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The Effects of the EXXON VALDEZ Oil Spill on Shallow Subtidal Communities in Prince William Sound, Alaska 1989-91

Study Identification Number ST2A

Final Report
December, 1993

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SUMMARY

This report examined the effects of the EXXON VALDEZ oil spill (EVOS) on shallow (< 20 m) subtidal communities within Prince William Sound. We observed effects on a number of plant, invertebrate, and fish species. The effects were most pronounced within deeper strata within the eelgrass habitat, where there was a marked reduction in the diversity and abundance of benthic infauna at the oiled sites relative to controls. We also noted lower densities of eelgrass (within the eelgrass habitat), helmet crabs, and leather stars (within all habitats) at oiled sites. The species affected included several that are of particular importance as prey for fish, birds, and otters.

We also noted an abundance of dead animals within a fjord in Herring Bay in 1989. By 1990, the community at this site was reduced from the over 20 taxa observed in 1989 to 6 taxa in 1990, and the system was almost totally dominated by one polychaete (*Nephtys cornuta*) which is noted for its tolerance to pollution. These changes were at least in part attributable to the effects of oil.

The various components within the shallow subtidal system demonstrated varying rates of recovery. Algal populations had almost fully recovered by 1990, and eelgrass populations recovered by 1991. Benthic infaunal communities showed significant progress toward recovery by 1990, but recovery was not complete. Only the larger epibenthic invertebrates (crabs and sea stars) failed to show significant recovery by 1991.

The Effects of the EXXON VALDEZ Oil Spill on Shallow Subtidal Communities in Prince William Sound, Alaska

1.0 OBJECTIVES

This study was aimed at determining the effects of the EXXON VALDEZ oil spill (EVOS) on shallow (<20 m) subtidal communities of plants, invertebrates, and fish, within Prince William Sound, Alaska.

2.0 INTRODUCTION

2.1 Background

The shallow subtidal habitat of Prince William Sound, from the intertidal zone to depths of approximately 20 m, typically has dense macrophyte (algal) assemblages, and is a critical habitat for many commercially and ecologically important animals (Rosenthal et al., 1977; Rosenthal, 1980; Feder and Jewett, 1987). The region is most noted as a nursery for salmon, King crab, Dungeness crab, and some pandalid shrimps, the spawning grounds for Pacific herring, and the feeding grounds for sea otters, river otters and many marine birds. As primary producers, the benthic marine macrophytes are probably at least as important as the transient phytoplankton blooms. Seaweeds are a main source of food for several marine invertebrates, including sea urchins and crabs, and provide a food source for detrital based food webs in the deeper subtidal zone. Subtidal eelgrass and algal beds are extremely important feeding grounds for migratory waterfowl (McConnaughey and McRoy, 1979). These shallow subtidal regions typically contain numerous polychaete worms, small snails and clams, amphipods, copepods, isopods, sea urchins, and sea stars, many of which serve as food for coastal-feeding otters, birds, fishes, crabs and shrimps (see review in Feder and Jewett, 1981, 1987; Hogan and Irons, 1988; McRoy, 1988).

It was expected that a certain proportion of oil from the EXXON VALDEZ oil spill (EVOS) (either the original oil from surface waters, oil leached from contaminated shorelines, and/or oil dispersed into receiving waters via shoreline remediation procedures) would reach the bottom by physical and biological processes. Shallow subtidal data collected in polluted waters elsewhere indicate that changes in species number, abundance, biomass, and diversity occur if sizable quantities of oil flow to the bottom (e.g., Cabioch et al., 1978; Kineman et al., 1980; and Sanders et al., 1980). Changes in composition of benthic fauna and flora can have serious trophic implications. Further, the larvae of most benthic organisms in Prince William Sound move into the water column (March through June) and are utilized as food by large zooplankters and larval and juvenile stages of pelagic fishes, salmon fry, and herring. Thus, damage to the benthic system by hydrocarbon contamination could affect feeding interactions of important species in the water column, as well as on the bottom.

2.2 History of the Project

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/training cruise was conducted. An initial subtidal survey was conducted in Prince William Sound in October, 1989. Effects on plants, invertebrates, and fish were evaluated in sheltered rocky habitats at 5 sites (a subset of those visited by Coastal Habitat intertidal sampling team).

The October 1989 sampling program indicated that, in general, the sampling design and the site selection process used in the initial surveys were not 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. Sampling continued in the Spring and Summer of 1991 at a subset of sites visited the previous year.

2.3 Overview of the Study Design

In 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 and control sites that were matched to the oiled sites with regard to geomorphology, degree of freshwater input, substrate type, and general circulation and wave exposure regimes. A similar design was used in 1991, except that only a subset of those sites sampled in 1990 was visited in 1991.

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

2.4 Report Organization

This report summarizes the subtidal data collected in 1989, 1990, and 1991. Emphasis is on the 1990 and 1991 data. The results section of the report is organized around different taxonomic groupings (plants, epibenthic invertebrates, infaunal invertebrates, and fish) and further subdivided according to habitat (eelgrass, *Laminaria/Agarum* habitats in island bays, *Laminaria/Agarum* habitats on island points, and in *Nereocystis* habitats along relatively exposed coastlines).

3.0 METHODS

3.1 Sampling Design

3.1.1 Stratified Random Sampling at Oiled and Control Sites

Rationale

For most of our studies on the subtidal communities, we used a stratified random sampling design in order to determine the effects of the EVOS. We measured population parameters (e.g. abundance, biomass, diversity, reproductive success) for the dominant plant, invertebrate, and fish species at both oiled and control sites within 4 specified habitats: Eelgrass (*Zostera marina*) beds, *Laminaria/Agarum* beds (areas where either *Laminaria saccharina* or *Agarum cribrosum* dominate) both in bays and on points within the Knight Island archipelago, and *Nereocystis* beds. These strata were defined with respect to dominant plants, physiography, and location within the Sound in order to insure that variance due to factors other than oil were minimized, thereby increasing the power to detect differences among oiled and control sites.

We selected habitat types primarily based on the dominant vegetation type. The dominant vegetation at a particular site is generally determined by a suite of important environmental factors (e.g., substrate type, salinity, water motion). Therefore, we could indirectly assess the physical environment by assessing vegetation type. Classification by the dominant vegetation also offered an advantage in that we could generally determine the vegetation type (and indirectly the substrate type and other physical factors) by observing the habitat from the surface (either from a boat or plane), thereby eliminating the need for preliminary dive surveys. Both eelgrass and *Nereocystis* habitats have vegetation that grows from the bottom to near the water's surface and can be observed from the surface. Most of the remainder of the shallow subtidal within Prince William Sound is dominated by *Laminaria/Agarum*.

