcoxan matched pairs test for differences between fucus densities for the control sites and matched oiled sites over all Sheltered Rocky (Habitat 4) sites from the first round of the 1990 field season. The last two rows give significance levels for both tests in testing the hypothesis H_0: The probability of an oiled site having a higher density than the control site is p=.5. These are one-tailed probabilities.

REGION	SITE PAIRS	1ST METER[a]	2ND METER[a]	3RD METER[a]	4TH METER[a]
PWS	601/601C	+ 0.335	+ 0.174	+ 3.886	*
	598/598C	- 0.125	- 0.161	- 0.133	- 1.941
	453/453C	+ 0.149	- 3.593	+ 0.355	*
	1522/1522C	- 0.089	- 5.692	+ 4.523	*
	1424/4825	+ 1.237	+ 4.938	+ 0.550	*
CIK	14-1/14-1C	+ 3.620	+ 0.006	- 0.569	+ 1.524
	14-2/14-2C	+ 0.329	+ 1.274	- 1.613	tie
	50893/62762	- 0.039	+ 0.490	- 0.843	*
KAP	30196/30196C	- 0.134	+ 2.610	- 0.220	- 0.426
	31248/99826	- 0.333	- 0.141	- 0.211	*
	33141/99826	- 0.054	+ 0.182	tie	*
	31252/31252C	+ 0.376	+ 3.455	- 0.198	- 0.299
proportion positive differences[b]		6/12	8/12	4/11	1/4
P-value(sig. level) sign test		P=.613	P=.194	P=.887	P=.938
P-value(sig. level) Wilcoxan test		P=.112	P=.183	P=.553	P=.819

a sign and magnitude of difference between density estimate for control site and density estimate for the matched oiled site (control - oiled).

b the number of positive differences over the total number of pairs excluding ties

* not enough data

Table 5.1.14. Sign and Wilcoxan matched pairs test for differences between limpet densities for the control sites and matched oiled sites over all Estuarine (Habitat 5) sites from the first round of the 1990 field season. The last two rows give significance levels for both tests in testing the hypothesis H_0: The probability of an oiled site having a higher density than the control site is p=.5. These are one-tailed probabilities.

REGION	SITE PAIRS	1ST METER[a]	2ND METER[a]	3RD METER[a]	4TH METER[a]
PWS	15.1/15.1C	*	*	*	*
	208/2397	+ 0.599	+ 4.555	+ 1.296	*
CIK	15-1/15-1C	- 0.1252	- 3.562	-20.186	tie
	50221/61679	tie	- 0.372	tie	tie
	50981/50981C	+ 0.156	+ 2.250	+ 1.589	*
KAP	15.1/103098	tie	tie	*	*
	32896/33875	tie	tie	*	*
proportion positive differences[b]		2/3	2/4	2/3	0/0
P-value(sig. level) sign test		P=.500	P=.688	P=.500	P=*
P-value(sig. level) Wilcoxan test		P=.211	P=.428	P=.605	P=*

[a] sign and magnitude of difference between density estimate for control site and density estimate for the matched oiled site (control - oiled).
[b] the number of positive differences over the total number of pairs excluding ties
* not enough data

Table 5.1.15. Sign and Wilcoxan matched pairs test for differences between mussel densities for the control sites and matched oiled sites over all Estuarine (Habitat 5) sites from the first round of the 1990 field season. The last two rows give significance levels for both tests in testing the hypothesis H_0: The probability of an oiled site having a higher density than the control site is p=.5. These are one-tailed probabilities.

REGION	SITE PAIRS	1ST METER[a]	2ND METER[a]	3RD METER[a]	4TH METER[a]
PWS	15.1/15.1C	*	*	*	*
	208/2397	+ 1.028	+ 4.771	- 2.279	*
CIK	15-1/15-1C	- 3.062	-3.233	+ 0.229	tie
	50221/61679	- 0.574	- 1.958	tie	tie
	50981/50981C	+ 0.508	+10.571	+ 8.730	*
KAP	15.1/103098	tie	tie	*	*
	32896/33875	tie	tie	*	*
proportion positive differences[b]		2/4	2/4	2/3	0/0
P-value(sig. level) sign test		P=.688	P=.688	P=.500	P=*
P-value(sig. level) Wilcoxan test		P=.500	P=.140	P=.572	P=*

[a] sign and magnitude of difference between density estimate for control site and density estimate for the matched oiled site (control - oiled).
[b] the number of positive differences over the total number of pairs excluding ties
* not enough data

Table 5.1.16. Sign and Wilcoxan matched pairs test for differences between fucus densities for the control sites and matched oiled sites over all Estuarine (Habitat 5) sites from the first round of the 1990 field season. The last two rows give significance levels for both tests in testing the hypothesis H_0: The probability of an oiled site having a higher density than the control site is p=.5. These are one-tailed probabilities.

REGION	SITE PAIRS	1ST METER[a]	2ND METER[a]	3RD METER[a]	4TH METER[a]
PWS	15.1/15.1C	*	*	*	*
	208/2397	tie	+ 0.742	− 0.263	*
CIK	15-1/15-1C	tie	tie	*	*
	50221/61679	tie	tie	tie	tie
	50981/50981C	tie	tie	tie	*
KAP	15.1/103998	tie	tie	*	*
	32896/33875	tie	tie	*	*
proportion positive differences		0/0	1/1	0/1	0/0
P-value(sig. level) sign test		P=*	P=.500	P=1.0	P=*
P-value(sig. level) Wilcoxan test		P=*	P=.500	P=.977	P=*

[a] sign and magnitude of difference between density estimate for control site and density estimate for the matched oiled site (control − oiled).
[b] the number of positive differences over the total number of pairs excluding ties
* not enough data

Table 5.1.17. Sign and Wilcoxan matched pairs test for differences between limpet densities for the control sites and matched oiled sites over all Exposed Rocky (Habitat 1) sites from the second round of the 1990 field season. The last two rows give significance levels for both tests in testing the hypothesis H_0: The probability of an oiled site having a higher density than the control site is p=.5. These are one-tailed probabilities.

REGION	SITE PAIRS	1ST METER[a]	2ND METER[a]	3RD METER[a]	4TH METER[a]
PWS	305/2937	− 0.407	+ 0.422	+ 2.166	*
	979/4537	− 0.133	+ 4.394	− 5.827	+ 3.166
	19/19C	− 1.245	+ 1.494	+ 8.617	+11.110
	833/1642	− 0.603	− 0.451	+ 8.466	*
	232/1642	− 4.175	−17.621	−71.112	+ 1.514
CIK	11.1/11.1C	+ 0.038	+22.932	+218.43	*
KAP	11.1/11.1C	Data not available at time of analysis			
	11.2/11.2C				
	31461/31461C				
	33027/96665				
proportion positive differences[b]		1/6	4/6	4/6	3/3
P-value(sig. level) sign test		P=.984	P=.344	P=.344	P=.125
P-value(sig. level) Wilcoxan test		P=.982	P=.265	P=.265	P=.091

[a] sign and magnitude of difference between density estimate for control site and density estimate for the matched oiled site (control − oiled).
[b] the number of positive differences over the total number of pairs excluding ties
* not enough data

Table 5.1.18. Sign and Wilcoxan matched pairs test for differences between <u>mussel densities</u> for the control sites and matched oiled sites over all <u>Exposed Rocky (Habitat 1) sites from the second round</u> of the 1990 field season. The last two rows give significance levels for both tests in testing the hypothesis H_0: The probability of an oiled site having a higher density than the control site is p=.5. These are one-tailed probabilities.

REGION	SITE PAIRS	1ST METER[a]	2ND METER[a]	3RD METER[a]	4TH METER[a]
PWS	305/2937	+ 0.090	- 0.310	- 0.211	*
	979/4537	tie	+ 1.943	tie	tie
	19/19C	tie	+1.665	+ 0.846	tie
	833/1642	- 0.272	+ 0.990	+ 0.628	*
	232/1642	- 7.035	+ 0.596	+ 0.628	+ 0.608
CIK	11.1/11.1C	tie	- 0.005	tie	*
KAP	11.1/11.1C	Data not available at time of analysis			
	11.2/11.2C				
	31461/31461C				
	33027/96663				
proportion positive differences[b]		1/3	4/6	3/4	1/1
P-value(sig. level) sign test		P=.875	P=.344	P=.313	P=.500
P-value(sig. level) Wilcoxan test		P=.909	P=.071	P=.101	P=.500

a sign and magnitude of difference between density estimate for control site and density estimate for the matched oiled site (control - oiled).

b the number of positive differences over the total number of pairs excluding ties

* not enough data

Table 5.1.19. **Sign and Wilcoxan matched pairs test for differences between fucus densities for the control sites and matched oiled sites over all Exposed Rocky (Habitat 1) sites from the second round of the 1990 field season. The last two rows give significance levels for both tests in testing the hypothesis H_0: The probability of an oiled site having a higher density than the control site is p=.5. These are one-tailed probabilities.**

REGION	SITE PAIRS	1ST METER[a]	2ND METER[a]	3RD METER[a]	4TH METER[a]
PWS	305/2937	+ 0.269	tie	tie	*
	979/4537	tie	tie	tie	tie
	19/19C	tie	tie	tie	tie
	833/1642	tie	tie	tie	*
	232/1642	tie	tie	tie	tie
CIK	11.1/11.1C	tie	tie	tie	*
KAP	11.1/11.1C	Data not available at time of analysis			
	11.2/11.2C				
	31461/31461C				
	33027/96665				
proportion positive differences		1/1	0/0	0/0	0/0
P-value(sig. level) sign test		P=.500	P=*	P=*	P=*
P-value(sig. level) Wilcoxan test		P=.500	P=*	P=*	P=*

a sign and magnitude of difference between density estimate for control site and density estimate for the matched oiled site (control - oiled).

b the number of positive differences over the total number of pairs excluding ties

* not enough data

Table 5.1.20. Sign and Wilcoxan matched pairs test for differences between limpet densities for the control sites and matched oiled sites over all Coarse Textured (Habitat 3) sites from the second round of the 1990 field season. The last two rows give significance levels for both tests in testing the hypothesis H_0: The probability of an oiled site having a higher density than the control site is p=.5. These are one-tailed probabilities.

REGION	SITE PAIRS	1ST METER[a]	2ND METER[a]	3RD METER[a]	4TH METER[a]
PWS	846/846C	- 0.418	- 0.596	+40.386	tie
	506/506C	+ 0.114	+ 9.314	- 6.551	tie
	1650/1650C	+ 0.462	+ 8.286	+27.808	-20.060
	1627/1627C	tie	- 0.886	- 1.421	+ 1.290
	1598/1598C	+ 0.590	+ 1.079	-11.106	-51.023
	1580/1383	+ 0.114	- 7.865	- 1.380	-17.245
	1171/1171C	tie	- 1.180	-11.633	-20.295
CIK	50226/62802	tie	- 0.905	-23.150	*
	50389/50389C	- 0.151	- 0.234	- 1.424	+ 0.978
	50443/61937	tie	tie	tie	- 0.071
	51091/51091C	tie	tie	tie	+ 0.139
KAP	13.1/13.1C	tie	+ 0.146	- 0.477	- 0.012
	31288/94935	+ 0.444	+1.087	+ 5.612	+19.065
	31893/31893C	*	*	*	*
proportion positive differences[b]		5/7	5/11	3/11	4/10
P-value(sig. level) sign test		P=.227	P=.726	P=.967	P=.828
P-value(sig. level) Wilcoxan test		P=.136	P=.447	P=.748	P=.821

[a] sign and magnitude of difference between density estimate for control site and density estimate for the matched oiled site (control - oiled).

[b] the number of positive differences over the total number of pairs excluding ties

* not enough data

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Table 5.1.21. Sign and Wilcoxan matched pairs test for differences between mussel densities for the control sites and matched oiled sites over all Coarse Textured (Habitat 3) sites from the second round of the 1990 field season. The last two rows give significance levels for both tests in testing the hypothesis H_0: The probability of an oiled site having a higher density than the control site is p=.5. These are one-tailed probabilities.

REGION	SITE PAIRS	1ST METER[a]	2ND METER[a]	3RD METER[a]	4TH METER[a]
PWS	846/846C	- 0.252	- 0.641	+21.160	- 0.635
	506/506C	- 0.097	- 1.554	+23.537	+16.797
	1650/1650C	tie	+ 0.922	+11.129	-0.408
	1627/1627C	tie	tie	- 1.788	- 2.287
	1598/1598C	+ 0.606	+11.313	-39.415	+10.752
	1580/1383	tie	+ 0.011	- 0.003	tie
	1171/1171C	tie	+ 0.142	+ 0.669	+ 0.822
CIK	50226/62802	tie	- 0.913	-18.578	*
	50389/50389C	tie	- 1.069	- 3.603	+ 0.537
	50443/61937	tie	tie	tie	- 0.154
	51091/51091C	tie	tie	+ 0.136	+ 0.738
KAP	13.1/13.1C	tie	tie	- 1.497	- 2.97
	31288/94935	tie	+ 1.296	+ 2.261	+ 3.376
	31893/31893C	*	*	*	*
proportion positive differences[b]		1/3	5/9	6/12	6/11
P-value(sig. level) sign test		P=.875	P=.500	P=.613	P=.500
P-value(sig. level) Wilcoxan test		P=.605	P=.443	P=.484	P=.175

a sign and magnitude of difference between density estimate for control site and density estimate for the matched oiled site (control - oiled).

b the number of positive differences over the total number of pairs excluding ties

* not enough data

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Table 5.1.22. Sign and Wilcoxan matched pairs test for differences between Fucus densities for the control sites and matched oiled sites over all Coarse Textured (Habitat 3) sites from the second round of the 1990 field season. The last two rows give significance levels for both tests in testing the hypothesis H_0: The probability of an oiled site having a higher density than the control site is p=.5. These are one-tailed probabilities.

REGION	SITE PAIRS	1ST METER[a]	2ND METER[a]	3RD METER[a]	4TH METER[a]
PWS	846/846C	tie	tie	tie	tie
	506/506C	tie	+ 0.290	+ 0.189	tie
	1650/1650C	tie	+ 0.297	+ 0.136	tie
	1627/1627C	tie	tie	tie	tie
	1598/1598C	+ 0.164	tie	+ 0.169	tie
	1580/1383	tie	tie	tie	tie
	1171/1171C	tie	− 0.128	+ 0.142	+ 0.283
CIK	50226/62802	tie	tie	tie	*
	50389/50389C	tie	tie	tie	+ 0.457
	50443/61937	tie	tie	tie	tie
	51091/51091C	tie	tie	tie	tie
KAP	13.1/13.1C	tie	tie	+ 0.144	− 0.044
	31288/94935	tie	tie	+ 0.764	tie
	31893/31893C	*	*	*	*
proportion positive differences[b]		1/1	2/3	6/6	2/3
P-value(sig. level) sign test		P=.500	P=.500	P=.016	P=.500
P-value(sig. level) Wilcoxan test		P=.500	P=.211	P=.018	P=.211

a sign and magnitude of difference between density estimate for control site and density estimate for the matched oiled site (control − oiled).

b the number of positive differences over the total number of pairs excluding ties

* not enough data

Table 5.1.23. Sign and Wilcoxan matched pairs test for differences between limpet densities for the control sites and matched oiled sites over all Sheltered Rocky (Habitat 4) sites from the second round of the 1990 field season. The last two rows give significance levels for both tests in testing the hypothesis H_0: The probability of an oiled site having a higher density than the control site is p=.5. These are one-tailed probabilities.

REGION	SITE PAIRS	1ST METER[a]	2ND METER[a]	3RD METER[a]	4TH METER[a]
PWS	601/601C	+ 2.049	+ 4.610	+ 0.722	tie
	598/598C	+ 4.216	+14.133	+16.120	+ 5.469
	453/453C	+ 9.865	- 9.091	-13.163	*
	1522/1522C	- 0.557	- 1.029	- 0.943	tie
	1424/4825	+ 2.680	+ 2.167	- 1.235	*
CIK	14-1/14-1C	+ 0.913	-25.425	- 0.814	*
	14-2/14-2C	+ 0.261	+ 5.075	- 0.337	*
	50983/62762	+ 1.087	- 2.592	+ 0.773	+10.344
KAP	30196/30196C	+ 0.771	+ 0.649	+ 0.141	tie
	31248/99826	+ 1.432	+ 2.093	-31.524	-15.287
	33141/99826	+ 1.835	+ 3.824	+ 0.212	- 0.302
	31252/31252C	- 1.103	- 6.330	-16.357	+23.659
proportion positive differences[b]		10/12	7/12	5/12	3/5
P-value(sig. level) sign test		P=.019	P=.387	P=.806	P=.500
P-value(sig. level) Wilcoxan test		P=.008	P=.484	P=.915	P=.295

a sign and magnitude of difference between density estimate for control site and density estimate for the matched oiled site (control - oiled).

b the number of positive differences over the total number of pairs excluding ties

* not enough data

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Table 5.1.24. Sign and Wilcoxan matched pairs test for differences between mussel densities for the control sites and matched oiled sites over all Sheltered Rocky (Habitat 4) sites from the second round of the 1990 field season. The last two rows give significance levels for both tests in testing the hypothesis H_0: The probability of an oiled site having a higher density than the control site is p=.5. These are one-tailed probabilities.

REGION	SITE PAIRS	1ST METER[a]	2ND METER[a]	3RD METER[a]	4TH METER[a]
PWS	601/601C	+ 0.267	+ 2.773	- 1.401	tie
	598/598C	+ 1.320	+ 6.048	+ 1.341	tie
	453/453C	- 0.328	- 0.522	+ 1.031	*
	1522/1522C	12.205	- 9.059	- 8.046	- 7.058
	1424/4825	+ 0.383	+ 1.452	+ 3.754	*
CIK	14-1/14-1C	+ 0.353	+ 0.396	tie	*
	14-2/14-2C	+ 0.401	+ 0.609	+ 0.563	*
	50983/62762	+ 0.025	+ 0.149	- 0.030	tie
KAP	30196/30196C	tie	tie	tie	tie
	31248/99826	- 0.345	+ 0.510	+10.773	- 0.483
	33141/99826	- 0.788	+ 0.298	+12.835	tie
	31252/31252C	+ 1.198	+ 9.481	+14.195	+ 0.496
proportion positive differences[b]		7/11	9/11	7/10	1/3
P-value(sig. level) sign test		P=.274	P=.033	P=.172	P=.875
P-value(sig. level) Wilcoxan test		P=.282	P=.071	P=.077	P=.789

[a] sign and magnitude of difference between density estimate for control site and density estimate for the matched oiled site (control - oiled).

[b] the number of positive differences over the total number of pairs excluding ties

* not enough data

Table 5.1.25. Sign and Wilcoxan matched pairs test for differences between fucus densities for the control sites and matched oiled sites over all Sheltered Rocky (Habitat 4) sites from the second round of the 1990 field season. The last two rows give significance levels for both tests in testing the hypothesis H_0: The probability of an oiled site having a higher density than the control site is p=.5. These are one-tailed probabilities.

REGION	SITE PAIRS	1ST METER[a]	2ND METER[a]	3RD METER[a]	4TH METER[a]
PWS	601/601C	+ 0.156	+ 0.692	- 0.132	tie
	598/598C	+ 0.370	- 0.195	- 0.054	tie
	453/453C	+ 4.164	+ 0.417	- 0.350	*
	1522/1522C	+ 0.309	+ 2.366	+ 0.162	tie
	1424/4825	+ 0.852	+ 1.829	tie	*
CIK	14-1/14-1C	- 0.419	+ 0.715	+ 0.481	*
	14-2/14-2C	+ 0.640	+ 1.364	- 0.375	*
	50983/62762	+ 0.256	- 3.005	- 0.813	tie
KAP	30196/30196C	+ 0.159	- 0.245	+ 0.068	tie
	31248/99826	tie	+ 0.014	tie	tie
	33141/99826	tie	+ 0.538	tie	tie
	31252/31252C	+ 0.330	+ 0.350	+ 0.636	+ 0.237
proportion positive differences[b]		9/10	9/12	4/9	1/1
P-value(sig. level) sign test		P=.011	P=.073	P=.746	P=.500
P-value(sig. level) Wilcoxan test		P=.021	P=.046	P=.594	P=.500

[a] sign and magnitude of difference between density estimate for control site and density estimate for the matched oiled site (control - oiled).

[b] the number of positive differences over the total number of pairs excluding ties

* not enough data

Table 5.1.26. Sign and Wilcoxan matched pairs test for differences between limpet densities for the control sites and matched oiled sites over all Estuarine (Habitat 5) sites from the second round of the 1990 field season. The last two rows give significance levels for both tests in testing the hypothesis H_0: The probability of an oiled site having a higher density than the control site is p=.5. These are one-tailed probabilities.

REGION	SITE PAIRS	1ST METER[a]	2ND METER[a]	3RD METER[a]	4TH METER[a]
PWS	15.1/15.1C	*	*	*	*
	208/2397	tie	+ 1.580	+12.592	- 0.613
CIK	15-1/15-1C	- 0.125	- 3.562	-20.186	tie
	50221/61679	tie	tie	*	*
	50981/50981C	- 0.145	+ 3.659	+ 1.787	*
KAP	15.1/103098	tie	tie	*	*
	32896/33875	tie	*	*	*
proportion positive differences[b]		0/2	2/3	2/3	0/1
P-value(sig. level) sign test		P=1.0	P=.500	P=.500	P=1.0
P-value(sig. level) Wilcoxan test		P=.963	P=.395	P=.605	P=.977

[a] sign and magnitude of difference between density estimate for control site and density estimate for the matched oiled site (control - oiled).

[b] the number of positive differences over the total number of pairs excluding ties

* not enough data

Table 5.1.27. Sign and Wilcoxan matched pairs test for differences between mussel densities for the control sites and matched oiled sites over all Estuarine (Habitat 5) sites from the second round of the 1990 field season. The last two rows give significance levels for both tests in testing the hypothesis H_0: The probability of an oiled site having a higher density than the control site is p=.5. These are one-tailed probabilities.

REGION	SITE PAIRS	1ST METER[a]	2ND METER[a]	3RD METER[a]	4TH METER[a]
PWS	15.1/15.1C	*	*	*	*
	208/2397	tie	+49.907	+14.565	-84.883
CIK	15-1/15-1C	- 2.012	-15.673	+3.231	tie
	50221/61679	- 0.595	- 3.171	*	*
	50981/50981C	+ 0.953	+ 8.399	+ 3.660	*
KAP	15.1/103098	tie	tie	*	*
	32896/33875	tie	*	*	*
proportion positive differences[b]		1/3	2/4	3/3	0/1
P-value(sig. level) sign test		P=.875	P=.688	P=.125	P=1.0
P-value(sig. level) Wilcoxan test		P=.789	P=.428	P=.091	P=.977

[a] sign and magnitude of difference between density estimate for control site and density estimate for the matched oiled site (control - oiled).

[b] the number of positive differences over the total number of pairs excluding ties

* not enough data

Table 5.1.28. **Sign and Wilcoxan matched pairs test for differences between <u>fucus densities</u> for the control sites and matched oiled sites over all <u>Estuarine (Habitat 5) sites from the second</u> round of the 1990 field season. The last two rows give significance levels for both tests in testing the hypothesis H_0: The probability of an oiled site having a higher density than the control site is p=.5. These are one-tailed probabilities.**

REGION	SITE PAIRS	1ST METER[a]	2ND METER[a]	3RD METER[a]	4TH METER[a]
PWS	15.1/15.1C	*	*	*	*
	208/2397	tie	tie	tie	tie
CIK	15-1/15-1C	- 0.159	+ 0.390	tie	tie
	50221/61679	- 0.252	- 0.498	*	*
	50981/50981C	+ 0.768	+ 0.674	+ 2.898	*
KAP	15.1/103998	tie	tie	*	*
	32896/33875	tie	*	*	*
proportion positive differences[b]		1/3	2/3	1/1	0/0
P-value(sig. level) sign test		P=.875	P=.500	P=.500	P=*
P-value(sig. level) Wilcoxan test		P=.605	P=.395	P=.500	P=*

[a] sign and magnitude of difference between density estimate for control site and density estimate for the matched oiled site (control - oiled).

[b] the number of positive differences over the total number of pairs excluding ties

* not enough data

Fig. 5.1.1a

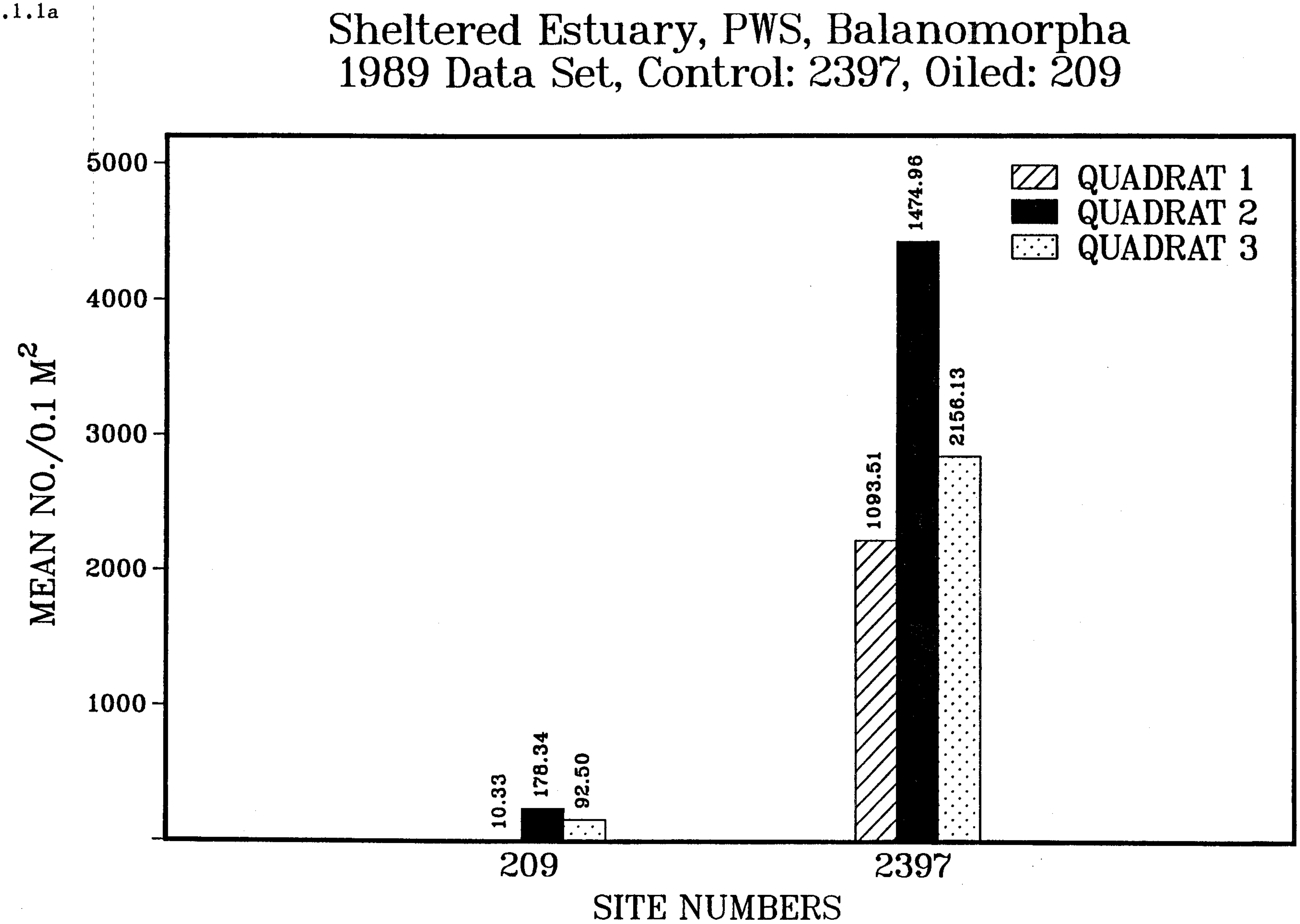

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Fig. 5.1.1b

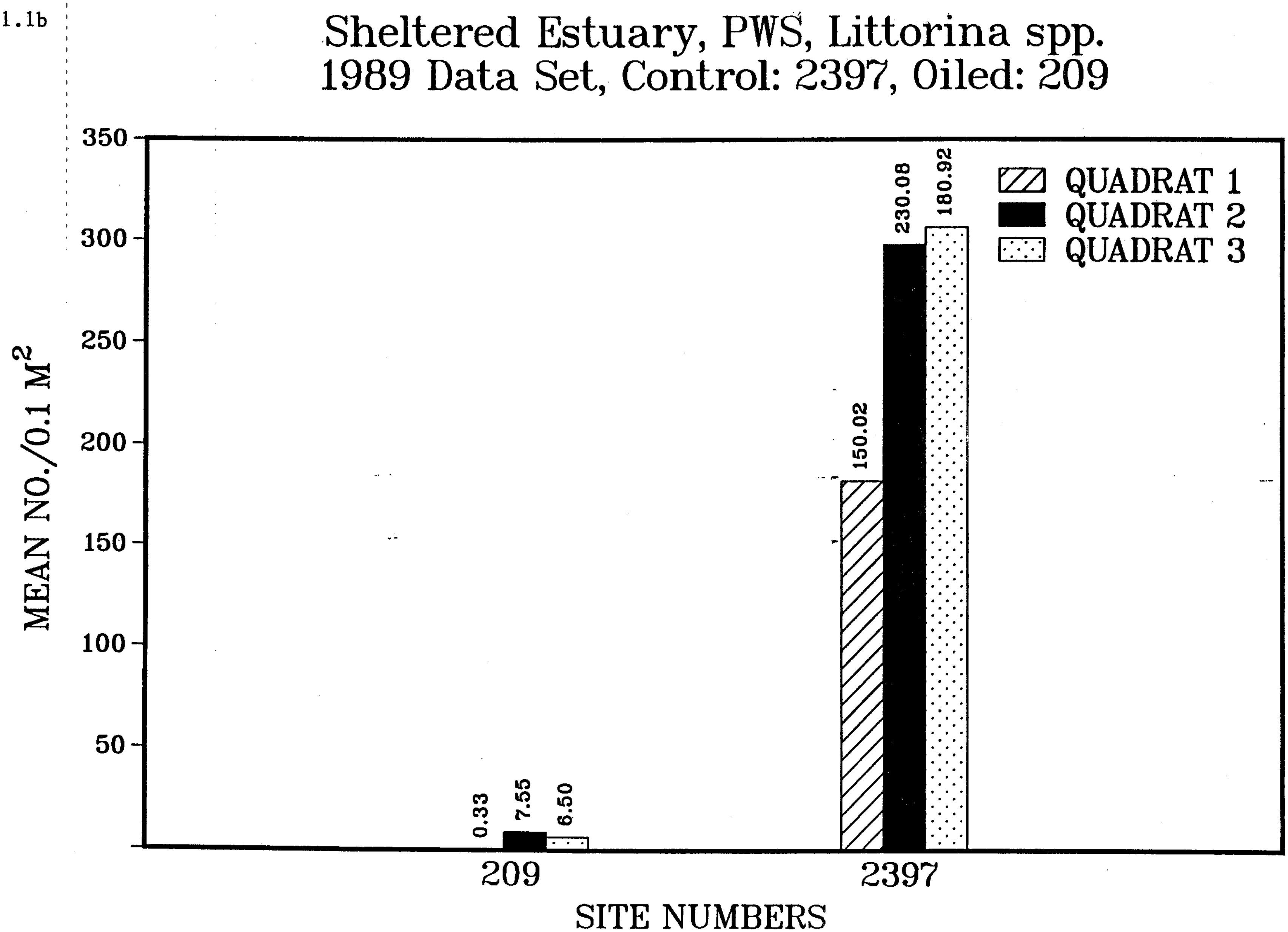

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Fig. 5.1.1c

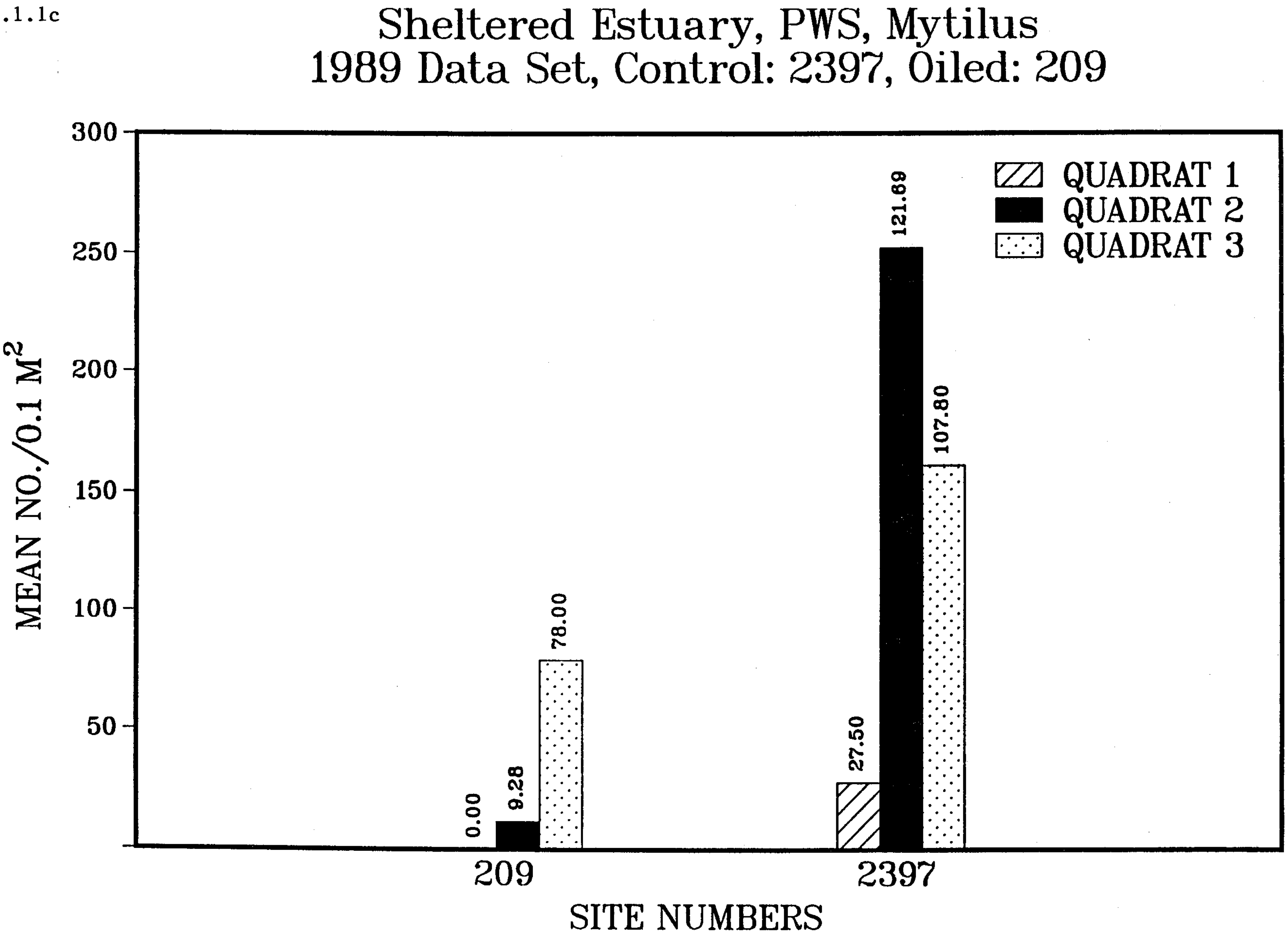
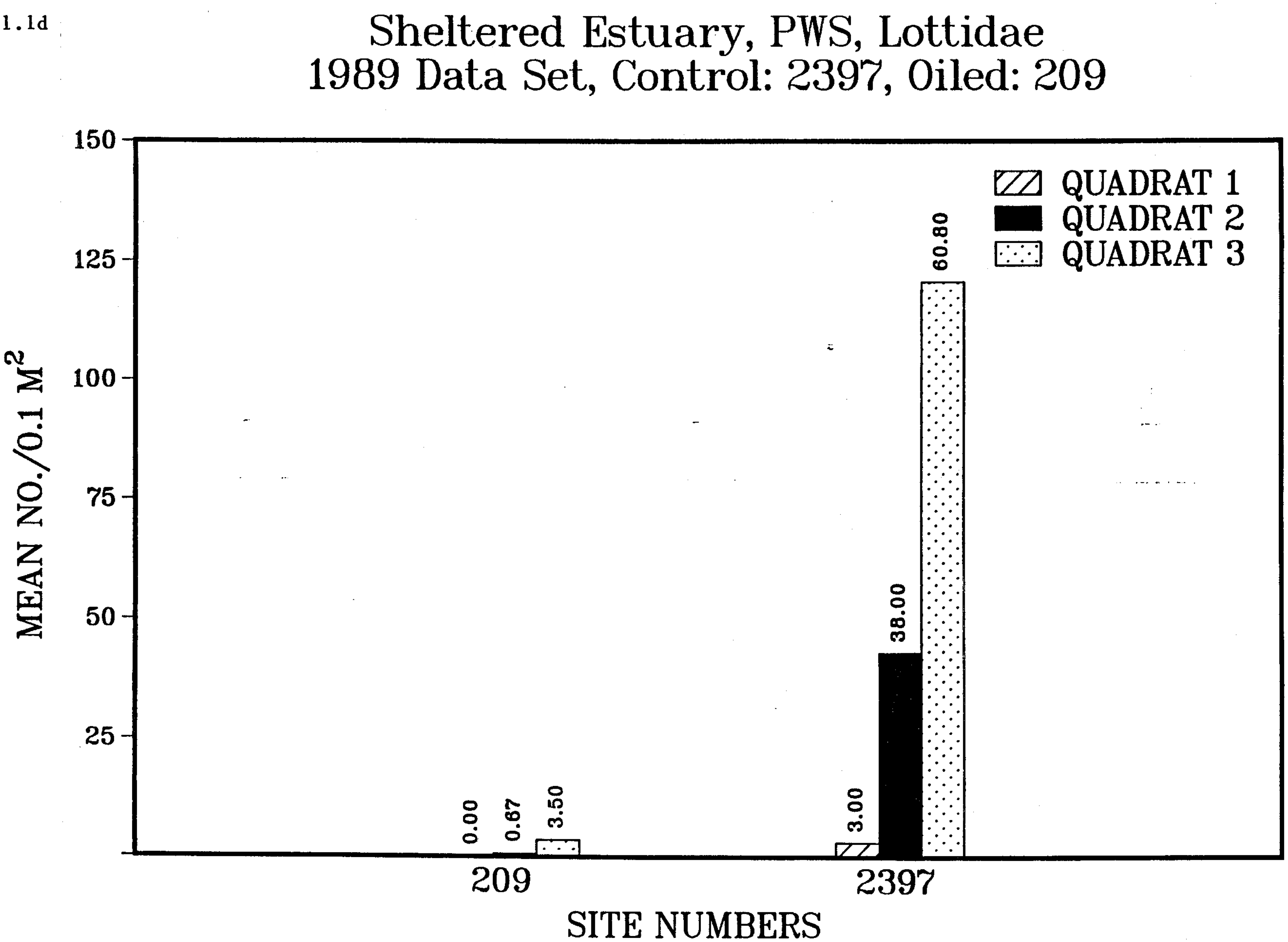

Sheltered Estuary, PWS, Mytilus
1989 Data Set, Control: 2397, Oiled: 209
MEAN NO./0.1 M2
300
250
200
150
100
50
QUADRAT 1
QUADRAT 2
QUADRAT 3
0.00
9.28
78.00
27.50
121.69
107.80
209
2397
SITE NUMBERS

Fig. 5.1.1d



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5.2 EXPERIMENTS IN HERRING BAY

Summary

As a part of the Coastal Habitat Injury Assessment program, an experimental field station was established in Herring Bay, Knight Island, Prince William Sound. The station was established as a result of a NRDA Management Team recommendation, to provide a research platform for intertidal damage assessment through field experimentation.

During the summer of 1990, five separate studies were implemented on 15 pairs of oiled and non-oiled sites in Herring Bay. Careful attention was given to matching pairs of sites, which included similarity in substrate composition, slope, directional and solar aspect, wave exposure, and common biological communities.

One study examined presence/absence differences between common intertidal species on impacted and reference sites. A second study examined differences in the population dynamics of several species of invertebrates between impacted and reference sites. Two separate studies examined settlement between oiled and non-oiled surfaces, and a fifth study examined differences in algal grazing by limpets.

Results from some of the studies conducted this summer are incomplete, pending certain analyses. Nevertheless, portions of the data presented in this report demonstrate that differences exist among components of intertidal communities between the selected oiled and reference sites in Herring Bay, and that some of these differences can be attributed to oil. For example, populations of one limpet species were significantly lower at all oiled sites compared to the non-oiled controls. Also, oiled surfaces appear to retard initial settlement by juvenile barnacles, compared to non-oiled surfaces.

Objectives

Several of the objectives for Phase Two of the Coastal Habitat Study are addressed by the experimental studies conducted from a field camp (barge) in Herring Bay, Knight Island. Specifically, the studies are relevant to objectives A, B, E, and H. While the experimental work may not address any of the objectives in their entirety, the results generated do contribute pertinent information. The general objectives identified in Coastal Habitat Study Number 1 are:

"Phase two:

A. Assess changes in critical trophic levels and interactions, and assess changes in terms of quantity (biomass and productivity/activity of population), quality (vigor, and utility to other trophic levels), and composition (composition of communities, diversity and standing crop of key species).

B. Assess injury to beach sediments and soils.

C. Establish the response of these parameters to varying degrees of oiling and subsequent clean-up procedures.

D. Quantify and extend impact results to the entire spill affected area.

E. Estimate the rate of recovery of these habitats and their potential for restoration.

F. Provide linkages to other studies by demonstrating the relationships between oil, trophic level impacts, and higher organisms.

G. Determine levels of toxicity resulting from hydrocarbon contamination in water/sediment columns along the shoreline.

H. Identify potential alternative methods and strategies for restoration of lost use, populations or habitat where injury is identified."

Introduction

Site Selection

Herring Bay, located at the northern end of Knight Island in Prince William Sound, Alaska, is a large embayment opening to the north. Many parts of this bay experienced extensive oiling from the *T/V Exxon Valdez* spill, as the slick moved south and west from Bligh Reef (Fig.5.2.1).

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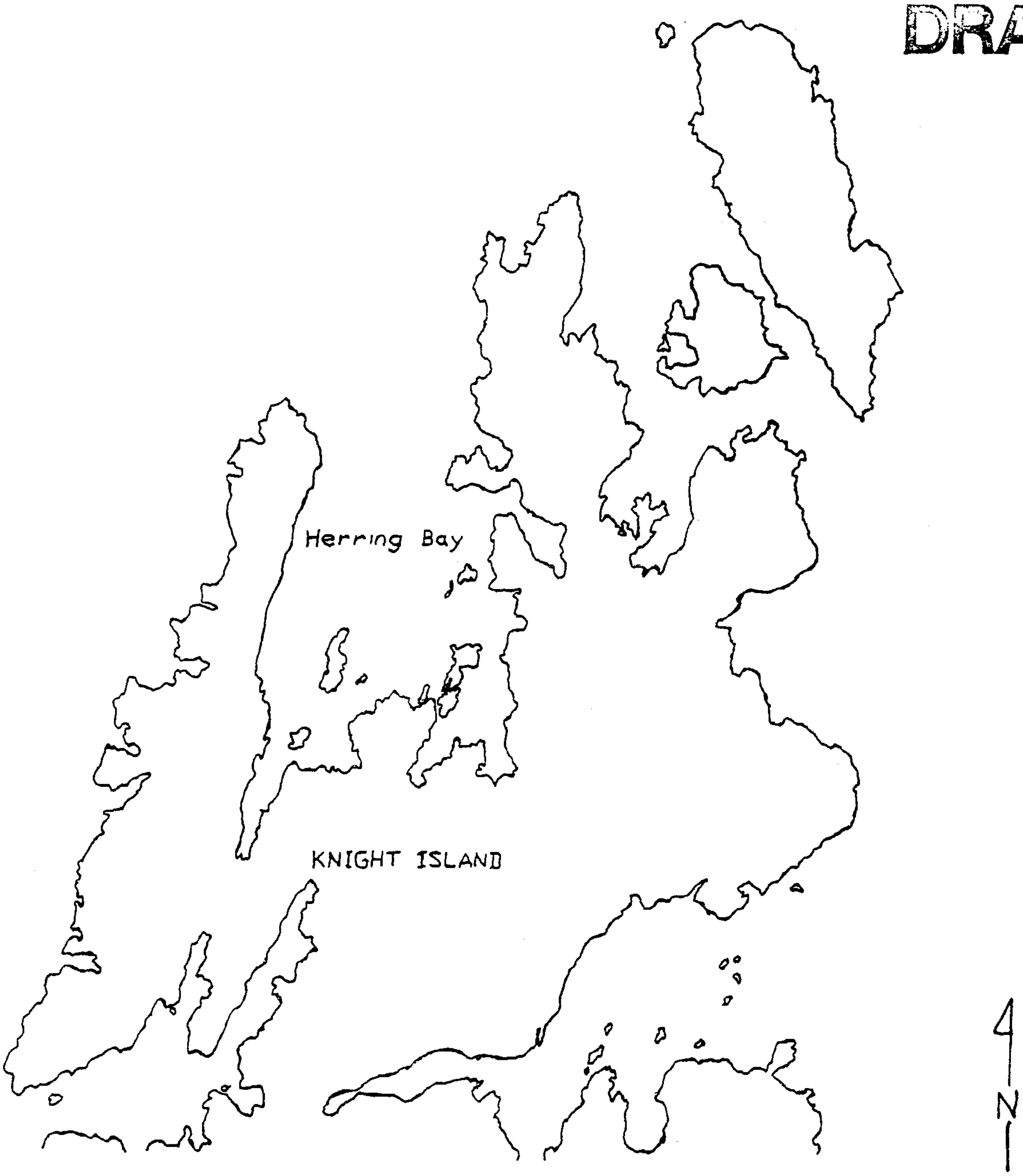

Figure 5.2.1 Herring Bay, Knight Island, Prince William Sound

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In response to the cleanup of oil, Exxon, the U.S. Coast Guard and the State of Alaska developed a classification system of shorelines, which were divided into distinct segments. These segments were arbitrarily defined and vary in shoreline length. Of the 500-plus segments established for the entire shoreline area impacted by the spill, 48 are in Herring Bay (Fig. 5.2.2). During the summer of 1989, the State of Alaska monitored the treatment histories associated with many of the segments. Herring Bay's treatment history during this period is varied. Many different types of mechanical and chemical treatments were applied throughout the course of the summer (Table 5.2.1). Even after many areas were cleaned by high pressure, hot water washing and Inipol, an oliophilic fertilizer used to stimulate bacterial degradation of oil, several areas within Herring Bay still retained a tarred condition or were observed slowly leaching oil. The intertidal communities studied in Herring Bay are categorized as sheltered rocky and sheltered coarse textured environments.

Protected rocky intertidal sites were chosen for study largely because they represent the most common intertidal habitats within Prince William Sound. These sites were not randomly selected, but were matched in an attempt to meet certain shoreline treatment criteria.

In selecting sites for experiments, a range of potential site combinations originally included the following:

A. a set aside site
B. a non-oiled "control" site
C. a mechanically treated site
D. a bioremediated site

A "set aside" is defined as a site that was oiled did not receive any treatment during Exxon's cleanup effort.

"Control sites", are sites which were either truly non-oiled, or received such a light degree of oiling, that they presently could be determined to be oil-free. As discussed by Southward and Southward (1978) and Mann and Clark (1978), use of the term "reference" site may be more appropriate for these areas.

"Mechanically treated" sites are defined as those areas which received one or more washings with various water temperatures and pressures.