Within each habitat, we selected oiled sites and then located and sampled at a control site that matched, as closely as possible, the selected oiled site with respect to non-biological factors other than oiling. The procedures used for the selection of sampling strata and selection of sites within sampling strata follow.

Selection of Sampling Strata

The first order of stratification used in our sampling plan was based on vegetation type. The shallow subtidal communities within Prince William Sound are structurally dominated by 3 vegetation types: Eelgrass, *Laminaria/Agarum*, and *Nereocystis*. Eelgrass dominates in areas of soft substrate that generally occur in back bays at the mouths of streams. It often forms extensive beds that cover large areas in these back bays. Eelgrass also occurs in scattered patches throughout much of the rocky subtidal zone, but we have restricted our definition of eelgrass habitat to the larger beds on soft substrate.

Nereocystis (bull kelp) dominates on points in more exposed areas with strong currents. *Nereocystis* forms a floating canopy and the subcanopy algal community is dominated by a suite of algae generally associated with strong water motion. While *Nereocystis* habitats are relatively rare in PWS, they represent habitats of special significance. *Nereocystis* beds have high diversities of algae, epifaunal invertebrates, and non-demersal fishes. It also represents the one habitat for which there were pre-spill data available.

By far the most widely represented habitat in PWS is the *Laminaria/Agarum* habitat. Generally, if a habitat is not dominated by eelgrass or *Nereocystis*, it is dominated by *Laminaria saccharina*, *Agarum cribrosum*, or a combination of these species. *Laminaria/Agarum* beds occur on rocky substrate throughout the Sound in all but the most exposed points.

For the *Laminaria/Agarum* habitat, we further stratified into three oceanographic regions (islands, mainland, and outer Sound) and into three physiographic types (bays, points, and straight shore line) per region. This stratification scheme resulted in 9 potential strata within the *Laminaria/Agarum* habitat, 1 within the *Nereocystis* habitat, and 1 within the eelgrass habitat, for a total of 11 potential strata in all.

In order to remain within budgetary constraints and yet sample a sufficient number of sites within each habitat, we limited our sampling effort in 1990 to only 4 of these 11 potential strata: eelgrass, *Laminaria/Agarum* in island bays, *Laminaria/Agarum* on island points, and *Nereocystis*. The strata sampled were selected based on ecological importance, potential for impact, and extent of the habitat within the oiled region.

We elected not to sample *Laminaria/Agarum* habitats on the mainland or in the outer Sound because there were relatively few of these habitats that were oiled. We also elected not to sample runs (sections of straight shoreline) on the islands because these represented habitats that were intermediate between points and bays, and we felt that we could extrapolate

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from results obtained in bays and on points in order to estimate effects on runs.

Locations of the different vegetation types were initially identified, based on information obtained in our 1989 survey, and by polling knowledgeable biologists familiar with Prince William Sound as to the location of eelgrass beds and *Nereocystis* beds. These were later verified in surveys conducted by plane or boat (see site selection below).

Selection of Sites within Habitats

An initial selection of oiled sites was conducted in the laboratory in winter 1990. We identified strata based on our experience in the fall of 1989, and on anecdotal evidence from biologists familiar with the Sound. Selection of sites within strata were initially chosen based on an overlay of oil information and habitat information on navigation charts. Oiled areas were identified, based on the summer 1989 oil maps and the September 1989 "walkathon" data. Areas that were moderately to heavily oiled in both surveys were marked as oiled areas. From those oiled areas for each strata (e.g. eelgrass beds or *Laminaria/Agarum* habitats in island bays), we selected a 200 m section of shoreline to be sampled. The selection of the sampling locations was based on the following hierarchy for order of preference: Sites for which there were pre-spill biological data, sites previously sampled in NMFS or DEC hydrocarbon surveys, sites sampled by Coastal Habitat intertidal crews, and randomly selected sites within the habitat. Details of the initial site selection process are described in Appendix A.

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Control sites were selected that were indicated as not oiled in both the summer oil survey and the September walkathon. Controls were matched with selected oiled sites, as closely as possible, with regard to aspect, proximity to sources of freshwater input, slope, wave exposure, and water circulation. We randomly selected a matched control site if more than one existed.

Alternate oiled and control site locations were chosen according to the above criteria, in the event that our initially produced maps proved inaccurate with respect to habitat type, or if controls did not match the oiled sites with respect to aspect, wave exposure, etc.

In spring 1990, we conducted a site confirmation cruise to insure that our preliminary selections of oiled sites were appropriate with regard to habitat type, and that the control sites matched these oiled sites with regard to habitat and to physiographic aspects. In several instances, our preliminary identification of habitat type was incorrect, and alternate sites were substituted for those chosen initially. For the oiled sites, all final selections were from our initial list of chosen or alternate sites. For the control sites, we occasionally had to deviate from the initial list and search the western portion of the Sound for appropriate controls that matched the oiled sites as closely as possible, but were not oiled (based on shoreline oiling maps). A total of 3 alternate control sites that were not on our initial list of selected or alternate sites were selected as controls (Moose Lips Bay, Puffin Bay, and Naked Island). The final locations of sites selected within each habitat are given in Figure 1 and Appendix B.

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Selection of Depth Strata Within Each Habitat Type

Within each habitat, we further stratified our sampling effort, primarily by depth. In eelgrass habitats, we elected to sample within 3 strata: 3 to 6 m, 6 to 20 m, and at the mid point of the eelgrass bed (independent of depth) (Figure 2). In the *Laminaria/Agarum* habitats we sampled at 2 depth strata: 2 to 11 m and 11 to 20 m. Within the *Nereocystis* habitat we sampled within the *Nereocystis* bed, (within a depth range of 2 to 8 m). We elected to sample only in the deeper portions of the subtidal (> 2 m) because preliminary data collected in 1989 suggested that at the shallower depths, the variability within a site was extremely large. As a result, the sampling effort was concentrated in the more homogeneous portions of the habitat where the power to detect differences was largest.

3.1.2 Sampling in Fjords

In October 1989 sampling, one of our sampling sites was within a fjord in northeastern Herring Bay that was heavily oiled (Figure 3). This small embayment (hereafter referred to as Herring Bay fjord) is located along the northwestern side of Knight Island. It covers approximately 0.5 km^2 and has a maximum depth of 35 m. The depth of a sill, that stretches along the mouth of the bay, is only 4 m. At depths greater than 10 m, the substrate in the bay is composed primarily of fine flocculent silt.

Sampling in 1989 indicated that sediments at depths greater than 13 m were hypoxic or anoxic, and many animals were either dead or dying. Similar 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.

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Three fjords were sampled in the Spring 1990: Herring Bay fjord (the same site as sampled in 1989), inner Lucky Bay (control) and inner Bay of Isles (oiled) (Figure 1). A more extensive survey of these and 2 additional sites (Disk Lagoon - oiled, and Humpback Cove - control) was conducted in fall 1990 (Figure 1). All of these sites had sills and restricted entrances similar to that observed at Herring Bay fjord in 1989.

The fjords in Herring Bay and inner Lucky Bay were the only fjord sites sampled in 1991. The sampling effort was reduced because this habitat was relatively rare within PWS, and because there was a potential confounding effect of natural disturbances (seasonally low oxygen) and the effects of oil within these sites.

The oiled sites chosen for the silled fjord studies represented all of the oiled silled fjords that were in the PWS region. Control sites were selected that matched these sites as closely as possible with regard to size and depth. However, the number of potential controls was small, and in reality, the oil and control pairs were often very different from one another. As a result, we will primarily rely on comparisons of temporal patterns within the Herring Bay fjord to examine the potential effects of oil.

3.2 Biological Sampling Methods

3.2.1. Sampling within the Eelgrass Habitat

1990 Sampling

At each eelgrass site, we established three 30 m long transects, within the eelgrass bed (Figure 2). These were placed in the middle of the depth

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range of eelgrass, and at randomly selected locations along the 200 m section of shoreline selected for sampling.

Large (> 10 cm) motile invertebrates and fishes were counted along each 30 m transect. Divers swam the transect and counted fishes, by species, within a 1 m swath to either side of the transect center line and within 3 m of the bottom. These surveys were made prior to other sampling efforts on the transect in order to avoid disturbance to the fish community and to achieve accurate counts of fishes. Larger sessile invertebrates, non-cryptic specimens of echinoderms and crustaceans larger than 10 cm, and newly recruited juvenile sea stars were also counted in this 2 m by 30 m band.

Along each transect, we harvested all eelgrass from 4 randomly placed 0.25 m^2 quadrats. The turions (above-sediment portions of the plant arising from the rhizome, usually with 4 or 5 leaves attached) of the plants were cut approximately 1 cm above the sediment surface. The plants were bagged underwater and returned to the boat. There, the number of turions and total number of leaves per quadrat were counted, and all turions in each quadrat were weighed. In addition, we noted the number of flowering stalks per quadrat.

Densities of infaunal invertebrates were estimated from two 0.1 m^2 suction dredge samples taken along each of the three transects within the eelgrass bed. One 0.1 m^2 quadrat was sampled from each of the first two quadrats on each transect. The dredge samples were taken from the upper left hand corner of each quadrat (determined while facing the shore) after the eelgrass had been collected. Similar dredge samples were taken from 3 additional transects in each of two strata (3 to 6 m and 6 to 20 m) that were established independent of the distribution of eelgrass. These transects were placed at random positions within the sampling site and at random depths within the stratum.

Eelgrass seeds were collected from 4 randomly placed 0.25 m^2 quadrats on each of 3 transects the eelgrass bed at each site. The sediment in each quadrat was collected to a depth of approximately 5 cm using an airlift. The sediments were sieved through a 1 mm mesh screen and the seeds within each sample counted.

Epibenthic invertebrates within the eelgrass bed were sampled using a dropnet. A 0.5 m diameter (0.196 m^2 area) circular steel frame, with a 1 mm mesh net attached, was dropped from a small boat within 3 meters, adjacent to the 2 random points where infauna were collected. After the net was dropped, it was pursed and retrieved aboard the boat. The contents of the net were washed into a jar and preserved with formalin.

We sampled at 8 eelgrass sites between 3 July and 11 August 1990. Four oiled sites (Bay of Isles, Herring Bay, Sleepy Bay, and Clammy Bay) and four paired control sites (Drier Bay, Lower Herring Bay, Moose Lips Bay, and Puffin Bay) were visited (Figure 1 and Appendix B).

1991 Sampling

In 1991, sampling continued in the eelgrass habitat as described above, except for the following modifications. All sampling was conducted between 10 and 28 July. For sampling of eelgrass, we counted the number of turions within each 0.25 m^2 quadrat without harvesting plants and counted the

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number of flowering stalks of eelgrass within a 1 m band on one side of the 30 m transect. Larger epibenthic invertebrates were sampled as in 1990, except that newly recruited sea stars were counted in a 2 m by 30 m band.

Infaunal invertebrates were sampled as in 1990, except that no sampling was conducted at the shallow (3 to 6 m) depth stratum and dropnet sampling was discontinued.

Small mussels (*Musculus* spp.) were sampled by collecting 4 randomly selected eelgrass turions from next to each epibenthic sampling quadrat. The turions were placed into sampling bags underwater, placed in containers with formalin aboard ship, and later examined to determine the density and size distribution of mussels. A maximum of 40 randomly selected mussels were measured from each site.

Two additional eelgrass sites were sampled in 1991. These were in the Short Arm portion of Bay of Isles (an oiled site), and in the Mallard Bay (a control site in Drier Bay) (Figure 1 and Appendix B). Only the eelgrass stratum was sampled at these sites.

3.2.2 Sampling in the *Laminaria/Agarum* Habitat in Island Bays

1990 Sampling

Three transects were randomly placed within each of two depth strata, 2 to 11 and 11 to 20 m, within the *Laminaria/Agarum* bay habitat. The percent cover by understory algae was determined in four 0.25 m^2 quadrats placed at random positions along each transect. All algae greater than 10 cm in height were collected from these quadrats and returned to the boat where each individual was identified, weighed, and measured.

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Infaunal invertebrates associated with pockets of soft sediment along the transects were sampled using a suction dredge. These samples were taken from the first two quadrats on each transect when possible. If there was no soft sediment within the quadrat, then the sample was taken from the first available patch while traveling toward the next quadrat. There were no dropnet samples taken at the *Laminaria/Agarum* habitats.

Large (>10 cm) motile invertebrates and fishes were counted in a 2 m swath along each transect as described in 3.2.1 above. These counts were made prior to the clearing of algae from quadrats.

We sampled at 6 sites within the *Laminaria/Agarum* bay habitat in 1990. Three oiled sites (Northwest Bay, Herring Bay, and Bay of Isles) and three paired control sites (Cabin Bay, Lower Herring Bay, and Mummy Bay) were visited (Figure 1 and Appendix B). All sites were sampled as described above between 22 May and 12 June 1990. A second visit was made to the sites between 21 July and 29 July, 1990 and fish abundances were determined within shallow depth stratum.