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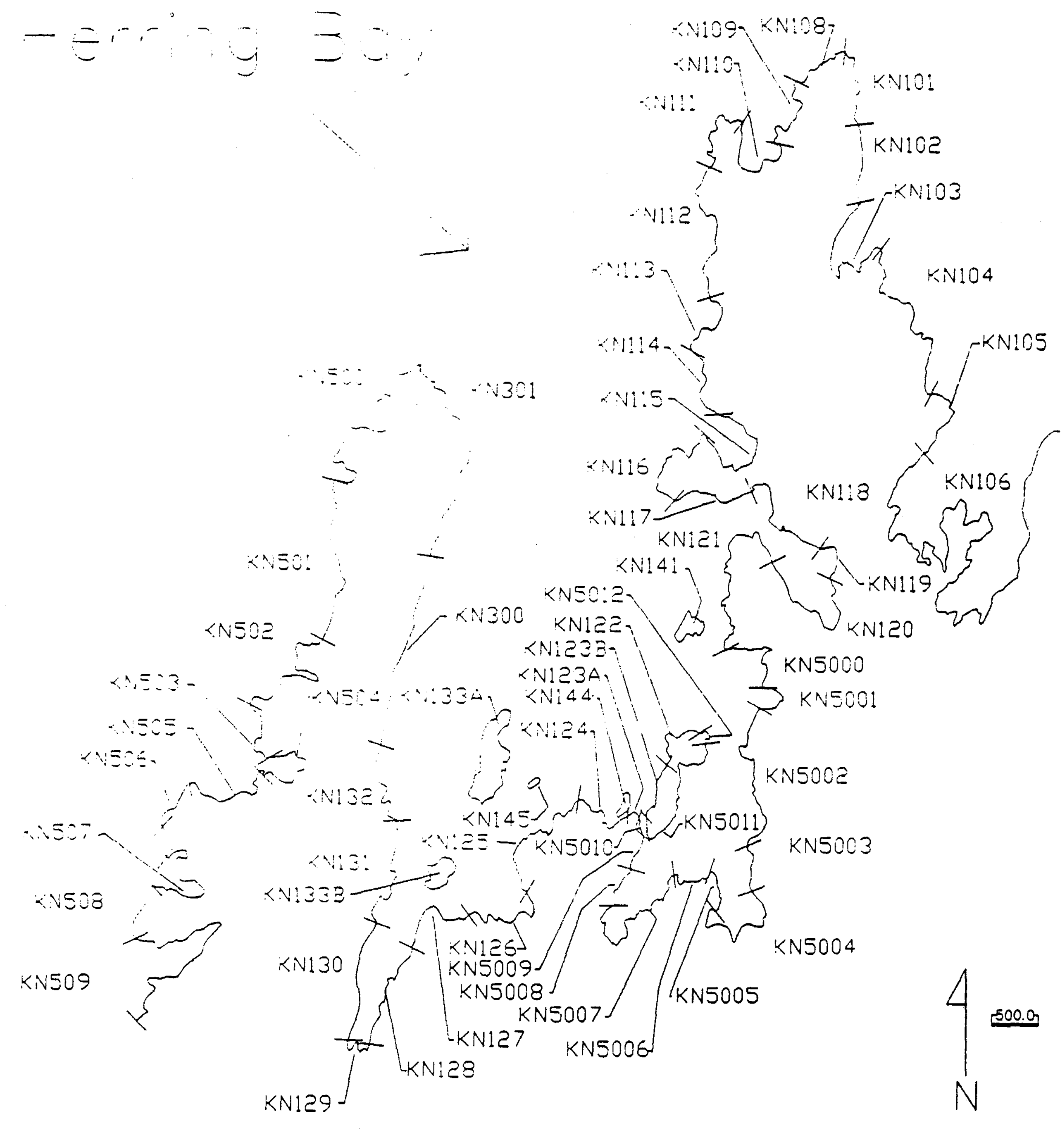

Figure 5.2.2 Segment Numbers in Herring Bay

Knight Island

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TABLE 5.2.1

VARYING TREATMENT TECHNOLOGIES USED IN HERRING BAY

Hot Water Moderate Pressure
Hot Water High Pressure
Cold Water High Pressure
Bioremediation (Inipol, Customblen)
Header Hose Flood
Maxi Barge
Omni Boom
Hand Wiping
Hand pickup, shoveling, etc.

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"Bioremediated sites" are those areas which have received an application of fertilizer (i.e. Inipol-EAP22, or "Customblen"), used by Exxon to accelerate bacterial degradation of oil.

Based on the above combinations, the original matrix created for site selection incorporated a representative from each of these categories. However, after surveys of sites in Herring Bay and review of data from the Exxon/Federal/State spring shoreline assessments, it became evident that division of sites within the above categories could not be clearly determined. Virtually all of the segments identified by Exxon and ADEC in Herring Bay had received bioremediation treatments, in addition to any mechanical cleaning, or had bioremediation occurring during the 1990 treatment season.

Thus, for the intertidal experiments presented in this report, only a sampling matrix of "impacted" and "non-impacted" site conditions could be constructed. Consequently, a total of 30 sites were chosen in Herring Bay, representing 15 pairs of impacted and reference sites (Table 5.2.2).

Matching pairs of sites for study was approached carefully. The selection criteria for study sites included similarity in substrate composition, slope, directional and solar aspect, wave exposure, and common biological communities. In considering pairs of sites, the following procedures were followed and information recorded:

- The length of each site was measured at the MHHW line (observed at the base of the Verrucaria zone).
- The substrate character of the site was described.
- The solar aspect of the site was determined by compass bearing and recorded.
- The wave energy of the site (H,M,L) was observed and recorded.
- Each site selected was noted by latitude/longitude coordinates and compass bearings.
- Video and still photographs of each site were taken.

The location of non-oiled reference sites within the bay were restricted to the southeast corner, where impacts from the spill were very light to none. As a result, the most suitable impacted counterparts also occurred deep within the bay.

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TABLE 5.2.2

List of Study Sites

Herring Bay Experimental Field Station

Site Number and Name	Experiment	Length (M)
1221C Eagle Point	OS	105
1221X Barnacle Pt.	OS	20
1222C Solf Points	OS	40
1322X Pa-hoi-hoi Rock	OS	16
1231C Flower Pop.	PDX, LC	55
1231X North Shore	PDX, LC	32
1251C FCOC	LC	22
1251X Pa-hoi Partner	LC	29
1312C Dead Tree Pt.	LG	34
1312X Barnacle Pt-E	LG	20
1411C Flower Cove	LG	22
1311X Waikiki	LG	15
1641A Barnacle Pt-A	BR	3
1641B Barnacle Pt-B	BR	2
1642C Sullivan	BR	2
1342D Barnacle Pt-D	BR	2
1713C Moon's Tomb	LG	45
1713X OTR	LG	39
1723C Dead Tree Pt.	OS	35
1723X Barnacle Pt-W	OS	29
1732C Nucella Dome	PDX	38
1732X Port Arthur	PDX	42
1852C Blueberry Hill	LC	34
1852X Blackstone	LC	42
2333C Mary's Beach	PDX	51
2333X Wreck Beach	PDX	42
2834C Dave's Beach	PDX	38
2834X Anchor Beach	PDX	31
3811C Gushing Wall	PDX, LG	24
3611X Grease Wall	PDX, LG	33

LEGEND:

OS - Oiled Substrate
PDX - Population Dynamics
LG - Limpet Grazing (Fences)
LC - Limpet Caging
BR - Barnacle Recruitment

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Field Experiments

Five studies were conducted during the 1990 field season. One study evaluated the presence/absence of invertebrates and algae at each site. A second study examined differences in recruitment of several species of invertebrates between impacted and reference sites. Two of the studies tested for settlement between oiled and non-oiled surfaces, and a fifth study examined the differences in algal grazing by limpets between impacted and reference sites.

Study Methodology

Description of Study Areas

Each study site was characterized by establishing three random transects perpendicular to the water line, starting at MHHW. Quadrats were located randomly within the first three meters of vertical fall along each transect. In each quadrat, presence/absence data for all invertebrates and algae were recorded, as well as determination of percent cover. Also, data for temperature and salinity were collected at each of the study sites on a weekly basis.

Population Dynamics

This study examined differences in numbers and recruitment of certain invertebrates with limited dispersal capability (with the exception of limpets) between oiled and non-oiled sites. Limpets were included in this monitoring study because of their likely importance as grazers to community structure.

Materials and Methods, Population Dynamics

Permanent plots were established at five pairs of sites: three sheltered rocky and two pairs of sheltered coarse grained environments. These plots were established at three meters of vertical fall along six randomly placed transects across the site length, establishing a total of 18 study plots per site. Quadrat dimensions were 20 X 50 cm.

Within each of these permanent plots, all limpets, *Nucella* spp., *Littorina sitkana* and *Leptasterias hexactis* were counted. Also, using semicircles with a radius of 1 m adjacent to and centered at the left of the 20 X 50 cm quadrat, the nearest of each of these species was measured and recorded.

Barnacles

Within Herring Bay, certain oiled locations have heavy accumulations of dried tar, especially in the upper intertidal zone, where desiccation and baking by sunlight have resulted in an asphalt condition of the oil. Established barnacle populations were obviously impacted in many of these areas.

The purpose of this study was to examine whether the presence of such tar reduces the settlement capability of barnacle larvae relative to cleaned areas within a tarred substrate. Further, does the presence of oil reduce the survival of barnacle juveniles, and how do such differences compare to barnacle settlement at reference sites?

Materials and Methods, Barnacles

Two oiled sites and two reference sites of similar character were selected in Herring Bay for this study. Sites 1641A and 1342D are oiled vertical faces located on the southern end of a small island, in the lower center of Herring Bay. All sites have vertical faces where barnacles presently exist, or in the case of sites that were heavily oiled and treated, having many skeletons still attached to the substrate (Fig. 5.2.3). Sites 1641B & 1642C are non-oiled reference sites in the southeastern cove of Herring Bay. All sites had high denisities of the barnacle Semibalanus balanoides.

At each site, we established paired 10 X 10 cm plots. One member of each pair was scraped and brushed to remove all visible tar (or barnacles in the cases of the non-oiled sites). The length of each site was measured, and the number of planned pairs divided into the site length. The first plot was placed randomly, within the first segment, and subsequent plots were placed at equal distances from the first. A coin was flipped to determine which 100 cm^2 area of the first pair to scrape. The subsequent scraped plots were then alternated.

Figure 5.2.3 Site 1641A - Asphalted tar in a barnacle community.

The sites were periodically examined for barnacle settlement, as well as germlings of the alga *Fucus gardneri*. The number of barnacle juveniles and germlings were recorded during each inspection. Each 100 cm^2 area was also photographed.

Settlement on Oiled and Non-oiled Substrate

A second study also examined differences in settlement of marine invertebrates and algae between oiled and non-oiled substrates. However, the substrates used in this second study were rocks retrieved from an oiled shoreline in Herring Bay, as well as rocks treated with fresh North Slope crude oil, taken from the *T/V Exxon Valdez* last year.The objectives of this experiment were to examine differences in: a) the percent cover of barnacles and macro algae; b) the number of individuals per unit area; and c) the presence/absence of invertebrate species on oiled and non-oiled substrates placed within various sites.

Materials and Methods, Substrate Transplant

On a beach lying along the western arm of Herring Bay, seventy two oiled rocks of similar size were collected and returned to the laboratory. These rocks represent a substrate coated with 1 year old *Exxon Valdez* Prudhoe Bay Crude (EV). All rocks were collected and packed in boxes and separated by aluminum foil, so that the rocks would not touch one another.

Upon return to the laboratory, all rocks were laid out and one-half of each rock was cleaned with the solvent, Methylene Chloride ($MeCl_2$), with the exception of 8, which were left completely oiled to serve as strata for a weathering analyses of the oil.

After each half was thoroughly cleaned, the rocks were allowed to dry. "Top" and "bottom" of each rock was determined with regard to symmetry and morphology. The "top" was assigned to the surface with the least irregularity. When dry, each rock received a unique identification number and was marked with an indelible marker. Each rock was measured with calipers for total length, and length of the cleaned and oiled sides, and each rock was then photographed.

Also, 72 rocks of approximately the same size were collected from a geologically similar, but un-oiled beach. Half of each rock surface was dipped in fresh Prudhoe Bay Crude (PB) until a "tarred" coating was achieved. These rocks were allowed to dry and were handled in a manner identical to the EV rocks.

In addition to the rocks, 72 clay tiles were incorporated into the experiment. The tiles, being uniform in surface texture and aspect, served as substrate heterogeneity controls for the rocks. Thirty six of these clay tiles were oiled with fresh PB oil and the other 36 remained clean. The tiles were placed side-by-side in the field as oiled and un-oiled pairs.

At each of the experimental sites, rocks and tiles were placed randomly at the 2 m elevation contour. Control rocks (i.e. rocks which were unoiled, but had half of the surface treated with $MeCl_2$) were also placed at each site to test for use of the MeCl2 solvent. Each site received an identical number of rocks and tiles representing the following experimental conditions: The basic experimental unit has been left in the field indefinitely, and consists of 3 EV rocks, 3 PB rocks and six pairs of tiles. The additional rocks were placed to be destructively sampled at three separate time periods. These time periods were mid summer 1990, early fall 1990, and mid spring, 1991.

After placement of all substrates in the field, settlement by barnacles and macro algae on each surface was recorded. Counting involved use of a 3 cm X 3 cm quadrat. The quadrat edge was placed at the midpoint of the line separating the oiled and un-oiled portions of the rock. Where possible, individual species were identified, counted and recorded. Rocks were photographed at a fixed focal length to incorporate the quadrat.

Throughout this substrate transplant experiment, the chemical composition of crude oil will change over time. Consequently, the "thickness" of oil coating of the substrates will gradually decrease. Thus, a procedure was developed to quantify a rate of change in the oil's character. The procedure employed a gravimetric analysis of an area of oil extracted by $MeCl_2$. Therefore, completely oiled EV and PB rocks were also placed in the field as controls for taking samples for this oil "weathering" analysis.

The oil weathering analysis entailed a $MeCl_2$ extraction of a 3 X 3 cm area on each of the control rocks, using a pre-weighed absorbent material. This absorbent material was then placed in a pre-weighed vial. Each vial was opened and stored at room temperature, and allowed to dry. The absorbent material was then reweighed. The sample vials were refilled with $MeCl_2$, and refrigerated for Gas Chromatography/Flame Ionization Detection analysis (GC/FID).

Grazing by Limpets

Studies of previous oil spills have identified the elimination of grazers within the intertidal to be of major consequence to algal and intertidal community structure (Nelson-Smith, 1977; Southward and Southward, 1978). Two studies were designed to examine differences in the grazing of algae by limpets between oiled and non-oiled sites, recolonization of algal species, and to monitor survivorship of limpets between sites.

Materials and Methods, Limpet Fencing

Four pairs of impacted/reference sites were chosen in Herring Bay based upon algal cover within two elevation zones for a total of 16 fences per site. Each fence enclosed 625 cm^2. The fences were constructed of 1/8" steel cloth mesh, and were affixed to the substrate with a two-part marine epoxy.

At each of the eight sites, algal beds were identified and measured at two tidal contours. Because treatment of oiled sites by Exxon resulted in extensive removal of organisms in the upper elevation zones (particularly *Fucus*), plots in the first elevation contour were defined at the control sites. As an example, if *Fucus* began at MHHW, then the horizontal transect was placed at the 1m contour. This dictated location of fence placement at the impacted shoreline where mechanical treatment, such as high pressure-hot water washing, removed large concentrations of *Fucus* cover. This first contour at the impacted sites was also verified by evidence of *Fucus* holdfasts or "skeletonized" stipes.

The second elevation contour was established in an algal zone dominated by a species other than *Fucus* (i.e. *Cladophora*). The oil-impacted sites were used to determine placement of fences at this contour. During cleanup operations Exxon was instructed to treat shorelines only to the mid-intertidal. Therefore, fences were established at the beginning of this zone, where impacts from treatment activities were observed. The elevation from MHHW was recorded, and all fences were placed along this selected contour. This procedure dictated contour and fence placement at the paired reference site.

Placement of the first fence at each contour was generated randomly, and subsequent fences were evenly spaced throughout the workable length of the site from the first fence. Each fence location was prepared by scrubbing a small band outside of the 625 cm area, so the epoxy and fencing would adhere to the substrate. Once constructed, all fences were allowed to stabilize for approximately two weeks prior to implementing the experiment. Small lips were constructed that pointed inward to prevent the crawling escape of limpets from the fences. Finally, large individual plants of the alga, *Fucus gardneri*, were trimmed back, either outside, or within the fencing to prohibit individual limpets from entering or leaving the fence by attaching to the algal blades.

Transects were established to determine the average limpet densities at different meters of vertical fall on ten different sites in Herring Bay. At each site, three transects were randomly established using the methods employed for population dynamics. The data generated from these transects were used to develop a mean number of limpets per 625 cm^2 area. Densities varied at the different meters of vertical fall, therefore, the limpet densities at two different fence contours varied. Also, ratios of two dominant species were observed. *Tectura persona* dominated at the first meter of vertical fall in all cases, and *Lottia pelta* occurred in largest numbers at the second meter of fall (Table 5.2.3).

A total of 2,128 limpets were collected from sites away from the study areas. The limpets collected were within a size range of 10-15 mm. This was a common size range that could be handled with low mortality. These limpets were given an individual ID number, and were tagged. Tags were made of plasticized paper, and ID numbers written in indelible ink were affixed to the shell of each limpet using clear fingernail polish. This method was tested for two weeks prior to implementation and

TABLE 5.2.3

Mean densities of limpets at upper and lower contours.

(1 MVD) UPPER:

Tectura persona	-	4	= 7 /625 cm^2
Lottia pelta	-	3	

(2 MVD) LOWER:

Tectura persona	-	3	= 12 /625 cm^2
Lottia pelta	-	9	

Data is based on a total of 30 quadrats for each contour.
MVD = Meter of Vertical Drop from Mean High High Water

the tag was found to last for this length of time with no loss. Each limpet was then weighed, and its shell width and length was measured and recorded.

Based upon size and species, limpets were assigned to "batches" that were equal to the previously determined mean density per 625 cm^2. These batches were uniquely labeled. Plastic freezer containers were constructed with screened openings to temporarily hold the limpets during processing. All limpets were held for less than two days.

A treatment matrix is shown in Figure 5.2.4. Treatments were randomly assigned to the fences at each site. Half of the fences contained algae, and the other half had all algae removed. Batches were assigned randomly to enclosures by drawing numbered poker chips. Because a batch of limpets comprised the mean number per 625 cm^2, batches were combined or divided to construct the appropriate density for a given treatment (i.e. X, 2X, X/2).

Once assigned, all limpets were placed in the field. Percent cover of algae in each of the fences was determined using a random point method. Percent cover of *Fucus* was separated from other species of macro algae, as it dominates the canopy and not the primary substrate in most cases. The fences were monitored weekly, and the number of limpets remaining were recorded, and percent algal cover determined.

Materials and Methods, Limpet Cages

A second experiment was established which employed cages. These were identical in design to the fences, but with a lid placed over the top of the fence to hold limpets inside and exclude predators.

Three different sheltered rocky site pairs were established for this study. Eight cages per site were randomly placed in algal beds along the 2 meter elevation contour, according to the procedures used for the fencing experiment.

For this experiment 504 limpets, within the same size range and representing the species composition at the second meter of vertical fall were collected identically to the procedure described for the fencing of limpets. An exception to the processing procedure was the use of a different tagging method for the limpets. The tagging

DENSITY OF LIMPETS PLACED

ALGAE RETAINED	2X	X	X/2	0
ALGAE REMOVED	2X	X	X/2	0

Matrix of Treatments applied in the Limpet Grazing Studies

Figure 5.2.4

method of plasticized paper glued with fingernail polish began to fail about 1 month into the fencing experiment. Therefore, plastic tags were acquired, that measure 5mm in length. These tags were affixed to the shell of each limpet, using orthodontic cement. These limpets were also assigned to "batches" and placed in the field in an identical manner to that described for the fencing experiment.

Cages were monitored immediately after the first tidal cycle, and all dead limpets were assumed to have died as a result of handling stress. These individuals were replaced with fresh tagged limpets one time only, and weekly monitoring of the experiment began after this replacement.

Study Results

Site Characterizations

Data for sediment hydrocarbons, water temperature, salinity, and presence/absence of invertebrates and algae at each study site are still being analyzed and therefore, are not ready for presentation in this status report. The presence/absence data analysis will be completed by the end of December, 1990.

Population Dynamics

At the first meter of vertical fall, densities of the limpet, *Tectura persona*, were significantly lower at every oiled site compared to reference sites (P=0.05, Student's T test, Fig. 5.2.5). The densities of another limpet species, *Lottia pelta*, were higher at the reference sites in four of the five site pairs, but the difference was only significant for site pair 1732 (Fig. 5.2.6).

The periwinkle, *Littorina sitkana*, showed no significant difference in densities at any of the three sheltered rocky site pairs; however, *L. sitkana* densities were significantly lower at the oiled sites of the protected, coarse-textured site pairs 2333 and 2834 (Fig. 5.2.7). At the second meter of vertical fall, *Tectura persona* was again found to be significantly less dense at the oiled sites in four of the five site pairs (Fig. 5.2.8). *Lottia pelta* was significantly reduced at the oiled sites in three of the five site pairs and *Littorina sitkana* was also found in fewer numbers at the oiled sites in

Tectura persona: 1st MVD

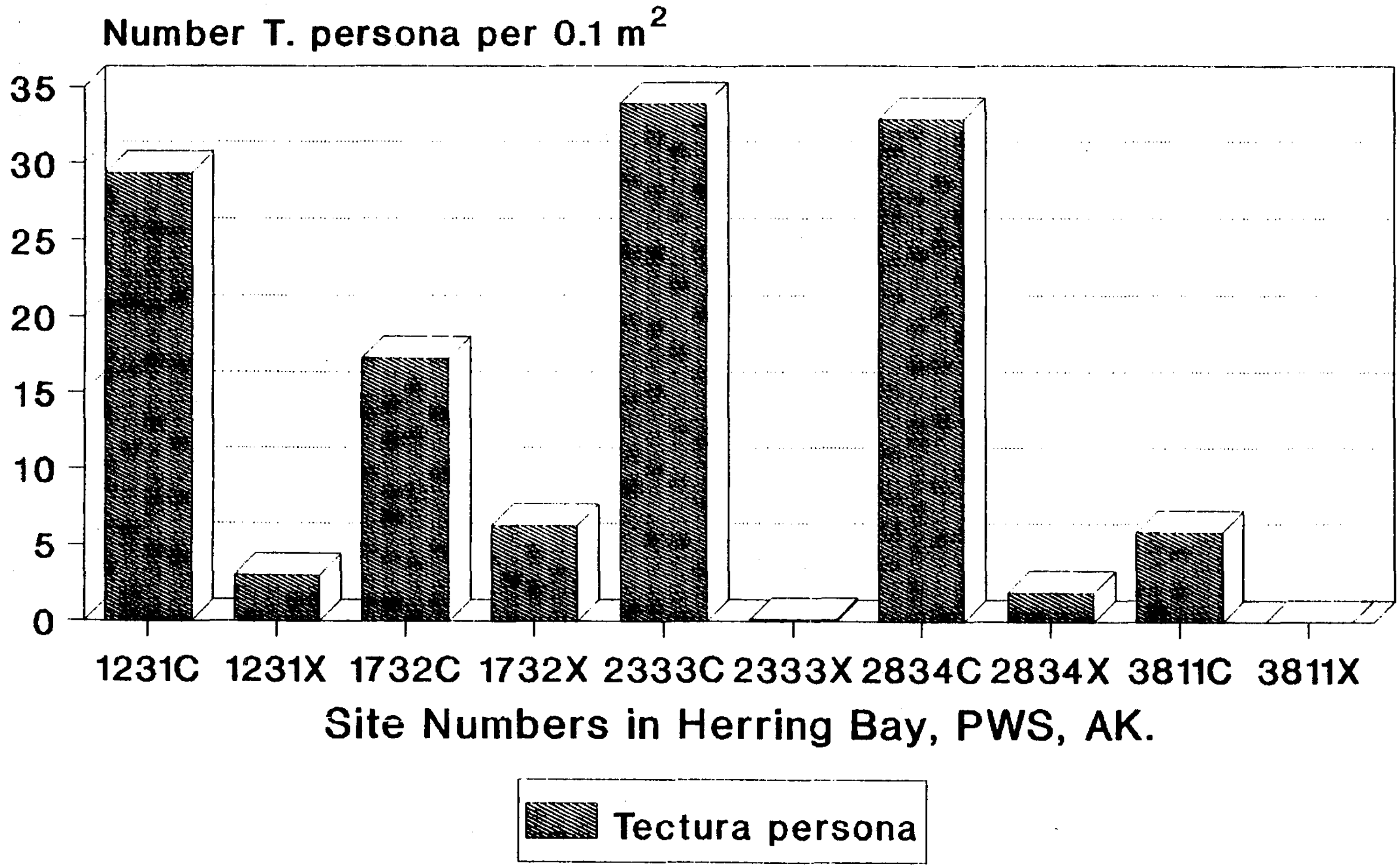

Figure 5.2.5 Mean density per site for all dates monitored. 6/17-9/15, 1990. For site numbers, C=Control, X=Oiled; MVD = Meter of Vertical Drop

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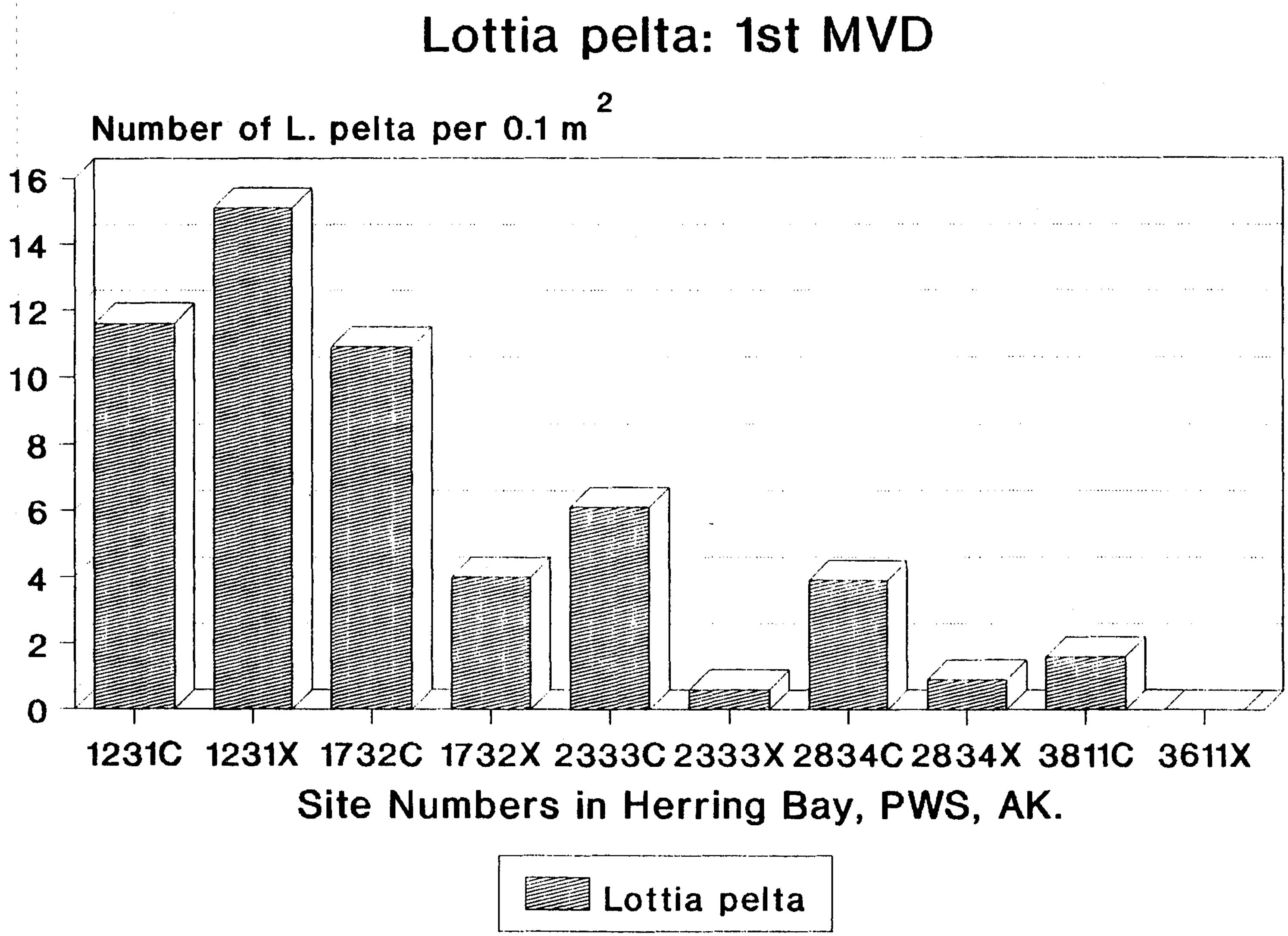

Figure 5.2.6 Mean density per site for all dates monitored, 6/17-9/15, 1990. For site nos., C=Control, X=Oiled. MVD=Meter of Vertical Drop.

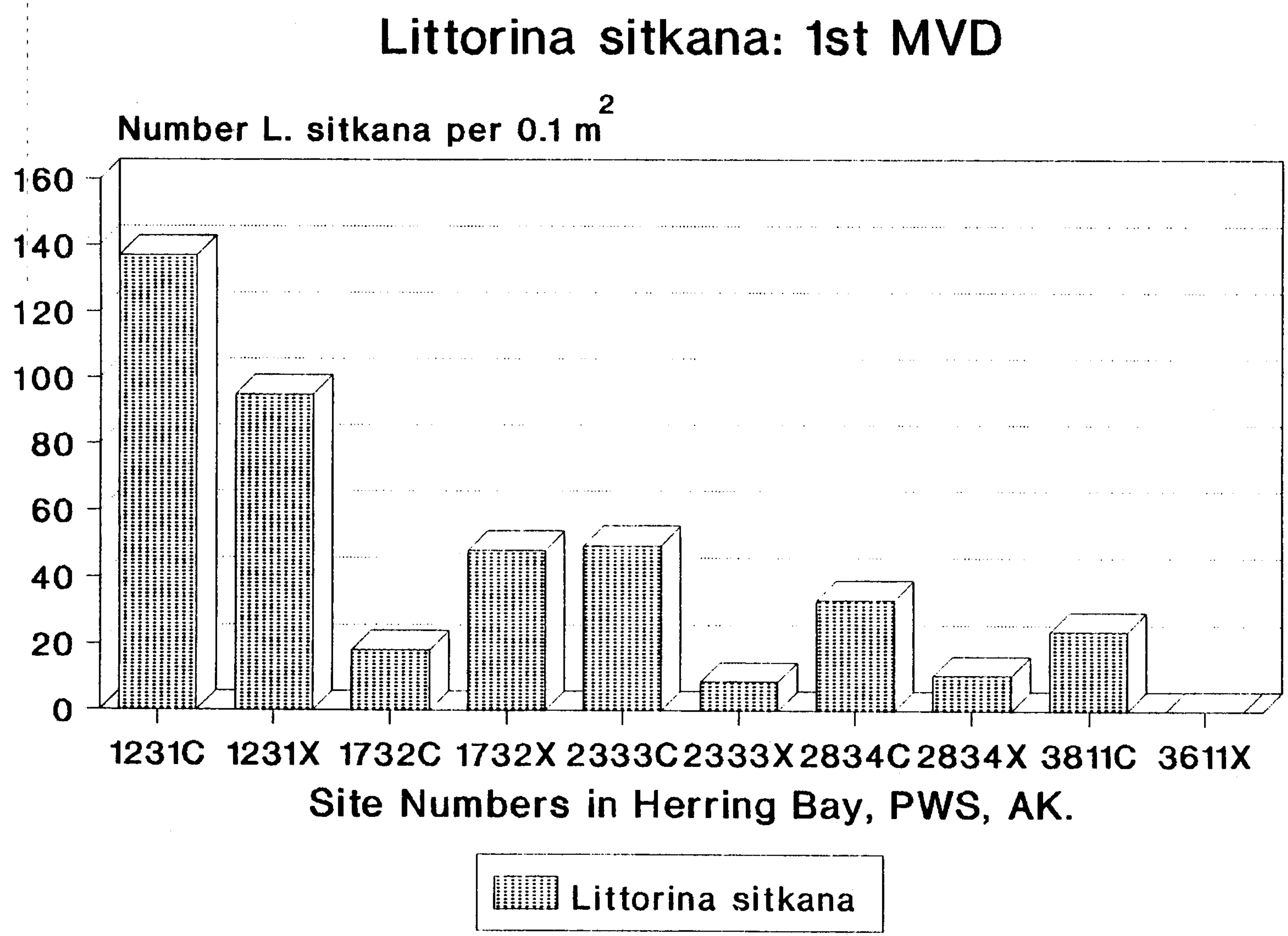

Figure 5.2.7 Mean density per site for all dates monitored, 6/17-9/15, 1990.
For site nos., C=Control, X=Oiled; MVD=Meter of Vertical Drop.

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Tectura persona: 2nd MVD

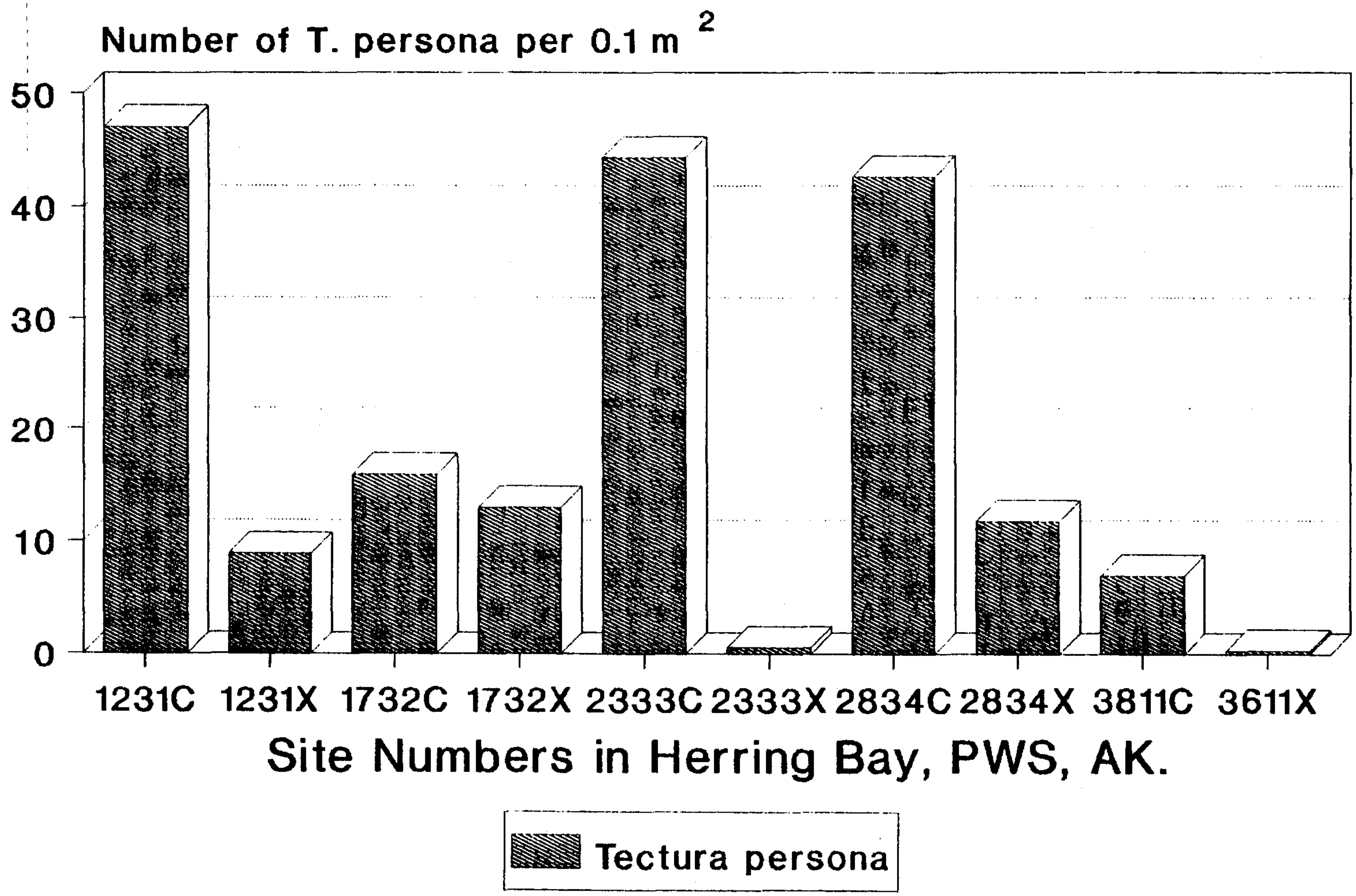


Figure 5.2.8 Mean density per site for all dates monitored, 6/17-9/15, 1990. For site nos., C=Control, X=Oiled; MVD=Meter of Vertical Drop.

three of the five pairs (i.e. sites 1231, 2333, and 2834 for both species, Fig. 5.2.9). Again, for *L. sitkana,* two of the site pairs, 2333 and 2834, were the protected, coarse-textured sites.

The predatory gastropod, *Nucella lamellosa*, was found in high densities at only one study site pair. Site pair 1732 showed no significant difference between *N. lamellosa* or any of the invertebrates studied, with the exception of the small six-armed starfish, *Leptasterias hexactis* (Fig. 5.2.10).

At the third meter of vertical fall *Tectura persona* was significantly less dense at four of the five oiled sites, compared to each control. *Lottia pelta* was more abundant at control sites in four of the five pairs, but the difference was only significant at the P=0.05 level between sites 1231C and 1231X (Fig. 5.2.11). Significant differences in density were not found for other species at this contour.

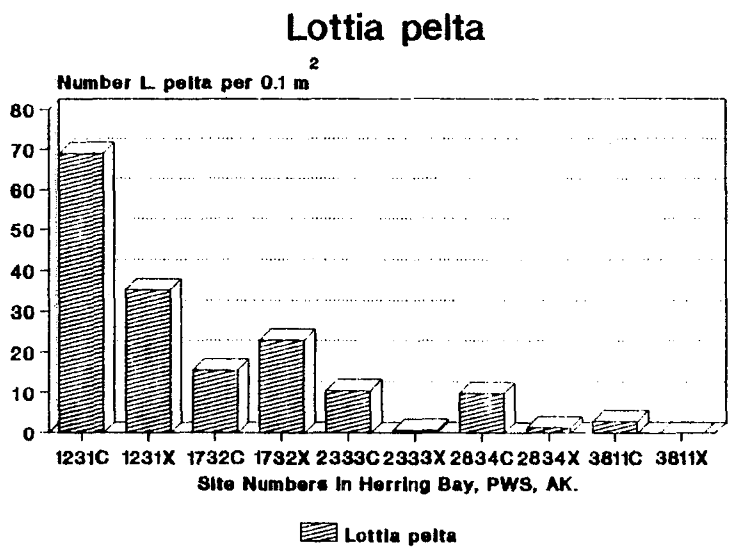
Data analyses for the limpet, *Tectura scutum*, and for limpet recruits too small to identify to species, are still ongoing. The very small limpets, referred to as "unknown" limpets, were observed in large numbers only at the third elevation contour, and beginning only during the middle of August.

Barnacles

Of the four barnacle study sites selected, 2 oiled and 2 reference, only three of the sites were colonized by barnacles. The most heavily tarred site received negligible barnacle recruitment.

For site 1342D (oiled) a higher mean number of barnacles were observed on the scraped 10 X 10 cm plots of the rock face than the tarred plots from August 5 to September 21, 1990 (Fig. 5.2.12). However, in monitoring dates prior to August 5 (June 12 through July 27), only small differences were observed.

At the control sites, 1641B (Fig. 5.2.13) and 1642C (Fig. 5.2.12), a higher mean number of barnacles recruited on the unscraped quadrats compared to the scraped areas during certain monitoring dates. Higher numbers of barnacle juveniles recruited on site 1641B from June 29 to July 18, but not after this time. Site 1642C



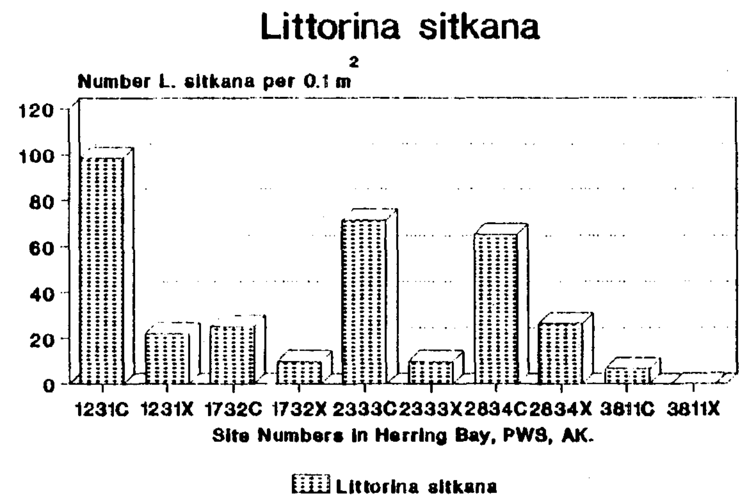


Figure 5.2.9 Mean densities of Lottia pelta and Littorina sitkana at the second meter of vertical fall from MHHW for all monitoring dates, 6/17-9/15, 1990. For site numbers, C = Control, X = Oiled.

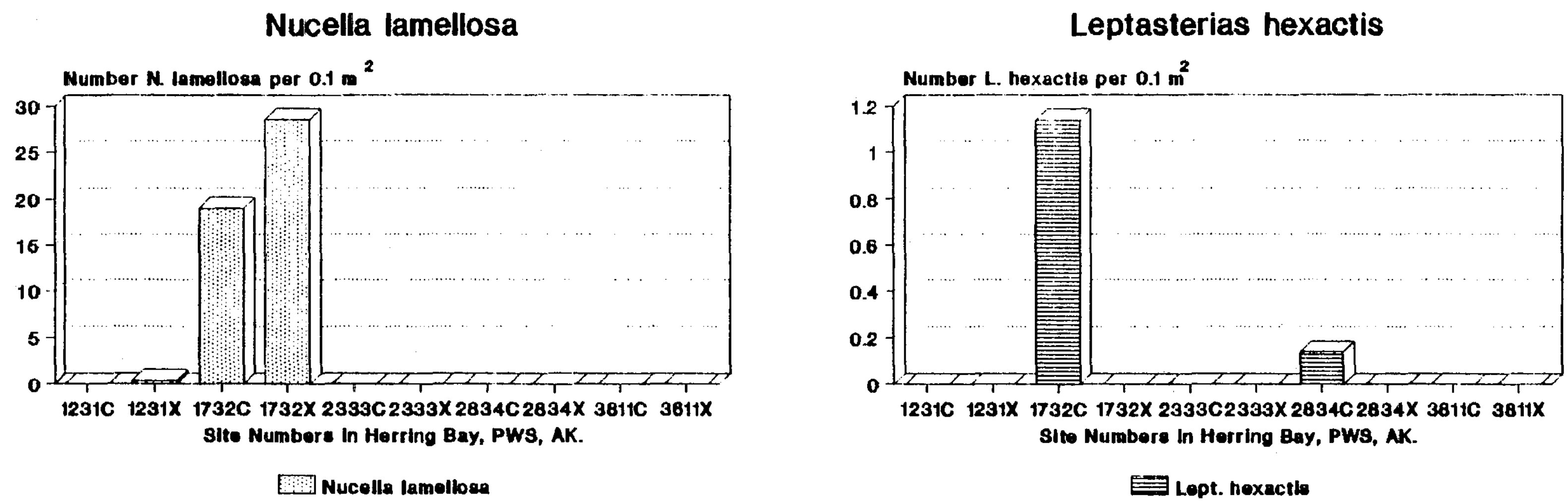


Figure 5.2.10 Mean densities of Nucella and Leptasterias at the second meter of vertical fall from MHHW for all monitoring dates, 6/17-9/15, 1990. For site numbers, C = Control, X = Oiled.

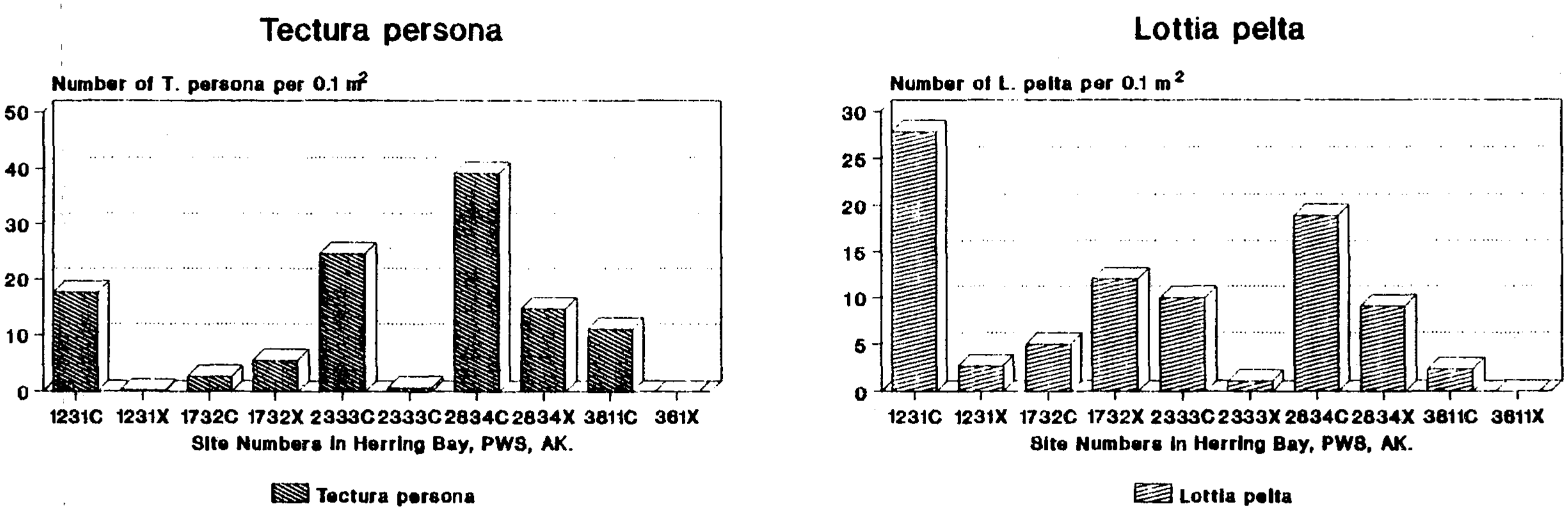


Figure 5.2.11 Mean densities of Tectura persona and Lottia pelta at the third meter of vertical fall from MHHW for all monitoring dates, 6/17-9/15, 1990. For site numbers, C = Control and X = Oiled.

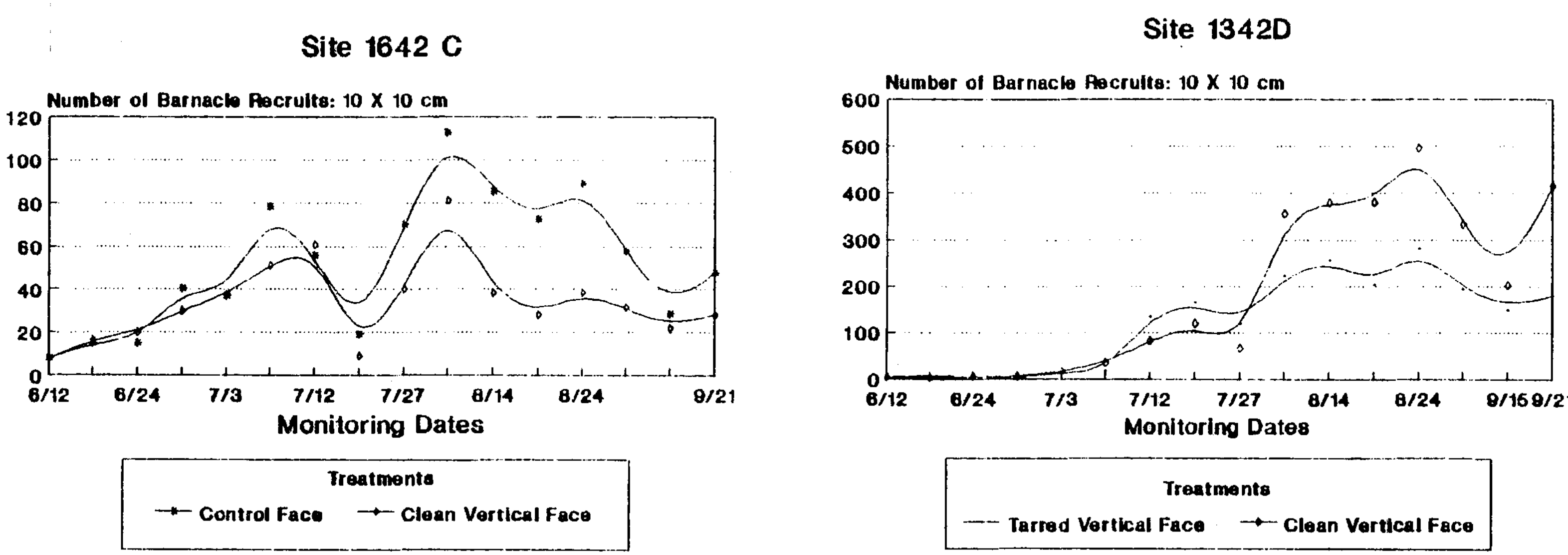


Figure 5.2.12 Mean Barnacle Recruitment, Site 1642C (Control) and 1342D (Oiled). Each site contained three pairs of 10 X 10 cm plots

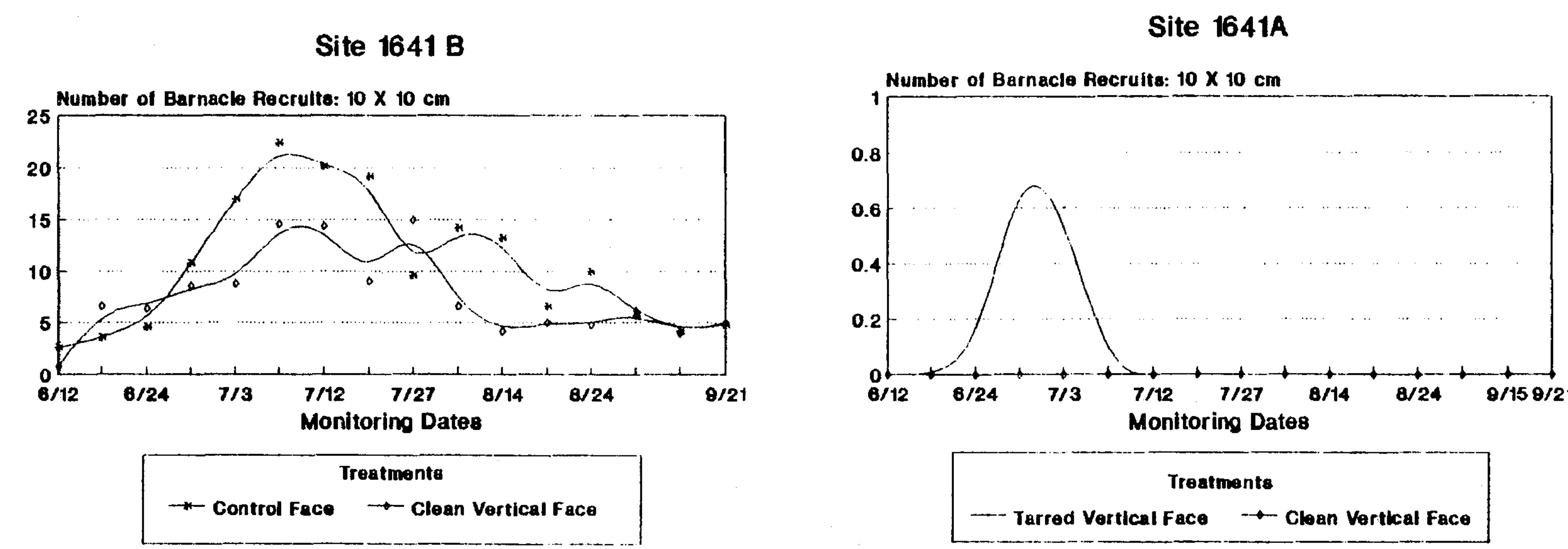


Figure 5.2.13 Mean Barnacle Recruitment, Site 1641B (Control) and 1641A (Oiled). Each site contained five pairs of 10 X 10 cm plots.

did not show difference in barnacle recruitment until July 18, but this difference remained through the end of the monitoring season.

In the case of the oiled site, the evidence suggests that a tarred surface does inhibit the ability of juvenile barnacles to settle compared to the scraped areas. The weakness of this evidence lies with only one of the replicate oiled sites having received barnacle recruitment significant enough to quantify. However, data from both control sites showed ample recruitment, and suggest that settling in and among adult barnacle populations is preferred by cyprids over scraped surfaces, and this finding is consistent with previous research (Knight-Jones, 1953; Strathmann and Branscomb, 1979).

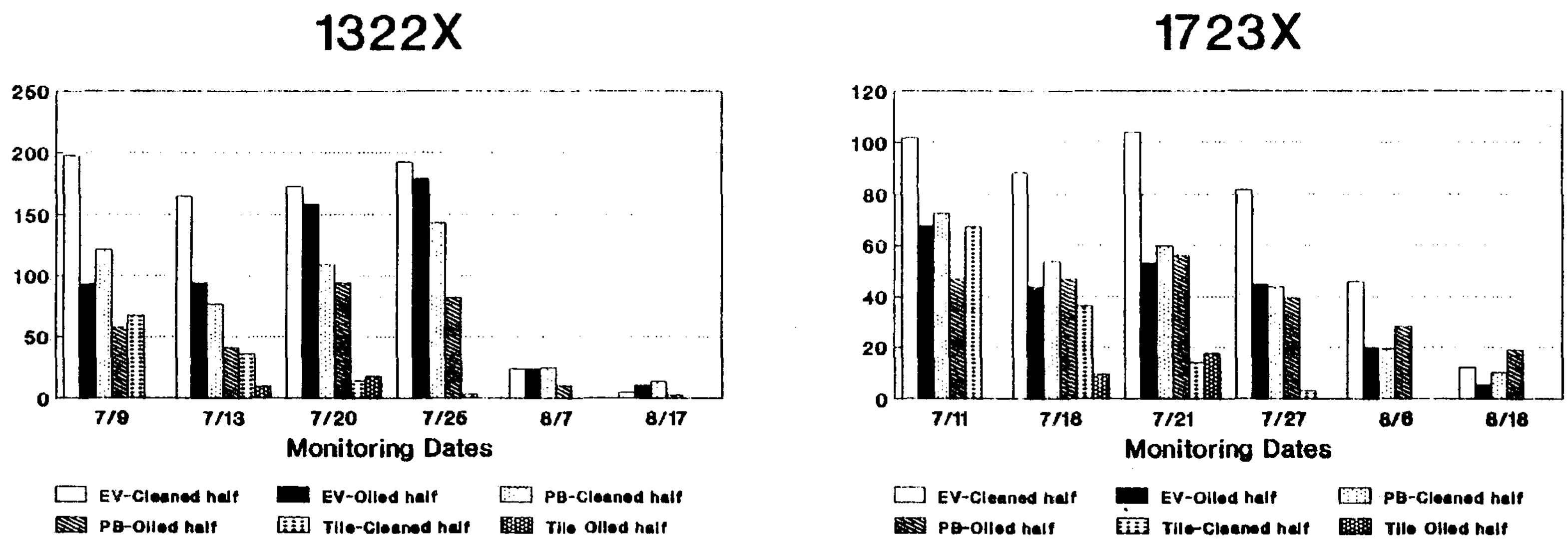
Settlement on Oiled and Non-oiled Substrates

Dates also appear important for observed differences in settlement between oiled and non-oiled substrates. For the monitoring dates of July 7 and 13, higher mean numbers of barnacles were observed on the cleaned halves of EV rocks compared to the oiled halves but not at any other time during the summer (Fig. 5.2.14). Also, fewer barnacle recruits were observed between oiled tiles compared to cleaned tiles on July 7, but again, not on any other monitoring date. No differences were observed on PB rocks at any time. This lack of observed difference may be attributed to a failure to efficiently coat the rocks with oil. Many of the PB rocks were observed to have "washed clean" within one week after placement.

The number of gastropods observed grazing on oiled versus non-oiled areas during each monitoring date were quantified for both of the above experiments. These data are still being processed, and were not ready in time for this report.

Grazing by Limpets, Fencing and Caging Studies

Portions of these limpet studies also remain incomplete, pending certain laboratory and data analyses. Data from hydrocarbon tissue samples for limpets has not been received from the laboratory. Furthermore, given the loss of many limpets in the



EV = 1 year old Exxon Valdez Crude Oil

PB = North Slope Crude applied in June, 1990

Figure 5.2.14 Settlement by Barnacles on Oiled vs. Non-Oiled Substrates.

fencing experiments, which compromised the treatment densities of several sites, the algal percent cover estimation will require additional time.

With the fencing experiment, high mortalities occurred shortly after placing all treatment-densities of limpets in the field. This mortality continued over the course of the experiment, such that no treatment densities of limpets were preserved. Figure 5.2.15 shows differences in the mortality of 2X and X density at the upper elevation contour of the sites. Figure 5.2.16 shows differences at the lower elevation contour.

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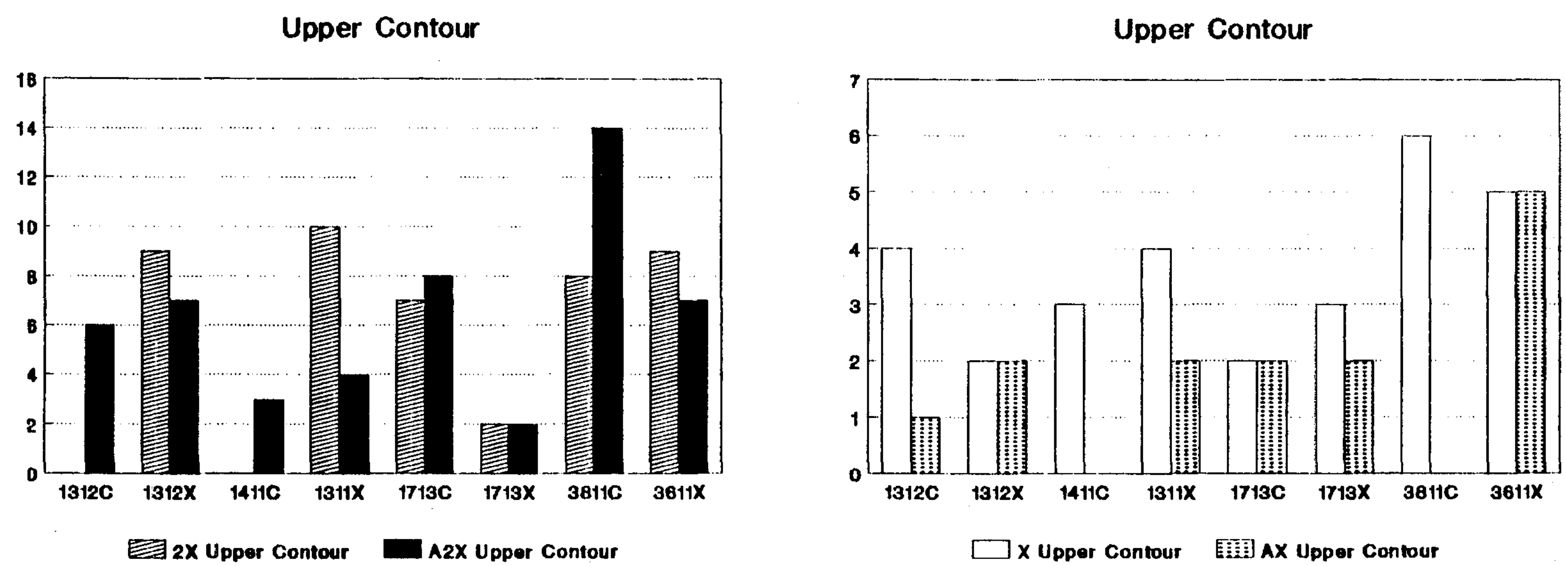

Figure 5.2.15 Limpet mortalities from two different density treatments at the upper contour of oiled and control sites. 2X and X refer to fences without algae. A2X and X refer to fences containing algae.

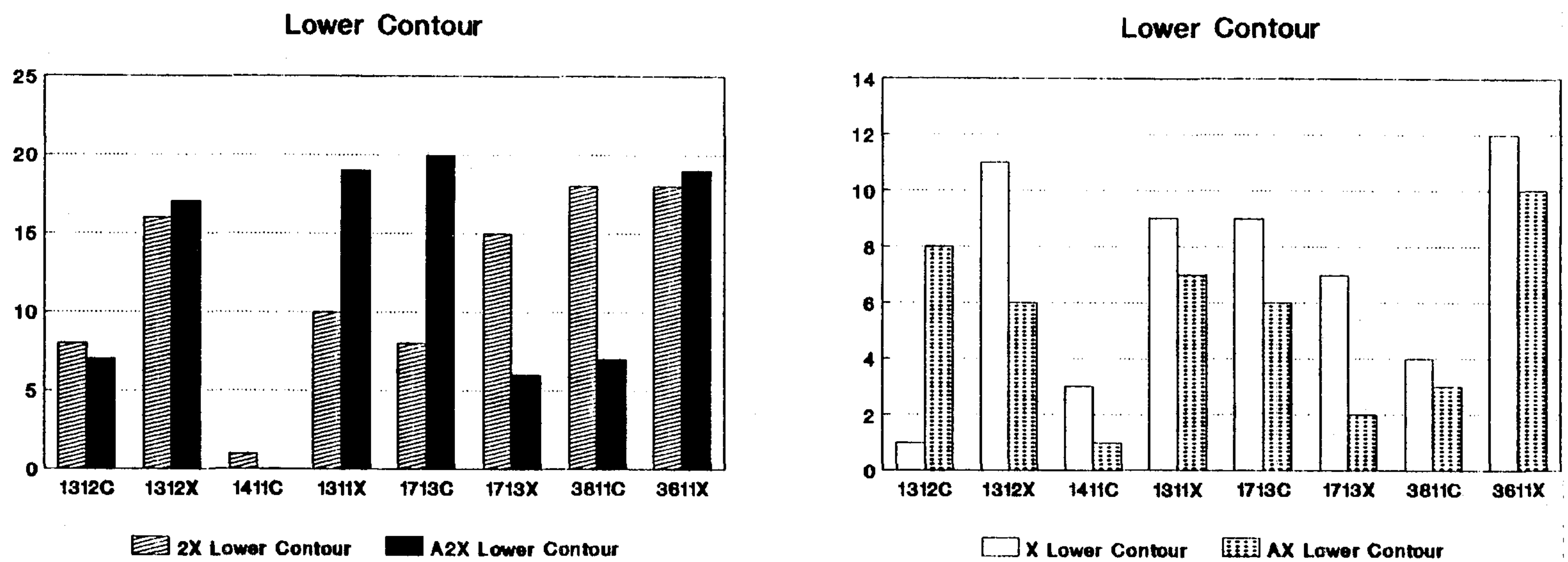

Figure 5.2.16 Limpet mortalities from two different density treatments at the lower contour of oiled and control sites. 2X and X refer to fences without algae. A2X and AX refer to fences containing algae.

5.3 MUSSEL HISTOLOGY

Summary

The purpose of the histological work on mussel tissues is to determine if the oil had an impact on the reproductive activities of the mussels or on the ability of the mussels to accumulate high-energy storage materials for future reproduction. Preliminary analyses of various tissues from mussels collected in all three study regions indicate that the reproductive cycle of mussels at oiled sites in the Lower Cook Inlet/Kenai Peninsula and Kodiak/Alaska Peninsula regions may have been delayed by a few months.

Objectives

The objective of histological analysis of *Mytilus edulis* is to determine if the *Exxon Valdez* Oil Spill had an affect on the gametogenic cycle that occurs during late spring and summer and an affect on the uptake of nutrient storage material of this filter feeding organism that occurs during fall.

Introduction

This preliminary report outlines the field sampling, histological preparation and data analysis of *Mytilus edulis* from the 1989 summer field season of the Coastal Habitat Damage Assessment Project. The report also includes discussion of trends in the data. The purpose of histological analysis of *M. edulis*, an intertidal primary filter feeder, is to determine if the reproductive timing and the ability to collect food stores (proteins, lipids and glycogen) were delayed, blocked or reduced.

Methods

Histology Sampling Technique

The 1989 histology samples for Prince William Sound, Cook Inlet/Kenai Peninsula and Kodiak/Alaska Peninsula were collected from established 1989 survivorship sampling areas. Prince William Sound mussels were collected from 3cm wide swath through the mussel band extending perpendicular to the waterline. Swaths were usually not more than 4 meters in length. Swaths were divided into thirds and approximately twenty mussels were taken from the middle third, which generally had the highest number of individuals. Cook Inlet mussels were collected from an area located 1 meter to the right at a forty-five degree angle from quadrat two at each transect. Kodiak had two sampling techniques depending upon the extent of mussel coverage. If the area was sparsely populated, a 50 cm x 30 cm sampling frame was placed 1 meter to the left of each transect quadrat. If the site had a substantial mussel band, three transects were established randomly within the band (random number chosen by calculator). Three samples were taken from each transect for a total of nine histology samples per site.

Histology Procedures for Tissue Analysis

Mussel samples collected in the field were stored in Formal calcium fixative then transferred to 70% ethanol in the lab for long term storage. Each mussel from a site was separately bagged and tagged as to site, date and given an individual number. The length from anterior to posterior was measured using a caliper and the ages of the mussels were estimated by counting the number of annuli. The adductor muscle was cut and a plug less than one centimeter in diameter was taken from the mantle tissue. The tissue was dehydrated using increasing concentrations of ethanol, to xylene and finally embedded in Paraplast. Thin sections were cut 7 microns in thickness using a Riechert-Jung rotary microtome, then mounted on slides. The tissue was stained using the Papanicolaou technique (Humasen, 1972) which utilizes Harris Hematoxylin,Orange G-6, and Eosin-50.

Stereological Analysis of *Mytilus edulis*

Stereology is defined by Briarty (1975) as the extrapolation from two-dimensional space to three-dimensional space. The relative quantities of different tissue components are derived from point counts using the Weibel type-2 grid superimposed on a random thin tissue section. The data are used to derive a volume fraction, signifying that percentage of the tissue which is occupied by the cell type or tissue component of interest (Weibel *et al.*, 1966; Briarty, 1975). The procedure for point counts is consistent with Lowe *et al.* (1982).

Cell and tissue type structures were determined as follows: Adipogranular (AG) cells stain pinkish-red with a purple center, are round, smaller than oocytes and usually occur in clusters. Vesicular connective tissue (VCT) appears as fine purple lines and / or as bluish-green threads. Spermatogonia are deep blue, fuller and line the internal periphery of the follicle. Spermatocytes occur in the lumen of the follicle and are smaller and darker. Oogonia are large, pinkish mauve cells, polygonal in shape and closely packed during the ripe stage but more diffuse in later stages.

The methods used to determine the reproductive stage of each mussel incorporate those used by Chipperfield (1953), Tranter (1958), Wilson and Hodgkin (1967), Ropes (1968), and Seed (1969a). The eight stages are: resting (T), early active (E), mid-active (M), late active (L), ripe (P), spawning-G (G) with continued gametogenesis, spawning-R (R) to regression and spent (S). The ripe (P) spawning-G (G), spawning-R (R) and spent (S) stages are the reproductively active stages that are observed to determine shift or variations in spawning behavior. The sum total percent volume for these four cell types is referred to as GRSP. Early active (E), mid-active (M), late active (L) and resting (T) are reproductively inactive stages. The sum total percent volume for these four cell types will be referred to as ELMT. The ratio of adipogranular cells to vesicular connective tissue is represented by AG/VCT. Normally, the percent volume GRSP is high at the beginning of the summer while the percent volume ELMT and AG is very low. Conversely, GRSP is very low at the end of summer and percent volume ELMT and AG is high.

Background

According to observations made on *M. edulis* in Port Valdez (McCumby, pers. comm.), spawning begins in April and continues through May to early June. Individuals spawn with continuing gametogenesis, leading eventually to regression and finally to the spent condition by about the end of July. The reproductive artifacts are then resorbed, follicles regress and VCT begins to proliferate. Accumulation of AG cells occurs from approximately the end of August through September. The energy stores of the AG cells provide a low level of nutrition for maintenance throughout the winter but the majority of the energy store is used for the anabolic process of gametogenesis during late spring (Lubet *et al.*, 1959). Accordingly, measurements for percent volume GRSP are expected to be high at the beginning of the summer with a low percent volume AG and AG/VCT ratio and low at the end of the summer with a high percent volume of AG, ELMT and AG/VCT.

Results

For each of the three regions sites were compiled into two time periods, July-August and September samples. Sites in Prince William Sound show a characteristically higher percent volume GRSP (nearly twice as much as AG cells) at the beginning of the summer as compared to the end (Table 5.3.1).

Both controls and oiled sites in September have relatively higher values for percent volume AG and AG/VCT. Interestingly, the percent volume GRSP is similar to the percent volume AG. Normally, this is indicative of a late spawning or possibly a second spawning. Review of slides from two of the sites showed there were many follicles that were in the resting condition but the contents were not completely resorbed by the surrounding tissue. Point counts on these follicles would count as reproductive tissue but not necessarily in the active state.

Sites in Kodiak had higher values in general than Prince William Sound for percent volume AG, AG/VCT and GRSP (Table 5.3.2). The percent volume GRSP in July- August is much higher for the oiled sites (three total) than the control site. The September control samples for Kodiak had high AG/VCT ratios and high percent volume AG as compared to the oiled sites.

Cook Inlet had four sites to work up for July-August 1989 histology and no sites for September (Table 5.3.3). There were two control sites, a coarse textured and a sheltered rocky site, and two oiled sites, a sheltered rocky site and a sheltered estuary. Comparing the control sheltered rocky site and the oiled sheltered rocky site, the control site had very high AG and AG/VCT values compared to the oiled site. Conversely, the oiled site had a high percent volume GRSP relative to the control site. Mussels at the oiled site seemed to be more active reproductively.

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Table 5.3.1 Prince William Sound statistical analysis for July-August 1989 and September 1989.

	Class	Mean
JULY-AUGUST 1989 SAMPLES		
% Vol / ΣAG	Control	10.67
	Oiled	9.85
Total AG / Total VCT	Control	0.39
	Oiled	0.25
% Vol / ΣGRSP	Control	29.53
	Oiled	20.046
% Vol / ΣELMT	Control	4.56
	Oiled	4.99
SEPTEMBER 1989 SAMPLES		
% Vol / ΣAG	Control	14.98
	Oiled	15.97
Total AG / Total VCT	Control	0.70
	Oiled	0.50
% Vol / ΣGRSP	Control	13.47
	Oiled	10.42
% Vol / ΣELMT	Control	5.57
	Oiled	4.88

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Table 5.3.2 Kodiak statistical analysis for July-August 1989 and September 1989.

	Class	Mean
JULY-AUGUST 1989 SAMPLES		
% Vol ΣAG	Control	27.14
	Oiled	6.24
Total AG / Total VCT	Control	0.91
	Oiled	0.18
% Vol ΣGRSP	Control	9.14
	Oiled	25.53
% Vol ΣELMT	Control	3.81
	Oiled	3.88
SEPTEMBER 1989 SAMPLES		
% Vol ΣAG	Control	25.87
	Oiled	15.52
Total AG / Total VCT	Control	0.92
	Oiled	0.49
% Vol ΣGRSP	Control	11.07
	Oiled	11.87
% Vol ΣELMT	Control	4.83
	Oiled	3.97

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Table 5.3.3 Cook Inlet statistical analysis for July-August 1989.

	Class	Mean
JULY-AUGUST 1989 SAMPLES		
% Vol	Control	38.71
ΣAG	Oiled	17.76
Total AG / Total VCT	Control	1.68
	Oiled	0.54
% Vol	Control	8.24
ΣGRSP	Oiled	18.38
% Vol	Control	4.67
ΣELMT	Oiled	5.72

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The single most striking trend in Kodiak and Cook Inlet during the July-August sampling period is that the GRSP values for oiled sites were substantially higher than the corresponding control values while the AG and AG/VCT values were substantially higher for the control sites than the corresponding values for the oiled sites. The above relationships indicate that the mussels from the control sites directed the majority of their energy to the uptake of storage material and connective tissue while the mussels from the oiled sites directed their energy to the maturation and release of gametes. A possible explanation is that the spawning period for mussels at oiled sites was delayed by a few months.

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5.4. FISHES

Summary

The intertidal fish study is divided into field and laboratory components. Objectives of field study were to determine abundance, biomass, recruitment, size distribution, and age of fish from oiled and unoiled sites. Objectives of laboratory studies were to determine changes in histopathology in gill tissues, gill parasite load, and respiration with exposure to oil. A general review of methods are presented with more in depth explanations for those methods that were generalized in the SOP or were modified.

Identification, counting, and measuring length and weight of the fish collected for the field study have just been completed and the data are currently being entered into the data base. Because of this, little can be said about field results. A hasty analysis of total abundance of all species combined was done for both sampling cycles; the Wilcoxon matched pairs signed-rank test detected a significant ($P<0.025$) difference between oiled and unoiled sites but the sign test did not. Within three of five quadrats tested, the sign test detected no difference between oiled and unoiled sites but the Wilcoxon test detected a significant ($P<0.02$) difference for quadrat 3 in sampling cycle 1 but not for quadrats 2 and 4. No significant difference between oiled and unoiled sites within quadrats for the second sampling cycle was found using the sign or Wilcoxon tests. Length frequency of the high cockscomb does not appear to be different for three pairs of sampling sites. From these cursory analyses it would appear that recovery is taking place. It should be stressed, however, that this analysis includes all species together and the effect of cover has not been considered.

Gill tissues have been embedded and the initial stages of examination have begun. No results, however, are available at this time. Gill parasite load was highest in fish collected from a heavily oiled site, intermediate for fish collected at an unoiled site and reared in an aquarium containing rocks coated with oil. Fish from an unoiled site had the fewest gill parasites. Respiration was highest for fish collected from an unoiled site reared in an aquarium with oiled rocks, intermediate for fish collected from an oiled site, and lowest for fish collected from an unoiled site.

Objectives

The intertidal fish in this study is divided into field and laboratory components. The field objectives were to determine: abundance, biomass, recruitment, size distribution, and age of intertidal fish. The laboratory objectives were to determine the injury to gill tissues of intertidal fish by oil. After the laboratory study began a pilot project was initiated which was not planned. The objectives were to determine the influence of chronic hydrocarbon exposure on respiration and gill parasite load.

Introduction

As stated in Objectives, a pilot study was initiated to determine the impact of hydrocarbon exposure on respiration and gill parasite load. The rationalization was that if there were gill histopathological effects respiration would be impaired. Additionally, it is known that chronic exposure of fish to petroleum hydrocarbons may show an increased prevalence and intensity of parasitism (Khan 1987; Khan and Kiceniuk 1988).

Methodology

The methods utilized in the field and laboratory studies are generally contained in the SOP. There were, however, some changes and additions. Following is a brief review of methods used and a description of changes or additions.

Field Collections and Data Acquisition

Intertidal fish abundance, biomass, and recruitment were determined by collecting fish within transects which were divided into quadrats. Each quadrat was defined by a one meter fall in elevation starting from the mean high tide mark. The entire quadrat and subsequently the entire transect was sampled utilizing a 1 x 1.5 meter frame. Biomass and size were determined in the laboratory by weighing and measuring each fish. Recruitment was also determined by ichthyoplankton sampling at each site and ichthyoplankton subsequently counted and identified in the laboratory. Aging will be attempted by examining a calcified body structure.

Fish for hydrocarbon analyses and gill tissue samples were also collected in the field as proposed. It was impossible, however, to obtain numbers of fish as proposed (six specimens each of high cockscomb and tidepool sculpin from each site for gill tissues and at least 10 g of fish from each taxonomic group present at each site for hydrocarbon analyses). In only one case were six specimens of one species collected for gill tissues from each of two matched sites (tidepool sculpin from 1522 and 1522C). Site location, numbers, and fish species collected for hydrocarbon analyses and gill tissues are listed in Appendix II, Tables 1 and 2, respectively.

Effects of Oil on Gill Tissues

For the laboratory study of oil injury to gill tissues in intertidal fish, it was originally proposed that 100 specimens each of the high cockscomb (*Anoplarchus purpurescens*) and the tidepool sculpin (*Oligocottus maculosus*) be collected from oiled sites in Prince William Sound and unoiled sites in the Seward area. Very few tidepool sculpin could be found, however, whereas large numbers of high cockscomb and a few crescent gunnels (*Pholis laeta*) were collected. Additionally, since the Seward area was impacted by oil, we collected fish from unoiled beaches near Seldovia (Kachemak Bay). From Seldovia, 562 high cockscombs and 10 crescent gunnels were collected on 27-28 May and held in aquaria supplied with clean sea water until fish were collected from an oiled site. On 20 June, 94 high cockscombs and 24 crescent gunnels were obtained adjacent to the northern boundary of the heavily oiled site 979 (Green Island). The number and species of fish were placed in three 2,368-l aquaria, each filled with 500-l of sea water with an exchange rate of 2 l/min on 22 June as follows:

Tank 1 - 94 high cockscombs and 24 crescent gunnels from Green Island in an aquarium with clean rocks;

Tank 2 - 206 high cockscombs from Seldovia in an aquarium with clean rocks (control);

Tank 3 - 356 high cockscombs and 10 crescent gunnels from Seldovia in an aquarium with oiled rocks collected from Herring Bay (Knight Island).

Six high cockscombs each from the oiled and unoiled sites were sampled on 22 June. Six crescent gunnels from Green Island and 4 from Seldovia also were sampled. Samples were subsequently obtained one day after their introduction into the tanks, and then with decreasing frequency (Appendix II, Table 3). This is in contrast to the weekly sampling initially proposed in the SOP. This will allow us to detect both acute and chronic effects. At each sampling, total fish length was measured, gills taken for histological analysis, liver for Cytochrome P-450 enzyme assay, and the remaining body for hydrocarbon analysis. No liver tissue could be identified in the crescent gunnels sampled on 22 June. The water in tank 3 also was sampled each sampling period; the water in tanks 2 and 3 was sampled at the beginning, middle and end of the experiment. Fish food was sampled and blank (background) sample jars were prepared periodically for hydrocarbon analyses. The protocols followed when sampling in the laboratory were not included in the SOP and are described in Appendix III.

A general statement regarding techniques to be used in embedding and sectioning the gill tissues collected in the field and during the laboratory study was included in the SOP. A more complete description is given in Appendix III. Dr. Susan Delisa, who is responsible for this portion of the study, modified the techniques from the literature with the assistance of Drs. R. Johnson and J. Tiege (U. S. Environmental Protection Agency, 6201 Congdon Blvd., Duluth, Minnesota, 55804). The second gill arch on the left side of all fishes collected in the field and laboratory, except those sampled in the laboratory on 13 October, have been dissected, processed, and embedded. Tissues have been sectioned and slides prepared of the following to date; high cockscomb taken on 22 and 28 June, and 16 August from each tank during the laboratory experiment and collected from sites 598 and 598C, as well as the tidepool sculpin collected at sites 1522 and 1522C. These were selected for initial qualitative analyses of acute and chronic changes. Following these analyses, all samples will be qualitatively and quantitatively analyzed for changes in gill tissue structure.

Respiration and Gill Parasite Load

Oxygen consumption (VO) was measured for 6-7 high cockscombs weighing between 0.9 to 3.7 g from each of the three test tanks established for determining hydrocarbon effect on gill tissues. Fish were acclimated and tested between 15 September and 5 October. Prior to measuring oxygen uptake, each fish was placed and acclimated for 48 hrs in respiration chamber with one-l flow, without substrate and feeding. The chambers were held in the dark in large constant temperature cooling baths with temperature averaging 9°C ($\pm$1 SD), the temperature at which fish were exposed to for at least one month prior to testing. Preliminary experiments showed no evidence of depressed rates of oxygen consumption. To determine this, fish were sealed in chambers and the background oxygen levels lowered by 0.5 ml l^{-1} and were not allowed to fall below 5.5 ml l^{-1}. In the experiments the oxygen content was therefore not allowed to fall below this level. To determine oxygen consumption the chambers were sealed for 8 to 24 hrs, depending on fish size. Measurements were made twice on two separate days, and averaged, with an electronic probe (Orion 97-08) and meter (Orion 701A) calibrated against Winkler titrations (Parsons *et al.* 1984).

Parasite loads (*Trichodina* sp., a ciliated protozoan inhabiting the gills) were determined following Kahn (1990) and the results to date are for only the sampling in the second week of August but not for the sampling during the last week of October. Fish were taken from the tank and pithed. The gills from the right side were dissected, and for each fish smeared three times each on a slide, dried, and numbers of parasites enumerated. The gills on the left side were excised, preserved in formaldehyde or glutaraldehyde solution, and sectioned following Kahn (1990). The numbers of *Trichodina* sp. per 10 sectioned gill filaments were enumerated.

Results

Abundance and Size

At this stage of the analyses it appears that resident intertidal fishes, all species combined, are recovering from the oil spill in Prince William Sound; there is little difference between oiled and control sites in total fish abundance and in size distribution of all species combined at two paired sites for 1990. Caution should be noted about the analyses; editing of the data has not been completed. It is not expected, however, that any corrections will change the results of the following analyses. It should also be noted that statistical analyses presented are for all species combined and the effects of cover have not been considered.

For both sampling cycles 15 species and unidentified species were captured. For sampling cycle 1 there was an average of 0.32 fish/m^2 on control and 0.19 fish/m^2 on oiled sites (Appendix II, Tables 1 and 2). During sampling cycle 2 there was an average 0.24/m^2 and 0.20 fish/m^2 for control and oiled sites, respectively. Averages for each quadrat within a sampling cycle are shown in Table 5.4.1. The sign test detected no significant ($P = 0.05$) difference between control and oiled sites for either sampling cycle (Table 5.4.2). Comparing control and oiled sites the Wilcoxon matched pairs signed rank test showed that the control sites had significantly ($P = 0.025$) more fish than the oiled sites (Table 5.4.2) in the first sampling cycle. Examining the abundance of fish within quadrats 2, 3, and 4 (generally there were no fish in quadrat 1 except for three sites and there were few samples taken for quadrat 5), in the sign test detected no significant ($P = 0.05$) differences in the first sampling cycle (Table 5.4.3). The Wilcoxon test, however, detected significantly ($P = 0.02$) fewer fish in quadrat 3 of the oiled sites (Table 5.4.3). There were no significant differences between the control and oiled sites for quadrats 2 and 4. For the second sampling cycle no significant differences within quadrats between oiled and unoiled sites were found with either test (Table 5.4.3). At this time we do not know if there are differences in numbers of particular species.

We are currently entering information into the data base for total fish biomass/m^2 and fish sizes. As an indication of the results, however, I have entered data on size of high cockscomb for the sites having the highest fish abundance. The information was summarized as size frequency histograms for 3-cm size groupings (Figures 5.4.1 and 5.4.2) and indicates there is little difference between oiled and unoiled sites. In comparing 1989 and 1990 size distribution data for oiled sites entered to date for high cockscomb, there is greater recruitment in 1990, indicating that recovery is taking place (Figure 5.4.3).

At this time biomass, sizes of fish, and ichthyoplankton data have not been completely entered into the data base nor have we had an opportunity to attempt to age the fish.

Table 5.4.1. Unweighted average number of fish/m2 (No.) for each quadrat in oiled and control sites (n) sampled in Prince William Sound during 1990.

Pair	Quadrat 1 No.	Quadrat 1 n	Quadrat 2 No.	Quadrat 2 n	Quadrat 3 No.	Quadrat 3 n	Quadrat 4 No.	Quadrat 4 n	Quadrat 5 No.	Quadrat 5 n
Cycle 1										
Oiled	<0.01	18	0.07	18	0.27	18	1.67	13	0.41	7
Control	0.02	19	0.09	19	1.29	19	1.63	15	2.49	8
Cycle 2										
Oiled	0.05	18	0.16	18	0.64	18	0.75	14	1.24	4
Control	0.03	18	0.21	18	0.94	18	3.17	14	1.06	5

Table 5.4.2. Results of sign and Wilcoxon matched pairs signed-rank tests for differences in numbers of fish/m2 in quadrats 2, 3, and 4 combined during the first and second sampling cycles in Prince William Sound in 1990. Quadrats 1 and 5 were not included in the analyses because of the frequency of zeros. Negative and positive are the number of signs in which oiled sites contained more fish than control sites (positive). T is test statistic for Wilcoxon, n is sample size, and P is the probability for appropriate test. Probability determined from Table D of Siegel (1956; sign test) and Table II of Wilcoxon *et al.* (1970; Wilcoxon test).

	Cycle 1	Cycle 2
Negative	5	7
Positive	12	10
T	35	47
n	17	17
Sign test P	0.072	>0.315
Wilcoxon test P	0.025	0.149

Table 5.4.3. Results of sign and Wilcoxon matched pairs signed-rank tests for differences in numbers of fish/m^2 for quadrats 2, 3, and 4 during the first and second sampling cycles in Prince William Sound in 1990. See Table 1 for further explanation.

	Cycle 1 Quadrat			Cycle 2 Quadrat		
	2	3	4	2	3	4
Negative	4	5	4	5	7	8
Positive	8	12	6	8	9	3
T	31.5	33	15.5	57	53.5	31
n	12	17	10	13	16	11
Sign text P	0.194	0.072	0.377	0.291	0.402	0.967
Wilcoxon P	0.311	0.020	0.138	>0.5	0.248	0.449

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SITE = 601

Cycle 1

N = 72

Group	#	%
0.000	2	2.78
3.000	36	50.00
6.000	28	38.89
9.000	6	8.33

SITE = 601C

N = 7

Group	#	%
0.000	2	28.57
3.000	1	14.29
6.000	3	42.86
9.000	1	14.29

SITE = 601

Cycle 2

N = 78

Group	#	%
0.000	26	33.33
3.000	30	38.46
6.000	17	21.79
9.000	4	5.13
12.000	0	.00
15.000	0	.00
18.000	0	.00
21.000	1	1.28

SITE = 601C

N = 44

Group	#	%
0.000	33	75.00
3.000	10	22.73
6.000	1	2.27

Figure 5.4.1. Length frequency (in 3 cm groups) of high cockscomb captured during sampling cycle 1 and 2 at oiled and control sites in Prince William Sound during 1990. # = number of fish; % = percent of total.

Cycle 1

SITE = 833

N = 19

Group	#	%
0.000	17	89.47
3.000	1	5.26
6.000	0	.00
9.000	0	.00
12.000	0	.00
15.000	0	.00
18.000	0	.00
21.000	0	.00
24.000	0	.00
27.000	0	.00
30.000	0	.00
33.000	1	5.26

SITE = 1642 (control)

N = 99

Group	#	%
0.000	4	4.04
3.000	50	50.51
6.000	34	34.34
9.000	11	11.11

Cycle 2

SITE = 833

N = 9

Group	#	%
0.000	5	55.56
3.000	4	44.44

SITE = 1642 (control)

N = 43

Group	#	%
0.000	8	18.60
3.000	26	60.47
6.000	8	18.60
9.000	1	2.33

SITE = 232

N = 51

Group	#	%
0.000	19	37.25
3.000	28	54.90
6.000	4	7.84

Figure 5.4.2. Length frequency (in 3 cm groups) of high cockscomb captured during sampling cycles 1 and 2 at oiled and unoiled sites in Prince William Sound during 1990. # = number of fish; % = percent of total.

THE FOLLOWING RESULTS ARE FOR:
YEAR = 1989

, N = 183

Group	#	%
0.000	0	.00
0.500	0	.00
1.000	0	.00
1.500	0	.00
2.000	0	.00
2.500	0	.00
3.000	0	.00
3.500	2	1.09
4.000	4	2.19
4.500	19	10.38
5.000	20	10.93
5.500	20	10.93
6.000	24	13.11
6.500	27	14.75
7.000	16	8.74
7.500	12	6.56
8.000	11	6.01
8.500	7	3.83
9.000	9	4.92
9.500	4	2.19
10.000	4	2.19
10.500	3	1.64
11.000	0	.00
11.500	1	.55

THE FOLLOWING RESULTS ARE FOR:
YEAR = 1990

, N = 198

Group	#	%
0.000	0	.00
0.500	0	.00
1.000	0	.00
1.500	0	.00
2.000	24	12.12
2.500	51	25.76
3.000	32	16.16
3.500	10	5.05
4.000	12	6.06
4.500	11	5.56
5.000	8	4.04
5.500	10	5.05
6.000	6	3.03
6.500	6	3.03
7.000	9	4.55
7.500	4	2.02
8.000	9	4.55
8.500	0	.00
9.000	1	.51
9.500	3	1.52
10.000	0	.00
10.500	0	.00
11.000	1	.51
11.500	0	.00
12.000	0	.00
12.500	0	.00
13.000	0	.00
13.500	0	.00
14.000	0	.00
14.500	0	.00
15.000	0	.00
15.500	0	.00
16.000	0	.00
16.500	0	.00
17.000	0	.00
17.500	0	.00
18.000	0	.00
18.500	0	.00
19.000	0	.00
19.500	0	.00
20.000	0	.00
20.500	0	.00
21.000	0	.00
21.500	1	.51

Figure 5.4.3. Length frequency (in 0.5 cm groups) of high cockscomb captured during 1989 and 1990 cycle 2 at oiled sites in Prince William Sound. # = number of fish; % = percent of total.

Gill Tissue Histopathology

At this time there are no results from the gill tissue and hydrocarbon analyses. The embedding of the gills has been completed and the analyses are being initiated.

Respiration and Gill Parasite Load

Petroleum hydrocarbon negatively affected the fish, both those held in an aquarium with oiled rocks and those from Green Island, the oiled site. The fish from the unoiled site (Seldovia) held in the aquarium with oiled rocks (CFOR) had the highest oxygen consumption rates followed by fish from Green Island (OFCR; Table 5.4.4). They were not significantly ($P > 0.05$; $t = 1.645$, $n = 11$) different from one another. Fish from Green Island (oiled site) and kept in an aquarium with clean rocks had the highest levels of *Trichodina* sp. whereas those from an unoiled site kept in an aquarium with oiled rocks had the second highest number (Table 5.4.4). The control group (CFR) had the lowest number of parasites (Table 5.4.4). The control group also had the lowest oxygen consumption rate and was significantly ($P < 0.05$, $t = 2.92$, $n = 12$) less than fish from Green Island (oiled site) kept in an aquarium with clean rocks.

Table 5.4.4. Oxygen consumption (µl g^{-1} h^{-1}) and parasite (*Trichodina* sp.) load of *Anoplarchus purpurescens* (high cockscomb) subjected to Exxon Valdez oil spill. CFOR=fish from Seldovia held in an aquarium with oiled rocks collected from Herring Bay; OFCR=fish from Green Island (adjacent to north side of site 979) held in an aquarium with clean rocks; CFCR=control fish collected from Seldovia and held in an aquarium with clean rocks. SD=standard deviation.

	Respiration			Parasites		
	n	$\bar{x}$	±1SD	n	% Infected	$\bar{x}$ number of Parasites ±SD
CFOR	7	18	5	12	77	5.75 ±0.12
OFCR	6	16	4	5	100	137.1 ±2.1
CFCR	7	12	2	11	64	0.31 ±0.12

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5.5 ALGAE - SITE SURVEYS

Summary

Several types of data were taken on the intertidal algae in the PWS, CIK, and KAP areas as part of the stratified, random sampling program. Measurements were taken on the percent algal cover, the density of fertile *Fucus* plants, the number of *Fucus* plants and receptacles, the average lengths of *Fucus* plants, the total *Fucus* biomass, *Fucus* egg viability, and the growth of *Fucus* germlings in the field. Preliminary results indicate that oiling and/or post oiling treatment caused damage to the *Fucus* populations in both the PWS and KAP areas. In general, the numbers, biomass, condition, and reproductivity of the dominant intertidal plant, *Fucus* gardneri were adversely affected by oiling. The extent of the damage and the estimated time for populations to recover await the completion of further data collection and analysis.

Introduction

The major visual impact of the Exxon Valdez oil spill occurred in the intertidal zones along the coastline of south central Alaska. Large sections of the intertidal, especially in the upper inter- tidal, were coated with oil and tar residues. The subsequent oil spill clean up effort was also concentrated in these areas. The oiling plus the treatments used in the clean up such as high pressure, hot water washes would almost certainly have impacted the resident intertidal plants. Since it is the intertidal plants along with the habitat type that define each ecological niche, it is important to assess the effects of the oil spill on these plant populations. Damage to the plant community will have ramifications throughout the intertidal ecosystem.

This aspect of the CHIA study examined the impact of the oil spill plus the subsequent clean up activities on the algal populations from five different habitat types in Prince William Sound, the Cook Inlet, Kenai area, and the Kodiak Island, Alaska Peninsula area. Much of the data were measured on the dominant intertidal species, *Fucus* gardneri. Data for this study were collected in cooperation with personnel working on the intertidal fish and invertebrate aspects of the CHIA project.

ATTORNEY WORK PRODUCT

Methods

The experimental design for the CHIA study has been given in the Overview Section of this report. Most of the data reported here were taken as part of the quadrat sampling procedures at each site during the 1990 field season. Additional experimental procedures are also described below.

Percent Cover of Algae Study

At each quadrat in the transect study, drift algae were removed and a visual percent cover estimate was made for every visible species of algae. Percentages were recorded in the field by common species names or descriptive terms. Photographs were taken of the quadrats.

Fucus Study

Fucus was collected along with other intertidal algae found within the 20 cm x 50 cm quadrat and preserved in formalin. At the Juneau Center for Fisheries and Ocean Sciences (JCFOS) the *Fucus* plants were sorted and the length, damage, reproductive stage, number of receptacles, presence of regenerating tissues, inflated blades, type of epiphytes, and percent cover of epiphytes were recorded for each plant.

Student's T-tests were used to compare the quadrat means between paired sites for *Fucus* wet weight, number of plants, number of receptacles, and average plant length per quadrat. *Fucus* damage and reproductivity indexes were also graphed.

Algae Study

Algae were collected within the 20 cm x 50 cm quadrat and preserved in formalin. The algae will be sorted, identified, and, as practical, wet weights will be determined for each species.

Fertile *Fucus* Density Study

Fucus plants were collected at every quadrat on every transect at all sites except estuarine and fine textured sites. The plants were selected at the left hand side of the sampling quadrat in a 1 m semi-circle. A search was made in increasing radii outward. The distance to the first reproductively ripe *Fucus* plant was measured from the middle of the inside left edge of the quadrat frame to the plant holdfast. If there were no *Fucus* plants with ripe receptacles within the 1 meter semi-circle, then the distance was recorded as 0.0.

Results were calculated using the following formula:

$$D = \frac{C-E-1}{\sum_{i=1}^{C-E} \times \frac{\pi d_i^2}{2} + E \times \frac{\pi r^2}{2}}$$

D = density of plants per meter²
C = number of semi-circles examined
E = number of semi-circles examined where fertile *Fucus* did not occur
d_i = distance to the nearest fertile *Fucus* plant in the "i"th semi-circle
r = radius of the semi-circle (1 meter)

Student's T-tests were used to compare the means between each paired site in each of the categories using the 0.01 level of significance.

Fucus Egg Viability Study

The whole plant was collected in the field as described in "5.2.4 Fertile *Fucus* Density Study". One reproductively ripe receptacle was chosen from each plant for egg release aboard the boat. The chosen receptacles were incubated in sterile seawater at 8-12°C for 48 hours, then stained with calcoflour and preserved with formalin. A control of this procedure was performed at the JCFOS Laboratory. The percentages of unfertilized eggs, fertilized eggs, and divided eggs were determined for all experiments at the JCFOS facility. Student's T-tests were used to compare the means between each paired site in each of the categories using the 0.01 level of significance.

Fucus Germling Survival Study

Fucus eggs were released from ripe *Fucus* receptacles collected in Juneau. The receptacles were washed, dried and placed in petri dishes covered with sterile sea water. The dishes were incubated at 10°C on a 16:8 light/dark cycle for 48 hours. Pre-made tiles (7.5 cm x 7.5 cm) were seeded with an egg density of 125-150 eggs/cm^2. The plates were incubated for an additional 4-5 days and then frozen for shipment to the field. The plates remained frozen until they were set out on the beaches.

Each site, excluding estuarine and fine textured habitats, received one pair of settlement plates per transect, one of the plates was not seeded and the other plate was seeded with *Fucus* as described above. The pair of plates, control and seeded, were placed at the 2.5 MVD contour below the high tide mark and 1.5 to 2.0 m to the right of the N.3 transects. Control and seeded plates were placed randomly to the left or right of each other and pictures were taken to record the surrounding area. All adult *Fucus* plants within 1 m radius of the plates were cleared from the area. Two pairs of plates from sites 506/506C and six pairs of plates from sites 1171/1171C were collected after 4 weeks in the field, preserved in formalin, and enumerated at JCFOS. New plates were put down on these sites. All plates will be collected in the summer of 1991 for enumeration. Pairs of plates were set in the JCFOS surge tank and on the beach in Auke Bay, Juneau to serve as controls for plant viability. These controls were also enumerated and the results included in this report. T-tests were performed at the 0.01 probability level on the enumerated plates.

Algae Species Diversity Study

At each site, a transect voucher collection and a site voucher collection of intertidal algae were made. The transect voucher collections were collected next to the quadrats and are representative of what was being collected in the quadrats. The site voucher collections were collected throughout the rest of the site containing those species not represented in the quadrat and any reproductive specimens. Quadrat and site voucher collections were labeled and preserved in formalin. Reproductive and newly encountered species were taken from these collections and pressed on herbarium paper. Species identifications were performed by Dr. Gayle Hansen, project algal taxonomist.

Sediment Hydrocarbon Study

Two transects were randomly chosen to collect sediment consisting of inorganic matter no more than 2 cm in diameter. If sediment in the sampling areas did not fall within this definition, no sample was taken and no new transects were chosen for sampling. The sampling area was a 1 m radius semi-circle located immediately to the left and center of the limpet/mussel/*Fucus* semi-circle which in turn is located next to the sampling quadrat.

Samples were collected using hydrocarbon-free spoons and 4 ounce I- Chem jars. The jars were filled by collecting the first surface sediment spoon full and every other spoon full until the sample was completed. A blank sample was taken along with the first sample collected on the site. Samples were properly labeled with corresponding chain of custody forms and frozen for shipment.

Temperature and Salinity Data

Temperatures and salinities were recorded at each site at the 15 m depth contour in the middle of the site using a YSI Model 33 S-C-T Meter. Readings were taken at the surface (0.2 m below the surface) and consecutive meter depths to 10 m. Weather and local freshwater sources were also recorded. Temperature and salinity readings were taken on the same day that the site was sampled.

Results

Prince William Sound

Percent Cover of Algae Study

A power analysis of the percent cover data from Prince William Sound showed that acceptable variances could only be obtained with sample sizes ranging from 37 to 151. The highest sample size in our data for percent cover was 36. To minimize this variability a more quantitative analysis of percent cover using slides taken during the field season will be performed.

Fucus Study

Paired sites 453 and 453C

The data from 453 and 453C show consistencies in effects at each MVD. The length frequency data at each MVD shows that there were more *Fucus* plants per quadrat in the control site, while the oiled site had relatively fewer but longer plants (Figure 5.5.1). This data is consistent with the average length of the *Fucus* plants and with the plant number per quadrat data in Figures 5.5.2 and 5.5.3. The biomass (wet weights) was higher for the *Fucus* plants in the control site (Figure 5.5.4). Although the trends in the data are consistent, the only differences that are significant at $p<0.01$ are the mean lengths at each MVD (Table 5.5.1).