1991 Sampling

The sampling in *Laminaria/Agarum* bay habitats in 1991 was restricted to infaunal invertebrates, large epibenthic invertebrates, and fish. All sampling was conducted between 29 July and 5 August. Fish and large epibenthic invertebrates were sampled only in the shallow (2 to 11 m) depth stratum. Sampling methods were the same as in 1990.

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3.2.3 Sampling in *Laminaria/Agarum* Habitats at Island Points.

1990 Sampling

Sampling in the *Laminaria/Agarum* habitats at island points was identical to that described for island bays. Dredge samples used to determine the abundance of infaunal invertebrates were not sorted in the laboratory and no data for infauna are reported for this habitat.

We sampled at 6 sites within the *Laminaria/Agarum* point habitat in 1990. Three oiled sites (Outer Herring Bay, Ingot Point, and Discovery Point) and three paired control sites (Outer Lower Herring Bay, Peak Point, and Lucky Point) were visited (Figure 1 and Appendix B). Sampling was conducted between 18 July and 7 August, 1990.

1991 Sampling

There was no sampling conducted within this habitat in 1991.

3.2.4 Sampling in *Nereocystis* habitats

1990 Sampling

Sampling in the *Nereocystis* habitat was conducted within the depth stratum in which *Nereocystis* was observed at all sites (2 to 8 m). Sampling was conducted between 14 June and 2 July 1990. Within the *Nereocystis* zone, sampling of smaller stipate kelps (*Agarum*, *Laminaria spp.*, *Pleurophycus*), large epibenthic invertebrates, and fish was as described for *Laminaria/Agarum* habitats in Island bays (see section 3.2.2 above except that at 2 of the sites, (Little Smith Island and Naked Island) we sampled along 5 and 6 transects, respectively. *Nereocystis* density was determined by counting all plants greater than 2 m in height within a 4 m swath along the transects.

The size distribution of *Nereocystis* was determined by measuring the diameter of the stipe, at a distance 1 m above the bottom, for the first 20 plants observed along each transect. Fewer than 20 were measured in cases where there were fewer than 20 individuals present on a particular transect. The relationship between stipe diameter and total wet weight was determined by weighing, and measuring the stipe diameter of each plant from 20 to 40 plants collected from each site. The plants were collected from near the transects and were selected in order to obtain as wide a range in sizes as possible. An analysis of these data indicated that stipe diameter was an excellent predictor of weight. The equation for the regression of stipe diameter *vs*. the log of the weight was :

$$\text{Log}_e \text{ weight (Kg)} = [0.457 \times \text{Stipe diameter (mm)}] - 2.68$$

The regression coefficient for this equation was = 0.85.

We sampled at 5 sites within the *Nereocystis* habitat in 1990 (Figure 1 and Appendix B); two oiled sites (Latouche Point and Little Smith Island) and three control sites (Procession Rocks, Naked Island, and Zaikof Pt.). We did not sample from an oiled site that matched the Zaikof site, and as a result, data from Zaikof are not presented here.

1991 Sampling

There was no sampling conducted within this habitat in 1991.

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3.2.5 Sampling in Silled Fjords

1989 Sampling

At the Herring Bay silled fjord in 1989, dredge samples were taken from two randomly placed stations that ran from shore to 20 m. The stations were positioned at randomly selected locations directly offshore of a 200 m section of shoreline that was chosen for sampling by the intertidal sampling team. Along each station a 30 m long transect was established within each of three depth strata: 0 to 2 m, 2 to 8 m, and 8 to 20 m. The sampling depth within each depth stratum was also selected at random. Dredge samples were taken from a 0.25 m^2 quadrat randomly placed along each transect within each depth stratum. We also made a video of each transect and prepared a bathymetric chart of the bay using a fathometer aboard a small boat. Additional videos were taken along transects through the deeper portions of the bay in order to document the presence of large numbers of dead organisms.

1990 Sampling

In 1990, estimates of density of infaunal invertebrates were obtained from 3 sites in the spring and 5 sites in the fall. At each site we first conducted a bathymetric survey as described above. Stations were then established at random positions along the 20 m depth contour at each site. At each station, divers collected duplicate 0.1m^2 suction dredge samples of sediment for analysis of benthic infauna.

Temperature, salinity, and dissolved oxygen were measured at the bottom (depth = 20 m) and the surface at each sampling site in 1990.

1991 Sampling

We sampled at Herring Bay and at Lucky Bay in 1991, using the same methods as described for 1990.

3.3 Germination of Eelgrass Seeds and Genetic Analysis of Seedlings

An experiment was conducted to examine the effect of oil on the potential germination of eelgrass seeds. Seeds were collected from the sediments at oiled and control sites and were germinated in filtered seawater in the laboratory.

Approximately 150 eelgrass seeds were collected from each of 4 stations (Herring Bay, Lower Herring Bay, Bay of Isles, and Drier Bay) between 11 and 19 July 1990. Sediments were collected from a depth of approximately 2 m at each site using a suction dredge. The sediments were sieved through a 1 mm mesh screen and the seeds were collected and placed into vials of filtered seawater. The vials were placed on ice and returned to the Seward Marine Laboratory.

There the seeds were removed and placed into randomly numbered, plastic Petri dishes containing 30 ml of 9 ppt filtered seawater. Salinities of 4.5 to 9 ppt are optimal for germination (Phillips, 1974). A total of 15 dishes was used for each site. Ten haphazardly selected seeds were placed into each dish, with one exception. Only 2 seeds were placed in one of the dishes from Herring Bay because too few seeds were available from this site.

The dishes were kept in a controlled temperature cold room at 9°C and a 10:14 hour light dark cycle. The number of seeds germinated was monitored daily for approximately 10 weeks. Any germinated seeds were removed and preserved in 10% formalin. These were placed in a vial labelled with the number of the Petri dish from which the seedling was removed.

A subset of seedlings that were germinated in the laboratory was collected and was subjected to microscopic examination to determine the proportion of mitotic figures that were normal. Preserved seedlings were selected haphazardly from the vials with germinated seeds. A total of 30 seedlings was examined; 11 from Herring Bay, 6 from Lower Herring Bay, 10 from Bay of Isles, and 5 from Drier Bay.

Meristematic regions of eelgrass seeds were dissected from formalin-fixed seedlings by making two cuts across the shoot. The resulting tissue was approximately 2 mm in length. The cotyledon sheath enclosing the meristematic tissue was scored longitudinally using a scalpel and a small cut was made into the area above each emerging root. The tissue was stored in a cellulase solution (pH 5.0) for two days at room temperature, then rinsed in distilled water. Tissue was post-fixed for 15 minutes in acid alcohol (3 parts 100% ethanol: 1 part glacial acetic acid) then rinsed again in distilled water. Mitotic figures were stained using the Feulgen squash technique developed for terrestrial plant root tips (Kihlman, 1971). The tissue was hydrolyzed in 1 N HCl for 10 min, then stained for 1 hr at 20°C using leucobasic fuchsin (Feulgen stain). The tissue was placed on a microscope slide and squashed in a drop of 45% acetic acid beneath a cover slip.

Approximately 2 hours later, the tissue was examined at 1000 X for aberrant anaphase/telophase mitotic figures (AT) (Hose, 1985). From each seedling, 20 AT were scored as normal or aberrant. Aberrant AT had at least one chromosome or chromatid aberration (translocation bridge, attached fragment, acentric fragment, stray chromosome, or lagging chromosome) or spindle abnormality (Multipolar spindle). Any pycnotic nuclei present in the meristematic regions were recorded.

3.4 Determining Growth Rates of *Agarum cribrosum*

The growth rate of *Agarum cribrosum* was determined at 2 pairs of oiled and control sites between 05 June and 29 July 1990: at Herring Bay (oiled) and Lower Herring Bay (control); and at Bay of Isles (oiled) and Mummy Bay (Control). At a depth of 8 m at each site, 20 plants between 50 and 100 cm in height were selected. The plants were all within 2, 2 m x 30 m swaths and were separated by 1 to 2 m. Each plant was marked by driving a steel spike, with a numbered plastic tag attached, into the seafloor next to each plant. A small piece of plastic surveyors flashing was placed through a hole near the midrib at a height approximately 10 cm above the juncture of the holdfast and the blade. We then measured and recorded this distance. Any surrounding plants were removed in order to eliminate potential competition.

After a period of 41 to 57 days, the stations were revisited and the distance from the bottom of the blades to the tag were remeasured and recorded. The growth of each plant was calculated as the change in distance from the base of the blade to the tag over the 41 to 57 days. All measurements were standardized to the growth (in cm) per 30 days.

3.5 Sampling and Analysis of Sediments for Hydrocarbon Content, Grain Size, and Carbon Isotope Ratios

Sediments were collected from each depth stratum at each study site visited in 1989, 1990, and 1991. All samples were taken from the second of three sampling stations, located approximately in the middle of each sampling site. SCUBA divers collected the sediment samples in pre-cleaned, wide-mouth 4 oz. jars. Divers took two sample jars into the water, cracked the jars' lid just below the waters surface, and proceeded to the bottom at each sampling site. There, the jar's lid was removed and the jar was used to scoop sediment to a depth of approximately 5 cm. A 10 to 100 g sample of sediment was obtained at each sampling location. The samples were taken from within 3 m of the buoy anchor marking each sampling station when possible. If the sediment could not be collected near the buoy, samples were taken at the closest adjacent patch of loose sediment.

One of the collected samples was used to determine hydrocarbon levels and the other to determine sediment composition and carbon isotope ratios. All hydrocarbon sediment samples were numbered sequentially, labelled, sealed with evidence tape, signed, and frozen on board. At the end of the field season, all hydrocarbon sediment samples were sent to the Technical Services Task Force, Analytical Chemistry Group (TSTF-ACG), NOAA/NMFS, Auke Bay, Alaska for processing. Hydrocarbons were extracted from the sediment samples and the extracted samples were analyzed for the concentration of various hydrocarbon fractions (Appendix BB) using gas chromatography combined with a mass spectrometer detector (GC-MS). The samples were prioritized for analysis, with highest priority given to samples collected from eelgrass and silled fjord habitats. To date, analyses have been

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completed for all samples collected from eelgrass habitats in 1990 and 1991; from Herring Bay fjord in 1989, 1990, and 1991; and from *Laminaria/Agarum* bays in 1990. A few additional samples (1 or 2 per site) have also been analyzed for samples collected from *Laminaria/Agarum* point and *Nereocystis* habitats in 1990. Remaining samples have been archived for possible future analyses.

The samples to be used for the determination of grain size and carbon isotope ratios were also numbered, labelled, and frozen aboard the ship. These were then shipped to the University of Alaska Fairbanks for analysis. Only samples from eelgrass and silled fjord habitats were processed. In the laboratory each of these samples were split into two subsamples. One fraction was used for analyses of grain size and the other for the analysis of organic carbon stable isotope ratios.

Sediments were analyzed for their grain sizes by the usual pipette-sieve method, and the sediment types and grain size distributions defined statistically following the conventional grain size parameters stated in Folk (1980).

Organic carbon, organic nitrogen, and stable carbon isotope ratios were also determined for sediments sampled within the eelgrass habitats and silled fjords. The methods, results, and discussion of stable carbon isotope ratios are given in Appendix C.

3.6 Sorting and Identification of Infaunal and Small Epifaunal Invertebrates

Samples of infaunal and small epifaunal invertebrates were returned to the University of Alaska, Fairbanks laboratory for sorting, counting, weighing, and identification. All samples were sieved through a 1 mm sieve. The methods are detailed in the Standard Operating Procedure for laboratory processing of the benthic samples (Appendix D).

An attempt was made to identify organisms to at least the family level, but there were a few instances when only higher taxonomic levels were assigned to an individual. Many of the more common organisms were identified to the genus and species.

3.7 Experiments Evaluating Reproductive Success of *Dermasterias*

We conducted a series of experiments to examine the effect of the EVOS on reproductive success in the sea star, *Dermasterias imbricata*. We collected stars from oiled and control sites and examined gonad weight, and spawning success. Animals used to determine gonad index were collected from Herring Bay and Lower Herring Bay. Spawning success was determined for animals collected from 2 oiled sites (Herring Bay and Northwest Bay) and 2 control sites (Lower Herring Bay and Cabin Bay).

At each site, divers swam along the bottom and collected organisms as they were encountered. No attempt was made to obtain a random sample within each site. We selected only those individuals that were presumably of reproductive size (greater than approximately 8 cm diameter from ray to ray).

In all experiments, animals were taken from the field to the Seward Marine Laboratory for these tests. Each animal was placed into a sealed plastic bag, with a small amount of O_2, and placed on ice in a cooler for transport. Separate coolers were used for animals from oiled and control sites. Animals were delivered to the laboratory on the day of collection.