The Reproductivity Index shows that the control site had less than 20% of its *Fucus* plants with receptacles present at each MVD (Figure 5.5.5). The oiled site had the highest percentage (42.9%) of reproductive plants, fully swollen with ripe conceptacles and mucilaginous, at the 3 MVD (Figure 5.5.5) However, the total number of receptacles per quadrat was highest in the control site (Figure 5.5.6).

The Damage Index shows that over 70% of the plants in the control site were healthy and normal (Figure 5.5.7), while at the oiled site only 17% and 27% of the plants were healthy at the 1 and 2 MVD. There were no healthy (undamaged) plants present at the 3 MVD at the oiled site. Most of the damaged plants displayed exterior erosion or abrasion. At the oiled site 72.5% of the plants in the 1 MVD, 40.9% in the 2 MVD,

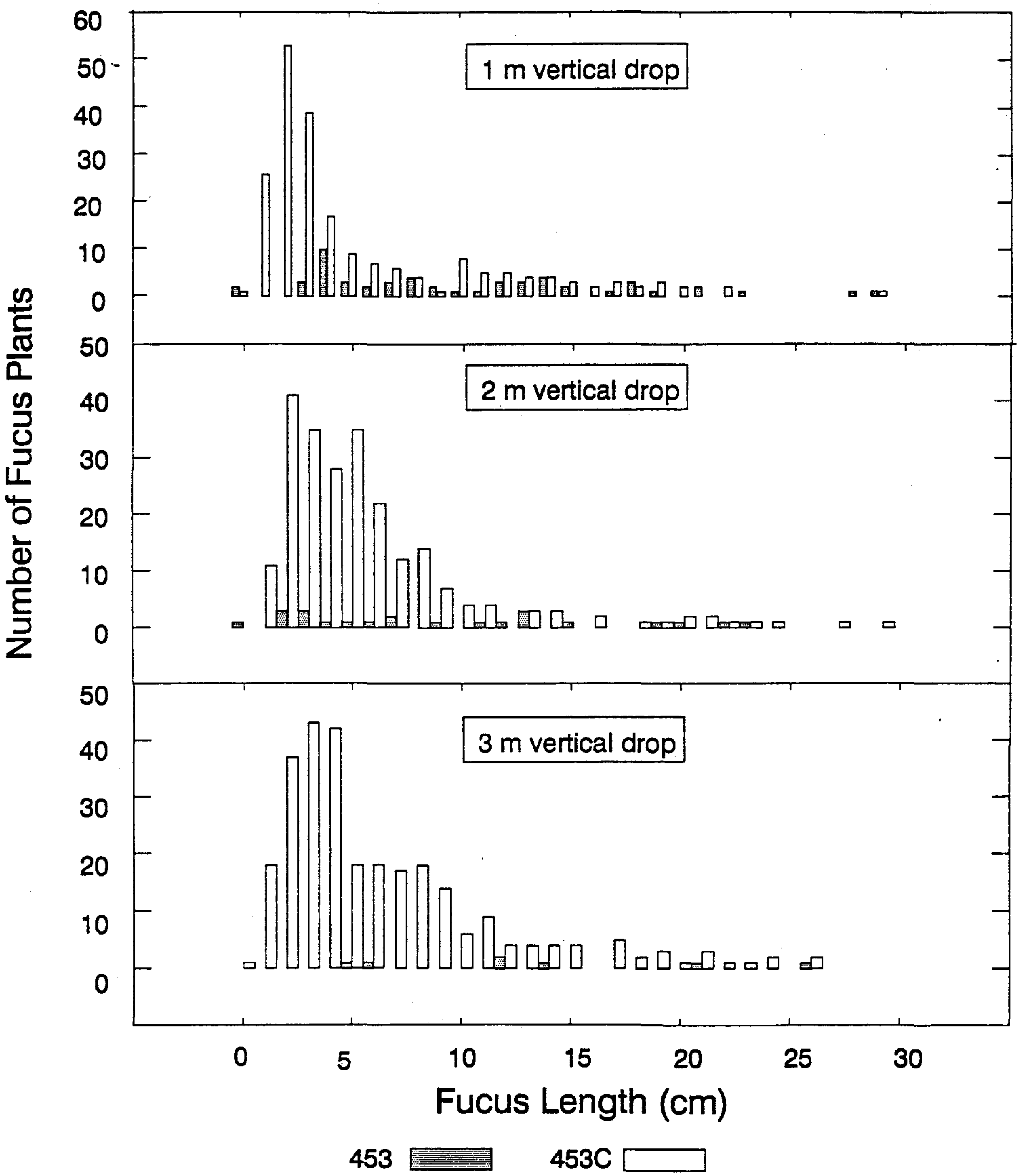

Figure 5.5.1. Fucus length frequencies in a sheltered rocky habitat, PWS, Alaska. First visit at paired sites 453 and 453C for three MVD's.

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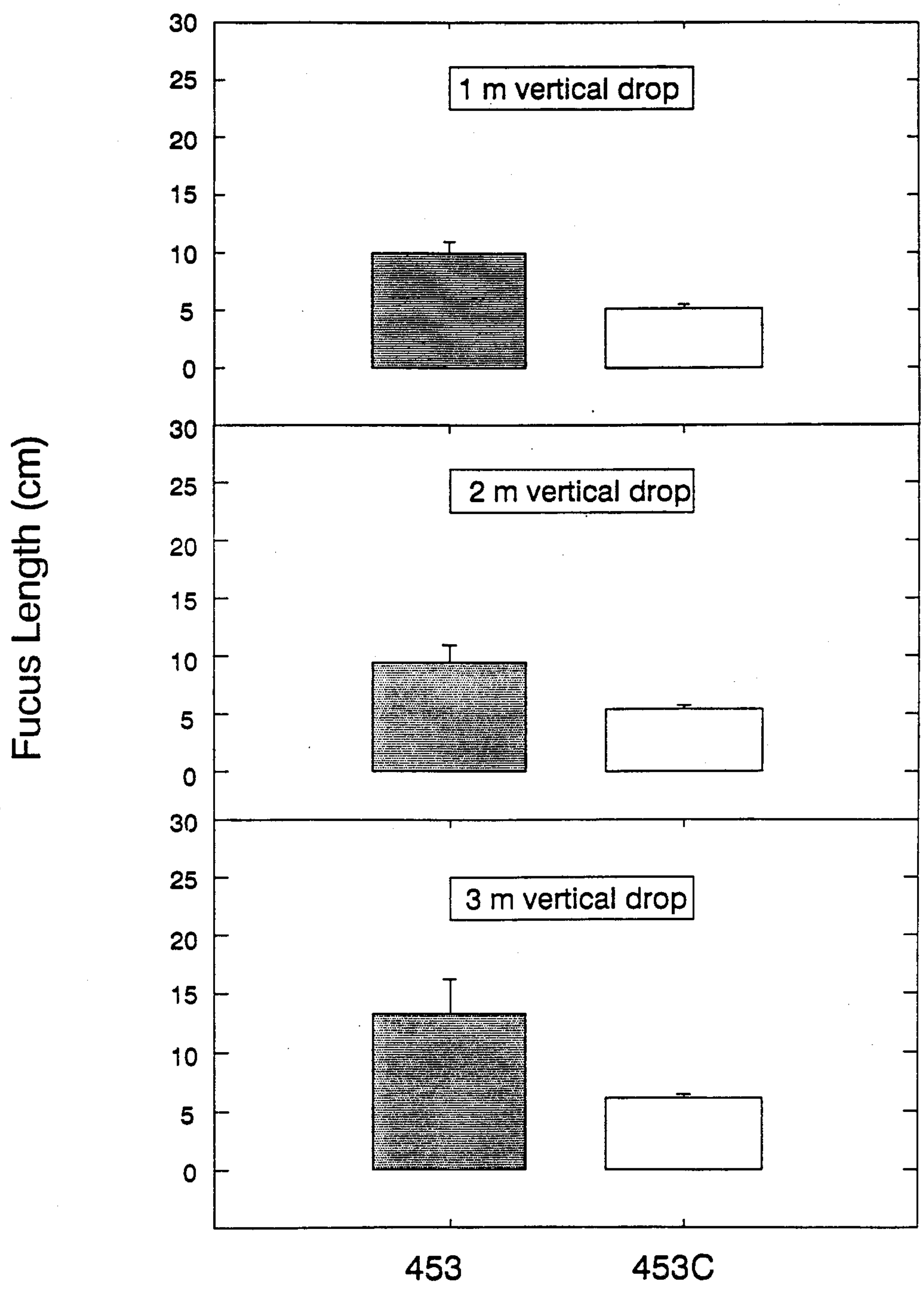

Figure 5.5.2. Fucus mean length per plant in a sheltered rocky habitat at paired sites 453 and 453C, first visit, PWS, Alaska. Values denoted are means and one standard error.

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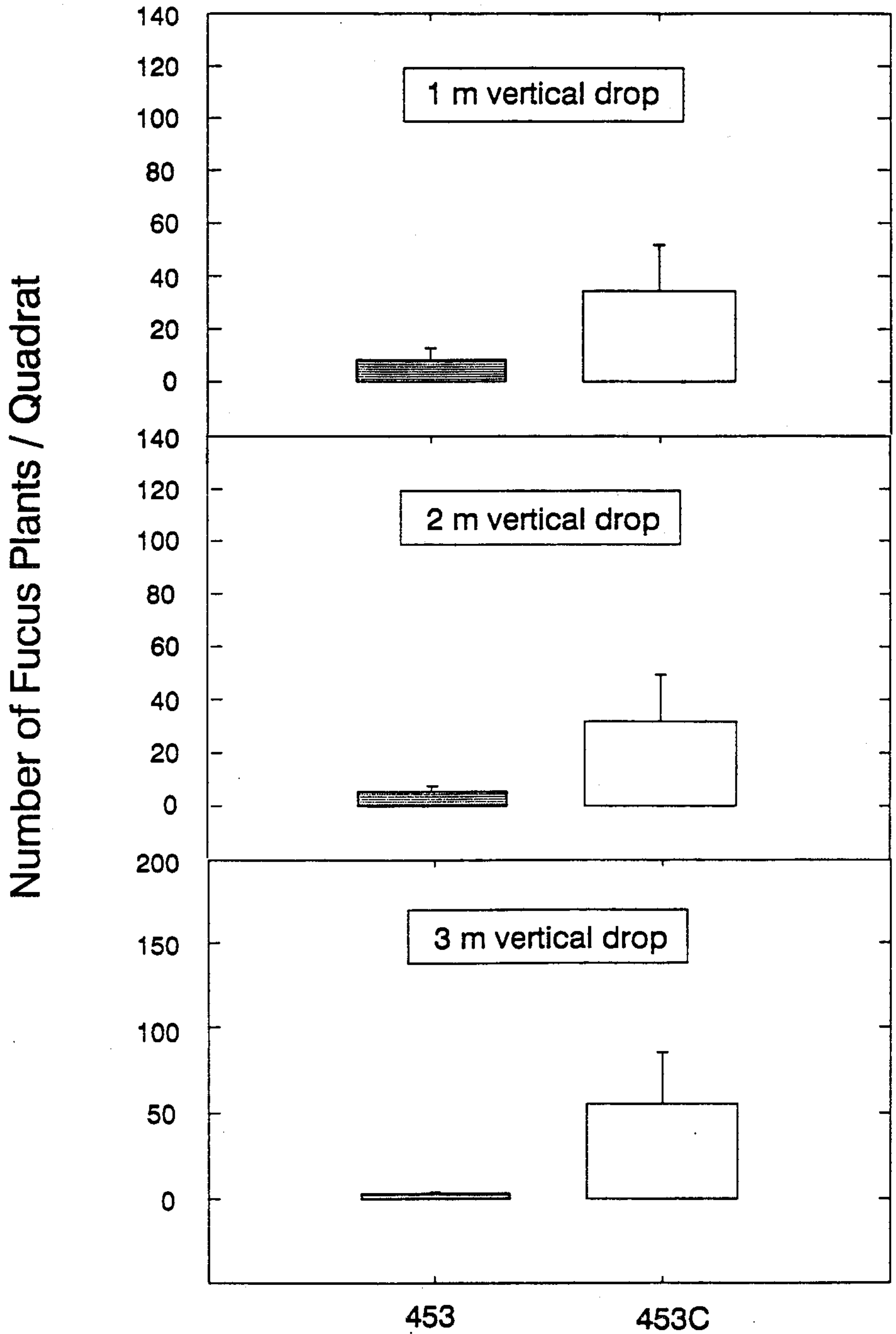

Figure 5.5.3. Number of Fucus plants in a sheltered rocky habitat at paired sites 453 and 453C for the first visit, PWS, Alaska. Values denoted are means and one standard error.

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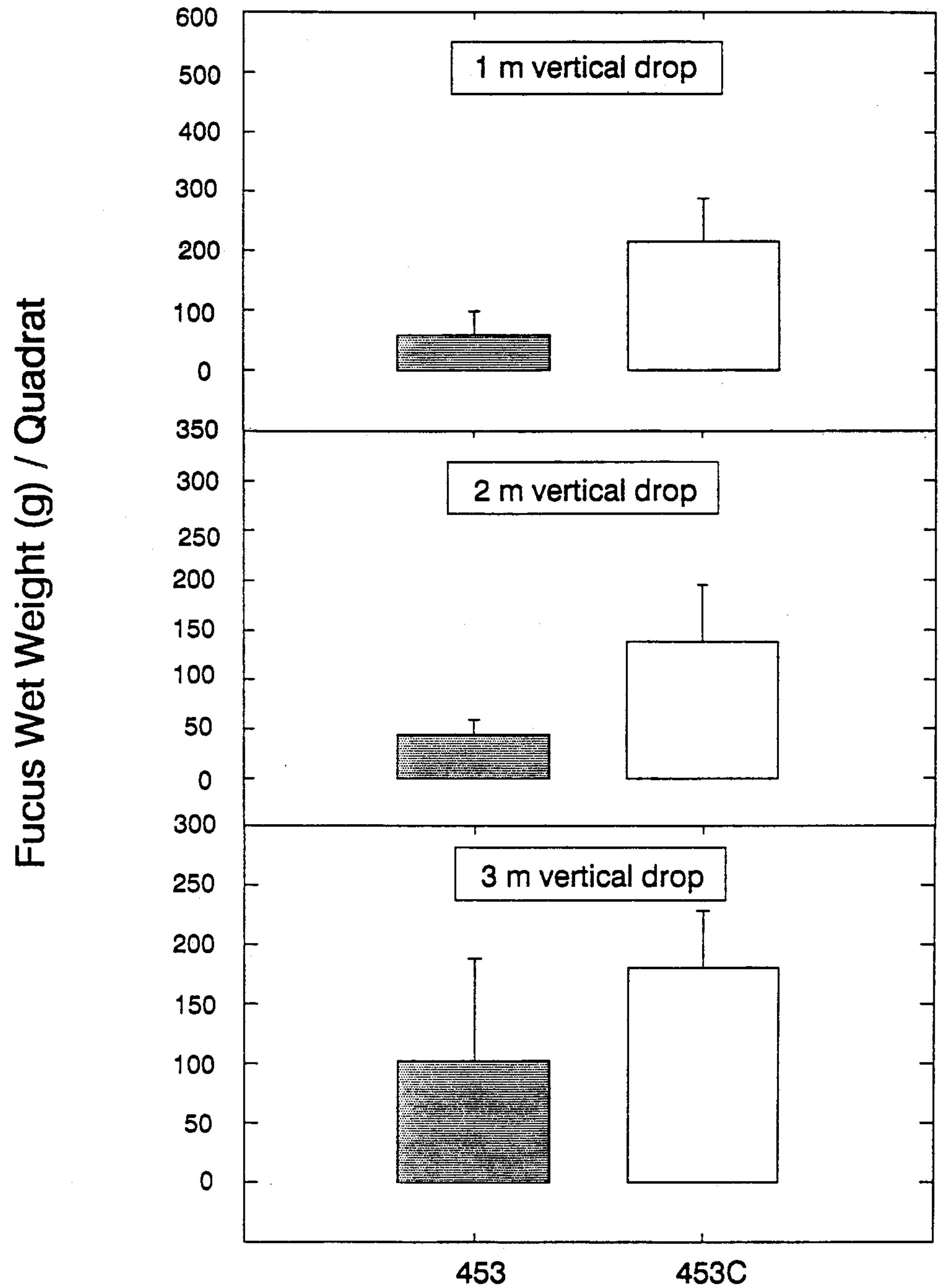

Figure 5.5.4. Fucus wet weight in sheltered rocky habitat paired sites 453 and 453C, first visit, PWS, Alaska. Values denoted are means and one standard error.

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Table 5.5.1. Students T-test results for Fucus variables; number of plants per quadrat, wet weight per quadrat, length per plant, and number of receptacles per quadrat at paired sites 453 and 453C at each MVD, first visit.

453/453C	#Plants/Quad		Wet Weight (g)/Quad		Length (cm)/Plant		#Receptacles/Quad	
1 MVD	**Oiled**	**Control**	**Oiled**	**Control**	**Oiled**	**Control**	**Oiled**	**Control**
Mean	8.50	34.33	57.57	214.40	10.02	5.19	45.66	244.66
Std Error	4.39	17.65	40.88	74.25	0.94	0.37	32.37	94.90
T Value		-1.4202		-1.8503		5.5443		-1.9855
Probability		0.1860		0.0940		0.0000		0.0752
2 MVD								
Mean	5.50	31.66	44.48	138.60	9.45	5.39	22.75	112.83
Std Error	2.21	17.64	15.11	57.15	1.46	0.30	9.01	66.87
T Value		-1.1829		-1.2993		3.8187		-1.0785
Probability		0.2708		0.2300		0.0002		0.3142
3 MVD								
Mean	3.5	55.2	102.84	180.95	13.29	6.12	82.67	120.4
Std Error	0.5	29.83	85.88	47.64	2.91	0.31	46.69	67.93
T Value		-1.0358		-0.8513		3.5883		-0.3899
Probability		0.3478		0.4335		0.0004		0.7101

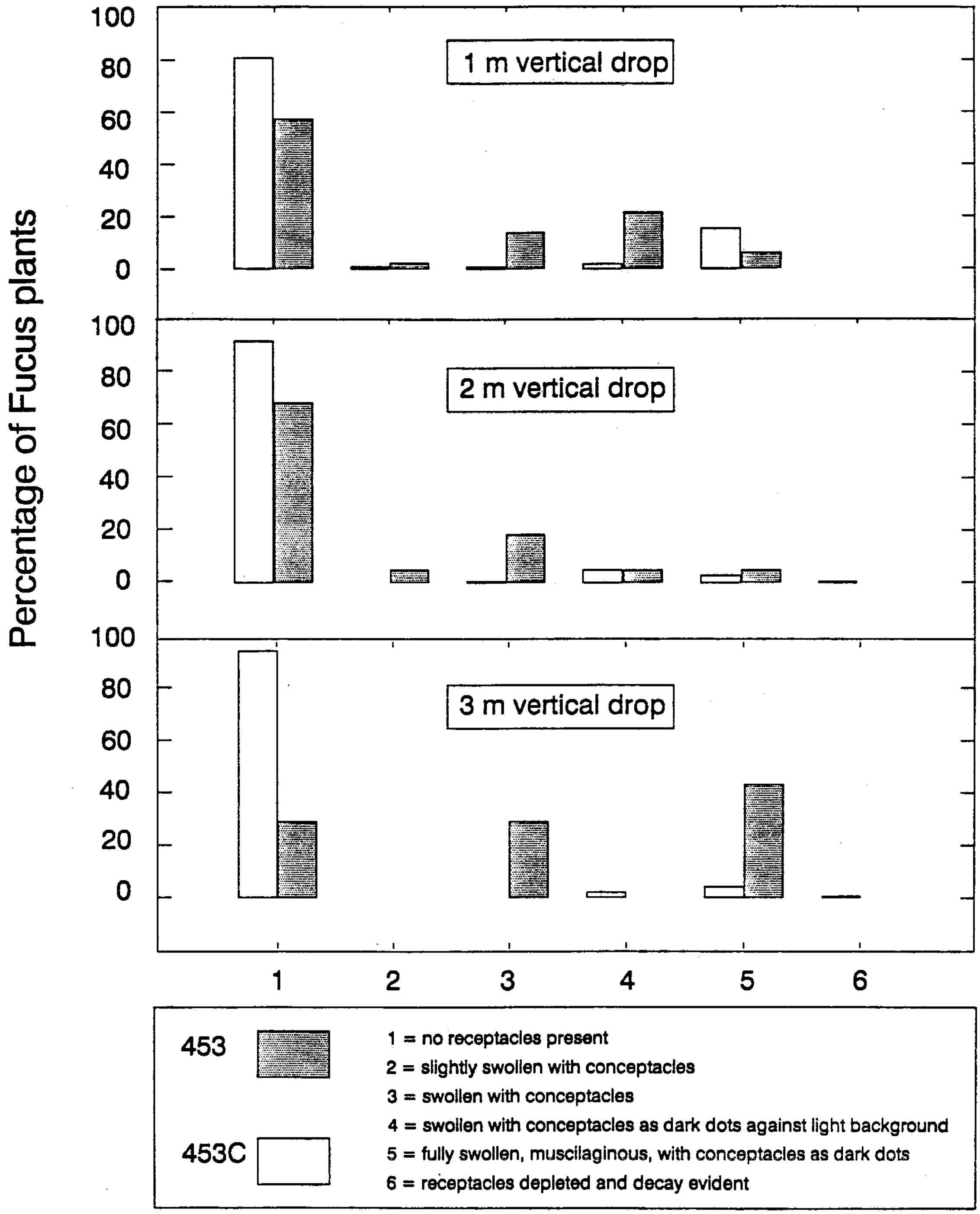

Figure 5.5.5. Reproductive Fucus Index in a sheltered rocky habitat at paired sites 453 and 453C, first visit, PWS, Alaska. Number of plants at site 453: 1 MVD = 51; 2 MVD = 22; 3 MVD = 7. Number of plants at site 453C: 1 MVD = 206; 2 MVD = 232; 3 MVD = 276.

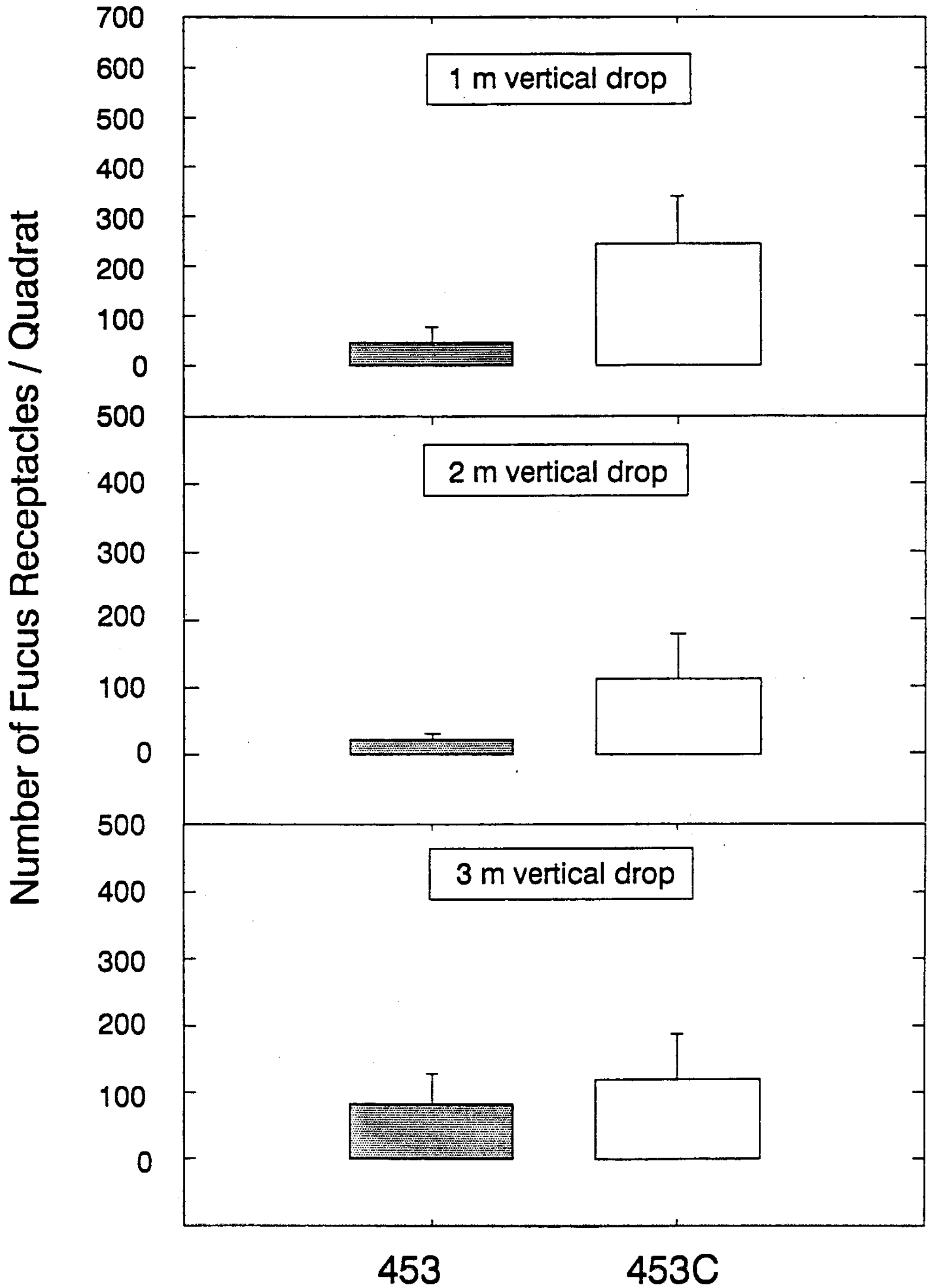

Figure 5.5.6. Number of <u>Fucus</u> receptacles per quadrat in a sheltered rocky habitat at paired sites 453 and 453C, first visit, PWS, Alaska. Values denoted are means and one standard error.

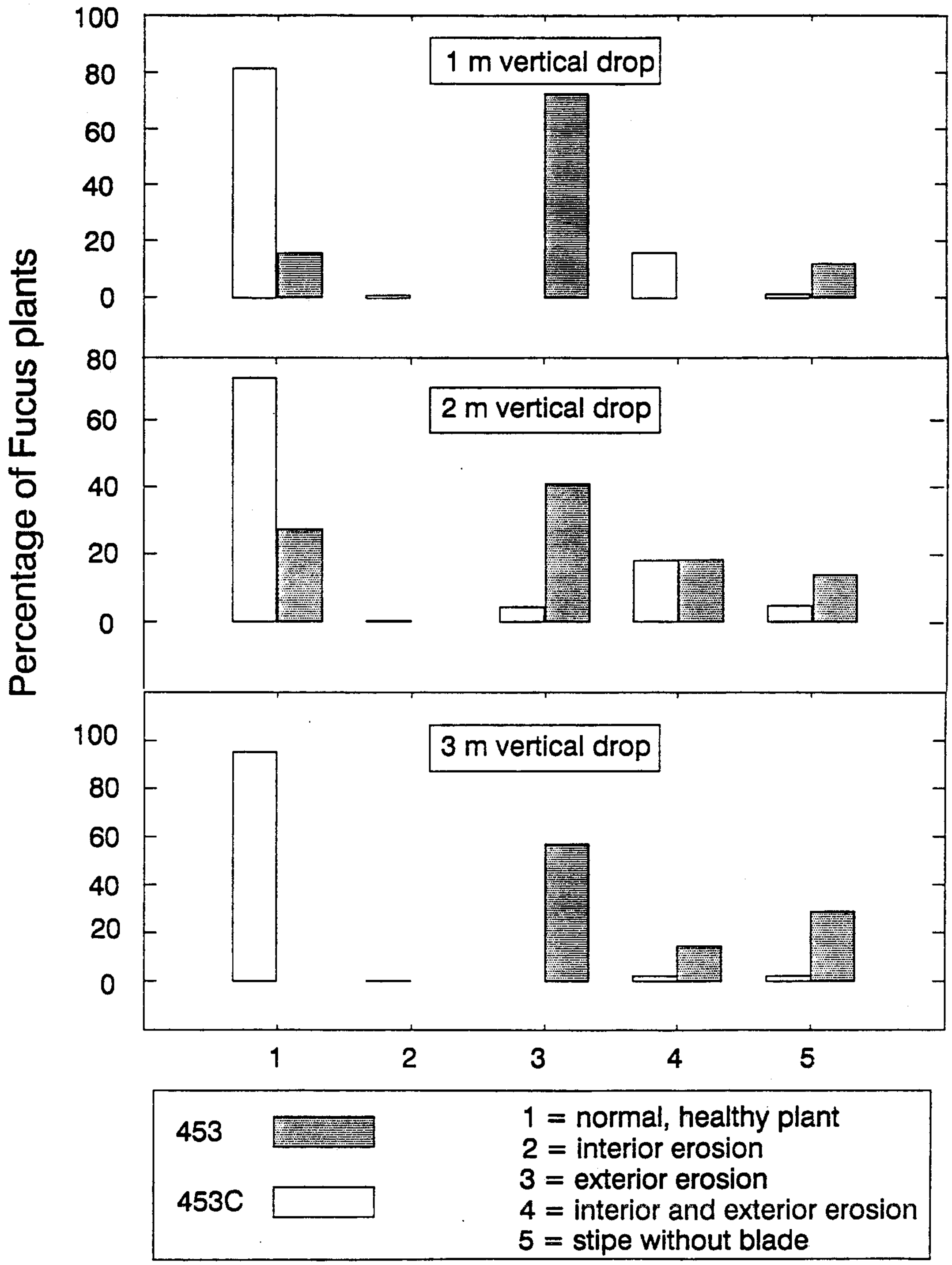

Figure 5.5.7. Damaged *Fucus* Index in a sheltered rocky habitat at paired sites 453 and 453C, first visit, PWS, Alaska. Number of plants at site 453: 1 MVD = 51; 2 MVD = 22; 3 MVD = 7. Number of plants at site 453C: 1 MVD = 206; 2 MVD = 232; 3 MVD = 276.

and 57.1% in the 3 MVD had exterior erosion evident. The oiled site also had a higher percentage of bare stipes (without blades) compared to the control site.

Paired sites 601 and 601C

Paired sites 601 and 601C had differences among many parameters at the 1 and 2 MVD, but many of the trends were reversed at the 3 MVD. From the length frequency data there were more *Fucus* plants, large and small, in the control site for the 1 and 2 MVD (Figure 5.5.8). But the 3 MVD showed an opposite trend. Here the oiled site had more of the smaller plants than the control (Figure 5.5.8). The mean lengths of the *Fucus* plants are longer at each MVD in the control site (Figure 5.5.9). Although, only at the 1 and 3 MVD were the differences significant (Table 5.5.2). *Fucus* plant number and wet weight per quadrat paralleled the length frequency data. Figures 5.5.10 and 5.5.11 show the control site with higher numbers of *Fucus* plants and greater biomass in the 1 and 2 MVD, while the 3 MVD had the opposite trend.

Similar trends also occur in the number of receptacles found in each quadrat (Figure 5.5.12). There were higher densities of conceptacles at the 1 and 2 MVD in the control quadrats, but fewer in the control quadrats at the 3 MVD. The reproductivity indices were similar in both the oiled and control sites (Figure 5.5.13). Over 77% of the plants were immature (absence of receptacles) at each MVD at both sites.

The damage index indicates no apparent difference between the two sites at each MVD (Figure 5.5.14). There appeared to be significant damage to the plants at both sites.

Algae Study

The data on algae other than *Fucus* in the quadrat samples have not been analyzed prior to this report.

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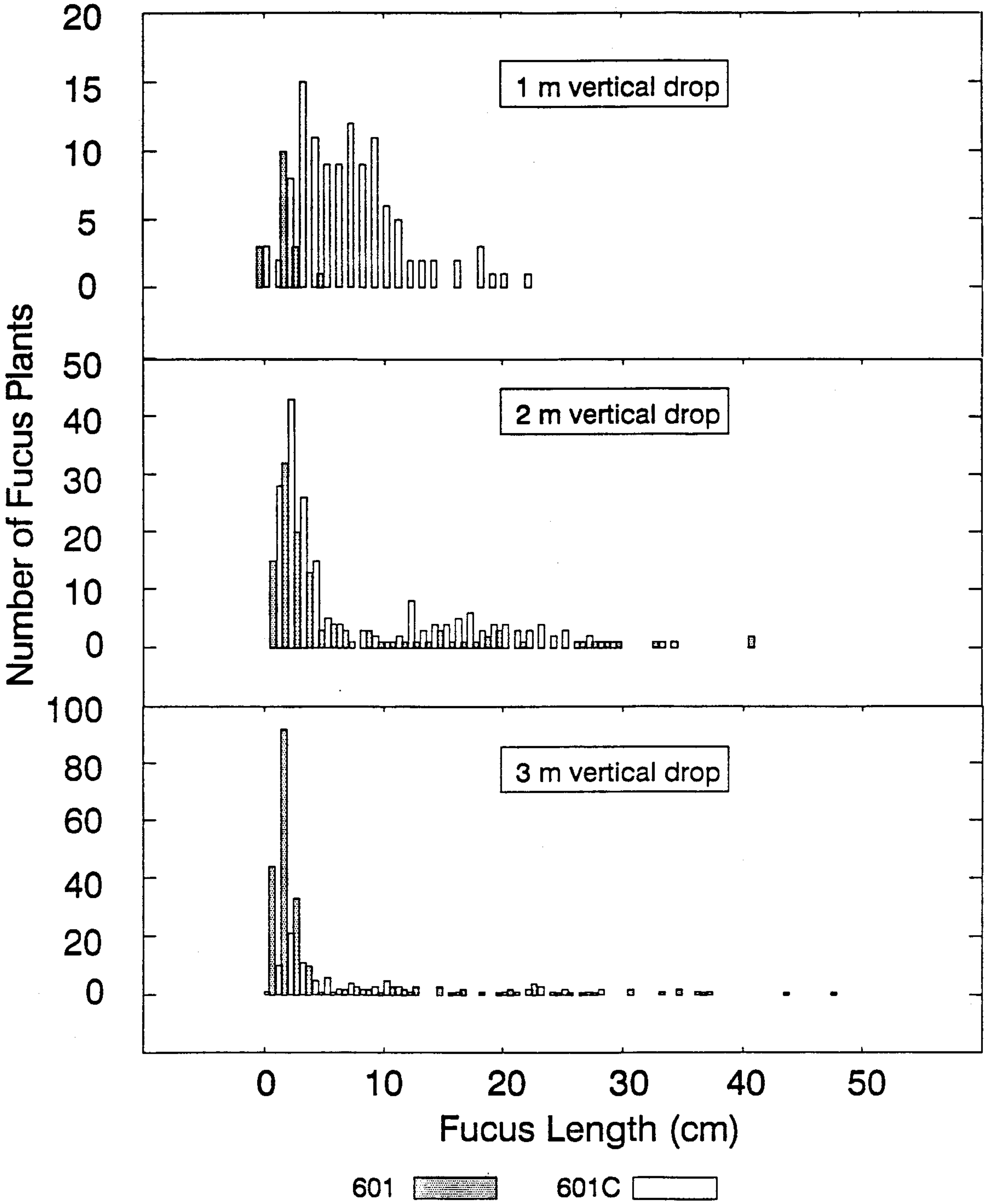

Figure 5.5.8. Fucus length frequencies in a sheltered rocky habitat at paired sites 601 and 601C, first visit, PWS, Alaska. Values denoted are means and one standard error.

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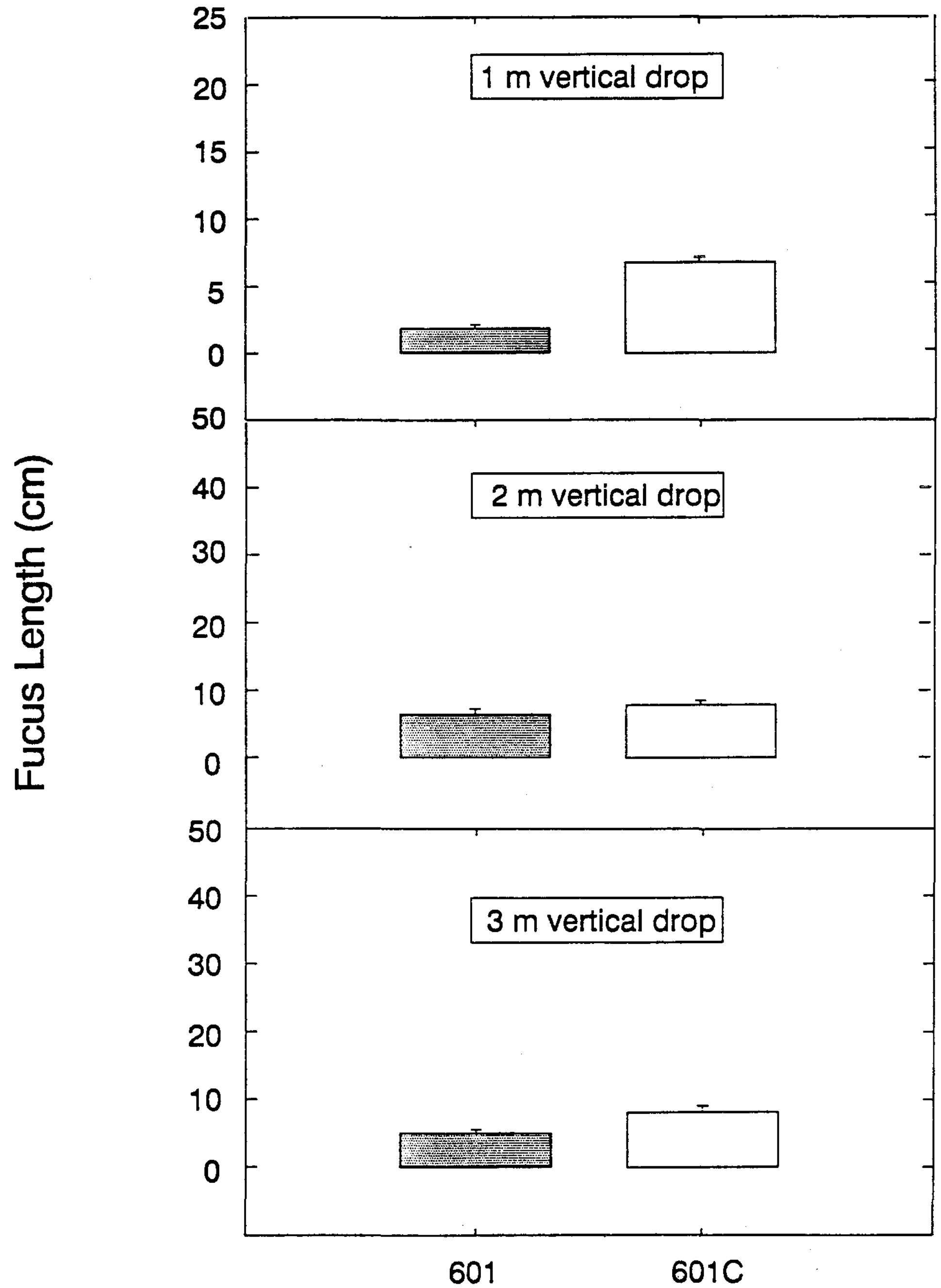

Figure 5.5.9. Fucus length per plant in a sheltered rocky habitat at paired sites 601 and 601C, first visit, PWS, Alaska. Values denoted are means and one standard error.

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Table 5.5.2. Students T-test results for <u>Fucus</u> variables; number of plants per quadrat, wet weight per quadrat length per plant, and number of receptacles per quadrat at paired sites 601 and 601C at each MVD for the first visit.

601/601C	#Plants/Quad		Wet Weight (g)/Quad		Length (cm)/Plant		#Receptacles/Quad	
1 MVD	**Oiled**	**Control**	**Oiled**	**Control**	**Oiled**	**Control**	**Oiled**	**Control**
Mean	3.50	18.50	0.04	75.07	1.82	6.75	0.00	19.67
Std Error	3.50	14.65	0.04	67.48	0.27	0.42	0.00	17.38
T Value		-0.8101		-0.8894		-4.5126		0.9054
Probability		0.4413		0.3998		0.0000		0.3917
2 MVD								
Mean	19.50	32.17	91.28	253.51	6.44	7.92	29.67	105.17
Std Error	9.11	9.45	51.94	93.23	0.78	0.60	19.24	44.72
T Value		-0.9650		-1.5201		-1.5041		-1.5508
Probability		0.3573		0.1594		0.1336		0.1520
3 MVD								
Mean	44.2	15.17	215.77	135.25	5.03	8.09	85	44.53
Std Error	18.09	6.53	99.02	84.24	0.54	0.95	45.74	84.24
T Value		1.626		0.6238		-2.9378		0.8567
Probability		0.1384		0.5482		0.0036		0.4138

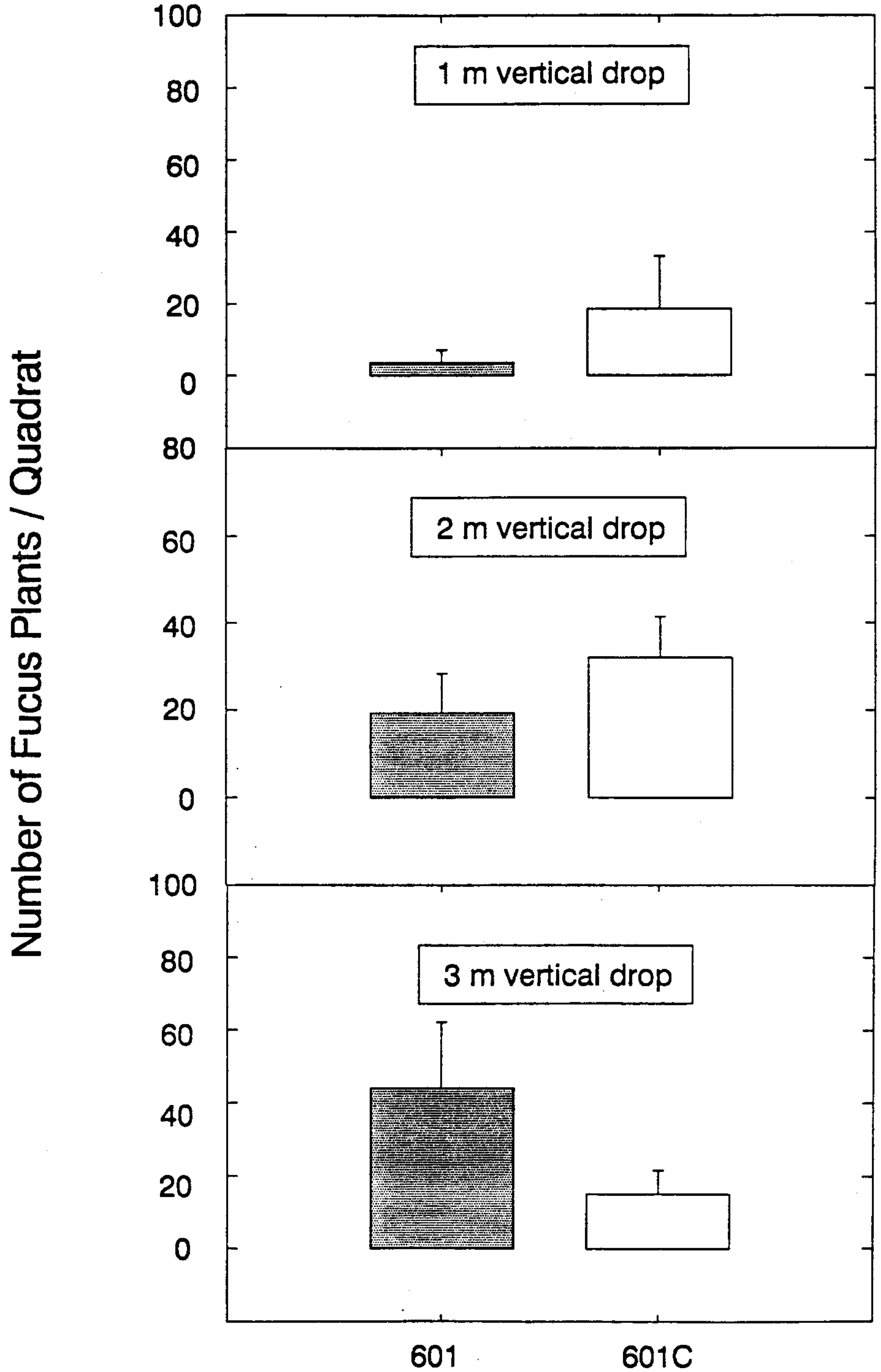

Figure 5.5.10. Number of <u>Fucus</u> plants in a sheltered rocky habitat at paired sites 601 and 601C first visit. Values denoted are means and one standard error.

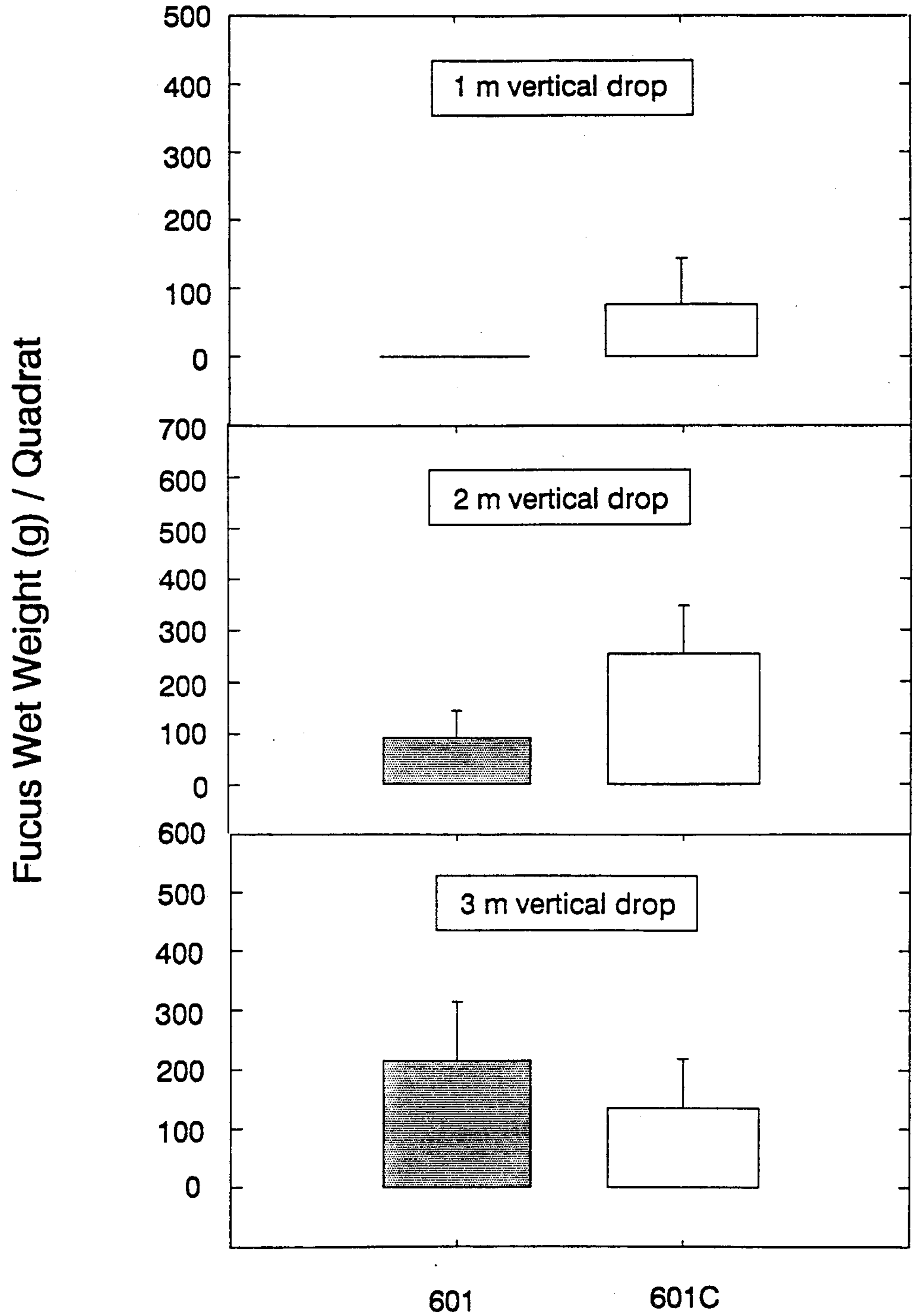

Figure 5.5.11. Fucus wet weight in a sheltered rocky habitat paired sites 601 and 601C, first visit, PWS, Alaska. Values denoted are means and one standard error.

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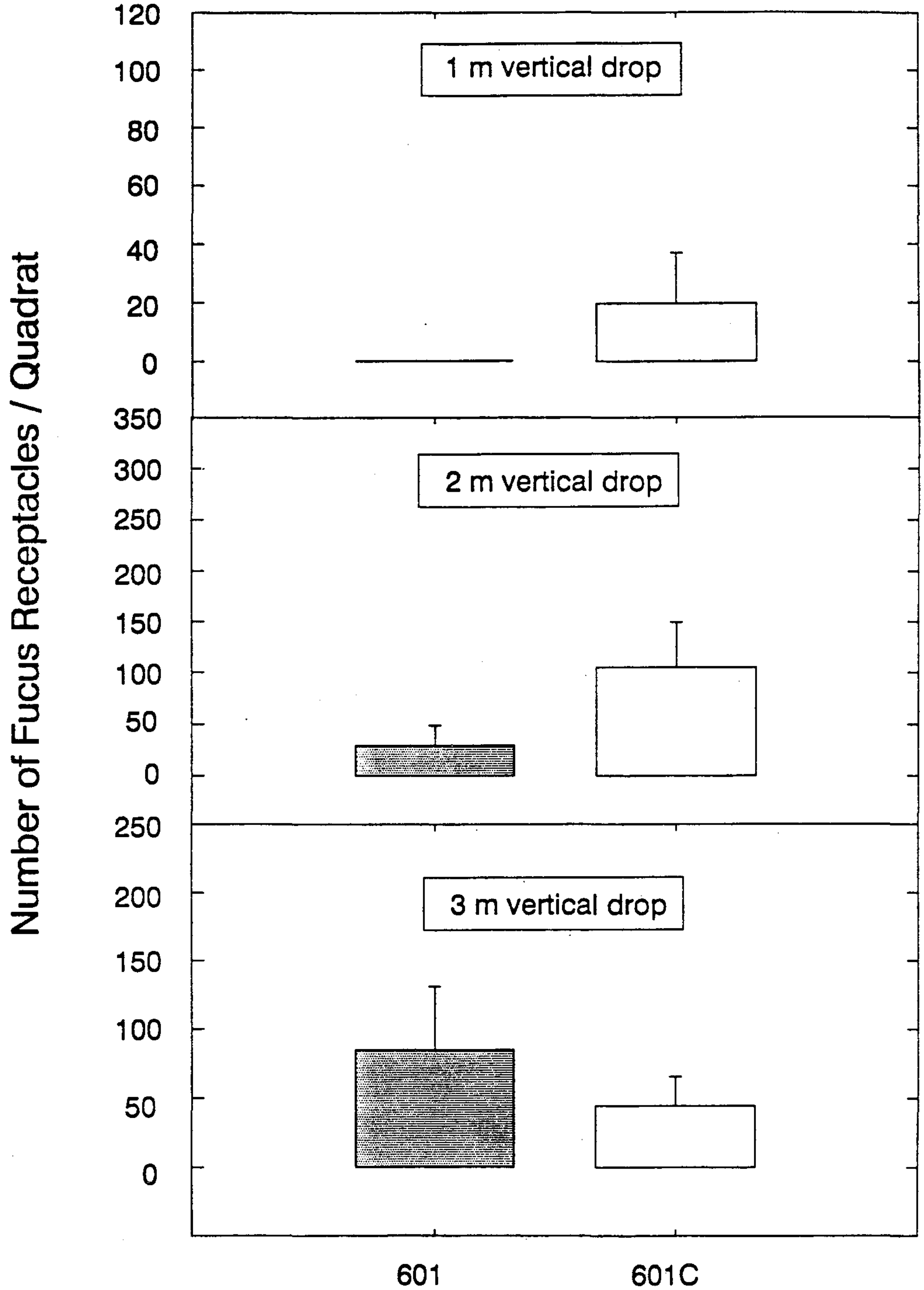

Figure 5.5.12. Number of *Fucus* receptacles per quadrat in a sheltered rocky habitat at paired sites 601 and 601C, first visit, PWS, Alaska. Values denoted are means and one standard error.

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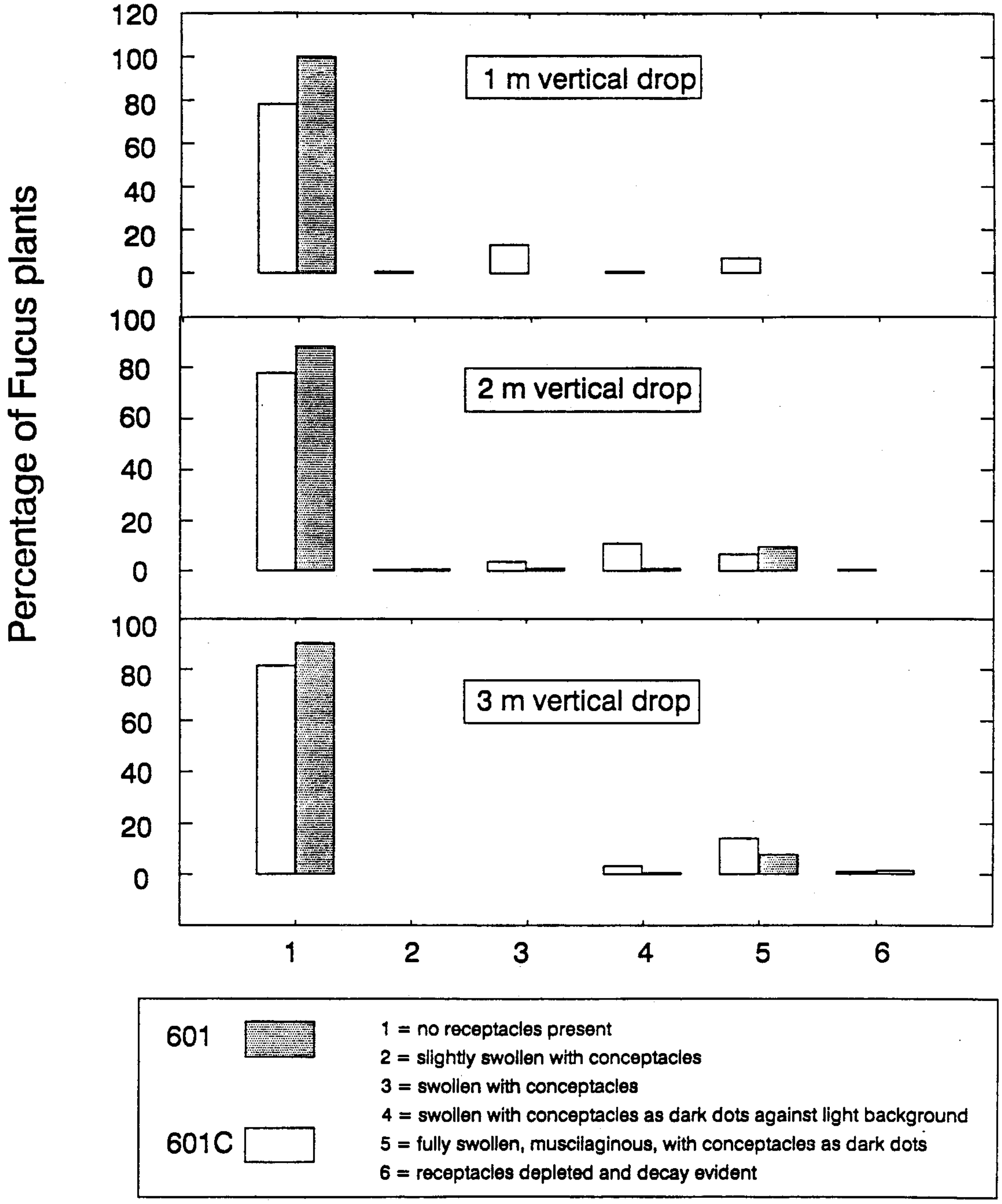

Figure 5.5.13. Reproductive _Fucus_ Index in a sheltered rocky habitat at paired sites 601 and 601C, first visit, PWS, Alaska. Number of plants at site 601: 1 MVD = 17; 2 MVD = 117; 3 MVD = 92. Number of plants at site 601C: 1 MVD = 114; 2 MVD = 193; 3 MVD = 221.

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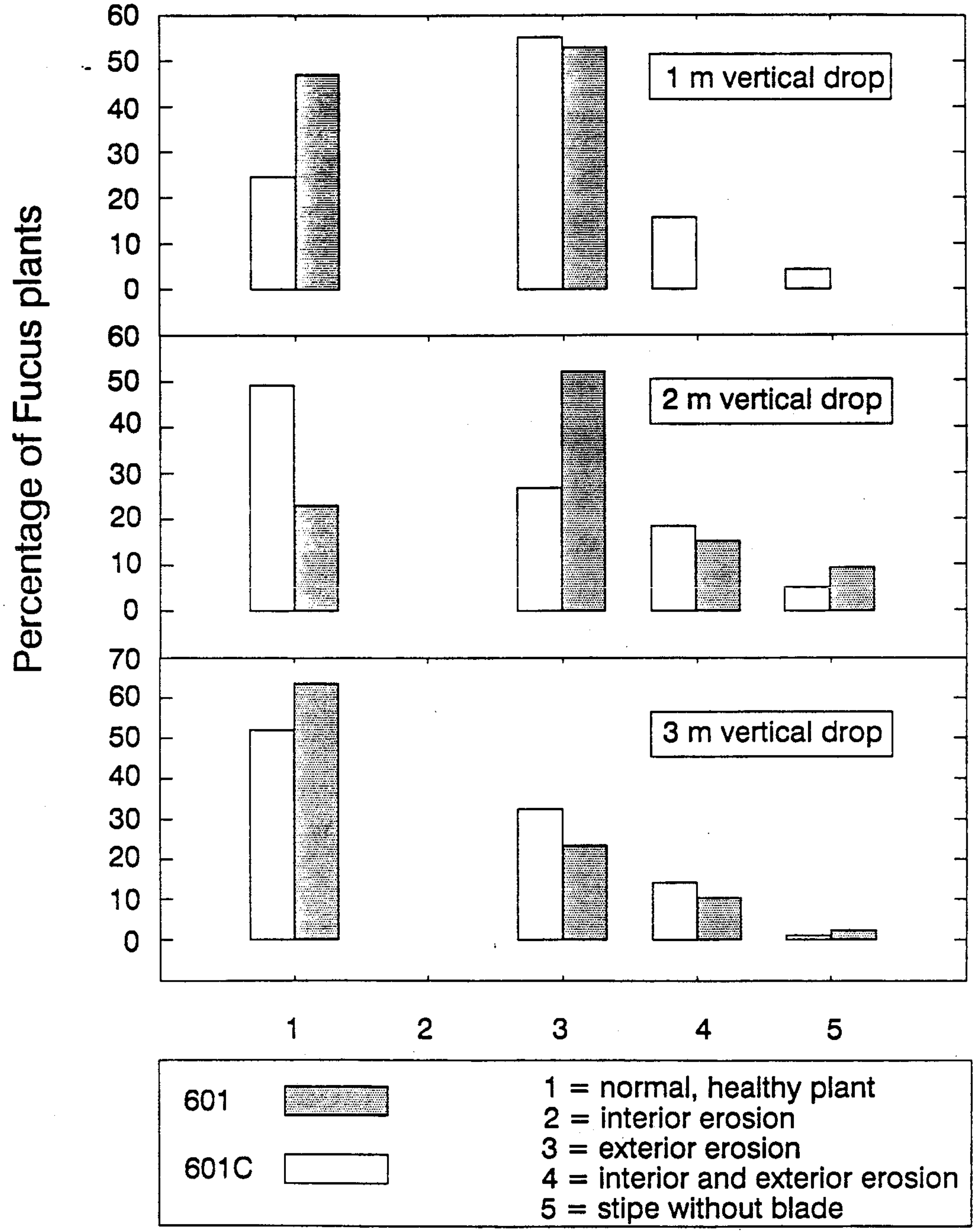

Figure 5.5.14. Damaged Fucus Index in a sheltered rocky habitat at paired sites 601 and 601C first visit, PWS, Alaska. Number of plants at site 601: 1 MVD = 17; 2 MVD = 117; 3 MVD = 92. Number of plants at site 601C: 1 MVD = 114; 2 MVD = 193; 3 MVD = 221.

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Fertile *Fucus* Density Study

Sheltered rocky habitat

The densities of fertile *Fucus* in the sheltered rocky habitats exhibited no trend with respect to oiled or control sites (Table 5.5.3). Values ranged from 0 to nearly 7 fertile plants per square meter. The densities were generally higher during the first visit of the summer than during the second visit.

Coarse textured habitat

In the coarse textured habitats the density of fertile *Fucus* plants was very low compared to the sheltered rocky habitats. During the first visit of the summer, where fertile *Fucus* plants were present, the control sites had higher fertile *Fucus* densities with the exception of paired sites 846 and 846C (Table 5.5.4). During the second visit few sites had any fertile *Fucus* plants, but of those that did, the control sites had higher fertile *Fucus* densities in seven of the nine quadrats containing fertile *Fucus* plants (Table 5.5.4). There were no fertile *Fucus* plants at any time at the 1 MVD at any of these sites.

Egg Viability Study

Fucus egg viability from four paired sites in sheltered rocky habitats, second visit, showed a similar trend in the control and oiled sites (Figure 5.5.15). Approximately 70 to 80% of the eggs became fertilized. However, the JCFOS control had over 95% of the eggs fertilized. Statistical analysis between each paired site showed no significant differences.

Fucus Germling Survival Study

Coarse textured paired sites 506 and 506C had higher *Fucus* germling densities in the control site on the seeded and unseeded plates, but paired sites 1171 and 1171C exhibited contrary results (Figure 5.5.16). No significant differences were found

Table 5.5.3. Densities of fertile Fucus plants (fertile plant/m^2) for first and second visits for five paired sites in sheltered rocky habitats, PWS, Alaska. Oiled sites are on the left and control sites are on the right of the paired site column. ND = no data was collected in that stratum.

FIRST VISIT

Site	598	598C	453	453C	1522	1522C	601	601C	1424	4825
1 MVD	0.13	0.00	0.62	1.02	0.55	0.17	0.00	0.26	0.24	1.10
2 MVD	1.05	0.32	4.46	1.11	6.92	1.23	0.71	1.75	2.17	5.95
3 MVD	3.24	0.75	0.57	0.00	0.00	1.35	0.80	1.32	1.31	1.86
4 MVD	1.94	0.00	ND	0.00	ND	ND	0.15	ND	0.54	ND

SECOND VISIT

Site	598	598C	453	453C	1522	1522C	601	601C	1424	4825
1 MVD	0.15	0.95	0.12	3.74	0.29	0.69	0.00	0.16	ND	0.85
2 MVD	0.57	0.38	0.52	0.73	0.80	2.93	0.13	0.83	0.00	1.83
3 MVD	0.72	0.23	0.35	0.16	0.15	0.31	1.03	0.90	ND	0.00
4 MVD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	ND	ND

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Table 5.5.4. Densities of fertile Fucus (fertile plant/m^2) for first and second visits at seven paired sites in coarse textured habitats, PWS, Alaska. Oiled sites are on the left and control sites are on the right of the paired site column. ND = no data was collected in that stratum.

FIRST VISIT

Site	1598	1598C	1627	1627C	1650	1650C	506	506C	846	846C	1171	1171C	1580	1383
1 MVD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 MVD	0.00	0.00	0.00	0.00	0.00	0.65	0.00	3.22	0.31	0.00	0.16	0.52	0.00	0.00
3 MVD	0.48	0.23	0.00	0.00	0.00	0.49	0.28	1.12	0.19	0.00	0.15	3.70	0.00	0.00
4 MVD	0.00	ND	0.00	0.00	0.00	0.00	0.00	0.00	0.00	ND	0.26	1.48	0.00	0.15

SECOND VISIT

Site	1598	1598C	1627	1627C	1650	1650C	506	506C	846	846C	1171	1171C	1580	1383
1 MVD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 MVD	0.00	0.17	0.00	0.00	0.00	0.30	0.00	0.29	0.00	0.00	0.13	0.00	0.00	0.00
3 MVD	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.19	0.00	0.00	0.00	0.14	0.00	0.00
4 MVD	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.53	0.00	0.00

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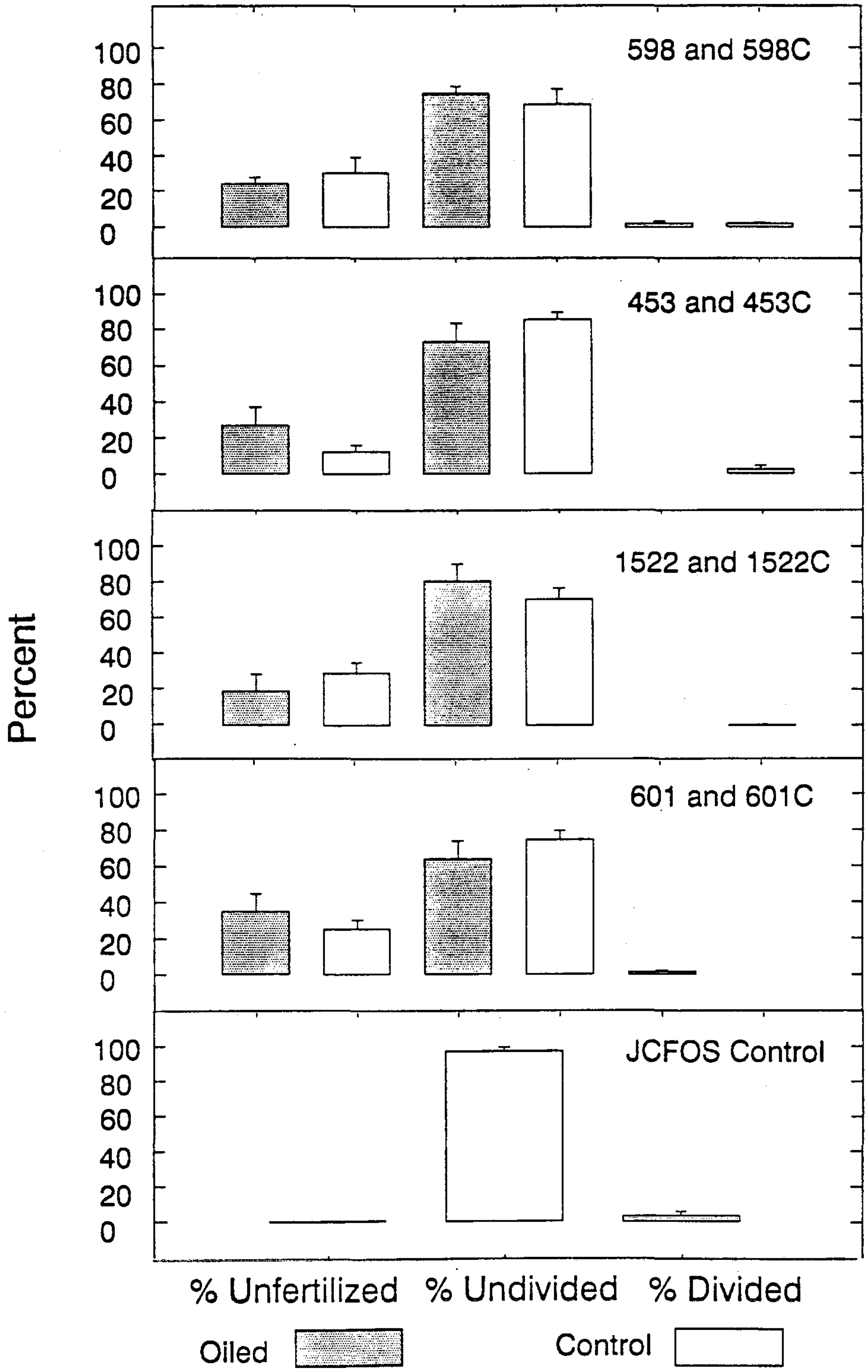

Figure 5.5.15. Fucus egg viability study results for four sites in sheltered rocky habitats for the second visit, PWS, Alaska. Egg percentages are means with one standard error.

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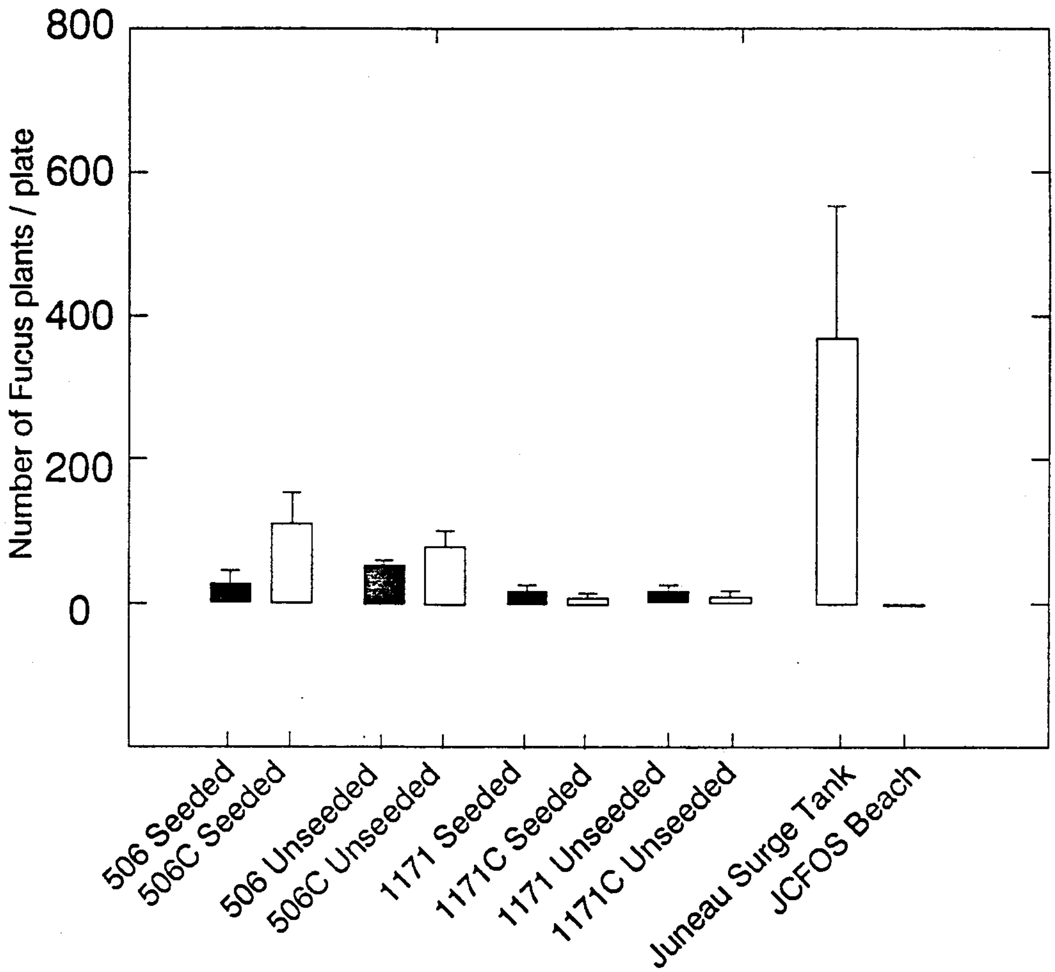

Figure 5.5.16. Fucus germling survival study settling plate data from paired sites 506/506C and 1171/1171C. Estimates of total number of Fucus plants per plate are given as means and one standard error.

between the oiled and control sites with either seeded or unseeded settling plates. It is also unlikely that pre-seeded plates had more *Fucus* germlings than the unseeded, control plates. The highest densities of plants were produced in the JCFOS surge tank. No *Fucus* plants were found on the seeded, control plates set out on the JCFOS beach.

Algal Species Diversity Study (All Areas)

A list of all the identified algal species collected in PWS, CIK, KAP are given in Table 5.5.5. Preliminary results indicate that 19.5% of the species in PWS and 10.5% in the CIK and KAP areas represent species range extensions for these areas.

Sediment Hydrocarbon Study

The sediment hydrocarbon samples were collected at each site and are waiting for analysis at the NMFS Auke Bay Laboratory.

Temperature and Salinity Data

The temperature and salinity recordings in Prince William Sound are given in Tables 5.5.6, 5.5.7, 5.5.8, and 5.5.9 for sheltered rocky, coarse textured, estuarine habitats and exposed rocky habitats. All the sheltered rocky sites have similar salinities between paired sites. In the coarse textured habitats no substantial salinity differences occurred to the depth of 10 m, although some fresh water lenses at the 0.2 m level occurred at 506C first visit, 1171C first and second visits, 1598C first visit, and 846C first and second visits. Paired sites 1171 and 1171C first and second visit showed the highest profile differences. Site 1171C was consistently more saline with the exception of the shallow freshwater lens at the surface. Estuarine habitat paired sites 2397 and 208/209 also had differing salinity profiles. In exposed rocky habitats site 1642 during the first visit of the summer had slightly lower salinities throughout the water column compared to its paired sites.

Table 5.5.5.a. Algal species list for Prince William Sound. An asterisk (*) indicates that this species is a new record for the area.

CHLOROPHYTA

Acrosiphonia arcta
Acrosiphonia coalita
* Blidingia chaudefaudii
* Bulbocolon piliferum
Chaetomorpha spp.
* Cladophora albida
* Cladophora columbiana
* Cladophora microcladioides
Cladorphora sericea
Cladophora sp.
Derbesia marina
Enteromorpha clathrata
* Enteromorpha flexuosa
Enteromorpha intestinalis
Enteromorpha linza
Enteromorpha prolifera
Gumontia polyrhiza
Monostroma arctica
* Monostroma undulata
Percursaria percursa
Prasiola borealis
* Prasiola delicatula
Prasiola meridionalis
* Rhizoclonium tortuosum
Rhizoclonium spp.
* Rosenvingiella consticta
Ulothrix implexa
Ulva fenestrata

PHAEOPHYTA

* Acrothrix gracilis
Alaria taeniata
Alaria marginata
Alaria praelonga
Agarum cribrosum
Analipus japonicus
Chorda filum
Chordaria flagelliformis
Coilodesme californica
Colpomenia peregrina
Costaria costata
Cymathere triplicata
Cystoseira geminata
Dictyosiphon foeniculaceus
* Dictyosiphon sinicola
Desmarestia aculeata
* Desmarestia foliacea
Desmarestia viridis
Elachista fucicola
Elachista lubrica
Eudesme virescens
Fucus gardneri
Fucus spiralis
* Fucus "muscoides"
Laminaria groenlandica
Laminaria saccharina
Laminaria yezoensis
Leathesia difformis
* Leathesia "nana"
Nereocystis leutkeana
Myelophycus intestinalis
* Omphalophyllum ulvaceum
Petalonia fascia
* Petalonia zosterifolia
Pilayella littoralis
* Pilayella washingtonensis
Punctaria lobata
* Punctaria plantaginea
Ralfsia fungiformis
Ralfsia sp.
Petroderma sp.
Scytosiphon lomentaria
Sornathera ulvoidea
Soranthera sp.
Sphacelaria caespitula
Schacelaria rigidula
Sphacelaria sp.

Table 5.5.5.a. Continued.

RHODOPHYTA

Ahnfeltia fastigiata
* Audouinella microscopica
Audouinella purpurea
Anthamnionella spirographidis
Bossiella cretacea
Bossiella spp.
Callophyllis crenulata
Callophyllis flabellulata
* Callophyllis thompsonii
* Caulacanthus ustulatus
Ceramium cimbricum
* Ceramium rubrum
* Ceramium washingtoniense
Ceramium spp.
Chondrus sp.
Clathromorphum reclinatum
Corallina officinalis
Corallina vancouveriensis
Constantinea subulifera
Cryptosiphonia woodii
Delesseria decepiens
Devaleraea ramentacea
    f. subsimples
    f. ramosum
Dumontia contorta
Endocladia muricata
Erythrotrichia carnea
Gloiopeltis furcata
Gloiosiphonia capillaris
Gracilaria pacifica
Halosaccion glandiforme
Halosaccion lepechini
Hildenbrandia occidentalis
Hildenbrandia rubra
Hollenbergia subulata
Iridaea spp.
Mastocarpus papillatus
Mastocaarpus stelatus
Mastocarpus spp.
Neorhodomela aculeata
Neorhodomela larix
Neorhodomela oregona
Neoptilota asplenioides
Neoptilota californica
Odonthalia floccosa
Odonthalia setacea
Opuntiella californica
* Ozophora latifolia
Palmaria callophylloides
Palmaria hecatensis
Palmaria marginicrassa
Palmaria mollis
Phycodrys riggii
Platythamnion pectinatum
* Polysiphonia hendryi
Polysiphonia pacifica
* Polysiphonia senticulosa
Polysiphonia urceolata
Polysiphonia spp.
Porphyra miniata
Porphyra nereocystis
Porphyra spp.
Pterosiphonia bipinnata
Pterosiphonia hamata
Pterosiphonia sp.
Ptilota pectinata
Ptilota serrata
* Pugetia fragilissima
Rhodomela "subfusca"
Rhodymenia pertusa
Scagelia pylaisaei
Tayloriella sp.
* Thuretellopsis peggiana
Tokidadendron kurilejnsis
Weeksia fryeana
Yendonia crassifolia

CYANOPHYTA

Calothrix rectangularis
Rivularia atra
Anabaena sp.

LICHENS

Verrucaria maura
Verrucaria sp.

Table 5.5.5.b. Algal species list for Cook Inlet-Kenai. An asterisk (*) indicates that this species is a new record for the area.

CHLOROPHYTA

Acrosiphonia spinescens
Acrossiphonia sp.
* Blidingia chaudifaudii
Cladophora sericea
Derbesia marina
* Enteromorpha clathrata
Enteromorpha intestinalis
Enteromorpha linza
* Monostroma undulata
Monostroma sp.
Prasiola meridionalis
Rhizoclonium riparium

PHAEOPHYTA

Agarum cribrosum
Alaria esculenta
Alaria fistulosa
Alaria marginata
Alaria pylaii
Alaria praelonga
Analipus japonicus
Chordaria flagelliformis
Chordaria costata
Coilodesme bulligera
Coilodesme cystoseirae
Colpomenia bullosa
Colpomenia peregrina
Cymathere triplicata
Cystoseira geminata
Desmarestia aculeata
Desmarestia viridis
Dictosiphon foeniculaceous
* Dictyosiphon sinicola
* Ectocarpus acutus
Elachista fucicola
Eudesme virescens
Hedophyllum sessile
Laminaria dentigera
Laminaria groenlandica
Laminaria yezoensis
Leathesia difformis
Petalonia fascia
Pilayella littoralis
Pleurophycus gardneri
Ralfsia fungiformis
Saundersella simplex
Scytosiphon lomentaria
Sorantheria ulvoidea
Soranthera sp.

RHODOPHYTA

Audouinella purpurea
Antitthamnionella pacifica
Callithamnion pikeanum
Chondrus sp.
Constantinea subulifera
Cryptosiphonia woodii
Dumontia contorta
Endocladia muricata
* Gloiopeltis furcata
* Gloiosiphonia capillaris
Gymnothamnion elegans
Halosaccion glandiforme
Hildenbrandia rubra
Iridaea heterocarpum
Iridaea sp.
Mastocarpus papillatus
Microcladia borealis
* Neorhodomela aculeata
Neorhodomela oregona
Neoptilota asplenioides
Neoptilota californica
Odonthalia floccosa
Odonthalia setacea
Palmaria callophylloides
Palmaria hecatensis
Palmaria mollis
Phycordrys rigggii
Polysiphonia senticulosa
Polysiphonia spp.
Porphyra torta
Porphyra spp.
Pter5osiphonia bipinnata
Pterosiphonia spp.
Ptilota pectinata
Rhodomela "subfusca"
Rhodymenia pertusa
Scagelia pylaisaei
Yedonia crassifolia

CYANOPHYTA

Callothrix rectangularis

LICHENS

Verrucaria maura

Table 5.5.5.c. Algal species list for Kodiak-Alaska Penninsula. An asterisk (*) indicates that this species is a new record for the area.

CHLOROPHYTA

Acrosiphonia coalita
Acrosiphonia spp.
Blidingia sp.
Cladophora sericea
Cladophora spp.
* Chaetomorpha brachygona
Chaetomorpha cannabina
Enteromorpha linza
Enteromorpha intestinalis
Enteromorpha torta
Percursaria percursa
* Rhizoclonium tortuosum
* Ulothrix pseudoflacca
Ulva fenestrata

PHAEOPHYTA

Alaria marginata
Alaria praelonga
Alaria spp.
Agarum cribrosum
Analipus japonicus
Chordaria flagelliformis
Coilodesme cystoseirae
Cymathera triplicata
Cystoseira geminata
Desmarestia aculeata
Desmarestia viridis
Dictyosiphon foeniculaceus
Elachista fucicola
Elachista lubrica
Fucus gardneri
Fucus muscoides
Laminaria groenlandica
Laminaria longipes
Laminaria saccharina
Leathesia difformis
Myelophycus intestinalis
Nereocystis leutkeana
Pilayella littoralis
Pleurophycus gardneri
Saundersella simplex
Soranthera ulvoidea
Soranthera sp.

RHODOPHYTA

Audouinella purpurea
Ahnfeltia fastigiata
Callithamnion pikeanum
Cryptosiphonia woodii
Constantinea subulifera
Devaleraea ramentacea
Endocladia muricata
Gloiopeltis furcata
Gloiosiphonia capillaris
Halosaccion glandiforme
Iridaea heterocarpa
Iridaea sp.
Membranoptera spinulosa
Mikamiella ruprechtiana
Microcladia borealis
Mastocarpus papillatus
Neodilsea borealis
* Neorhodomela aculeata
Neorhodomela larix
Neorhodomela oregona
Neoptilota asplenioides
Neoptilota californica
Odonthalia floccosa
Odonthalia setacea
* Opuntiella ornata
Palmaria callophylloides
Palmaria hecatensis
Palmaria marginicrassa
Phycordrys riggii
Phycordrys rubens
Phycordrys serratiloba
Porphyra "umbilicalis"
Porhyra perforata
Porphyra spp.
Ptilota pectinata
* Polysiphonia hendryii
* Polysiphonia eastwoodae
Polysiphonia sp.
Pterosiphonia hamata
Pterosiphonia bipinnata
Rhodymenia pertusa
Rhodoglossum sp.
* Smithora naiadum
Tokidadendron kurilensis
* Weeksia coccinea

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Table 5.5.6. Salinity and temperature values recorded at five paired sites in sheltered rocky habitats, first and second visits, PWS, Alaska. NS = not sampled.

FIRST VISIT

	TEMP (C)		SAL (0/00)	
	1522C	1522	1522C	1522
DATE	05/19/90	DATE:	05/19/90	DATE:
DEPTH				
0.2 M	26.0	NS	19.0	NS
1.0 M	NS	NS	NS	NS
2.0 M	NS	NS	NS	NS
3.0 M	NS	NS	NS	NS
4.0 M	NS	NS	NS	NS
5.0 M	NS	NS	NS	NS
6.0 M	NS	NS	NS	NS
7.0 M	NS	NS	NS	NS
8.0 M	NS	NS	NS	NS
9.0 M	NS	NS	NS	NS
10.0 M	NS	NS	NS	NS

	TEMP (C)		SAL (0/00)	
	598C	598	598C	598
DATE	05/28/90	05/16/90	05/28/90	05/16/90
DEPTH				
0.2 M	NS	9.0	15.0	25.0
1.0 M	NS	NS	NS	NS
2.0 M	NS	NS	NS	NS
3.0 M	NS	NS	NS	NS
4.0 M	NS	NS	NS	NS
5.0 M	NS	NS	NS	NS
6.0 M	NS	NS	NS	NS
7.0 M	NS	NS	NS	NS
8.0 M	NS	NS	NS	NS
9.0 M	NS	NS	NS	NS
10.0 M	NS	NS	NS	NS

	TEMP (C)		SAL (0/00)	
	453C	453	453C	453
DATE	06/22/90	05/21/90	06/22/90	05/21/90
DEPTH				
0.2 M	13.0	10.0	27.5	24.0
1.0 M	13.0	NS	27.5	NS
2.0 M	12.5	NS	28.0	NS
3.0 M	12.0	NS	28.0	NS
4.0 M	12.0	NS	28.0	NS
5.0 M	12.0	NS	28.0	NS
6.0 M	12.0	NS	28.0	NS
7.0 M	12.0	NS	28.0	NS
8.0 M	12.0	NS	28.5	NS
9.0 M	11.5	NS	28.5	NS
10.0 M	11.0	NS	28.0	NS

SECOND VISIT

	TEMP (C)		SAL (0/00)	
	1522C	1522	1522C	1522
DATE	07/07/90	07/08/90	07/07/90	07/08/90
DEPTH				
0.2 M	16.0	15.0	21.0	23.5
1.0 M	16.5	15.0	22.0	24.0
2.0 M	16.5	15.0	22.5	25.0
3.0 M	16.5	14.0	23.0	26.5
4.0 M	16.5	14.0	23.0	26.5
5.0 M	14.0	14.0	26.0	27.0
6.0 M	14.0	13.0	26.0	27.5
7.0 M	12.0	12.0	28.0	28.0
8.0 M	11.0	12.0	28.5	28.5
9.0 M	11.0	11.0	28.5	29.5
10.0 M	10.5	11.0	28.5	29.0

	TEMP (C)		SAL (0/00)	
	598C	598	598C	598
DATE	07/10/90	07/06/90	07/10/90	07/06/90
DEPTH				
0.2 M	16.0	16.0	26.0	22.5
1.0 M	16.0	16.0	26.5	23.0
2.0 M	16.0	16.0	26.5	23.0
3.0 M	16.0	16.0	26.5	23.0
4.0 M	16.0	16.0	26.5	24.0
5.0 M	16.0	16.0	27.0	24.0
6.0 M	15.0	15.0	27.5	25.0
7.0 M	14.0	14.0	27.5	26.0
8.0 M	12.5	12.5	27.5	26.0
9.0 M	12.0	12.0	29.5	27.0
10.0 M	11.5	11.5	29.5	27.0

	TEMP (C)		SAL (0/00)	
	453C	453	453C	453
DATE	07/12/90	07/15/90	07/12/90	07/15/90
DEPTH				
0.2 M	15.0	13.5	26.0	24.5
1.0 M	14.5	13.5	25.5	25.0
2.0 M	14.0	13.5	25.5	25.0
3.0 M	14.0	13.5	25.5	25.0
4.0 M	14.0	13.5	26.0	25.0
5.0 M	13.5	13.5	26.0	25.0
6.0 M	13.0	13.5	26.0	25.0
7.0 M	13.0	13.5	27.5	25.0
8.0 M	12.5	13.5	27.5	25.0
9.0 M	12.0	13.5	27.0	25.0
10.0 M	11.5	13.0	27.0	26.5

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Table 5.5.6. Continued.

FIRST VISIT

	TEMP (C)		SAL (0/00)	
	4825C	1424	4825C	1424
DATE	06/06/90	05/22/90	06/06/90	05/22/90
DEPTH				
0.2 M	12.0	NS	27.0	24.0
1.0 M	12.0	NS	28.0	NS
2.0 M	10.0	NS	29.5	NS
3.0 M	9.0	NS	30.0	NS
4.0 M	8.0	NS	30.0	NS
5.0 M	8.0	NS	30.0	NS
6.0 M	7.5	NS	30.5	NS
7.0 M	7.0	NS	31.0	NS
8.0 M	7.0	NS	31.0	NS
9.0 M	6.0	NS	31.0	NS
10.0 M	6.0	NS	31.0	NS

	TEMP (C)		SAL (0/00)	
	601C	601	601C	601
DATE	05/29/90	05/16/90	05/29/90	05/16/90
DEPTH				
0.2 M	NS	9.0	25.0	22.0
1.0 M	NS	NS	NS	NS
2.0 M	NS	NS	NS	NS
3.0 M	NS	NS	NS	NS
4.0 M	NS	NS	NS	NS
5.0 M	NS	NS	NS	NS
6.0 M	NS	NS	NS	NS
7.0 M	NS	NS	NS	NS
8.0 M	NS	NS	NS	NS
9.0 M	NS	NS	NS	NS
10.0 M	NS	NS	NS	NS

SECOND VISIT

	TEMP (C)		SAL (0/00)	
	4825C	1424	4825C	1424
DATE	07/14/90	07/13/90	07/14/90	07/13/90
DEPTH				
0.2 M	13.0	15.0	26.0	26.0
1.0 M	13.0	14.0	26.0	26.5
2.0 M	13.0	14.0	26.0	27.0
3.0 M	13.0	13.0	26.0	27.0
4.0 M	13.0	13.0	26.5	27.0
5.0 M	13.0	12.0	26.5	28.0
6.0 M	13.0	12.0	26.5	28.0
7.0 M	13.0	12.0	26.5	28.0
8.0 M	13.0	12.0	26.5	28.0
9.0 M	13.0	11.5	26.5	28.5
10.0 M	13.0	11.5	27.0	28.5

	TEMP (C)		SAL (0/00)	
	601C	601	601C	601
DATE	07/09/90	07/05/90	07/09/90	07/05/90
DEPTH				
0.2 M	15.0	16.0	23.0	23.0
1.0 M	15.0	16.0	23.0	23.0
2.0 M	15.0	16.0	23.5	24.0
3.0 M	15.0	16.0	23.5	24.0
4.0 M	15.0	15.0	24.0	25.0
5.0 M	15.0	14.0	25.0	26.0
6.0 M	14.0	13.0	27.0	27.5
7.0 M	13.0	12.0	27.5	28.0
8.0 M	12.0	11.0	28.0	29.0
9.0 M	11.0	10.0	29.0	29.0
10.0 M	11.0	10.0	29.0	29.0

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Table 5.5.7. Salinity and temperature values recorded at seven paired sites in coarse textured habitats, first and second visits, PWS, Alaska. NS = not sampled.

FIRST VISIT 1990

	TEMP (C)		SAL (0/00)	
	1171C	1171	1171C	1171
DATE	06/14/90	06/13/90	06/14/90	06/13/90
DEPTH				
0.2 M	8.5	12.0	15.0	25.0
1.0 M	9.5	12.5	29.0	25.5
2.0 M	9.5	12.5	30.0	26.0
3.0 M	10.0	12.5	31.0	26.0
4.0 M	10.0	12.5	31.0	26.0
5.0 M	10.0	12.5	31.0	26.0
6.0 M	10.0	12.0	28.0	27.0
7.0 M	10.0	12.0	31.0	27.0
8.0 M	10.0	11.0	30.0	26.0
9.0 M	10.0	11.5	30.0	26.5
10.0 M	10.0	11.0	30.0	27.0

	TEMP (C)		SAL (0/00)	
	1383	1580	1383	1580
DATE	06/10/90	06/09/90	06/10/90	06/09/90
DEPTH				
0.2 M	11.0	14.0	25.0	27.0
1.0 M	11.0	13.0	29.5	28.0
2.0 M	11.0	13.0	29.5	28.5
3.0 M	11.0	13.0	29.0	28.5
4.0 M	10.5	13.0	30.0	29.0
5.0 M	10.5	12.0	30.0	30.0
6.0 M	10.5	11.0	30.0	30.0
7.0 M	10.5	10.0	30.0	29.0
8.0 M	10.5	8.5	30.0	30.0
9.0 M	10.5	8.0	30.0	30.0
10.0 M	10.0	8.0	30.0	30.0

	TEMP (C)		SAL (0/00)	
	1598C	1598	1598C	1598
DATE	06/03/90	06/04/90	06/03/90	06/04/90
DEPTH				
0.2 M	16.0	13.0	24.0	28.0
1.0 M	16.0	14.0	26.0	29.5
2.0 M	15.0	13.0	28.0	30.0
3.0 M	13.0	13.0	29.5	30.0
4.0 M	13.0	12.5	30.0	30.0
5.0 M	12.5	12.0	30.0	30.5
6.0 M	12.0	11.0	30.0	30.5
7.0 M	12.5	10.0	30.0	31.0
8.0 M	12.5	9.0	30.0	30.5
9.0 M	12.5	8.0	30.0	31.0
10.0 M	13.0	7.0	30.0	32.0

SECOND VISIT 1990

	TEMP (C)		SAL (0/00)	
	1171C	1171	1171C	1171
DATE	08/02/90	08/05/90	08/02/90	08/05/90
DEPTH				
0.2 M	12.0	12.5	16.5	20.0
1.0 M	12.0	12.5	27.0	21.0
2.0 M	12.5	12.5	27.5	21.0
3.0 M	12.5	12.5	27.5	21.0
4.0 M	12.5	12.5	27.5	21.0
5.0 M	12.5	12.5	27.5	21.5
6.0 M	12.0	12.5	28.0	21.5
7.0 M	12.5	12.5	27.5	21.5
8.0 M	12.5	12.5	27.5	23.0
9.0 M	12.5	12.5	27.5	24.0
10.0 M	12.5	13.0	27.5	24.0

	TEMP (C)		SAL (0/00)	
	1383	1580	1380	1580
DATE	09/05/90	08/07/90	09/05/90	08/07/90
DEPTH				
0.2 M	13.5	13.0	23.0	25.5
1.0 M	13.5	13.0	23.0	25.5
2.0 M	13.5	13.0	23.5	25.5
3.0 M	13.5	13.0	23.5	25.5
4.0 M	13.5	13.0	24.0	25.5
5.0 M	13.5	13.0	24.0	25.5
6.0 M	13.5	13.0	24.0	26.0
7.0 M	13.5	13.0	24.0	26.0
8.0 M	13.5	13.0	24.0	26.0
9.0 M	13.5	13.0	24.0	26.0
10.0 M	13.5	13.0	24.0	26.0

	TEMP (C)		SAL (0/00)	
	1598C	1598	1598C	1598
DATE	07/24/90	07/23/90	07/24/90	07/23/90
DEPTH				
0.2 M	17.0	17.0	22.5	22.5
1.0 M	17.0	17.0	24.5	23.0
2.0 M	17.0	17.0	24.5	24.5
3.0 M	17.0	16.0	25.0	25.0
4.0 M	16.5	16.0	25.0	25.0
5.0 M	16.0	15.5	25.5	25.5
6.0 M	16.0	15.0	25.5	25.5
7.0 M	16.0	15.0	25.5	25.5
8.0 M	15.5	15.0	26.0	25.5
9.0 M	15.0	14.5	26.0	26.0
10.0 M	15.0	14.5	26.0	26.0

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Table 5.5.7. Continued.

FIRST VISIT 1990

	TEMP (C)		SAL (0/00)	
	506C	506	506C	506
DATE	06/08/90	06/11/90	06/08/90	06/11/90
DEPTH				
0.2 M	15.0	14.0	19.0	25.0
1.0 M	15.0	13.0	25.0	25.5
2.0 M	15.0	13.0	25.0	26.0
3.0 M	15.0	13.0	25.0	26.0
4.0 M	12.0	13.0	28.0	26.0
5.0 M	11.0	13.0	28.0	26.5
6.0 M	9.0	13.0	29.0	27.0
7.0 M	9.0	13.0	29.0	27.0
8.0 M	8.0	13.0	29.5	27.5
9.0 M	8.0	13.0	29.5	27.5
10.0 M	7.0	13.0	30.0	27.5

	TEMP (C)		SAL (0/00)	
	1627C	1627	1627C	1627
DATE	06/19/90	05/26/90	06/19/90	05/26/90
DEPTH				
0.2 M	13.0	NS	21.0	20.0
1.0 M	13.0	NS	22.0	NS
2.0 M	12.5	NS	25.0	NS
3.0 M	12.0	NS	27.0	NS
4.0 M	12.0	NS	27.0	NS
5.0 M	12.0	NS	28.0	NS
6.0 M	12.0	NS	29.0	NS
7.0 M	12.0	NS	29.0	NS
8.0 M	12.0	NS	29.0	NS
9.0 M	12.0	NS	29.0	NS
10.0 M	12.0	NS	29.0	NS

	TEMP (C)		SAL (0/00)	
	1650C	1650	1650C	1650
DATE	06/04/90	06/05/90	06/04/90	06/05/90
DEPTH				
0.2 M	17.0	14.0	27.5	29.0
1.0 M	16.0	13.0	27.5	30.0
2.0 M	15.0	11.0	29.0	31.0
3.0 M	15.0	10.0	29.0	31.0
4.0 M	11.0	9.0	30.0	31.0
5.0 M	10.5	8.5	30.0	31.0
6.0 M	10.0	8.0	30.0	31.0
7.0 M	10.0	8.0	30.0	31.0
8.0 M	10.0	8.0	30.0	31.0
9.0 M	9.5	8.0	30.5	31.0
10.0 M	9.0	8.0	30.5	31.0

SECOND VISIT 1990

	TEMP (C)		SAL (0/00)	
	506C	506	506C	506
DATE	07/19/90	07/26/90	07/19/90	07/26/90
DEPTH				
0.2 M	15.0	15.0	20.5	22.0
1.0 M	16.0	15.0	20.5	22.0
2.0 M	16.0	15.0	21.0	22.0
3.0 M	16.0	15.5	22.0	22.0
4.0 M	16.0	15.0	22.0	22.0
5.0 M	15.0	15.0	24.0	22.5
6.0 M	14.0	15.0	25.5	22.5
7.0 M	14.0	15.0	26.0	22.5
8.0 M	13.5	15.0	26.0	22.5
9.0 M	13.0	15.0	27.5	22.5
10.0 M	11.0	15.0	29.0	22.5

	TEMP (C)		SAL (0/00)	
	1627C	1627	1627C	1627
DATE	08/09/90	08/06/90	08/09/90	08/06/90
DEPTH				
0.2 M	13.0	13.0	17.0	18.5
1.0 M	13.0	13.0	17.5	19.0
2.0 M	13.0	13.0	17.5	19.5
3.0 M	13.0	13.0	18.0	19.5
4.0 M	13.0	13.0	18.0	19.5
5.0 M	13.0	13.0	18.5	19.5
6.0 M	13.0	13.0	18.5	22.0
7.0 M	13.0	13.0	20.0	22.5
8.0 M	13.0	13.0	20.0	23.0
9.0 M	13.0	13.0	22.0	23.0
10.0 M	13.0	13.0	24.5	23.0

	TEMP (C)		SAL (0/00)	
	1650C	1650	1650C	1650
DATE	07/20/90	07/21/90	07/20/90	07/21/90
DEPTH				
0.2 M	15.0	15.0	23.0	24.0
1.0 M	15.0	15.0	24.5	24.0
2.0 M	14.5	15.0	25.5	24.0
3.0 M	14.0	15.0	26.0	24.0
4.0 M	14.0	15.0	26.0	25.0
5.0 M	14.0	15.0	26.0	25.0
6.0 M	14.0	15.0	26.0	25.0
7.0 M	13.5	15.0	26.5	25.0
8.0 M	13.5	15.0	26.5	25.0
9.0 M	13.0	15.0	27.0	25.0
10.0 M	13.0	15.0	27.5	25.0

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Table 5.5.7. Continued.