In our first experiment conducted on 5 May 1990, 140 animals were collected; 70 from an oiled site (Herring Bay) and 70 from a control site (Lower Herring Bay). Once in the laboratory, a subset of 24 animals from each site was selected at random, and each individual selected was placed into a Pyrex baking dish with filtered seawater. Each animal was injected with 3 to 5 ml of 1 Molar -1-Methyladanine to induce spawning (Strathmann, 1987). We noted whether the animals spawned and then dissected all animals to determine their sex (for those animals that did not spawn) and condition of the gonads. The remaining animals were dissected to determine gonad index.

In dissecting animals collected from Herring and Lower Herring Bay for their gonads, we noted a relatively high proportion of animals were parasitized by an undescribed species of barnacle, *Dendrogaster* sp. (Grygier, 1982; Kozloff, 1987). In order to examine the possible effects of oil on the level of infection by these parasites, and the effects of the parasite on spawning success, we noted the presence of parasites in the animals used in spawning experiments.

A second experiment was conducted on 25 May 1990. A total of 89 *Dermasterias* was collected from the field; 43 from an oiled site (Northwest Bay) and 46 from a control site (Cabin Bay). The animals were transported to Seward as described above. All animals were injected with methyladanine and the spawning success noted. All animals were then dissected and the number of rays parasitized was recorded.

More animals were collected in June 1990 and July 1991 to provide additional information on the possible effects of oil on the rate of parasitism. On 7 June 1990, 42 *Dermasterias* were collected from Mummy Bay (a control site) and on 12 June 1990, 53 animals were collected from Bay of Isles (an oiled site). In 1991, *Dermasterias* were collected from 2 control sites (Lower Herring Bay and Mummy Bay), and from 2 oiled sites (Sleepy Bay and Bay of Isles) between 24 July and 30 July. A total of 52 animals was collected. All animals were dissected aboard ship immediately after collection and the presence or absence of parasites was noted.

3.8 Sampling and Analysis of Fish Gut Contents

Young-of-year (YOY) Pacific Cod were collected from 3 oiled (Herring Bay, Bay of Isles, and Clammy Bay) and 3 control (Lower Herring Bay, Drier Bay, and Puffin Bay) eelgrass sites for gut content analysis. Collections were made at Herring Bay, Lower Herring Bay, Drier Bay, and Bay of Isles between 4 July and 15 July, 1990. Clammy and Puffin Bay samples were collected 9 August to 11 August, 1990. Divers collected fish from within the study site by spearing fish with small pole spears. Twelve to eighteen fish were collected per site ranging in size from 48 to 78 mm (standard length). The fish were then frozen and transported to the University of Alaska, Juneau for analysis.

In the laboratory, each fish was weighed and measured. The fish were dissected and a visual estimate of the proportion of the gut that was filled was obtained. The contents of the gut were removed, sorted, identified (generally to order), counted, and the volume for each taxon was determined.

3.9 Data Analysis

3.9.1 Analysis of Data from Stratified Sampling

Analysis of Percent Cover, Abundance, Biomass, Diversity, and Hydrocarbon Data

For the percent cover, abundance, and biomass estimates for each of the dominant taxa, and for diversity measures for benthic infauna, we tested the null hypothesis of no significant difference among oiled and control sites using a randomization procedure (Manly, 1991). In most instances, separate analyses were performed for each depth stratum within each habitat and year. We tested for oil category (oil or control) as the main effect, with pair (arbitrarily assigned as 1 through 4) as a blocking factor. For those taxa that occurred in several habitats, we also examined the effect of oil over all habitat types using a similar procedure. In cases where we had data from both 1990 and 1991, we performed a 2-factor randomization procedure, and tested for significant effects due to oil, to year, and to the interaction of oil and year.

Replicate stations were sampled within each site, and in some cases, replicate quadrats were sampled within each station. In all cases we used station rather than quadrat means as replicates in our analyses.

The randomization procedure can be briefly summarized as follows. 1) A blocked analysis of variance (ANOVA) was performed, and a sum of squares produced. 2) Next, using the original data set, we randomly reassigned values for oil code to each station value. The ANOVA was then rerun on this new data set. 3) Step 2 was repeated 1000 times. 4) The sums of

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squares from the ANOVA of the original data set was compared with sums of squares of the 1000 randomly drawn data sets.

The proportion of instances in which the sums of squares for the randomly drawn data exceeded the sums of squares for the original data was recorded. This value is the significance level of the test as described by Fisher (1935). The significance level is interpreted in the same manner as for parametric procedures. If the randomly drawn sums of squares exceeded the sums of squares for the original data less than 10 % of the time, then this is equivalent to P=0.10 for an ANOVA, and there is some evidence of an effect of oiling. If the value is 1% (equivalent to P=0.01), then there is very strong evidence that oiling had an effect.

Analysis of Size Frequency Data for Algae and Mussels

Size (wet weight, length, or stipe diameter) frequency distributions were established for the dominant algal species in each habitat in 1990. We compared the distributions at oiled sites *vs.* control sites, within each habitat and depth stratum, using a randomization procedure similar to that described above, but using a Komolgorov-Smirnoff (KS) D value (Siegel, 1956) as the test statistic. We performed a KS test on the original data set, randomly reassigned oil and control categories to plants found on particular quadrats (for *Agarum*), or transect (for *Nereocystis*), and reran the KS test. We randomized with regard to groups of plants from quadrats and transects rather than each individual plant because we felt that the sizes of plants in close proximity to one another may have been correlated in some way and were not truly independent samples. The randomization

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process was repeated 1000 times, and the D statistic from the randomized data sets was compared with the D statistic from the initial data set.

Selection of Taxa

In the data sets for infauna and smaller epifauna, there was a large number of taxa represented. Many of these taxa were rare, occurring in only a few samples. We omitted the rare species from our analyses of abundance and biomass for individual taxa in order to reduce analysis time. There was generally little power to detect differences among sites for these taxa.

In most benthic biological studies, as well as the study reported here, organisms collected and subsequently used in analyses, include infaunal macrofauna, slow-moving macrofaunal surface dwellers, and small, sessile epifauna. Large motile epifauna such as shrimps, crabs, and sea stars are typically not adequately sampled and therefore are not included in the analyses. However, since only small representatives of these larger motile epifauna were collected with the dredge sampler that we have employed, these epifauna were included in the analyses.

The mesh size of the collection bag was 1 mm, and as a result, organisms smaller than 1 mm (meiofauna) were generally not sampled. Those few individuals smaller than 1 mm that remained in the samples were excluded from the analyses. Also excluded from the analyses were organisms that are considered highly motile and non-benthic, such as calanoid copepods, mysids, euphausiids, chaetognaths, and fishes.