FIRST VISIT 1990

	TEMP (C)		SAL (0/00)	
	846C	846	846C	846
DATE	06/07/90	06/04/90	06/07/90	06/04/90
DEPTH				
0.2 M	8.5	14.0	16.0	29.0
1.0 M	11.5	14.0	25.0	29.0
2.0 M	11.0	14.0	26.0	29.0
3.0 M	11.0	13.0	27.0	30.0
4.0 M	10.0	13.0	28.0	30.0
5.0 M	9.0	12.5	28.5	30.0
6.0 M	8.5	12.0	29.0	30.5
7.0 M	8.0	11.0	29.0	31.0
8.0 M	7.0	10.0	30.0	30.5
9.0 M	7.0	9.0	30.0	30.5
10.0 M	7.0	8.0	30.0	31.5

SECOND VISIT 1990

	TEMP (C)		SAL (0/00)	
	846C	846	846C	846
DATE	07/25/90	07/22/90	07/25/90	07/22/90
DEPTH				
0.2 M	12.0	17.0	18.5	22.5
1.0 M	13.0	16.5	21.0	23.0
2.0 M	13.0	16.0	21.0	23.5
3.0 M	13.0	17.0	23.0	23.5
4.0 M	13.5	17.0	22.0	25.0
5.0 M	13.5	16.5	22.0	25.0
6.0 M	13.5	16.0	23.5	25.0
7.0 M	13.0	15.5	24.5	25.5
8.0 M	12.5	15.0	25.0	26.0
9.0 M	12.0	15.0	25.5	26.0
10.0 M	11.5	15.0	27.5	26.0

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Table 5.5.8. Salinity and temperature values recorded at two paired sites in esturaine habitats, first and second visits, PWS, Alaska. NS = not sampled.

FIRST VISIT 1990

	TEMP (C)		SAL (0/00)	
	2397	208/209	2397	208/209
DATE	06/12/90	06/20/90	06/12/90	06/20/90
DEPTH				
0.2 M	13.0	13.0	19.0	22.0
1.0 M	11.0	13.0	20.0	24.0
2.0 M	10.0	12.5	28.5	25.0
3.0 M	9.0	12.5	29.0	26.0
4.0 M	9.0	12.5	29.0	26.5
5.0 M	9.0	12.0	29.0	27.0
6.0 M	8.0	12.0	30.0	27.0
7.0 M	8.0	12.0	30.0	27.0
8.0 M	7.5	12.0	30.0	27.0
9.0 M	7.0	12.0	30.0	27.0
10.0 M	7.0	12.0	30.0	27.0

	TEMP (C)		SAL (0/00)	
	15.1C	15.1	15.1C	15.1
DATE				
DEPTH				
0.2 M	NS	NS	NS	NS
1.0 M	NS	NS	NS	NS
2.0 M	NS	NS	NS	NS
3.0 M	NS	NS	NS	NS
4.0 M	NS	NS	NS	NS
5.0 M	NS	NS	NS	NS
6.0 M	NS	NS	NS	NS
7.0 M	NS	NS	NS	NS
8.0 M	NS	NS	NS	NS
9.0 M	NS	NS	NS	NS
10.0 M	NS	NS	NS	NS

SECOND VISIT 1990

	TEMP (C)		SAL (0/00)	
	2397	208/209	2397	208/209
DATE	08/08/90	08/04/90	08/08/90	08/04/90
DEPTH				
0.2 M	12.0	12.0	23.5	17.0
1.0 M	12.0	12.0	24.0	17.0
2.0 M	12.0	12.0	24.0	17.0
3.0 M	12.0	13.0	24.5	16.5
4.0 M	12.0	13.0	24.5	17.0
5.0 M	12.0	13.0	24.5	17.0
6.0 M	12.0	13.0	24.5	17.0
7.0 M	12.0	13.0	25.0	17.0
8.0 M	12.0	13.5	25.0	17.0
9.0 M	12.0	14.0	25.0	16.5
10.0 M	12.0	13.0	25.0	17.5

	TEMP (C)		SAL (0/00)	
	15.1C	15.1	15.1C	15.1
DATE				
DEPTH				
0.2 M	NS	NS	NS	NS
1.0 M	NS	NS	NS	NS
2.0 M	NS	NS	NS	NS
3.0 M	NS	NS	NS	NS
4.0 M	NS	NS	NS	NS
5.0 M	NS	NS	NS	NS
6.0 M	NS	NS	NS	NS
7.0 M	NS	NS	NS	NS
8.0 M	NS	NS	NS	NS
9.0 M	NS	NS	NS	NS
10.0 M	NS	NS	NS	NS

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Table 5.5.9. Salinity and temperature values recorded at five paired sites in exposed rocky habitats, first and second visits, PWS, Alaska. NS = not sampled.

FIRST VISIT 1990

	TEMP (C)			SAL (0/00)		
	1642	833	232	1642	833	232
DATE	06/23/90	06/18/90	06/22/90	06/23/90	06/18/90	06/22/90
DEPTH						
0.2 M	13.0	13.0	13.0	25.0	28.0	28.0
1.0 M	12.5	12.0	12.0	26.0	28.0	28.5
2.0 M	12.0	11.5	12.0	26.0	28.0	28.5
3.0 M	13.5	11.5	12.0	25.5	29.0	28.5
4.0 M	13.5	11.0	12.0	25.5	29.5	28.5
5.0 M	13.5	11.0	12.0	26.0	29.5	28.5
6.0 M	13.5	11.0	12.0	26.0	30.0	28.5
7.0 M	13.0	11.0	12.0	26.0	30.0	28.5
8.0 M	13.0	11.0	12.0	26.0	30.0	28.5
9.0 M	13.0	11.0	11.0	26.0	30.0	29.0
10.0 M	13.0	10.5	11.0	26.0	30.0	29.0

SECOND VISIT 1990

	TEMP (C)			SAL (0/00)		
	1642	833	232	1642	833	232
DATE	08/21/90	08/24/90	08/20/90	08/21/90	08/24/90	08/20/90
DEPTH						
0.2 M	13.0	14.5	13.5	22.0	23.0	24.5
1.0 M	13.0	14.5	13.5	22.0	23.0	25.0
2.0 M	13.0	14.0	13.5	22.5	23.5	25.0
3.0 M	13.0	14.0	13.5	23.0	23.5	25.0
4.0 M	13.0	14.0	13.5	23.5	23.5	25.5
5.0 M	13.0	14.0	13.5	23.5	23.5	25.5
6.0 M	13.0	14.0	13.5	24.0	24.0	25.5
7.0 M	13.0	14.0	13.5	24.5	24.0	25.5
8.0 M	13.0	14.0	13.5	24.5	24.0	25.5
9.0 M	13.0	14.0	13.5	24.5	24.5	25.5
10.0 M	13.0	14.0	13.5	24.5	24.5	26.0

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Table 5.5.9. Continued.

FIRST VISIT 1990

	TEMP (C)		SAL (0/00)	
	19C	19	19C	19
DATE	06/30/90	06/30/90	06/30/90	06/30/90
DEPTH				
0.2 M	16.0	16.0	20.0	24.0
1.0 M	15.0	16.0	23.0	24.5
2.0 M	15.0	16.0	24.0	24.5
3.0 M	15.0	16.0	24.0	24.5
4.0 M	14.5	16.0	24.5	25.0
5.0 M	13.5	15.0	25.0	26.0
6.0 M	13.0	14.0	25.0	27.0
7.0 M	13.0	14.0	25.5	27.0
8.0 M	13.0	14.0	26.0	27.0
9.0 M	12.0	13.0	27.0	27.0
10.0 M	12.0	13.0	27.0	27.5

	TEMP (C)		SAL (0/00)	
	4537	979	4537	979
DATE	06/26/90	06/29/90	06/26/90	06/29/90
DEPTH				
0.2 M	NS	11.0	NS	28.5
1.0 M	NS	12.0	NS	28.0
2.0 M	NS	12.0	NS	28.0
3.0 M	NS	12.0	NS	28.0
4.0 M	NS	12.0	NS	28.0
5.0 M	NS	11.5	NS	28.0
6.0 M	NS	11.5	NS	28.0
7.0 M	NS	11.0	NS	29.0
8.0 M	NS	11.0	NS	29.0
9.0 M	NS	11.0	NS	29.0
10.0 M	NS	11.0	NS	29.0

	TEMP (C)		SAL (0/00)	
	2937	305	2937	305
DATE	06/21/90	06/27/90	06/21/90	06/27/90
DEPTH				
0.2 M	13.0	16.0	21.5	22.0
1.0 M	13.0	15.0	22.0	22.5
2.0 M	12.0	15.0	23.0	23.0
3.0 M	12.0	14.5	24.0	24.0
4.0 M	12.0	14.0	24.0	24.0
5.0 M	12.5	14.0	24.0	24.0
6.0 M	12.5	14.0	24.0	25.0
7.0 M	12.5	14.0	26.0	25.0
8.0 M	12.5	14.0	26.0	25.0
9.0 M	12.0	14.0	27.0	25.0
10.0 M	12.0	14.0	27.0	25.0

SECOND VISIT 1990

	TEMP (C)		SAL (0/00)	
	19C	19	19C	19
DATE	09/04/90	09/04/90	09/04/90	09/04/90
DEPTH				
0.2 M	13.0	13.0	23.0	23.0
1.0 M	13.0	13.0	23.0	23.5
2.0 M	13.0	13.0	23.0	23.5
3.0 M	13.0	13.0	23.0	23.5
4.0 M	13.0	13.5	23.0	23.5
5.0 M	13.0	13.5	23.0	23.5
6.0 M	13.5	13.5	23.0	23.5
7.0 M	13.5	13.5	23.5	24.0
8.0 M	13.5	13.5	24.0	24.0
9.0 M	13.5	13.5	24.5	24.5
10.0 M	13.5	13.5	25.0	25.0

	TEMP (C)		SAL (0/00)	
	4537	979	4537	979
DATE	08/23/90	08/22/90	08/23/90	08/22/90
DEPTH				
0.2 M	14.0	15.0	27.5	25.0
1.0 M	14.0	14.5	27.5	25.0
2.0 M	14.0	14.0	27.5	26.0
3.0 M	14.0	14.0	27.5	26.0
4.0 M	14.0	14.0	27.5	26.0
5.0 M	13.5	14.0	27.5	26.0
6.0 M	13.5	13.5	27.5	26.0
7.0 M	13.5	13.5	27.5	26.0
8.0 M	13.5	13.5	27.5	26.0
9.0 M	13.5	13.5	27.5	26.0
10.0 M	13.5	13.5	27.5	26.0

	TEMP (C)		SAL (0/00)	
	2937	305	2937	305
DATE	08/19/90	08/18/90	08/19/90	08/18/90
DEPTH				
0.2 M	NS	13.0	NS	26.0
1.0 M	NS	13.0	NS	25.5
2.0 M	NS	13.0	NS	25.5
3.0 M	NS	13.0	NS	25.5
4.0 M	NS	13.0	NS	25.0
5.0 M	NS	13.0	NS	25.0
6.0 M	NS	13.0	NS	25.0
7.0 M	NS	13.0	NS	25.0
8.0 M	NS	13.0	NS	25.0
9.0 M	NS	13.0	NS	25.0
10.0 M	NS	13.0	NS	25.0

Cook Inlet - Kenai

No quadrat or other data from the transect cruises have been analyzed as of this writing. Algal species lists can be found in Table 5.5.5.b.

Kodiak - Alaska Peninsula

Percent Cover of Algae Study

The percent cover values of total algal cover and *Fucus* in this report were estimated in the field immediately before the study quadrats were cleared. Because these estimates were made without rigorous quantitative methods they should be viewed as preliminary. Final data on algal cover will be derived from the photographs of each quadrat as they become available.

The data for total algal cover at the sheltered rocky habitats for each of the two visits to these sites is summarized in Figure 5.5.17. The data on *Fucus* percent cover is presented in Figure 5.5.18. These two figures show the same basic patterns in the comparisons between the oiled and control sites. The only comparison that shows a significant oiling effect is in the 2 meter vertical drop at site 31252 in Foul Bay (Tables 5.5.10 - 5.5.13). Lower total algal and *Fucus* cover were also seen in the quadrats in the 2 meter vertical drop at the Foul Bay oiled site (31288) in the comparison of coarse textured sites (Figure 5.5.19, Table 5.5.11).

Both total algal cover and *Fucus* were very low in the upper intertidal quadrats at all the exposed rocky sites along the Alaska Peninsula and no oiling effect can be discerned. (Figure 5.5.120). The algal cover at these sites appears to be low due to the buildup of ice on the rocks that abrades the seaweeds. The only place where plants are abundant at these sites is in cracks and crevices.

Fucus Study

The *Fucus* samples for the 1990 field season in Kodiak have not yet been processed.

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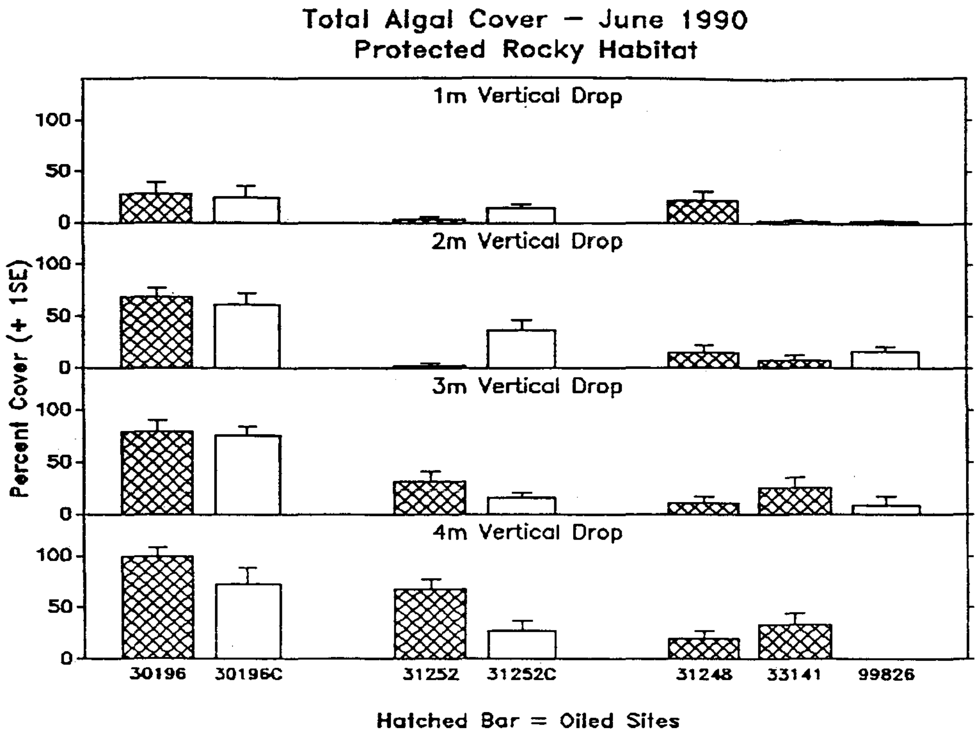

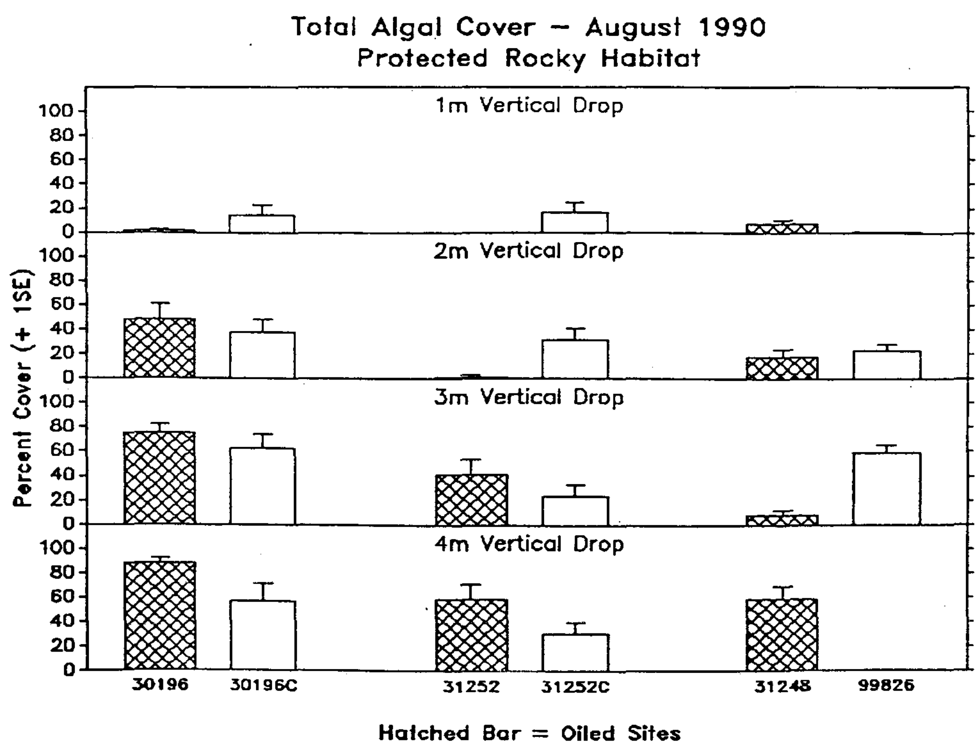

Figure 5.5.17. Percent cover of Total Algae for both visits to paired sites in the sheltered rocky habitat.

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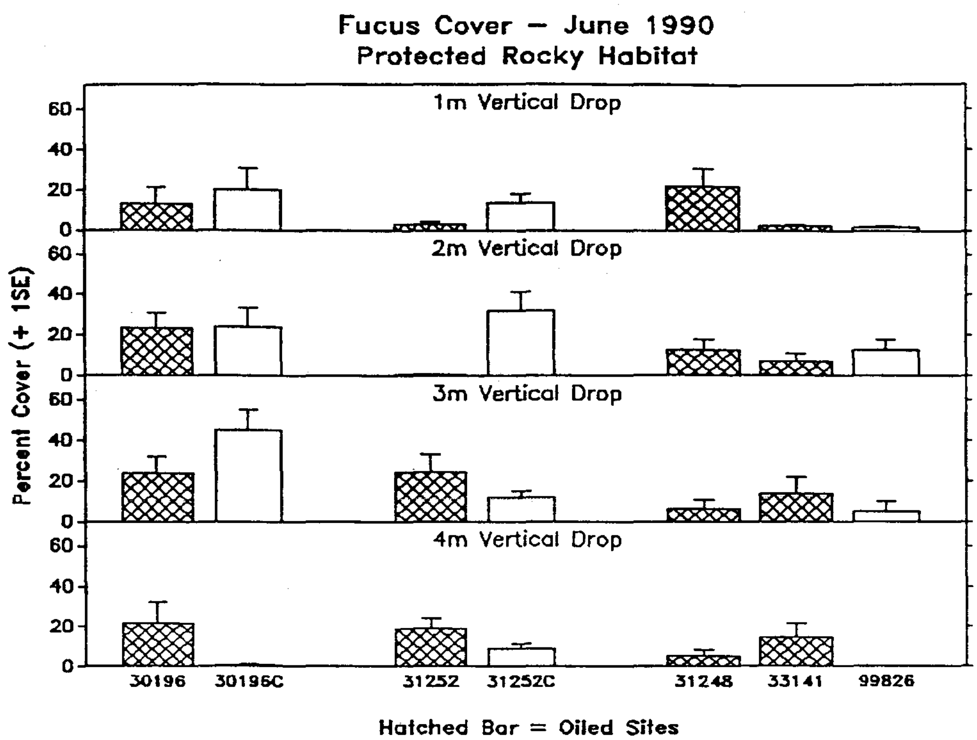

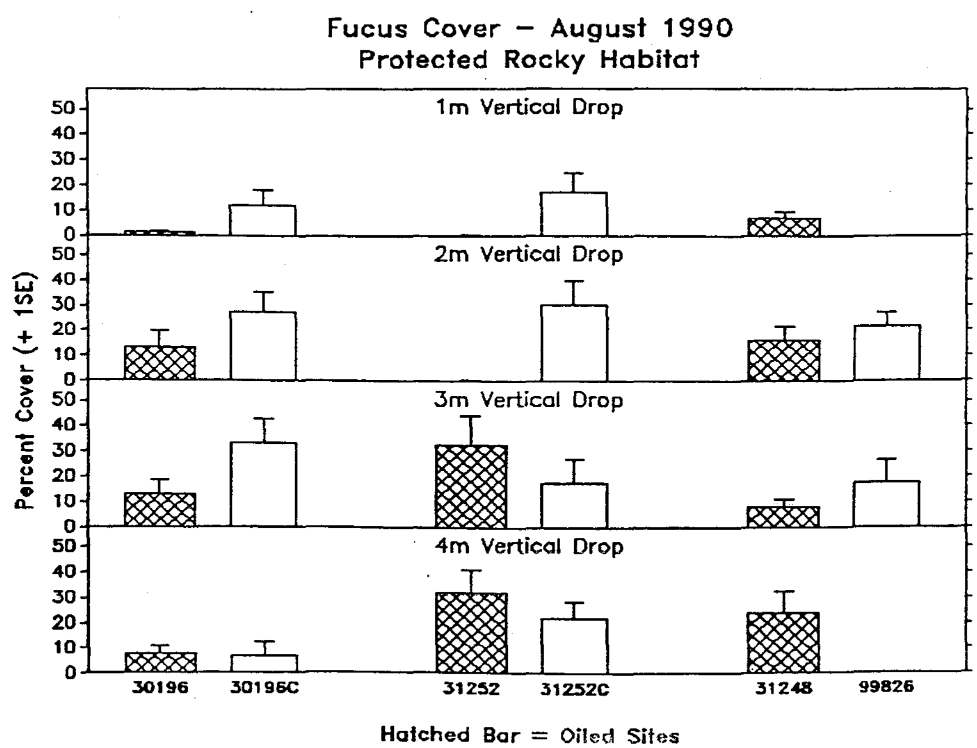

Figure 5.5.18. Percent cover of *Fucus* for both visits to paired sites in the the sheltered rocky habitat.

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Table 5.5.10. T-test comparisons of total percent algal cover and Fucus cover at the sheltered rocky habitat sites during the first visit in June, 1990. All percent covers have been arcsine transformed.

1 meter drop	30196 Oiled	30196C Control	31252 Oiled	31252C Control	31248 Oiled	99826 Control	33141 Oiled	99826 Control
Mean Algal	29.5	25.0	5.9	17.6	21.5	6.1	5.4	6.1
Std Error	8.2	8.9	2.8	4.3	6.9	1.9	2.0	1.9
T Value		0.37		-2.28		2.13		-0.26
Probability		0.710		0.032		0.053		0.790
Mean Fucus	17.0	21.5	5.5	17.3	21.5	5.0	5.3	5.0
Std Error	6.9	8.8	2.5	4.3	6.9	1.5	2.0	1.5
T Value		-4.44		-2.39		2.32		0.13
Probability		0.690		0.026		0.039		0.890

2 meter drop	30196 Oiled	30196C Control	31252 Oiled	31252C Control	31248 Oiled	99826 Control	33141 Oiled	99826 Control
Mean Algal	58.9	52.9	6.8	34.3	17.1	20.6	11.1	20.6
Std Error	6.1	8.7	2.4	7.8	5.4	4.2	3.9	4.2
T Value		0.56		-3.39		-0.51		-1.67
Probability		0.580		0.003		0.610		0.110
Mean Fucus	24.2	24.0	3.3	31.1	15.6	16.4	10.4	16.4
Std Error	5.8	7.5	1.0	7.8	4.7	4.4	3.7	4.4
T Value		0.02		-3.53		-0.14		-1.06
Probability		0.980		0.002		0.890		0.300

3 meter drop	30196 Oiled	30196C Control	31252 Oiled	31252C Control	31248 Oiled	99826 Control	33141 Oiled	99826 Control
Mean Algal	63.2	63.0	30.9	20.3	14.4	13.1	22.5	13.1
Std Error	6.1	5.7	6.7	4.0	4.7	11.3	8.4	11.3
T Value		0.02		1.37		0.11		0.43
Probability		0.980		0.180		0.920		0.670
Mean Fucus	26.6	41.0	25.4	17.8	9.1	10.2	14.0	10.2
Std Error	5.6	7.1	6.2	3.1	3.8	8.4	6.5	8.4
T Value		-1.62		1.10		-0.11		0.23
Probability		0.120		0.280		0.910		0.820

4 meter drop	30196 Oiled	30196C Control	31252 Oiled	31252C Control	31248 Oiled	99826 Control	33141 Oiled	99826 Control
Mean Algal	78.0	61.7	57.9	28.6		No data		No data
Std Error	3.8	11.3	6.5	6.7				
T Value		1.73		3.16				
Probability		0.110		0.005				
Mean Fucus	22.4	3.9	22.8	15.4				
Std Error	8.2	2.1	4.2	2.6				
T Value		2.18		1.49				
Probability		0.061		0.150				

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Table 5.5.11. T-test comparisons of total percent algal cover and Fucus cover at the sheltered rocky habitat sites during the second visit in August, 1990. All percent covers have been arcsine transformed.

1 meter drop	30196 Oiled	30196C Control	31252 Oiled	31252C Control	31248 Oiled	99826 Control	33141 Oiled	99826 Control
Mean Algal	5.7	15.8	2.3	16.3	11.6	3.1	No data	
Std Error	1.5	6.0	0.4	6.5	3.1	1.0		
T Value		-1.63		-2.16		2.57		
Probability		0.127		0.053		0.023		
Mean Fucus	5.2	13.7	2.2	16.3	11.6	2.0		
Std Error	4.4	17.9	0.4	6.5	3.1	0.2		
T Value		-1.59		-2.16		3.04		
Probability		0.136		0.053		0.011		

2 meter drop	30196 Oiled	30196C Control	31252 Oiled	31252C Control	31248 Oiled	99826 Control	33141 Oiled	99826 Control
Mean Algal	44.9	37.2	4.4	30.3	19.4	24.3	No data	
Std Error	9.8	6.8	1.9	7.5	5.4	5.1		
T Value		0.64		-3.34		-0.66		
Probability		0.527		0.003		0.515		
Mean Fucus	14.5	29.1	2.5	28.9	18.3	23.6		
Std Error	5.5	5.7	0.7	7.4	5.1	5.0		
T Value		-1.86		-3.56		-0.75		
Probability		0.077		0.002		0.463		

3 meter drop	30196 Oiled	30196C Control	31252 Oiled	31252C Control	31248 Oiled	99826 Control	33141 Oiled	99826 Control
Mean Algal	63.0	54.0	30.1	26.2	13.1	50.5	No data	
Std Error	5.5	8.7	9.7	7.8	3.5	4.2		
T Value		0.88		0.32		-6.89		
Probability		0.386		0.754		0.000		
Mean Fucus	16.1	32.6	22.3	28.1	12.8	17.2		
Std Error	4.8	7.7	8.1	6.8	3.3	7.3		
T Value		-1.82		0.26		-0.55		
Probability		0.082		0.800		0.600		

4 meter drop	30196 Oiled	30196C Control	31252 Oiled	31252C Control	31248 Oiled	99826 Control	33141 Oiled	99826 Control
Mean Algal	73.5	49.5	51.9	32.2	52.2	1.8	No data	
Std Error	3.9	12.1	8.0	6.8	6.7	0.0		
T Value		1.90		1.87		7.50		
Probability		0.092		0.075		0.000		
Mean Fucus	13.0	8.9	31.6	25.4	25.0	6.2		
Std Error	3.1	5.2	6.8	4.6	1.8	0.0		
T Value		0.71		0.76		3.70		
Probability		0.481		0.455		0.003		

Table 5.5.12. T-test comparisons of total percent algal cover and Fucus cover at the coarse textured habitat sites during the first visit in July, 1990. All percent covers have been arcsine transformed.

1 meter drop	31288 Oiled	94935 Control
Mean Algal	1.8	12.8
Std Error	0.0	4.1
T Value		-2.71
Probability		0.020
Mean Fucus	1.8	12.8
Std Error	0.0	4.1
T Value		-2.71
Probability		0.020

2 meter drop	31288 Oiled	94935 Control
Mean Algal	1.8	20.5
Std Error	0.0	5.7
T Value		-3.30
Probability		0.007
Mean Fucus	1.8	20.4
Std Error	0.0	5.7
T Value		-3.30
Probability		0.007

3 meter drop	31288 Oiled	94935 Control
Mean Algal	7.3	17.0
Std Error	3.5	8.1
T Value		-1.10
Probability		0.289
Mean Fucus	3.8	15.9
Std Error	1.1	7.7
T Value		-1.55
Probability		0.148

4 meter drop	31288 Oiled	94935 Control
Mean Algal	12.8	7.6
Std Error	6.2	3.4
T Value		0.68
Probability		0.504
Mean Fucus	2.2	2.1
Std Error	0.4	0.3
T Value		0.17
Probability		0.871

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Table 5.5.13. T-test comparisons of total percent algal cover and Fucus cover at the exposed rocky habitat sites during the the first visit in July, 1990. All percent covers have been arcsine transformed.

1 meter drop	K11.1 Oiled	K11.1C Control	K11.2 Oiled	K11.2C Control	31461 Oiled	31461C Control	33027 Oiled	96665 Control
Mean Algal	2.8	3.1	8.0	1.8	5.9	1.8	2.5	2.0
Std Error	0.8	1.0	3.0	0.0	2.2	0.0	0.5	0.2
T Value		-0.22		2.05		1.83		0.93
Probability		0.829		0.065		0.095		0.369
Mean Fucus	2.5	3.1	6.0	1.8	5.0	1.8	2.5	2.0
Std Error	0.7	1.0	2.1	0.0	1.7	0.0	0.5	0.2
T Value		-0.46		1.97		1.84		0.93
Probability		0.643		0.075		0.094		0.369

2 meter drop	K11.1 Oiled	K11.1C Control	K11.2 Oiled	K11.2C Control	31461 Oiled	31461C Control	33027 Oiled	96665 Control
Mean Algal	3.0	5.8	15.2	1.8	10.5	15.5	11.8	12.1
Std Error	1.2	2.8	3.6	0.0	2.9	4.0	5.9	1.4
T Value		-0.89		3.72		-1.01		-0.05
Probability		0.386		0.003		0.322		0.957
Mean Fucus	2.2	3.5	7.5	1.8	4.0	9.7	8.1	7.1
Std Error	0.4	1.1	2.2	0.0	0.9	3.9	3.3	1.7
T Value		-1.11		2.57		-1.43		0.26
Probability		0.286		0.026		0.179		0.797

3 meter drop	K11.1 Oiled	K11.1C Control	K11.2 Oiled	K11.2C Control	31461 Oiled	31461C Control	33027 Oiled	96665 Control
Mean Algal	12.2	9.7	18.4	1.8	15.9	14.6	12.8	17.8
Std Error	5.2	2.5	3.7	0.0	3.2	4.8	4.7	4.3
T Value		0.44		4.46		0.23		-0.73
Probability		0.668		0.001		0.817		0.472
Mean Fucus	3.0	8.0	8.7	1.8	13.6	9.9	2.5	5.8
Std Error	0.9	2.4	1.4	0.0	2.9	4.2	0.5	1.6
T Value		-1.96		5.12		0.72		-2.00
Probability		0.069		0.000		0.479		0.080

4 meter drop	K11.1 Oiled	K11.1C Control	K11.2 Oiled	K11.2C Control	31461 Oiled	31461C Control	33027 Oiled	96665 Control
Mean Algal	23.5	20.6	19.7	34.0	21.4	34.7		No data
Std Error	7.6	4.5	7.6	10.8	4.1	7.6		
T Value		0.31		-1.03		-1.54		
Probability		0.760		0.317		0.138		
Mean Fucus	5.7	6.9	7.4	8.7	17.3	5.2		
Std Error	2.3	2.1	1.8	2.8	3.6	1.8		
T Value		-0.39		-0.36		3.06		
Probability		0.700		0.721		0.008		

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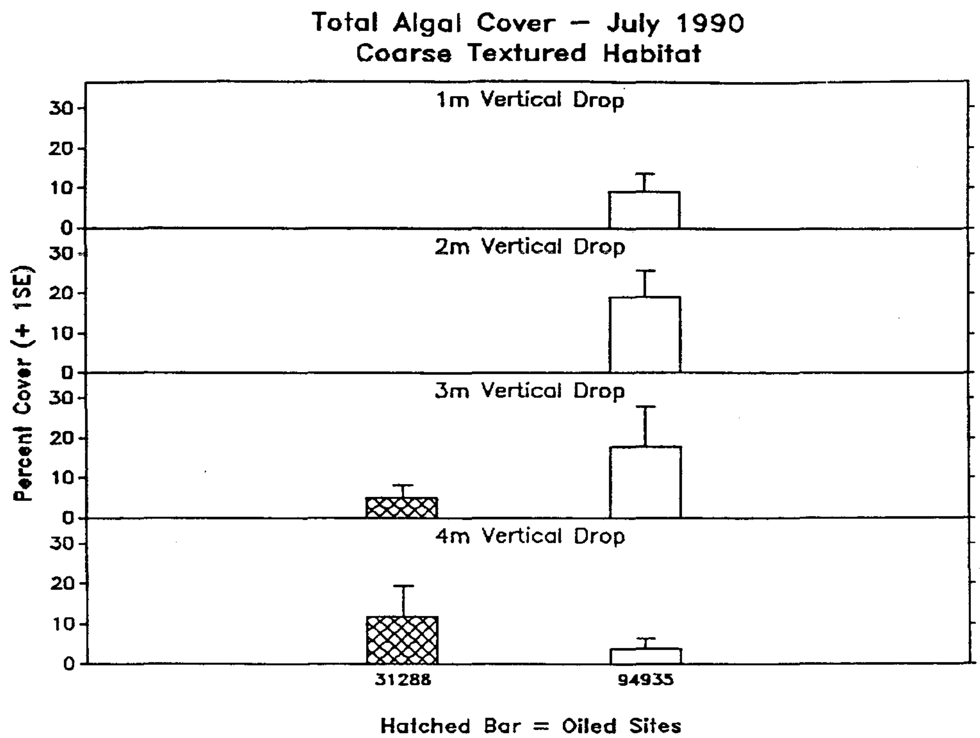

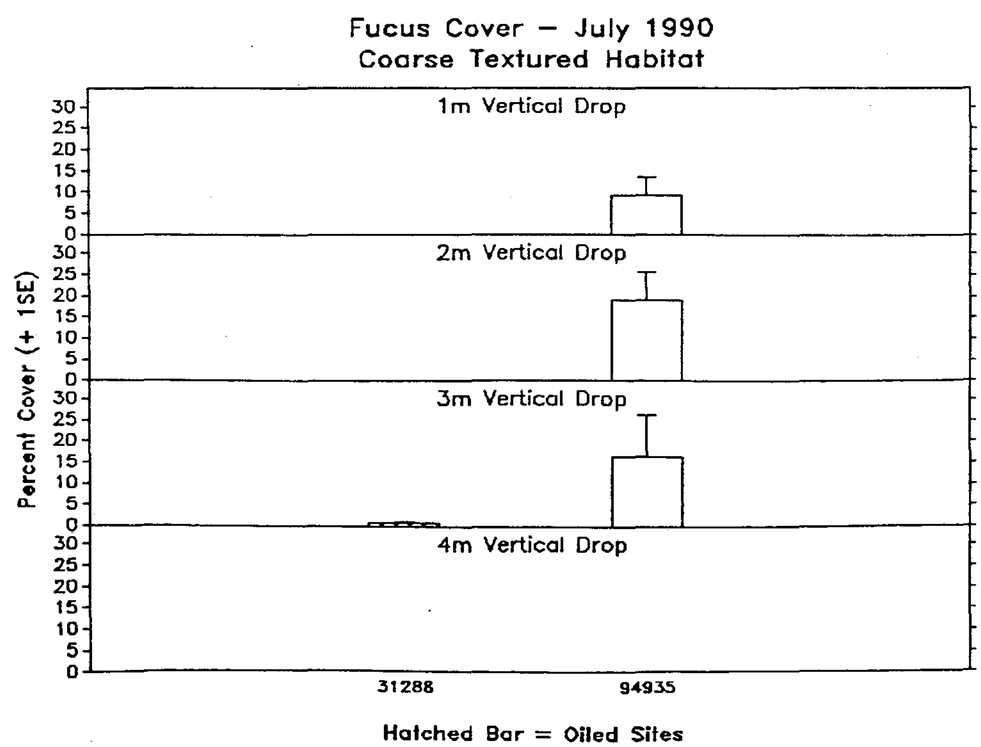

Figure 5.5.19. Percent cover of Total Algae and Fucus during July, 1990 at paired sites in the coarse textured habitat.

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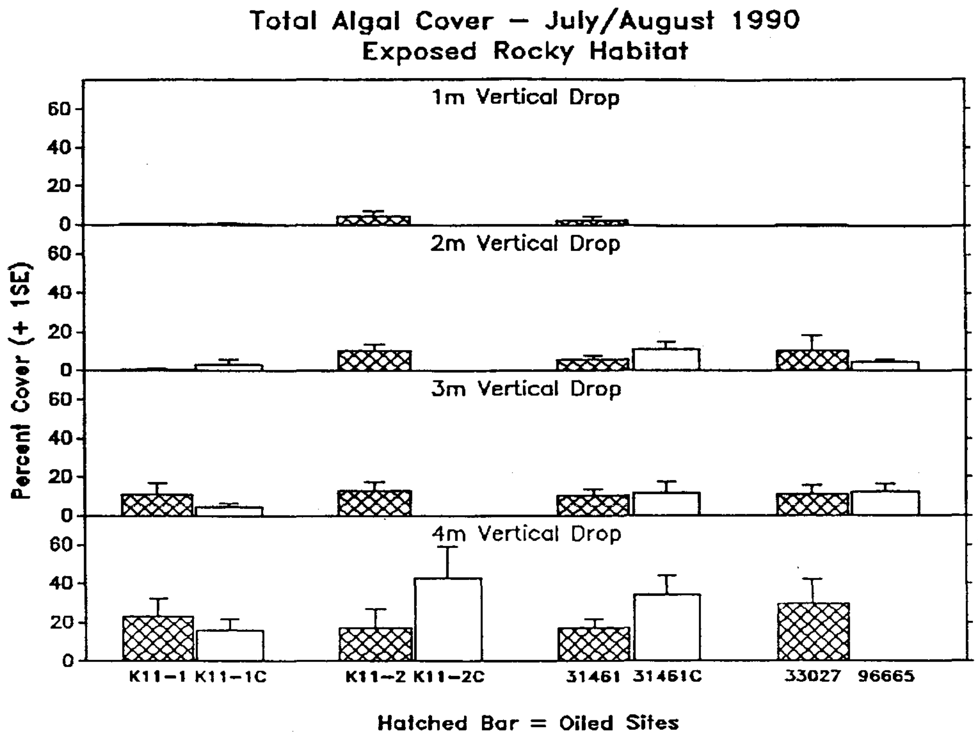

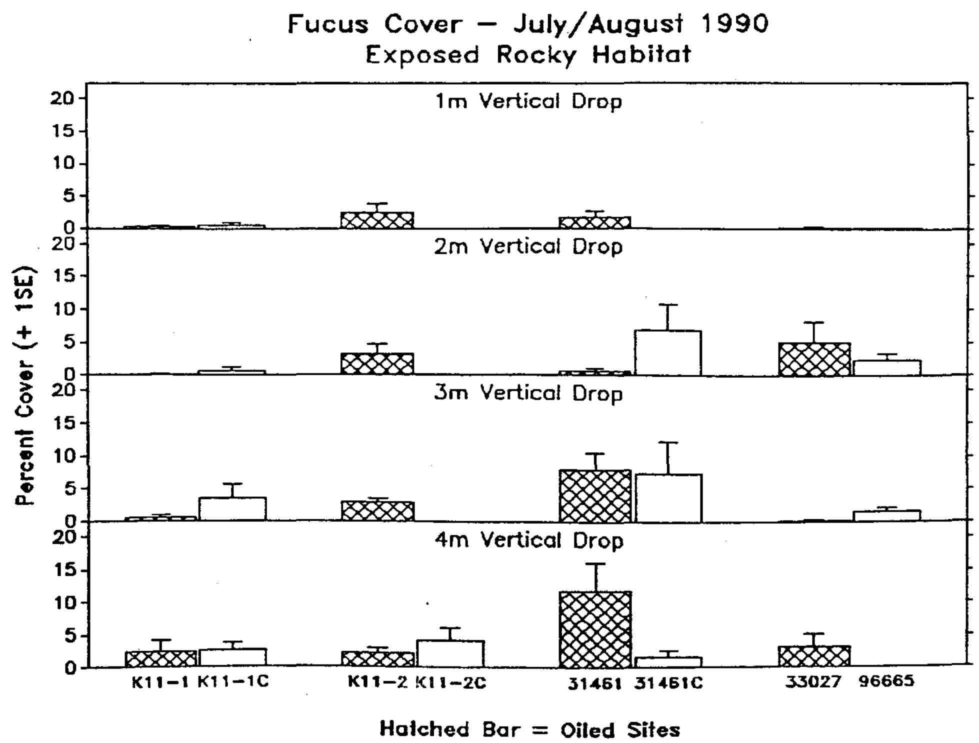

Figure 5.5.20. Percent cover of Total Algae and <u>Fucus</u> during July/August, 1990 at paired sites in the exposed rocky habitat.

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Fertile *Fucus* Density Study

Data on fertile *Fucus* density were derived from the distances of the nearest fertile plant from the cleared quadrat. This set of data, therefore, was derived from a separate group of plants than those used to estimate percent covers. This density data is summarized in Figures 5.5.21, 5.5.22, and 5.5.23. The patterns in density parallel those of percent cover with the oiled sites in Foul Bay having a lower density of fertile plants in the upper intertidal than the control sites. The exposed rocky sites had very few fertile plants in the upper intertidal locations at both the oiled and control sites.

Temperature and Salinity Data

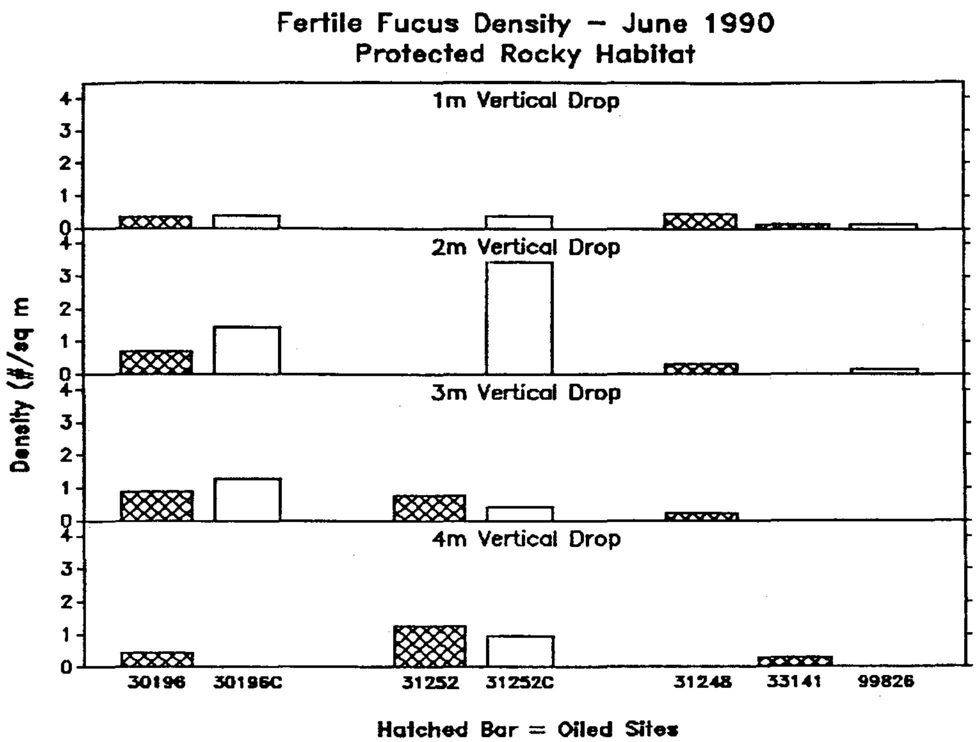
The temperature and salinity for the Kodiak - Alaska Peninsula region are given in Table 5.5.14 for the sheltered rocky habitat sites. Data in exposed rocky and coarse textured habitats was not collected because of instrument failure.

Both temperatures and salinities were similar between the paired and control sites. Temperatures increased an average of 2 degrees between the first visits in June and the second visits in August. Salinities increased from 5 to 10 ppt between the spring and summer.

Discussion

Although we have found significant differences between the oiled and control sites with respect to some of the measured parameters in the data analyzed to date, more data work-up and analyses need to be done before clear patterns may emerge. Effects of oiling may be stratified with respect to area, habitat type, and beach aspect. Variances in the data were found to be too large in most cases to find significant differences at the 0.01 level. However, there appeared to be trends in the data indicating that the oil spill plus subsequent clean-up activities had serious impact on the intertidal algal populations.

A results summary of two sheltered rocky site pairs in PWS is given in Table 5.5.15. In general the oiled sites had fewer *Fucus* plants and less biomass in the upper



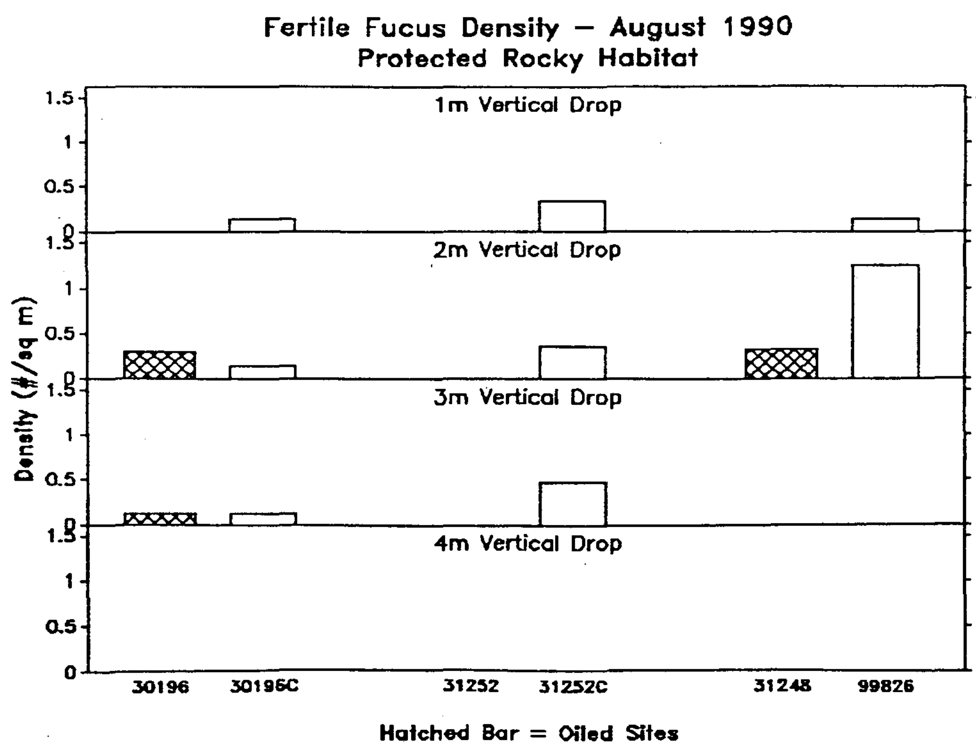


Figure 5.5.21. Density of fertile Fucus for both visits to paired sites in the the sheltered rocky habitat.