All analyses were conducted for groups of organisms identified to the family level (or order in cases where individuals could not be identified to family). We eliminated all taxa that occurred in fewer than one-sixth of the samples for a particular habitat, depth stratum, and year, and then ranked the remaining taxa. This eliminated species that occurred at only a few of the sampling sites, and thereby eliminated species for which there was extremely little power to detect effects. The 15 highest ranking taxa in each year were then selected for analysis. Generally, the 15 highest ranking taxa for one year were also the highest ranking for another. However, occasionally a taxon was ranked in the top 15 one year but not another. As a result the number of taxa for which analyses were performed was generally between 15 and 25. Separate rankings were made for abundance (number of individuals per sample) and biomass within each habitat, depth stratum, and year. A list of the rankings for each habitat, depth stratum, and year is given in Table 1.

The Use of Covariates in Analysis of Benthic Infaunal Data

Previous studies of infauna and preliminary analyses of our data indicate that the faunal composition and the abundance of infaunal species is determined to a degree by sediment grain size. While our paired design was generally successful in controlling for grain size, sediment types differed among some pairs. Because of our inability to completely control for this factor, and because it was anticipated that grain size would be unaffected by oiling, we felt it appropriate to use grain size as a covariate in analysis of infaunal organisms. For individual taxa from the eelgrass habitats that were considered predominantly infaunal, we used the percent mud (% silt plus % clay) as a covariate in our analyses.

Some species collected in our dredge samples were epifaunal rather than infaunal (e.g., spirorbid worms and mussels). We did not use grain size as a covariate in our analysis of these taxa. Assigned designations of "infauna" or "epifauna" were based on a review of the literature for each taxon.

We did not collect grain size data for *Laminaria/Agarum* habitats, and no covariates were used in the analyses of these data.

Computation of Diversity Measures

Species diversity can be thought of as a measurable attribute of a collection or a natural assemblage of species and consists of two components: the number of species or "species richness" and the relative abundance of each species or "evenness". We have elected to characterize communities of benthic infauna and smaller epifauna using several common measures of diversity: The "species richness" component was measured using the total number of taxa per sample, and Margalef's species richness index (Green, 1979) which scales the total number of taxa with respect to the total number of individuals. The species richness index, SR, was computed as:

$$SR = \frac{S - 1}{\log_e N}$$

Where S = the number of species [taxa]

N = the total number of individuals,

We used Simpson's index (Simpson, 1949) as a measure of dominance. The Simpson dominance index, D, was calculated as:

$$D = \frac{\Sigma\, n_i(n_i - 1)}{N(N-1)}$$

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Where n_i = number of individuals of i^{the} species

N = total number of individuals.

The maximum value for the Simpson dominance index (1.0) is obtained when there is a single species [taxon] (i.e., complete dominance). Simpson's dominance values approaching 0 are obtained when there are numerous species [taxa], each comprising a small fraction of the total (i.e. no dominance).

We also measured diversity using the Shannon index (Shannon and Weaver, 1963). This is one of the most widely used measures of diversity and incorporates both species richness and evenness components. The Shannon index, H', was calculated as:

$$H' = -\Sigma_i P_i \log_e P_i, N$$

Where n_i = number of individuals in the i^{the} species

N = total number of individuals

In all of the above indices, we have used taxa identified to family (or above) as opposed to species. While diversity indices are normally applied to species, the overall diversity of a community is comprised of hierarchical components (e.g. family, genus, and species) and the concept can be applied to any of these components (Pielou, 1974). Diversity values computed using taxon identifications higher than species have been reported by Lloyd et al. (1968), Valentine (1973) and Ferraro and Cole (1990,1992). Better resolution of multivariate data is also possible when taxonomic levels higher than species are used (Warwick, 1988; Rosenberg, 1972; Heip et al., 1988).

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For the analyses of community parameters (diversity, dominance etc.) all taxa sampled were used, including both infauna and small epifauna. No covariates were used in these analyses.

Analysis of Fish Abundance

In our analysis of abundance of fish species, we have eliminated all schooling fishes (e.g. herring). These fish were observed only in a few of our samples, but when observed they were found in extremely high numbers. This distribution pattern precluded us from obtaining reasonable estimates of abundance for these species using the diver survey techniques we employed.

We grouped some species of fish into higher order functional groups prior to analysis. These groups generally correspond to families, or subgroups of families. For example, we grouped all species of greenlings into a single family grouping of "Hexagrammidae" for purposes of the analysis. Groupings were made among species that were behaviorally and functionally similar in order to increase sample sizes and to increase our power to detect differences among sites.

3.9.2 Analysis of Data from Fjords

A visual examination of the trends in diversity and relative abundance of species was used to detect changes in these measures over time. The trends were so obvious that no statistical analyses were performed.

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3.9.3 Analysis of Data from Experiments with Sea Star Fertility

The effect of the EVOS on spawning success was examined by comparing the proportion of animals spawning at oiled *vs.* control sites using a chi-square test (Siegel, 1956). Chi-square tests were also used to examine the effect of oil on the proportion of sea stars that were parasitized, and on the effect of parasitism on spawning success. The effect of oil on gonad development was examined by comparing mean gonad indices for animals from oiled and control sites using a student's t-test (Sokal and Rohlf, 1969).

3.9.4 Gut Content Analysis

We tested for differences in the diets of young-of-year Pacific cod at oiled and control sites using a blocked analysis of variance, with oil code (oiled or control) as the main effect and sites as blocks. We examined differences in total volume, and in the proportion of the gut that was filled with the two principal food items, molluscan larvae and microcrustaceans.

3.9.5 Analysis of Sediment Data

Student's t-tests (Sokal and Rohlf, 1969) were conducted to test for differences in sediment parameters at oiled *vs.* control sites. Separate analyses were conducted for each pair of oiled and control sites, and for each of 3 sediment parameters (proportions of mud, sand, and gravel). All data were arcsin transformed prior to analyses.

3.9.6 Analysis of Hydrocarbon Data

Chemical analysis of the sediments collected yielded values for several component hydrocarbon analytes. We report the concentrations of those polycyclic aromatic hydrocarbon fractions that were present in EXXON VALDEZ crude oil (EVOS PAHs, see Appendix BB) as indicators of the contribution of oil spilled by the EXXON VALDEZ. These values also include some PAHs from non-anthropogenic sources and from sources other than the EVOS. However, these represent relative values of oil from the EXXON VALDEZ that allow us to compare concentrations of oil at oiled vs. control sites.