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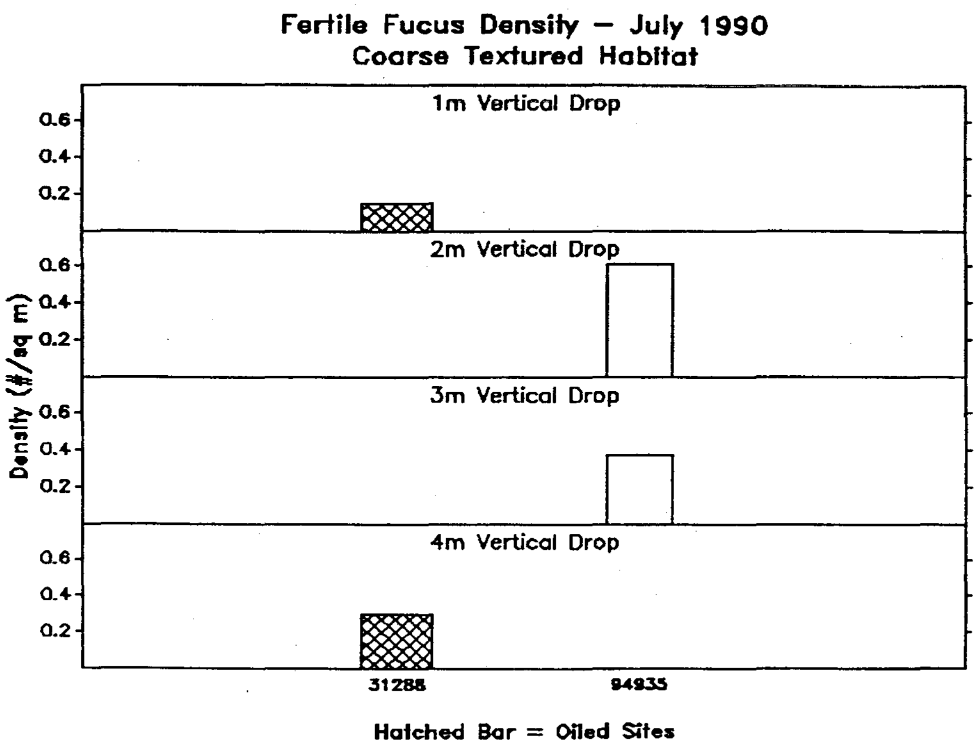

Figure 5.5.22. Density of fertile <u>Fucus</u> for the paired sites in the the coarse textured habitat. Site 31288 is in Foul Bay and site 94935 is in Terror Bay, both on Kodiak Island.

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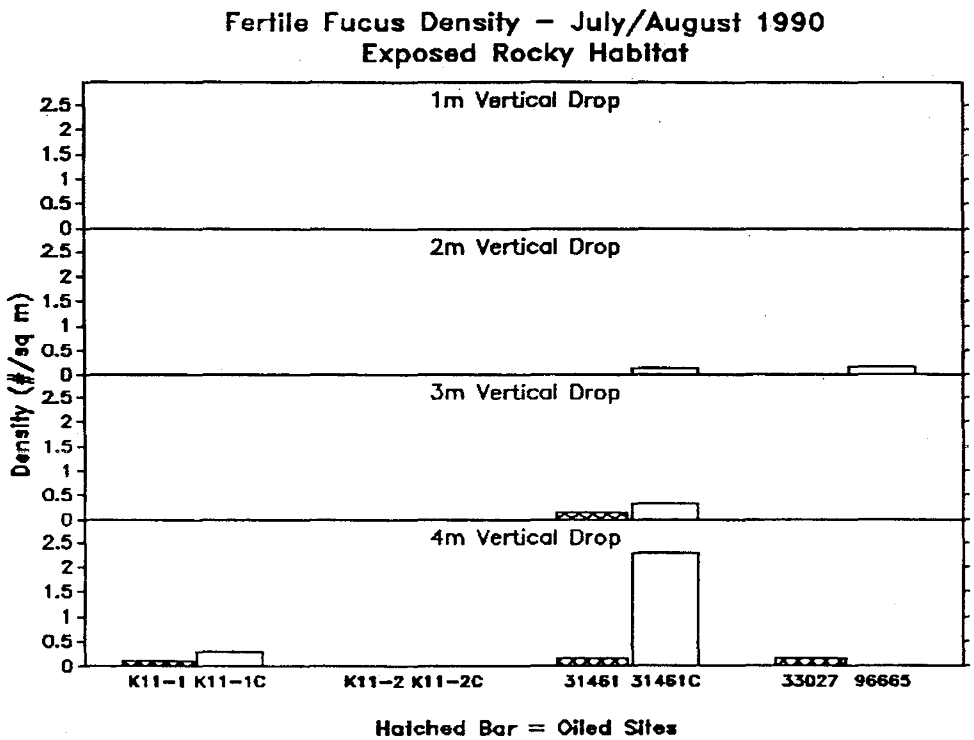

Figure 5.5.23. Density of fertile *Fucus* for the paired sites in the the exposed rocky habitat.

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Table 5.5.14 Temperature and salinities recorded in sheltered rocky habitats in the Kodiak - Alaska Peninsula region. NS = Not Sampled.

FIRST VISIT

	TEMP (C)		SAL (0/00)	
	31252C	31252	31252C	31252
DATE	06/22/90	06/22/90	06/22/90	06/22/90
DEPTH				
0.2 M	11.0	10.2	14.3	16.0
1.0 M	11.0	11.0	18.0	16.1
2.0 M	10.8	10.9	18.0	16.0
3.0 M	10.8	10.8	17.5	16.5
4.0 M	10.5	10.5	17.5	17.0
5.0 M	10.2	10.3	13.0	17.0
6.0 M	10.1	10.2	14.0	17.1
7.0 M	10.0	10.1	14.2	17.1
8.0 M	10.0	10.1	14.8	17.2
9.0 M	10.0	10.0	15.0	17.3
10.0 M	10.0	10.0	15.1	17.8

SECOND VISIT

	TEMP (C)		SAL (0/00)	
	31252C	31252	31252C	31252
DATE	08/15/90	08/13/90	08/15/90	08/13/90
DEPTH				
0.2 M	12.0	12.0	26.7	21.0
1.0 M	12.0	10.1	27.0	22.9
2.0 M	11.2	10.1	27.7	23.0
3.0 M	11.0	9.9	27.0	23.1
4.0 M	11.0	9.8	28.2	23.2
5.0 M	10.9	9.4	28.3	23.3
6.0 M	10.7	9.1	28.2	23.4
7.0 M	10.8	9.0	28.1	23.6
8.0 M	9.8	9.0	28.6	23.6
9.0 M	9.8	8.8	28.9	23.8
10.0 M	9.2	8.8	28.9	23.9

	TEMP (C)		SAL (0/00)	
	-	31248	-	31248
DATE		06/22/90		06/22/90
DEPTH				
0.2 M		10.8		14.8
1.0 M		11.0		14.8
2.0 M		10.8		16.0
3.0 M		10.4		16.0
4.0 M		10.1		16.3
5.0 M		10.1		16.9
6.0 M		10.1		16.9
7.0 M		10.1		17.0
8.0 M		10.1		17.0
9.0 M		10.0		17.1
10.0 M		10.0		17.0

	TEMP (C)		SAL (0/00)	
	-	31248	-	31248
DATE		08/13/90		08/13/90
DEPTH				
0.2 M		11.1		23.9
1.0 M		10.2		25.9
2.0 M		9.2		26.9
3.0 M		9.0		26.9
4.0 M		8.9		26.1
5.0 M		8.8		27.2
6.0 M		8.8		27.1
7.0 M		8.3		27.1
8.0 M		8.1		27.2
9.0 M		8.1		27.1
10.0 M		8.0		27.1

	TEMP (C)		SAL (0/00)	
	30196C	30196	30196C	30196
DATE	06/20/90	06/20/90	06/20/90	06/20/90
DEPTH				
0.2 M	7.5	7.5	22.0	17.5
1.0 M	7.5	7.5	22.0	16.5
2.0 M	7.5	7.5	21.0	16.0
3.0 M	7.5	7.5	20.0	16.0
4.0 M	7.5	7.0	19.0	16.0
5.0 M	7.0	7.0	19.0	16.0
6.0 M	7.0	7.0	18.5	16.0
7.0 M	7.0	7.0	19.5	16.2
8.0 M	7.0	7.0	18.0	16.5
9.0 M	7.0	7.0	18.0	16.5
10.0 M	7.0	7.0	17.5	16.5

	TEMP (C)		SAL (0/00)	
	30196C	30196	30196C	30196
DATE	08/20/90	08/20/90	08/20/90	08/20/90
DEPTH				
0.2 M	9.1	9.1	26.8	29.6
1.0 M	9.1	9.1	28.0	29.6
2.0 M	9.0	9.1	29.0	29.8
3.0 M	9.2	9.1	29.0	29.2
4.0 M	9.2	9.0	29.0	29.8
5.0 M	9.2	9.0	29.0	29.8
6.0 M	9.2	9.0	29.0	29.9
7.0 M	9.0	9.0	29.1	29.9
8.0 M	9.0	8.9	29.2	30.0
9.0 M	9.0	9.0	29.2	30.0
10.0 M	9.0	9.0	29.3	30.0

	TEMP (C)		SAL (0/00)	
	99826	33141	99826	33141
DATE	06/25/90	06/25/90	05/29/90	06/25/90
DEPTH				
0.2 M	11.0	10.0	18.3	19.2
1.0 M	10.2	10.0	19.8	20.2
2.0 M	NS	9.5	NS	20.2
3.0 M	NS	9.5	NS	20.5
4.0 M	NS	NS	NS	NS
5.0 M	NS	NS	NS	NS
6.0 M	NS	NS	NS	NS
7.0 M	NS	NS	NS	NS
8.0 M	NS	NS	NS	NS
9.0 M	NS	NS	NS	NS
10.0 M	NS	NS	NS	NS

	TEMP (C)		SAL (0/00)	
	99826	33141	99826	33141
DATE	08/08/90	-	08/08/90	-
DEPTH				
0.2 M	NS		NS	
1.0 M	NS		NS	
2.0 M	NS		NS	
3.0 M	NS		NS	
4.0 M	NS		NS	
5.0 M	NS		NS	
6.0 M	NS		NS	
7.0 M	NS		NS	
8.0 M	NS		NS	
9.0 M	NS		NS	
10.0 M	NS		NS	

Table 5.5.15. This table shows a summary of the variables analyzed for this report at paired sites 453/453C and 601/601C. Arrows indicate a greater or lesser than comparison of oiled sites to controls for each variable. Treatment codes: NT = no treatment; DR = debris removal; BR = bioremediation; HPHW = high pressure hot water ; MPHW = medium pressure hot water; HPCW = high pressure cold water; HS = high pressure steam; OB = omni boom.

VISIT	1ST		VISIT	2ND		VISIT	1ST		VISIT	2ND	
SITES	453	453C	SITES	453	453C	SITES	601	601C	SITES	601	601C
ASPECT	NORTH	NORTH	ASPECT	NORTH	NORTH	ASPECT	NORTH	SOUTH	ASPECT	NORTH	SOUTH
OILING	14	24	OILING	14	24	OILING	14	94	OILING	14	94
TREAT- MENT	BR, OB HS, HPH MPHW	DR, BR	TREAT- MENT	BR, OB HS, HPH MPHW	DR, BR	TREAT- MENT	HPCW HPHW BR, DR	NT	TREAT- MENT	HPCW HPHW BR, DR	NT
FERTILE FUCUS DENSITY			FERTILE FUCUS DENSITY			FERTILE FUCUS DENSITY			FERTILE FUCUS DENSITY		
1 MVD	<		1 MVD	<		1 MVD	<		1 MVD	<	
2 MVD	>		2 MVD	<		2 MVD	<		2 MVD	<	
3 MVD	>		3 MVD	>		3 MVD	<		3 MVD	>	
4 MVD			4 MVD	=		4 MVD			4 MVD	=	
FUCUS WET WEIGHT			FUCUS WET WEIGHT			FUCUS WET WEIGHT			FUCUS WET WEIGHT		
1 MVD	<		1 MVD			1 MVD	<		1 MVD		
2 MVD	<		2 MVD			2 MVD	<		2 MVD		
3 MVD	<		3 MVD			3 MVD	>		3 MVD		
FUCUS LENGTH			FUCUS LENGTH			FUCUS LENGTH			FUCUS LENGTH		
1 MVD	>		1 MVD			1 MVD	<		1 MVD		
2 MVD	>		2 MVD			2 MVD	<		2 MVD		
3 MVD	>		3 MVD			3 MVD	<		3 MVD		
NUMBER OF FUCUS PLANTS			NUMBER OF FUCUS PLANTS			NUMBER OF FUCUS PLANTS			NUMBER OF FUCUS PLANTS		
1 MVD	<		1 MVD			1 MVD	<		1 MVD		
2 MVD	<		2 MVD			2 MVD	<		2 MVD		
3 MVD	<		3 MVD			3 MVD	>		3 MVD		
NUMBER OF RECEPTACLES			NUMBER OF RECEPTACLES			NUMBER OF RECEPTACLES			NUMBER OF RECEPTACLES		
1 MVD	<		1 MVD			1 MVD	<		1 MVD		
2 MVD	<		2 MVD			2 MVD	<		2 MVD		
3 MVD	<		3 MVD			3 MVD	>		3 MVD		

intertidal areas. Paired sites 453 and 453C may show effects of oiling or treatment. The major effect was the lack of reproductive ability of the *Fucus* in the oiled site, 453. There were very few small (newly recruited) plants. This absence of little plants caused the average plant length to be longer in the oiled site. However, the frequency distribution indicates that the control site (453C) had as many or more plants that were just as long as at the oiled site, but in addition had many more small plants. The number of plants was greater in the control as was the biomass because of this large number of small plants. There was more visible damage to the plants in the oiled site which may be responsible for the lower number of receptacles per quadrat. These results suggest the oil and/or treatment on the oiled site either inhibited the reproduction of the *Fucus* plants or caused small plants to be washed away while damaging the remaining large plants.

The results from paired sites 601 and 601C in PWS also indicate damage was done from the oiling in the upper intertidal zone. Most of the results can be explained by the decrease in the numbers of *Fucus* plants at the oiled site. There were some differences in the damage pattern when compared to sites 453/453C. Plant distributions were not different between the sites, and the *Fucus* plants were damaged at both the oiled and the control sites. These results can possibly be attributed to the different treatments given to the control sites. At this point no legitimate discussion would be appropriate without analyzing the other sheltered rocky paired sites.

The densities of fertile *Fucus* plants were higher at sites in the sheltered rocky habitats than sites in coarse textured or exposed rocky habitats. This can be attributed to physical perturbations in the coarse textured and exposed habitats. Although the variance in the data is large, oiling effects appear to cause the density of fertile *Fucus* plants to decrease.

The similar trend between the oiled and control sites show no effect of oiling on egg viability. It is unknown why the egg survival at Juneau is so much better than for the sites in PWS. Variances in all of these data are quite good. Data analysis will be continued on exposed rocky habitat paired sites. If this trend of no effect continues, further analysis will be discontinued.

Because of a late start setting out the settling plates, and the fact that the *Fucus* plants grow very slowly, all settling plates were left in the field and will be observed in the coming field season. Two paired sites in this report were pulled to observe a possible trend in densities over the summer. The contrary results between the two paired sites could be attributed to a combination of physical and biological parameters. No conclusions can be drawn from these preliminary results on the settling and growth of baby *Fucus* plants in oiled areas.

The clean up activities subsequent to the oil spill compound the analysis of all of the results. There was no consistent treatment of the sites, and often even the "control" sites received some degree of treatment (Table 5.5.15). Differences in treatments are undoubtedly responsible for some of the inconsistencies in the data reported here. It is unfortunate that there are not enough "set aside" sites with appropriate controls to allow for the separation of the oiling effects from the effects of the clean-up and treatment activities.

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5.6 ALGAL EXPERIMENTS - HERRING BAY

Summary

By examining *Fucus* plants at oiled and control sites within Herring Bay on Knight Island this study has shown that the intertidal dominant alga *Fucus gardneri* was severely affected by the oil spill and subsequent clean-up activities. A major finding was that the percent cover of *Fucus* was reduced by the oil spill. In response to this reduction, algae other than *Fucus* increased in abundance. Most of these other algae consisted of "weedy" annual species indicative of disturbed areas. The average size of *Fucus* plants in oiled areas tended to be smaller than the plants in control areas, suggesting a reduction of large plants at oiled sites. The number of reproductive *Fucus*, which are all at least 10 cm in length, was greatly reduced at oiled sites, and those plants which were still reproductive at oiled sites tended to have fewer receptacles per plant. Combined with the information on density of reproductive plants and the number of receptacles per plant, egg release data showed dramatic reductions in the number of eggs released per beach from local plants. Experiments inoculating control and oiled beaches indicate reduced recruitment in oiled areas relative to similarly inoculated control beaches. Transplanted newly settled *Fucus* plants, especially the larger plants, showed longer survival in oiled areas due to decreased herbivore pressure in oil impacted areas.

Introduction

The effect of oil spills on resident populations of intertidal organisms has been documented for various oil spills. Unfortunately, little is known about how an oil spill effects the reproductive output, settlement, recruitment, and subsequent growth rates of invertebrates and algae living in the intertidal zone. The goal of this project is to assess the effects of the *Exxon Valdez* oil spill on the resident population of *Fucus* as well as the reproductive output, recruitment, and growth of this dominant intertidal plant.

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Methods

Site Selection

All sites were located within Herring Bay on Knight Island in Prince William Sound, Alaska. To reduce the variability between control and oiled sites, each control site was paired with a similar oiled site. Each pair of sites had about the same vertical slope, orientation to the sun, exposure to waves, and substrate heterogeneity. The control sites were in the east arm of the bay while the oiled sites were in the west arm of the bay.

Fucus Population Dynamics

The population structure of *Fucus* was monitored in five pairs of control and oiled areas. The sites include 3 sheltered rocky and 2 coarse textured site pairs. Each site had 6 randomly placed quadrats (20x50 cm) in each of three tidal levels, giving a total of 18 quadrats per site.

The size-frequency distribution of *Fucus* was determined in each quadrat by measuring all visible *Fucus* plants to the nearest 0.5cm without removing the plants from the substrate. For each plant, one of six reproductive categories and the general condition of the plant were recorded. The density of dead *Fucus* stipes and holdfasts was also monitored. Finally, the number of receptacles on each reproductive plant was recorded once in the middle of summer. Percent cover of all organisms and oil was estimated by placing a systematic 50-point grid over the quadrat. All drift algae were removed before assessment of percent cover. These plots were monitored a total of six times at intervals of two weeks from mid June 1990 to mid September 1990.

Fucus Reproductive Potential and Egg Viability

This experiment assessed the relative fertility of *Fucus* in oiled and control sites by measuring the rate of egg release from randomly selected receptacles. In addition the viability of the released eggs was monitored. Plants for this study were collected from the same sites and plots as those used for the population dynamics study (see above). Plants were collected from search areas extending to either side of each quadrat. If no plants with receptacles were found, then this was recorded as such.

Fucus Field Inoculation

The effect of oiling on *Fucus* settlement and growth was investigated by inoculating oiled and unoiled areas by suspending ripe receptacles collected from Juneau above the inoculation area. This experiment was done in the presence and absence of limpets to assess the effect of these herbivores on recruitment and growth of *Fucus*. Steel fences secured to the rock with epoxy were used to manipulate the limpets. In addition, artificial tiles and tarred rocks were inoculated. This experiment was replicated four times at each of three control sites and their matched oiled sites. All *Fucus* germlings >1mm in length were counted and measured every two weeks throughout the summer.

Fucus Germling Growth

To test the relative growth rates of germlings in oiled and unoiled areas, rocks with small, newly settled *Fucus* plants were collected from an unoiled site and transplanted to both oiled and control sites. The number and length, to the nearest millimeter, of plants on each rock were monitored every two weeks after transplantation until 15 September 1990. This experiment was conducted at the site pairs used for the *Fucus* inoculation experiment. Four rocks were transplanted to each site.

Results

Population Dynamics

Fucus cover was lower at oiled sites at all meters of vertical drop on protected rocky shores (Figure 5.6.1). On coarse textured beaches there was very little *Fucus* in the first two meters of vertical fall. In the third meter of fall, *Fucus* cover was reduced in oiled areas (Figure 5.6.1). Along with this decrease in *Fucus* cover there was an

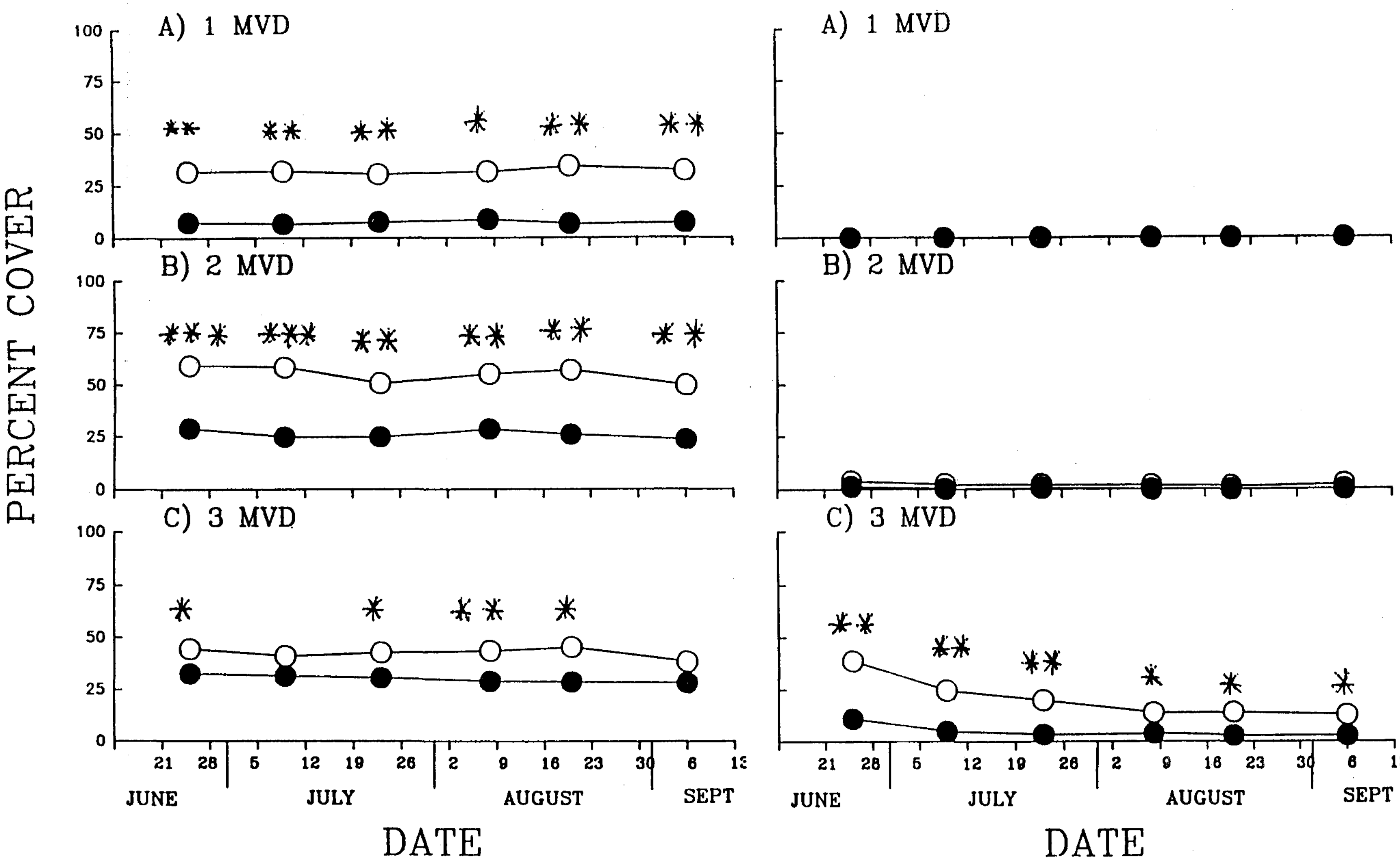

Figure 5.6.1. The percent cover of <u>Fucus</u> at oiled (filled circles) and control (open circles) sites in both protected rocky and coarse textured habitats and at all three meters of vertical drop (MVD). Each point is the mean of six replicates at two (coarse textured, right) or three (protected rocky, left) sites, giving a sample size of 12 or 18.
* = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$.

increase in the amount of algae other than *Fucus* on protected rocky shores (Figure 5.6.2). Most of these other species were short lived and fast growing annuals. There was not a similar increase in other algae on coarse textured beaches (Figure 5.6.2).

There was no difference in the density of *Fucus* plants between control and oiled beaches at both protected rocky and coarse textured beaches (Figure 5.6.3). The average size of *Fucus* plants was larger in control areas in the first and second MVD on protected rocky shores (Figure 5.6.4). The same trend can be observed on coarse textured beaches, but no significant differences were detected. This trend to smaller sizes suggests that oiled sites may be characterized by disproportionately large numbers of small plants and/or low numbers of large plants.

Reproductive plants are large (at least 10 cm in length) and are more abundant in control areas. The density of reproductive plants was greater at the control sites at the beginning of summer at all tidal heights on protected rocky beaches (Figure 5.6.5). In the second and third meters of vertical fall at protected rocky sites the density of reproductive plants at oiled and unoiled sites tended to converge later in the summer, due to the plants in the control areas losing their receptacles after releasing their propagules.

The reproductive *Fucus* plants living in oiled areas in protected rocky environments had fewer receptacles per plant (Figure 5.6.6). This difference was significant for plants at the 1 MVD only. There was too much variability in the plants at the 2 MVD to show significant results. There was little difference in the number of receptacles per plant at the 3 MVD.

After dying, a *Fucus* plant will often leave a dead holdfast or stipe. The number of stipes and holdfasts was generally observed to be greater at oiled sites than at control beaches (Figure 5.6.7). This difference is most noticeable in the first two meters of vertical fall on protected rocky shores and in the third MVD at the coarse textured beaches. This results are indicative that there used to be more large, live plants living in the oiled sites in the recent past (within two years).

Tar covered up to 30 percent of the rocky surface at oiled sites and was not seen in the sampling areas at control sites (Figure 5.6.8). On rocky coasts, tar was much more abundant in the first meter of fall, while at coarse textured sites tar was observed most frequently in the first two meters of vertical fall. This distribution of tar

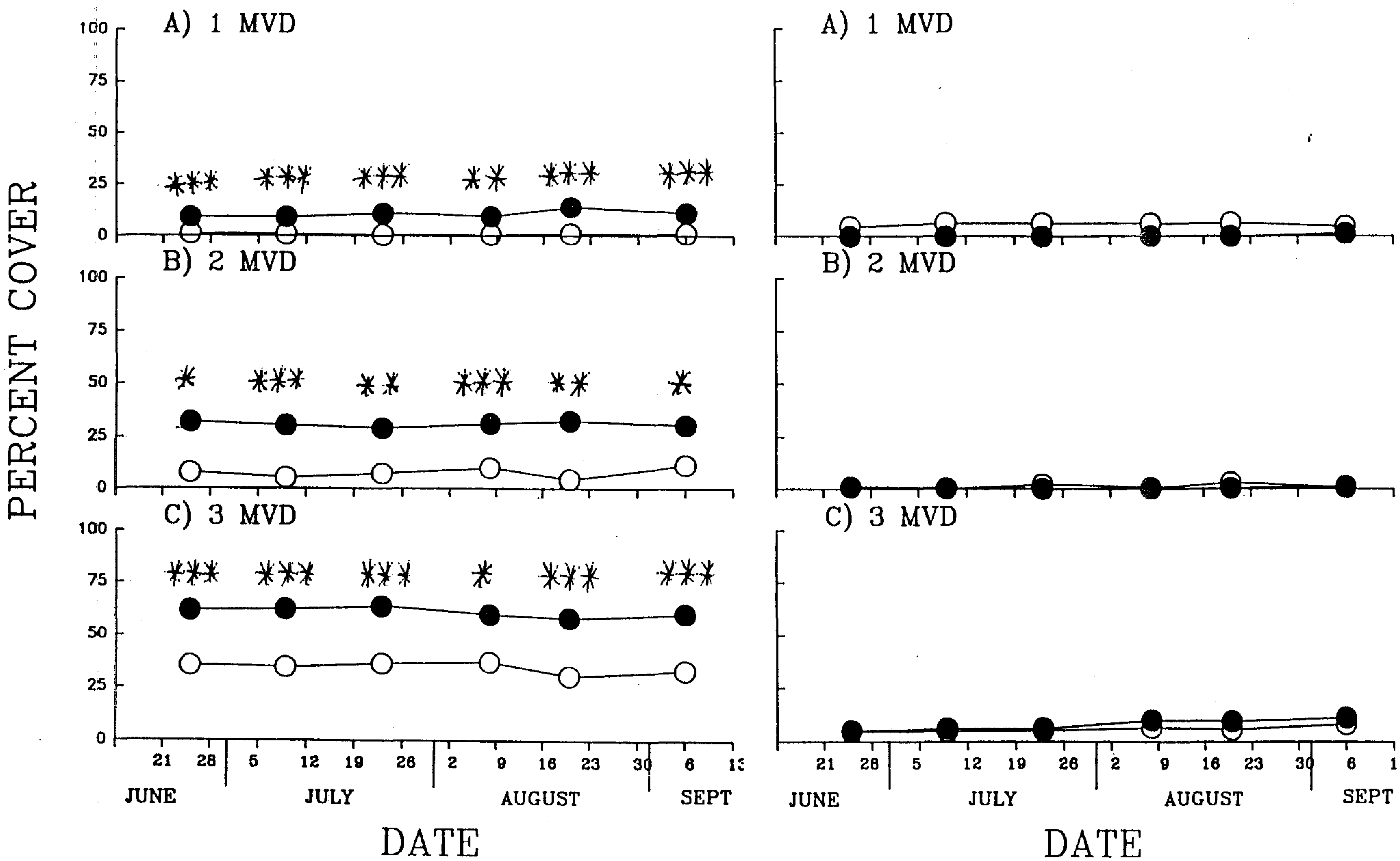

Figure 5.6.2. The percent cover of algae other than Fucus at oiled and control sites. Symbols, legends, and replication are the same as in Figure 6.3.1.

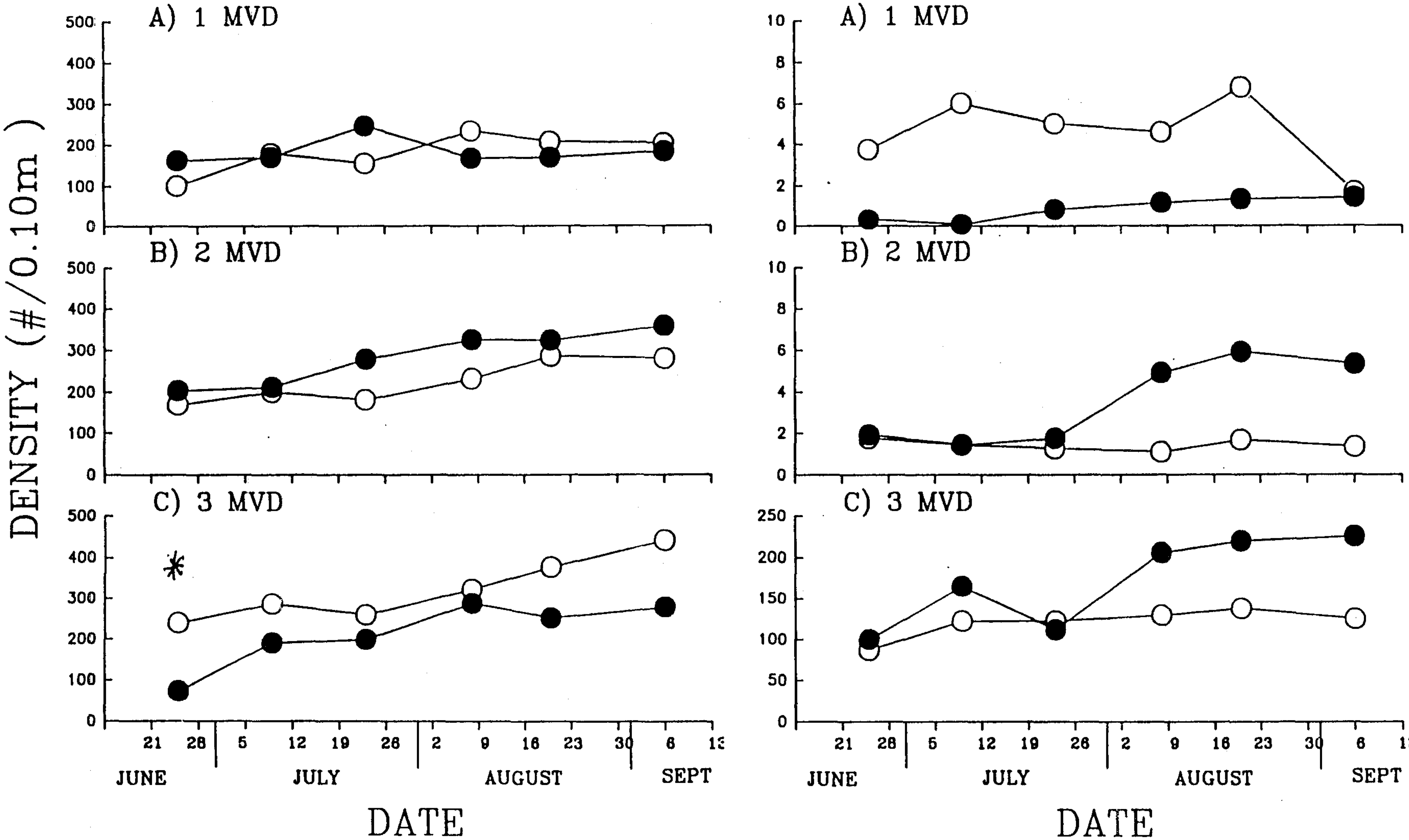

Figure 5.6.3. The number of living Fucus plants at oiled and control sites. Symbols, legends, and replication are the same as in Figure 6.3.1.

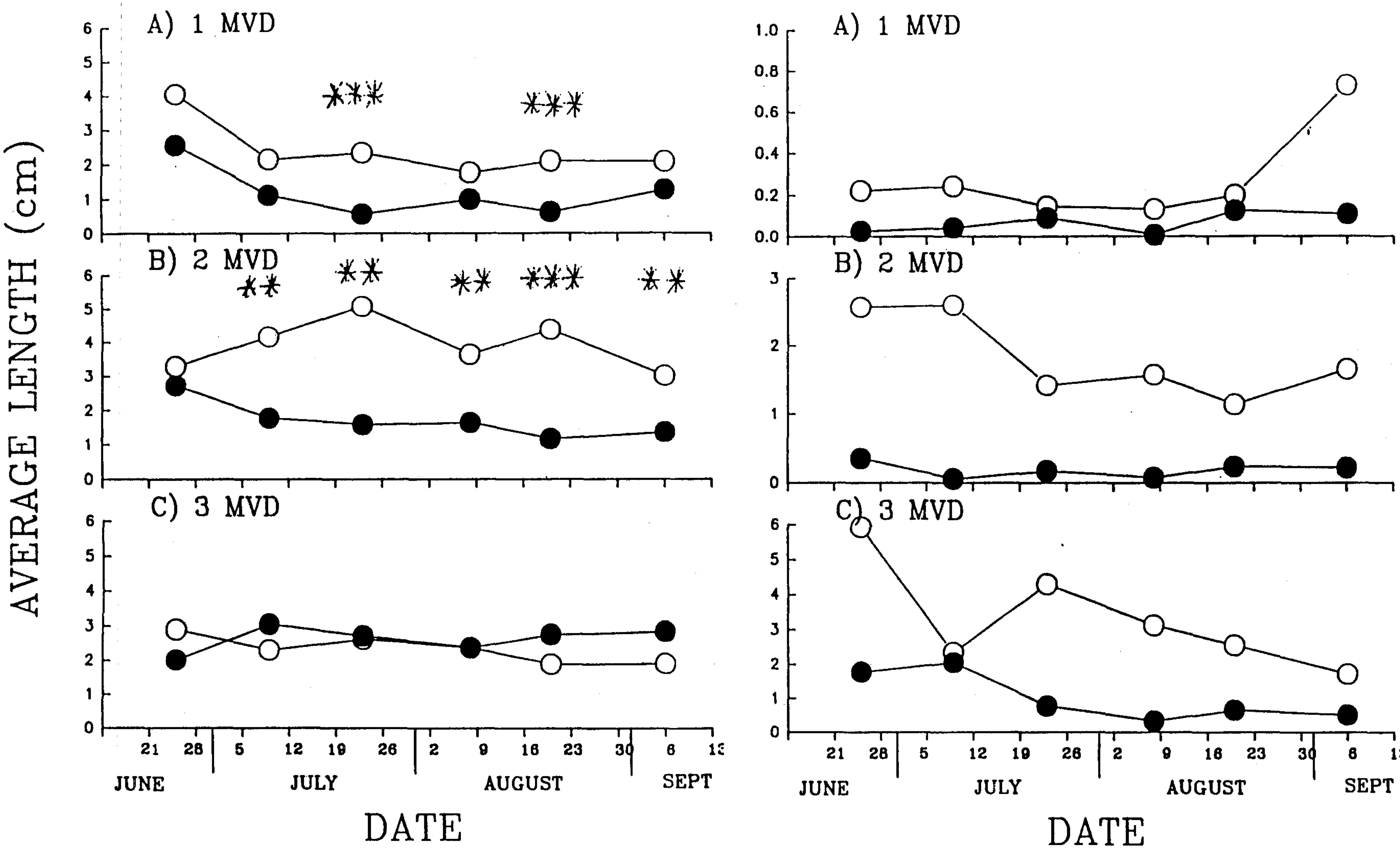

Figure 5.6.4. The average size of living Fucus plants at oiled and control sites. Symbols, legends, and replication are the same as in Figure 6.3.1.

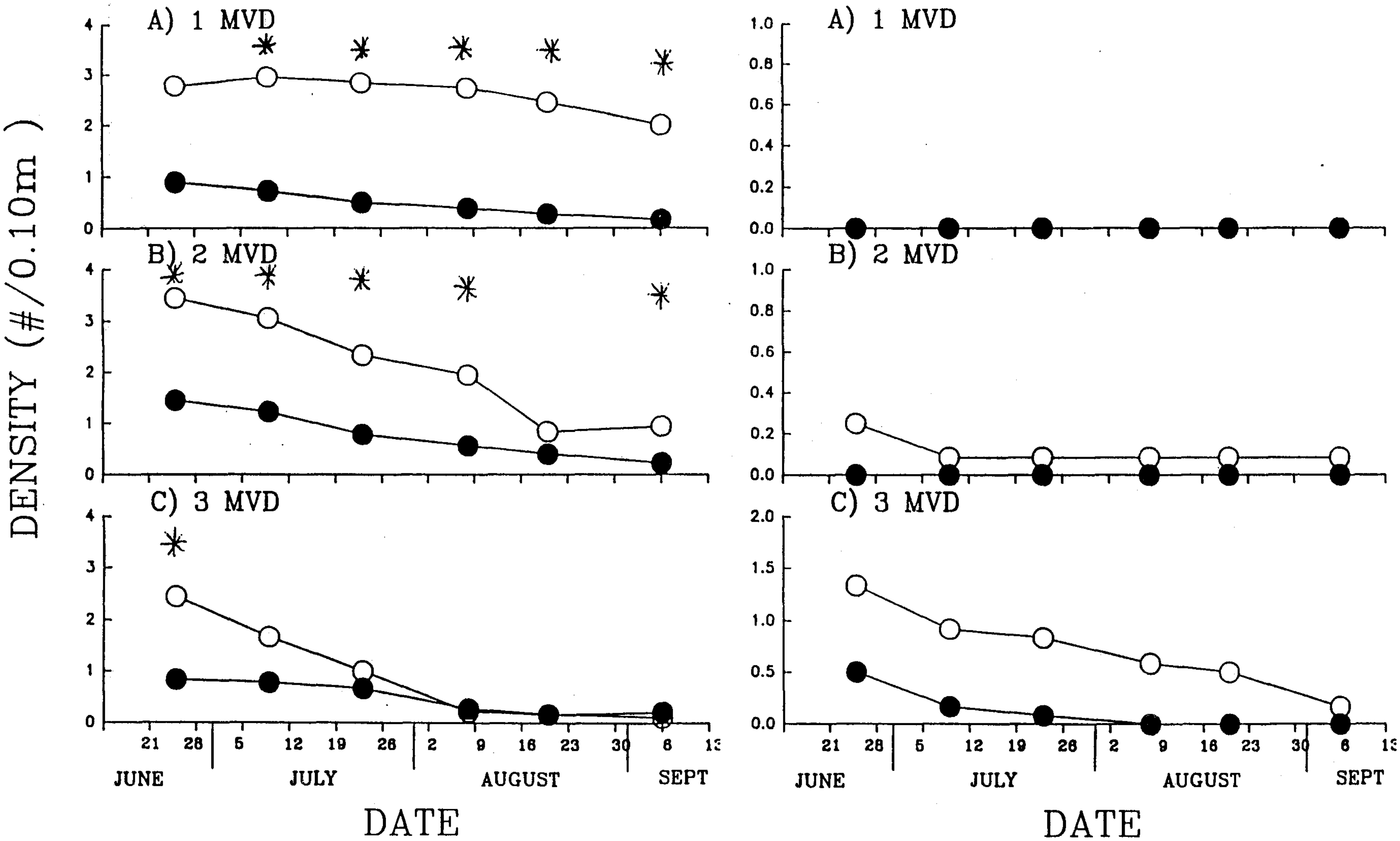

Figure 5.6.5. The number of reproductive Fucus plants at oiled and control sites. Symbols, legends, and replication are the same as in Figure 6.3.1.

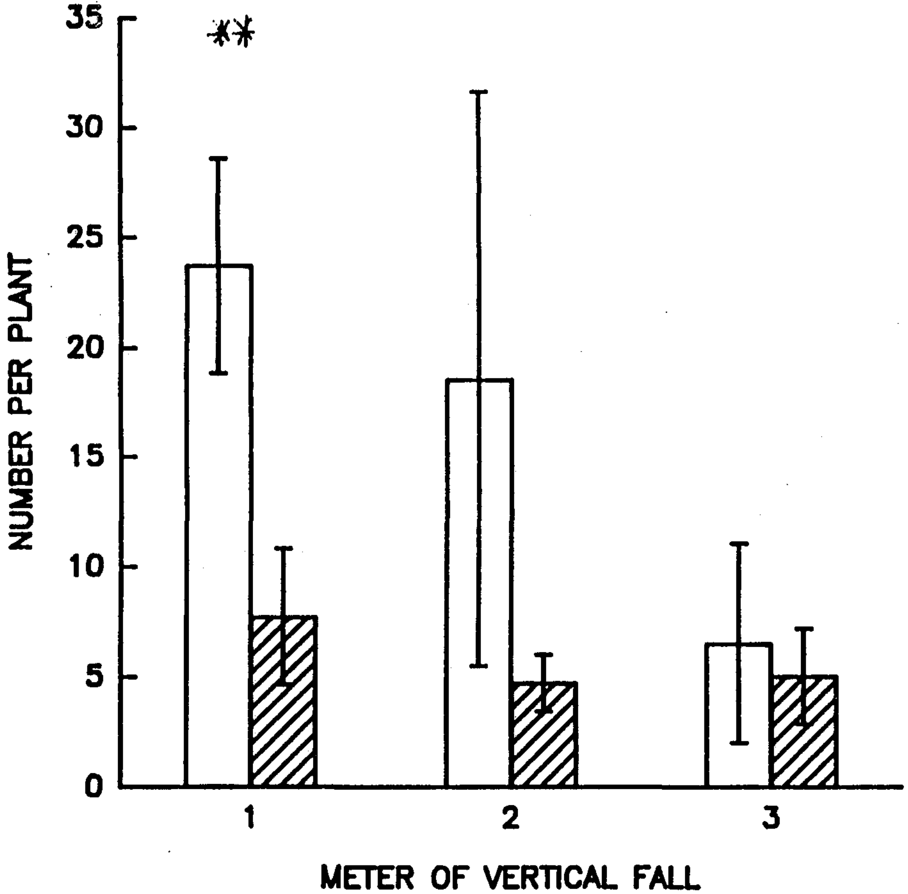

Figure 5.6.6. The average number of receptacles per reproductive plant at protected rocky beaches in control (open) and oiled (hatched) areas at all three tidal levels. The error bars represent one standard error.

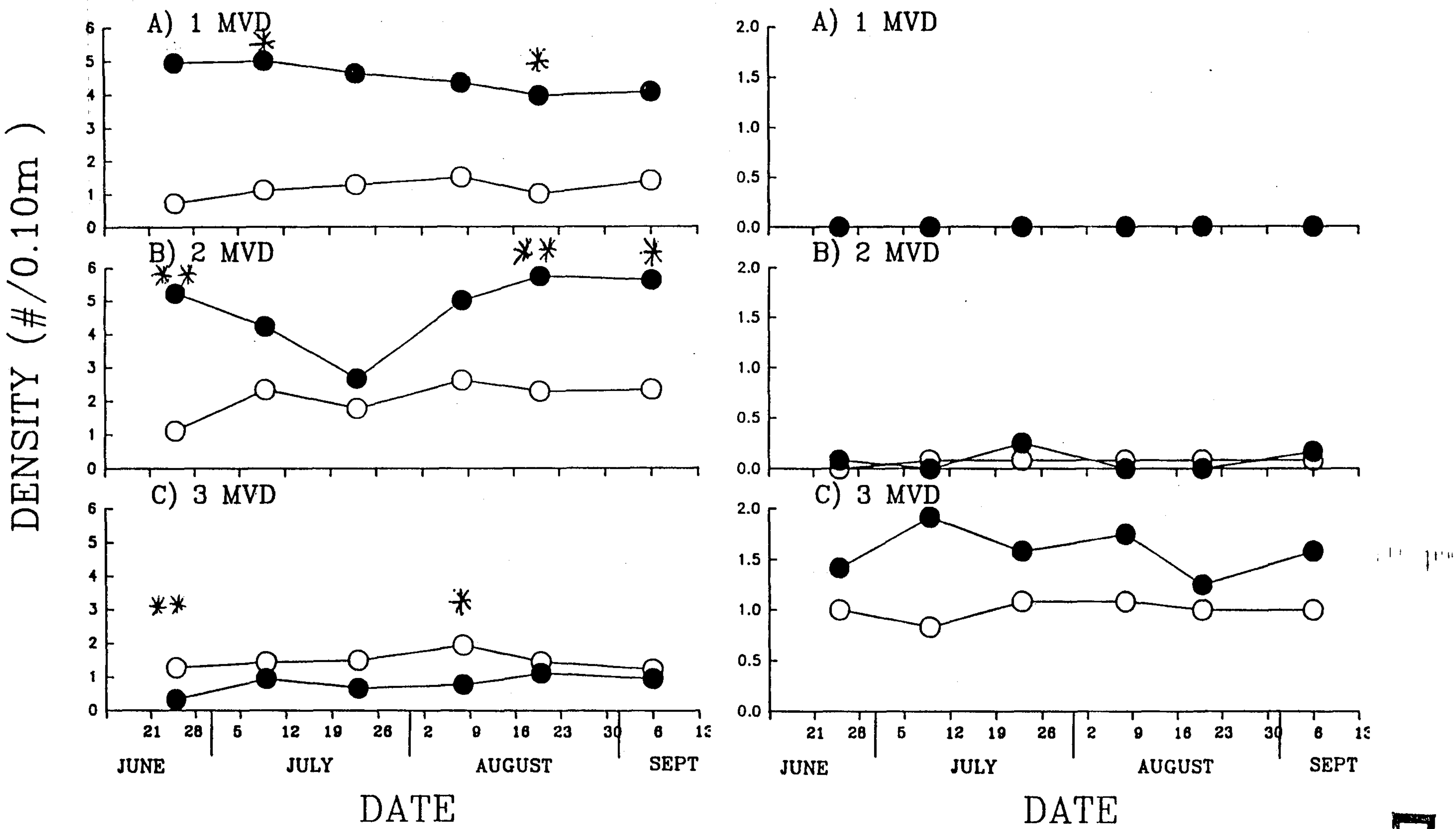

Figure 5.6.7. The number of dead *Fucus* stipes and holdfasts at oiled and control sites. Symbols, legends, and replication are the same as in Figure 6.3.1.

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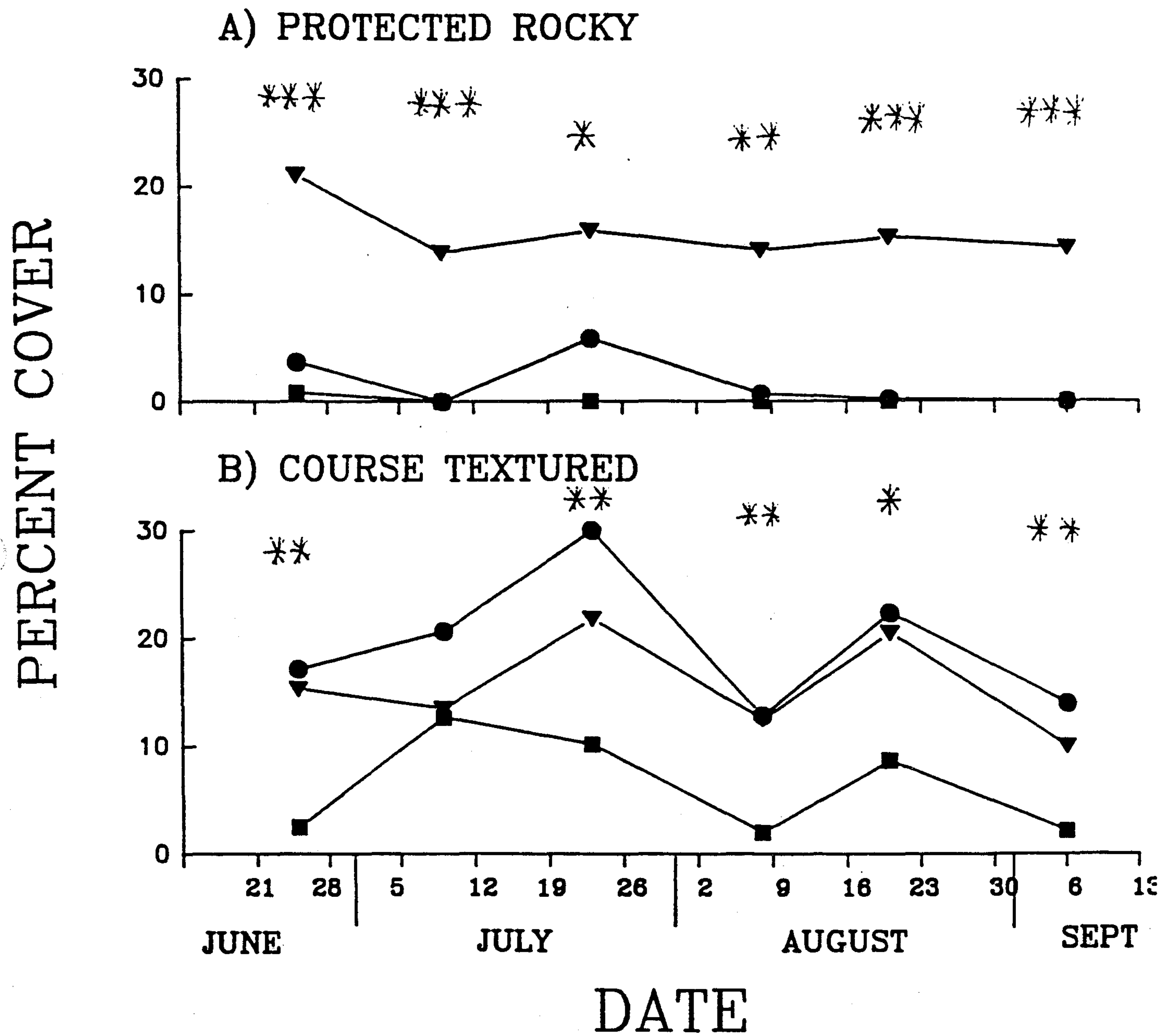

Figure 5.6.8. The percent cover of oil (tar spots) at protected rocky and coarse textured, oiled beaches in the first (triangles), second (circles), and third (squares) meters of vertical drop through the summer. Replication is the same as in Figure 6.3.1.

indicates that certain effects of the oil spill were concentrated in the upper intertidal at both rocky and coarse textured sites in Herring Bay.

Egg Release Experiment

At all times and tidal heights more fertile plants were collected from control sites than oiled sites for this experiment (Figure 5.6.9). The difference was only significant during the second sampling period at the 1 and 3 MVD's. These data are further evidence that the number of reproductive plants was reduced in oiled areas relative to control sites. This is an underestimate of the number of reproductive plants at a site, since it is possible to have more than one plant in a search. The numbers here are just the number of areas in which reproductive plants were found and are not an estimate of density.

The number of eggs released from the collected receptacles was highly variable. Due to this high variability only one data set had a detectable significant difference between oiled and control sites (Figure 5.6.10). There was no consistent trend in the egg release rate at oiled and control sites.

When combined with the data taken on the number of receptacles per plot, the egg release data was used to estimate the relative number of eggs released onto a beach by resident plants. The estimated density of released eggs was greater in control areas than in oiled areas (Table 5.6.1), but due to the low sample size (N=3) no significant differences were detected. The difference in eggs released per beach is greater in the upper intertidal at rocky beaches. At coarse textured sites because there were no reproductive plants in the first two meters of vertical fall, differences could only be detected in the third meter of fall.

Inoculation and Growth Experiments

The herbivore treatments were effective at keeping limpet densities higher in fences designated as limpet fences (Figure 5.6.11). At the end of each week there were about five limpets per fence on the average. This is slightly lower than the expected average natural density of limpets for the area of seven per fence. In the limpet

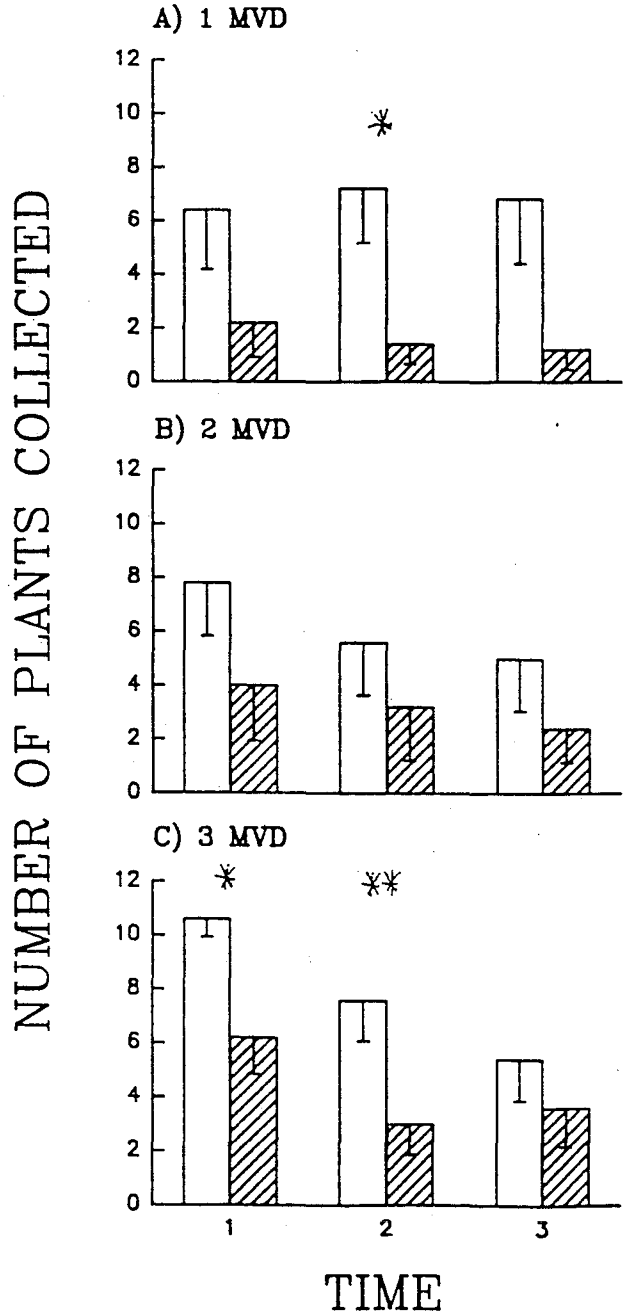

Figure 5.6.9. The number of reproductive plants collected for the egg release experiments at the beginning (Time 1), middle (Time 2), and end (Time 3) ofsummer at all three meters of vertical drop at oiled (hatched) and control (clear) sites. There was a maximum of 12 plants per site and tidal level. Each bar represents the five control or oiled beaches. There were no tar spots at oiled sites.

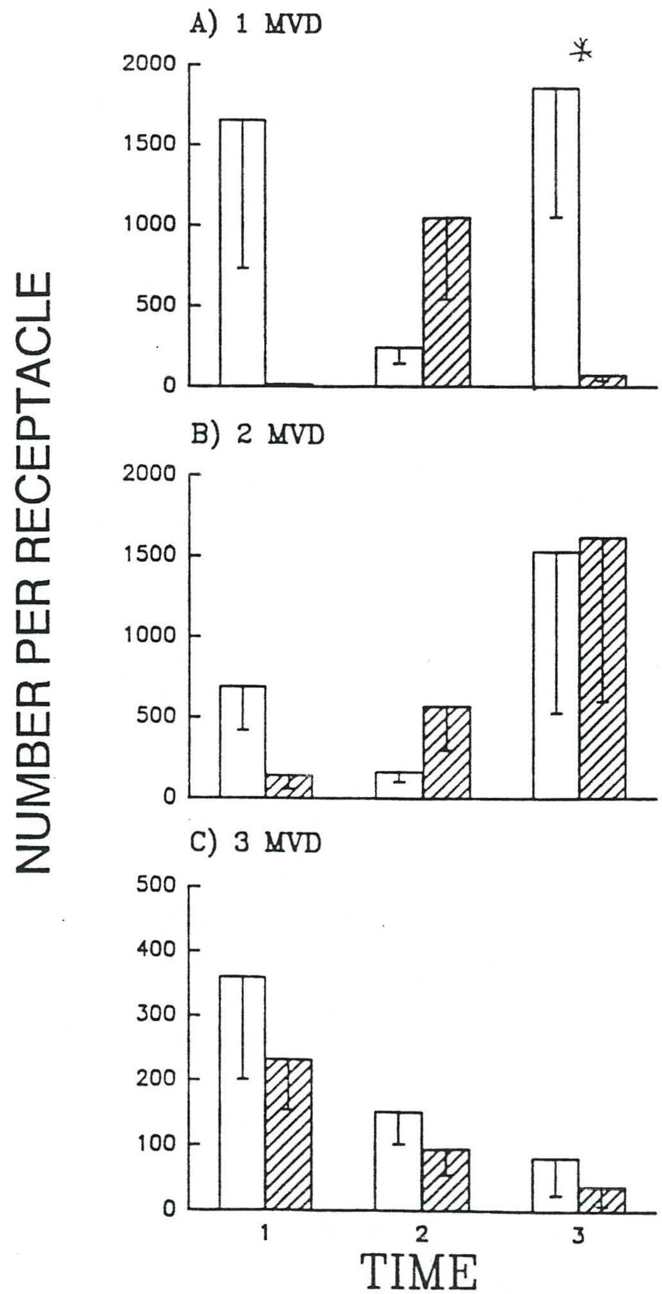

Figure 5.6.10. The number of eggs released per receptacle over a 48 hour period from oiled and control sites at all three meters of vertical drop. Symbols and legends are the same as in Figure 6.3.9.

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Table 5.6.1. The calculated number of eggs released per tenth meter square of protected rocky and coarse textured beach at all three meters of vertical drop in oiled and control areas.

	PROTECTED ROCKY				COARSE TEXTURED			
MVD	CONTROL	SE	OILED	SE	CONTROL	SE	OILED	SE
1	11541	(4752)	3304	(2169)	0	(0)	0	(0)
2	3231	(1472)	1535	(829)	0	(0)	0	(0)
3	267	(267)	85	(64)	461	(402)	0	(0)

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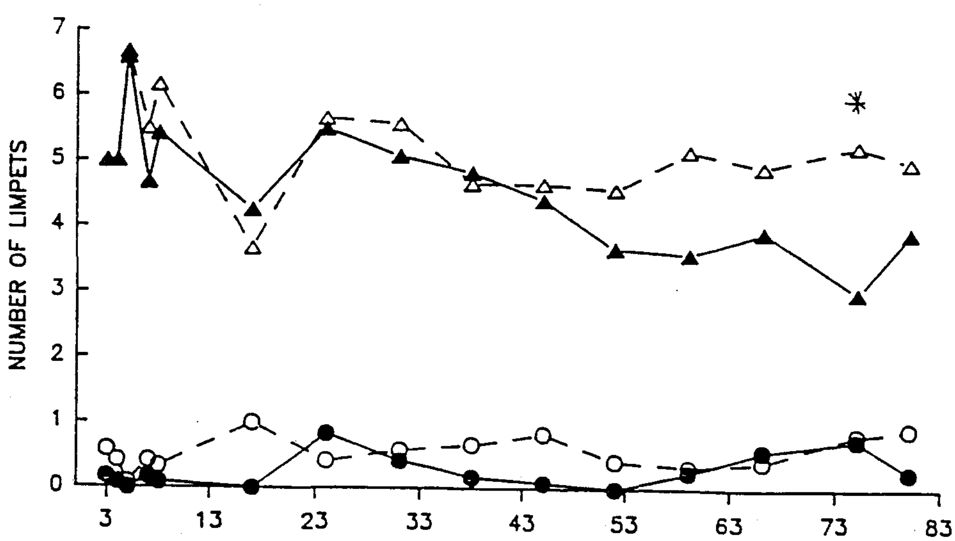

Figure 5.6.11. The number of limpets remaining in the limpet fences since replenishment on the previous sampling date. Triangles represent plus limpet fences and circles represent minus limpet fences. Filled symbols represent fences in oiled areas and open symbols represent fences in control areas. Each point is the mean of 12 fences. The starting date was 24 June 1990.

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removal fences there never more than an average of one limpet per cage after each weekly census.

The number of newly settled germlings on the bare rock surface under the inoculation bags was higher, but not statistically significant, at control sites than at oiled sites (Figure 5.6.12). Oiling had no observable effect on the growth of recruited germlings. There was no difference in the average size of germlings in control and oiled areas. The presence or absence of limpets made no difference in the number of recruited *Fucus* germlings. The presence of limpets seemed to retard the growth rate of *Fucus* germlings, since the average size of germlings tended to be greater where limpets were removed (Figure 5.6.12).

The germling growth experiment using transplanted natural germlings suffered heavy losses of plants. Germlings survived longer in oiled areas than in control areas (Figure 5.6.13). They also tended to be larger in oiled areas, but average size of plants in both areas decreased, indicating little or no growth of most plants and better survival of larger plants in oiled areas.

Discussion

The effects of the *Exxon Valdez* oil spill and subsequent clean-up efforts not only had direct effects on the abundance of *Fucus* in Herring Bay, but also had indirect effects by reducing the number of eggs released at a beach, causing a reduction in the recruitment of *Fucus* germlings into oiled areas, and possible alteration of their subsequent growth and survival.

A decrease in the dominant species of an area is indicative of some type of serious disturbance. In this study, *Fucus* was observed to have lower abundances at oiled sites. Other "weedy" algal species were observed to have increased their abundances at these oiled sites. An abundance of "weedy" annual species is typical of disturbed sites where the competitive dominant species has been removed. In this case, *Fucus* was the competitive dominant, and the disturbance was the oil spill and subsequent clean-up efforts.

In addition to the decrease in percent cover of *Fucus*, there were differences in the population and size structure of *Fucus* at oiled and control sites that are indicative of

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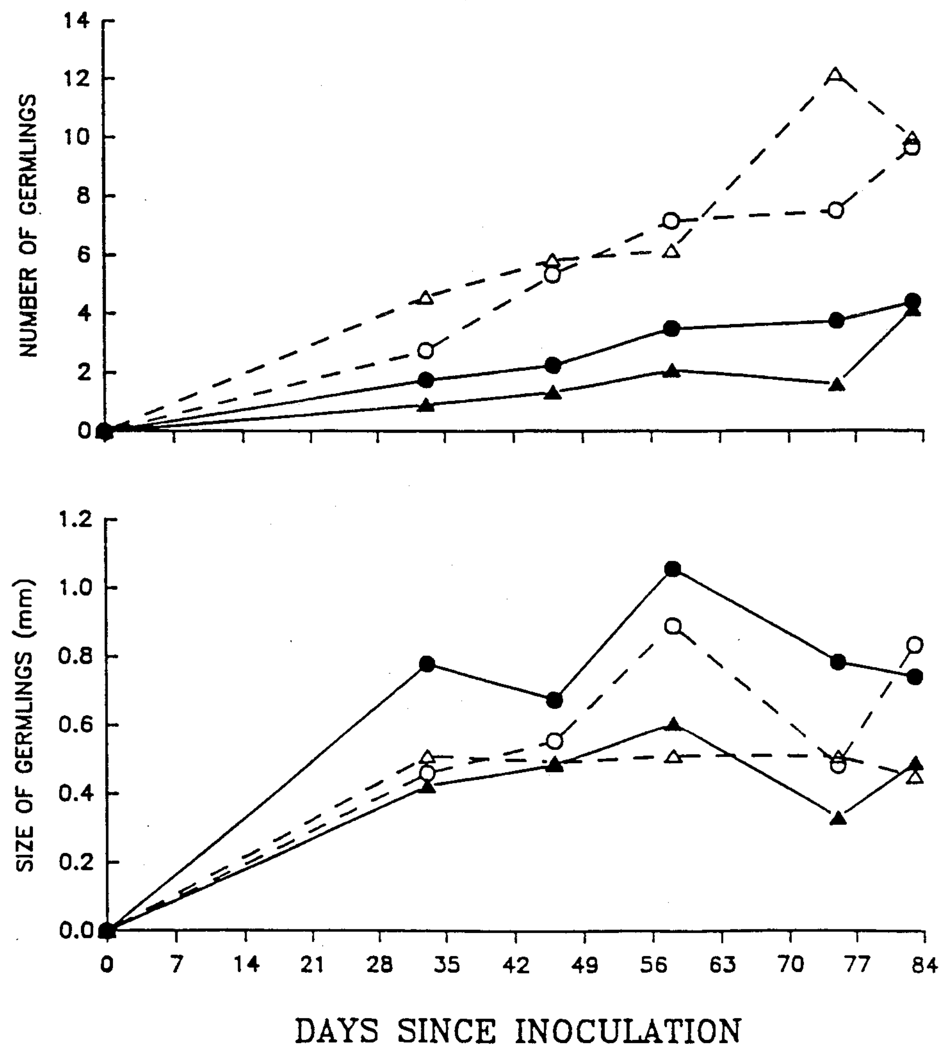

Figure 5.6.12. The number and average size of germlings in the inoculation experiment. Symbols, legends, and replication is the same as in Figure 6.3.11. The inoculation date was 23 June 1990.

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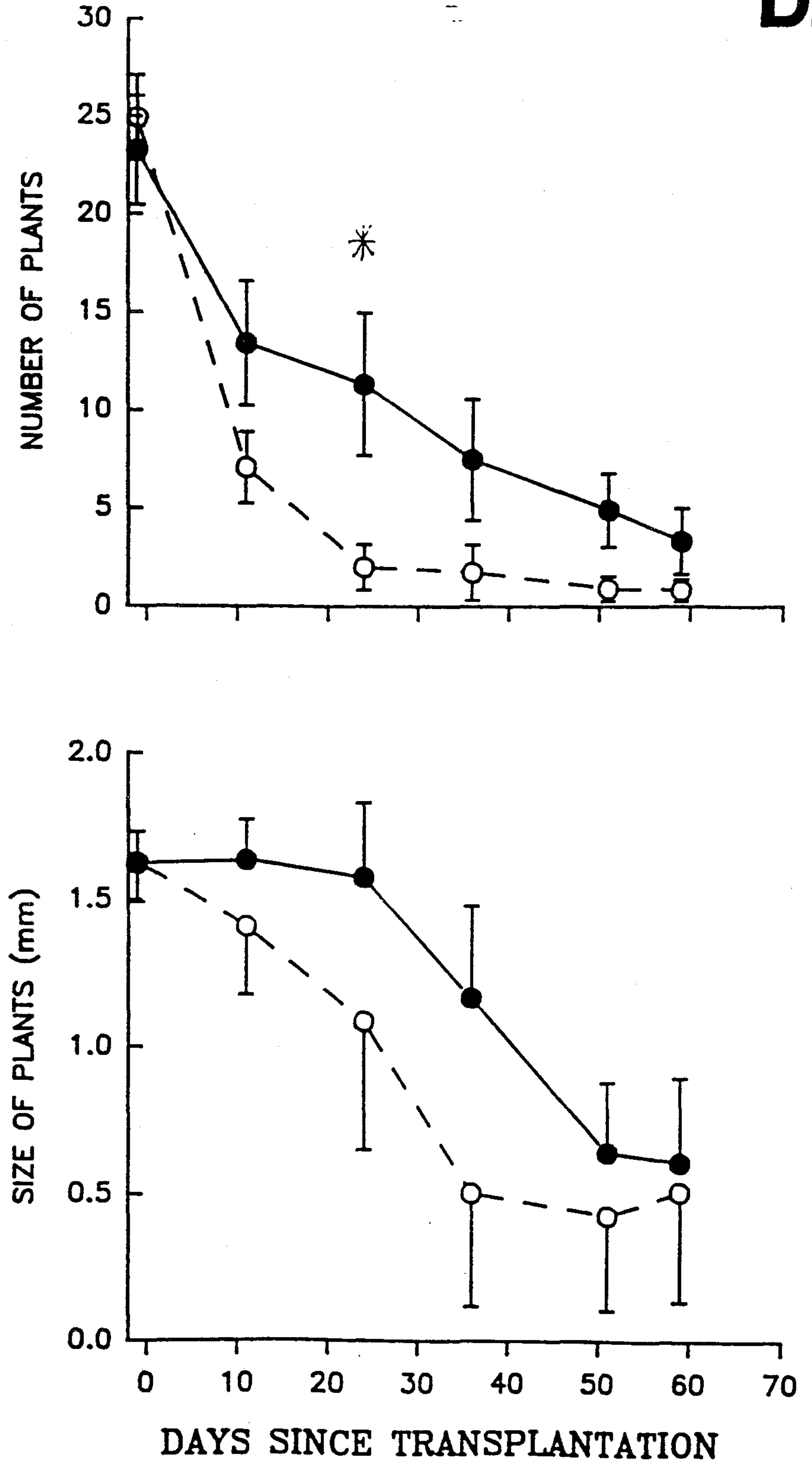

Figure 5.6.13. The number and average size of the transplanted *Fucus* germlings at oiled (filled circles) and control (open circles) sites. Each point is the mean of 12 transplanted rocks and the error bars represent one standard error of the mean. The transplantation date was 19 July 1990.

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a large scale disturbance. At oiled sites the plants were smaller, there were fewer reproductive plants, and there were more dead *Fucus* stipes and holdfasts. These results indicate that many of the large and reproductive *Fucus* plants were removed by some sort of disturbance. This reduction of large plants was probably what led to the observed reduction of percent cover of *Fucus* discussed above.

The effects of removing the *Fucus* canopy extend beyond the current population of *Fucus*. The reduction in the number of reproductive plants and the number of receptacles per plant were the primary determinants of the observed decrease in the egg release rate per unit area of beach. This reduction limits the number of eggs and embryos produced from local plants. Once an egg or embryo reaches a beach, its chances of recruiting to the present population of *Fucus* may be reduced in oiled areas (Figure 5.6.12), due to residual toxic effects from the oil.

After successful recruitment of the embryonic *Fucus* plants into the juvenile plant population, *Fucus* germlings may experience less mortality and higher growth rates at oiled sites due to the fewer numbers of limpet and herbivorous littorine snails at these sites. Much of the mortality of transplanted *Fucus* germlings at the control sites was probably caused by the more intense grazing pressure there. Herbivores were often observed to be eating the transplanted germlings at the control sites. At the oiled sites, mortality was probably due to desiccation and heating caused by increased exposure to solar radiation, due to the lack of a *Fucus* overstory.

The results discussed above are likely to have been caused by the *Exxon Valdez* oil spill. There are two main reasons for this assertion. First, the results are consistent over all sites even though the site pairs were selected to be as different as possible, ranging from gently sloping coarse textured beaches to vertical rock faces. This indicates that the patterns observed here were widespread occurrences. There are few, if any, natural disturbances which would produce such patterns over such widespread areas. The size structure and population dynamics of *Fucus* in oiled areas is indicative of a major disturbance. Disturbed sites are usually characterized by smaller plants and fewer reproductive plants. The presence of stipes and holdfasts from dead *Fucus* plants shows that many large *Fucus* plants were recently killed at the oiled sites. Secondly, the effects demonstrated here were observed or most dramatic in the upper intertidal where oiling and clean-up activities were concentrated.

Although this study has shown injury done to the *Fucus* populations of Herring Bay, there are many aspects of the data which need to be investigated further. For example, the effect of the oil spill on the diversity of organisms in the permanent plots should be calculated and examined. Also, much of the data violates the assumptions of ANOVA. No attempt has yet been made to transform the data to satisfy these assumptions. Most of the conclusions drawn by this report will not be altered by these transformations. Transforming the data will typically result in more significant effects so the conclusions outlined here are probably conservative; there are actually more significant effects than were presented here.

Due to the mortality of the transplanted germlings no information was gathered concerning growth rates of individual plants in oiled and unoiled sites. This information is essential to estimate the recovery time of *Fucus* in areas impacted by the oil spill and subsequent clean-up activities. One way of getting this information is to mark individual plants in oiled and control areas. By doing this, growth rates of both small and large plants can be assessed. For reproductive plants, the number of receptacles can be monitored to see if this variable increases over time at oiled areas. Also, revisitation to the permanent marked plots will allow evaluation of recovery rates of *Fucus* beds. By following the development of the *Fucus* bed and its associated community, recovery rates could be assessed.

To hasten recovery of areas which originally had *Fucus* but are now denuded of *Fucus*, it may be necessary to attempt restoration of this community. Studies evaluating the potential and feasibility of large scale restoration need to be conducted. The first thing which needs to be assessed here is the time frame in which young *Fucus* plants are likely to survive. From the results of the germling transplantation experiment performed here, it is clear that *Fucus* germlings are unlikely to survive in the summer time. *Fucus* germlings of various sizes need to transplanted into the field at various times of the year. Also, methods of seeding large areas of substrata with *Fucus* eggs need to be tested.

6.0 SUBTIDAL

Summary

The effects of oil on subtidal habitats in Prince William Sound is being assessed through comparisons of pairs of oiled and control study sites in five habitat types: silled fjords, eelgrass areas, *Laminaria/Agarum* bays, *Laminaria/Agarum* points, and *Nereocystis* areas. Silled fjords were sampled three times to date: Fall 1989, Spring and Fall 1990. Remaining habitats were sampled in Spring 1990 only. This report provides preliminary results from the first three of these habitats in 1990. Results for the silled fjords are based on samples collected in the Fall 1989 and Spring 1990.

In Fall 1989, numerous dead organisms, including highly mobile forms such as squid and fishes, were observed at depths >13 m in an oiled silled fjord (Herring Bay). In Spring 1990 this site was revisited, as were three other similar habitats. Few dead organisms were observed in the Spring survey, suggesting that the mortalities observed in 1989 could have been oil-related or oxygen-related. Examination of the 1990 samples revealed greater disturbance than observed in 1989. Low values for diversity, richness, evenness and biomass, with a corresponding high dominance value reflected gross disturbance. A more extensive survey of silled fjord habitats was completed in Fall 1990, and will provide additional data to assess the possible role of seasonal anoxia as a cause of disturbance. Therefore, until we obtain and integrate results of oxygen data and hydrocarbon analysis, we are unable to determine the exact sources of disturbance.

In eelgrass habitats, there was a consistent trend to lower density of eelgrass at oiled sites, although individual paired comparisons were not significant. There also was a similar, but weaker, trend to lower density of flowering turions and spathes at oiled sites. Among large epibenthic invertebrates, there were no patterns associated with oiled sites, with the exception of the crab *Telmessus*, which showed depressed densities. No data on infauna are yet available. Fishes tended to be less abundant at the control sites. This difference was due almost entirely to a non-significant, but persistent, trend to higher densities of young-of-the-year Pacific cod at oiled eelgrass sites. Densities of other fishes were similar between oiled and control paired sites.

In *Laminaria/Agarum* bay habitats, there was little difference in density or percent cover of algae, including the dominant *Agarum* and *Laminaria* species. Large

epibenthic invertebrates were also similar between oiled and control paired sites; however, the crab *Telmessus* again displayed a consistent trend to lower density in oiled sites. No data on infauna are yet available. Fishes tended to occur at higher density at oiled sites. In the deep stratum (9-20 m) the trend was due principally to a group of small sculpin species; whereas in the shallow stratum, the pattern was due to significantly higher densities of arctic shanny at two or three oil/control site pairs.

Objectives

The proposed study plan for subtidal habitats in 1990 was aimed at demonstrating effects of the *Exxon Valdez* oil spill, and secondarily on the extrapolation of effects at specific sites to the entire area affected by oil.

Introduction

The subtidal coastal habitat program was initiated in late summer 1989. Shortly after approval of the project by the Management Team, logistic arrangements were made and a shakedown and training cruise was conducted. An initial subtidal survey was conducted in Prince William Sound in October, 1989. Effects on fish, invertebrates, and plants were evaluated in sheltered rocky habitats, at 5 sites (a subset of those visited by the intertidal sampling team).

The October sampling program revealed apparent effects of the spill at one of the three oiled sites visited. A large "Dead Zone" was observed at one sampling site within Herring Bay, in a shallow (47 m depth) silled fjord. A large number of dead and deformed animals were observed, including some highly motile forms such a squid and flatfish.

The fall 1989 sampling program also indicated that, in general, the sampling design and site selection process used in the initial surveys may not be adequate to detect statistically significant effects on subtidal organisms. A major problem was the variance among sites, especially as related to fresh water input at sites (all controls) on the mainland portion of the Sound. As a result, changes were made to the study plan for 1990. We concentrated our sampling and experimental efforts on selected habitat types, chosen based on the relative ecological importance of these habitats, their risk to damage from oil, and on their proportion of total habitat in the oiled area. All studies were conducted at oiled sites (selected at random when possible) and control sites that are matched to the oiled sites with regard to geomorphology, degree of freshwater input, substrate type, and general circulation and wave exposure regimes. Experimental studies focused on the effects of the spill on sublethal impacts. These included reproductive potential and viability of offspring for selected invertebrate and algal species, and on the effects of oiling on recruitment.

All studies were conducted within Prince William Sound. We excluded other areas (Kenai and Kodiak regions) because we anticipated that effects were greatest within PWS and because of the logistical and monetary constraints of sampling in those other regions.

This is a preliminary report which presents results from only a small portion of the subtidal data collected in 1990. Samples taken are still being processed and data analyzed. We will focus our attention on infaunal and epifaunal invertebrate data collected from silled fjords in Fall 1989 and Spring 1990, and on plant, epibenthic invertebrate, and fish data from eelgrass and *Laminaria*/*Agarum* habitats in island bays.

Methods

Only a small fraction of the data gathered in 1990 have been analyzed for this report. The following description focuses on the methods used in obtaining and analyzing the data presented here. A full description of methods used for other parts of our study that are not reported on can be found in Appendix IV.

Study Sites

In 1990 subtidal sampling was un-coupled from the intertidal study, due to fundamental differences in stratification criteria for the two tidal zones. The subtidal zone was stratified into silled fjords, and four other habitats defined by dominant macrophytes and exposure to wave action: 1) *Nereocystis*, 2) eelgrass,

3) *Laminaria/Agarum* in bays and 4) *Laminaria/Agarum* on points. The study site names, numeric codes and locations are listed in Table 6.1. The locations are indicated in Figure 6.1.

Sampling in Silled Fjords

In October 1989 sampling, one of our sites was within a silled fjord that was heavily oiled. There, we noted that, at depths deeper than approximately 13 m, the sediments were anoxic and many animals were either dead or dying. Similar silled fjords within the Knight Island area were sampled in 1990 to determine the extent of such "dead zones" and to better establish a possible relationship between the existence of dead zones and oiling.

Four fjords were sampled in the Spring 1990: Herring Bay fjord (the same site as sampled in 1989), inner and outer Lucky Bay and inner Bay of Isles (Figure 6.2). All of these sites had sills and restricted entrances similar to that observed at Herring Bay fjord in 1989. A more extensive survey of these and 3 additional sites was conducted in Fall 1990, but these data are not yet available to report.

A bathymetric survey of each bay was made using a portable fathometer aboard a small inflatable boat. At each site we characterized the substrate by making videos of the bottom. We also conducted visual surveys over larger sections of each bay. These were conducted along the long axis of the bay, along the short axis and through the deepest part of the bay, and along a line that bisected the short and long axis.

In 1990, estimates of density of infaunal invertebrates were obtained from 0.1 m^2 suction dredge samples taken by divers. This was smaller than the sample area of 0.25 m^2 used in 1989. We sampled three stations at Herring Bay, four at Outer Lucky Bay, and one each at inner Lucky Bay and inner Bay of Isles. Two replicate samples were taken at each station.

Stratified Sampling in Other Habitats

A stratified sampling design, modified from the design used in our 1989 survey, was be employed in order to obtain estimates of basic population parameters (abundance,

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Table 6.1 Study site locations and codes for 1990 subtidal studies.

SITE NAME	CODE	TYPE	LAT	LONG
LAMINARIA/AGARUM - ISLAND BAYS				
Cabin Bay	1	C	60 39.5	147 27.0
Northwest Bay	2	O	60 33.4	147 34.6
Lower Herring Bay	4	C	60 26.8	147 48.7
Herring Bay	3	O	60 26.3	147 47.0
Mummy Bay	5	C	60 13.8	147 49.0
Bay of Isles	6	O	60 23.0	147 42.5
NEREOCYSTIS				
Procession Rocks	8	C	60 00.8	148 16.0
Latouche Point	7	O	59 57.0	148 03.3
Zaikof Point	9	C	60 18.3	146 55.0
Montague Point	10	O	60 12.7	147 18.3
Naked Island	11	C	60 37.5	147 22.2
Little Smith Is.	12	O	60 31.3	147 26.0
EELGRASS				
Drier Bay	14	C	60 19.1	147 44.2
Bay of Isles	13	O	60 23.2	147 44.5
Lower Herring Bay	15	C	60 24.2	147 48.0
Herring Bay	16	O	60 26.7	147 47.2
Moose Lips Bay	18	C	60 12.7	147 18.5
Sleepy Bay	17	O	60 04.0	147 50.3
Puffin Bay	26	C	60 44.0	147 25.0
Clammy Bay	25	O	60 39.1	147 22.5
LAMINARIA/AGARUM - ISLAND POINTS				
Lucky Point	20	C	60 13.2	147 52.5
Discovery Point	19	O	60 14.9	147 41.9
Lower Herring Bay	21	C	60 24.0	147 51.0
Herring Bay	22	O	60 26.6	147 50.4
Peak Point	24	C	60 42.9	147 21.8
Ingot Point	23	O	60 28.9	147 36.5

Table 6.1, Continued

SILLED FJORDS				
Lucky Bay	27	C	60 12.7	147 62.1
Herring Bay	28	O	60 27.8	147 42.1
Lucky Bay	29	C	60 13.9	147 51.5
Bay of Isles	30	O	60 23.0	147 45.3
Disk Lagoon	32	C	60 29.6	147 39.7
Bay of Isles	31	O	60 23.0	147 43.6
Humpback Cove	33	C	60 12.5	148 17.5

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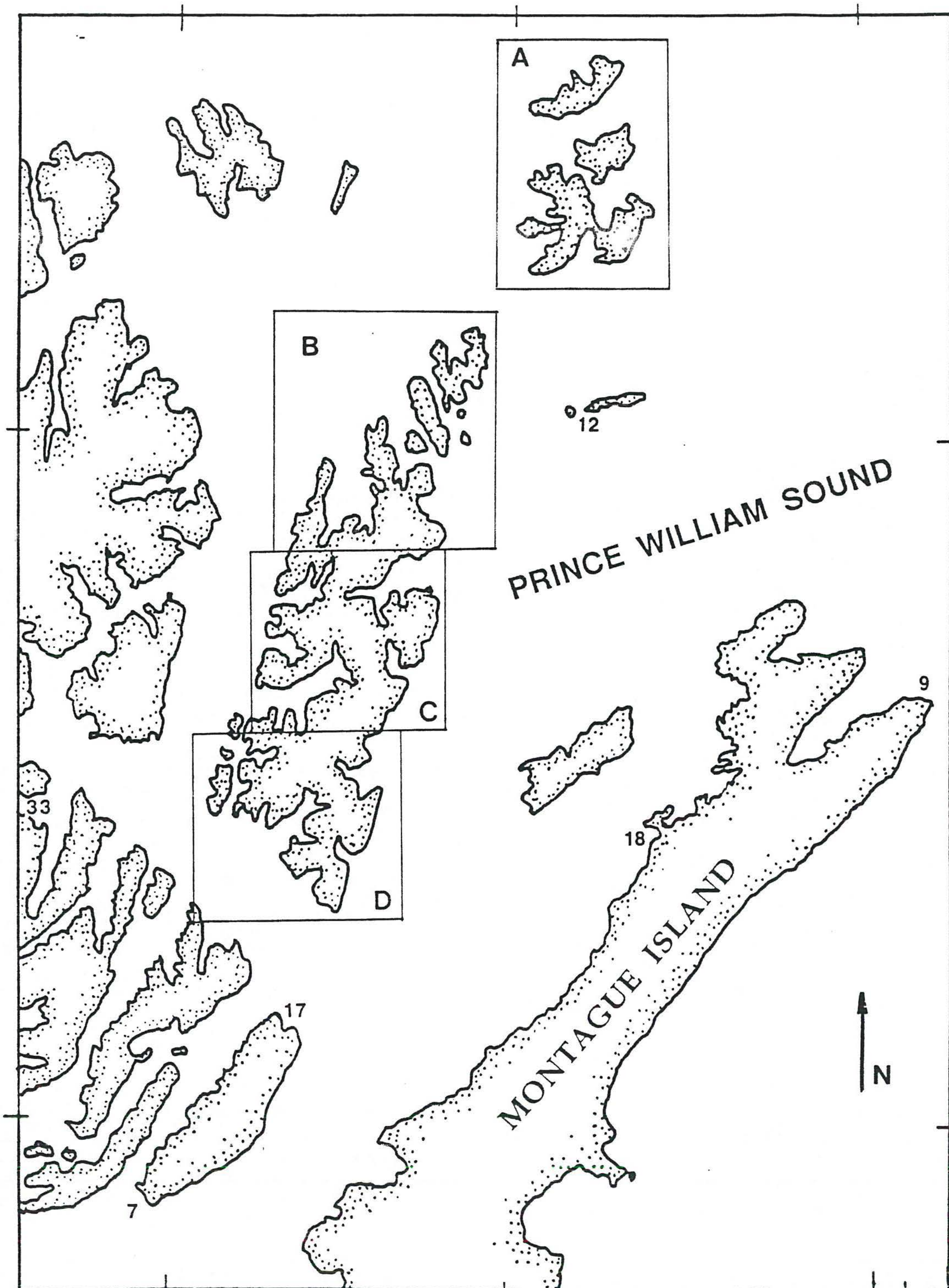

Figure 6.1 Locations of study sites in Prince William Sound. Areas A through D are expanded for details of site location.

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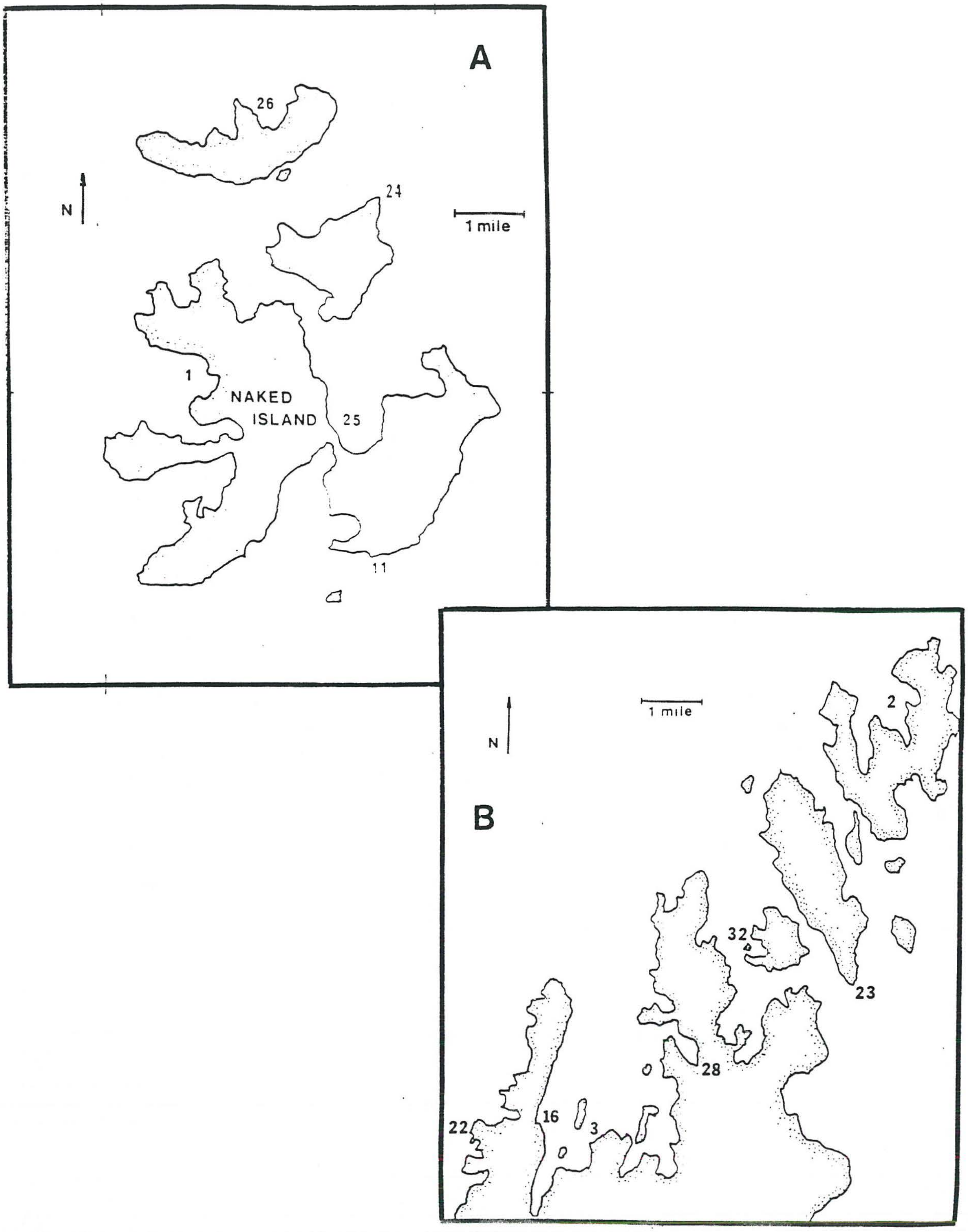

Figure 6.1 (continued) Details of expansion areas A and B, with locations of study sites in Prince William Sound.

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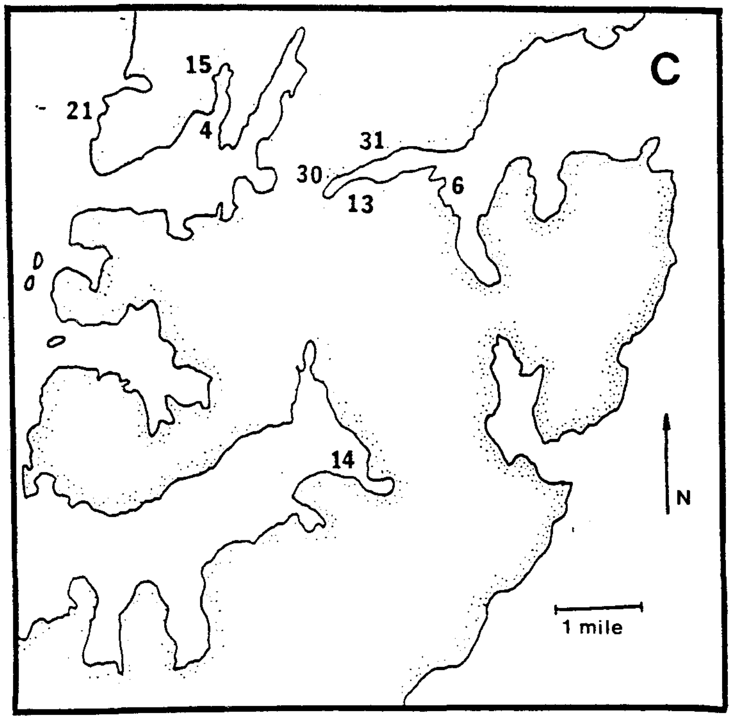

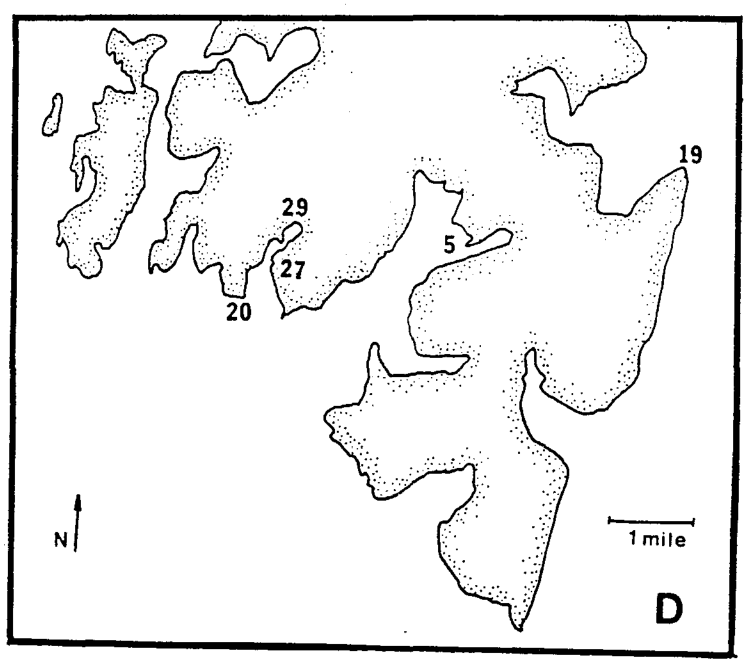

Figure 6.1 (continued) Details of expansion areas C and D, with locations of study sites in Prince William Sound.

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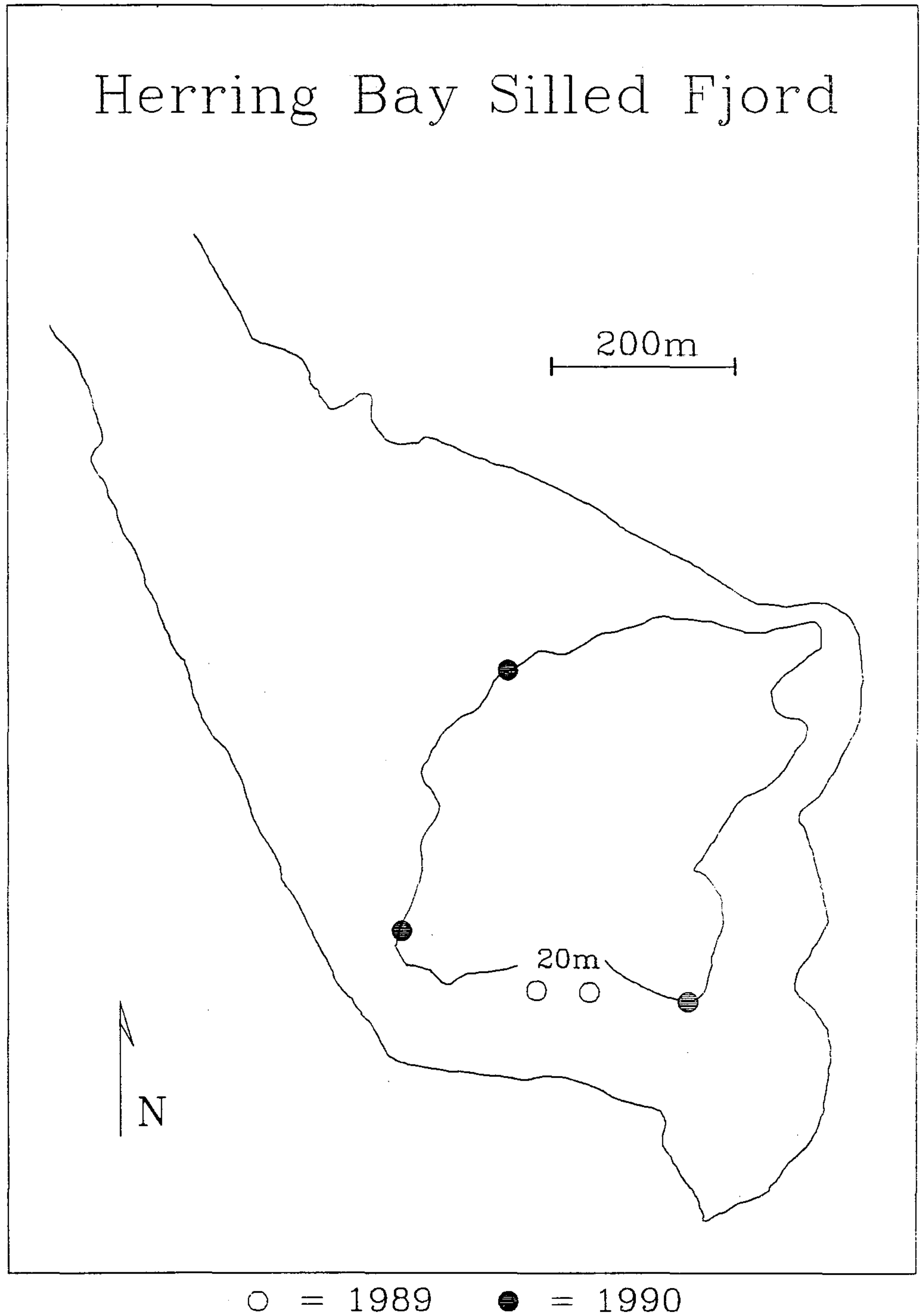

Figure 6.2 Maps of silled fjord study sites. A. Herring Bay