Statistical analyses were performed to test the hypothesis of no significant differences among oiled *vs.* control sites or among years with respect to EVOS PAH concentrations. Randomization ANOVA procedures similar to those described above for biological variates were used as the statistical test.

3.9.7 Interpretation of Statistical Results

The statistical inference for randomization test results is with respect to the sites that were sampled, and not the population of all possible sites of a similar type within Prince William Sound. The extrapolation required to apply the results of the statistical analyses to the population within the entire Sound is a deductive rather than an inductive process, and relies partly on the professional judgement using the weight of all evidence available. However, we feel that it is reasonable to deduce that in cases where there is relatively strong evidence for an effect of oil at the sites sampled (i.e. if $P<0.10$ in the randomization tests), that this is indicative of the effects of oil as expressed within that particular habitat over the entire Sound.

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4.0 RESULTS

4.1 Effects on Plants

4.1.1 Eelgrass

The dominant plant in the eelgrass habitat was eelgrass (*Zostera marina*). This is an aquatic angiosperm with true roots, leaves, and seeds. The density of eelgrass turions (uprights protruding from the substrate) was higher at the control sites relative to oiled sites in 1990 (Figure 4 and Table 2). The mean densities of turions were higher at control sites in 3 of the 4 pairs of sites sampled, and averaged over 200 m^2 at control sites compared to approximately 150 m^2 at oiled sites. Mean values for turion density in 1990 differed at P=0.08. (Appendix E)

Mean densities of flowering stalks were also higher at control sites (P=0.06, Table 2 and Figure 4). Means densities of flowers were higher at control than at oiled sites in all four pairs of sites sampled, and the average density of flowers was 7 m^{-2} at control sites compared with 3 m^{-2} at oiled sites. Most surprising was the total lack of flowers at Herring Bay. We found no flowering stalks in the quadrats sampled and more extensive swims of the eelgrass bed at this site revealed no flowers.

We found no differences among oiled and control sites with respect to biomass of eelgrass (P=0.63, Figure 4).

The average number of seed pods per flowering stalk was similar among oiled and control sites (mean = 9.2 per stalk at oiled sites and 9.8 per stalk at controls, P=0.99). As a result, the lack of flowers at oiled sites

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translated directly to a lack of seeds produced, and the differences in the density of seed pods also differed among oiled and control sites (P=0.08).

We also sampled the density of seeds in the sediments at each site, but found no difference among oiled and control sites (P=0.74). Average densities were 102 and 134 seeds m^{-2} at oiled and control sites respectively. Presumably, many of the seeds in the sediments were predominantly from seed crops produced in prior years, since most seed pods were still immature at the time of sampling in 1990. The seed density varied considerably both among and within sites. Average densities per site ranged from 1.3 m^{-2} to 472 m^{-2}, and the number of seeds collected within each 0.10 m^2 quadrat within a site often ranged from 0 to over 100. Seed densities in sediments were presumably a product of several factors including the number of seeds produced, their dispersal distance, their retention rate at a particular site, and the germination rate of seeds. As a result, the density of seeds in sediments probably did not accurately reflect the reproductive potential of plants at a given site for this or prior years.

We examined both the potential germination rate and the number of mitotic aberrations in seedlings produced from germinated seeds collected from each of 4 sites (Herring Bay, Bay of Isles, Lower Herring Bay, and Drier Bay). Seeds from Herring Bay had a higher germination rate than seeds from its paired control site (Lower Herring Bay), but the seedlings produced from these seeds also had higher rates of genetic abnormalities (Table 3). The germination rates and rates of abnormal mitoses were similar for Bay of Isles and Drier Bay. We suspect that the higher germination rates and concomitant higher rates of genetic abnormalities at Herring Bay were related to the older average age of seeds at this site. Since there were no flowers present at Herring Bay in 1990, all seeds found in sediments must have been at least 1 year old. Unpublished data from eelgrass beds in Southern California (T.A. Dean, unpublished) suggest that germination rates of newly produced seeds are lower than for seeds that have remained in the sediment for several months.

In 1991, there was significant recovery of eelgrass populations at oiled sites (Figure 4 and Table 2). There were still significantly greater densities of turions at control sites when both 1990 and 1991 data were analyzed together (P=0.03, Table 2). However, there were no significant differences among sites with respect to either the density of turions or flowers in analysis of 1991 data alone (P=0.52 and P=0.60 respectively, Table 2). In 1990, the average density of turions at oiled sites was only 38% of the control density, and by 1991, density at oiled sites was 86% of that at the controls. Similarly, the differences in turion density among oiled and control sites were substantially reduced by 1991. Turion densities at oiled sites were 76% of the control in 1990, but nearly 95% of the control density in 1991.

4.1.2 Algae

The dominant plants in bay habitats are the stipate kelps *Agarum cribrosum* and *Laminaria saccharina*. (A listing of algal species is given in Appendix F). The density, biomass and percent cover of *Laminaria* spp. (the vast majority of which was *L. saccharina*) were greater at the oiled sites relative to the control sites in the deeper stratum, and both density and percent cover were greater at oiled sites in the shallow stratum (Figure 5,

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Table 4, and Appendix G). *Laminaria* represented about 45%, on average of the total algal cover at oiled sites, but only 13% of the total cover at control sites.

The density and biomass of *Agarum* did not differ among sites (for density, P=0.40 shallow and P=0.70 deep; for biomass, P=0.16 shallow and P=0.28 deep; Appendix G). However, there were observable differences with regard to size distributions of *Agarum*. There tended to be proportionally more small plants, and proportionally fewer large plants at the oiled sites, especially in the shallower depth strata (Figure 6).

The total biomass of all algae tended to be greater at control than at oiled sites. The biomass in the shallow stratum averaged 1,132 g m^{-2} at the oiled sites and 1,766 g m^{-2} at the control sites. In the deeper stratum, mean biomass values were 387 and 529 g m^{-2} at oiled and control sites respectively. However, mean biomass did not significant significantly among oiled and control sites in either depth stratum (P=0.15 shallow, and P=0.53 deep).

Points around the islands of the Knight Island group tended to have slightly higher algal diversity than the Bays, but were still dominated by *Agarum cribrosum* and *Laminaria saccharina*. The density of *Agarum* was more than twice as great at oiled sites than at control sites (P=0.02 deep and P=0.06 shallow, Table 4 and Figure 7). This difference was largely due to the significantly higher density of small *Agarum* (<10 cm in height) at the oiled sites, especially in the deeper stratum (Figure 7 and Table 4). Also, the size distributions of *Agarum* (for plants larger than 10 cm) revealed a pattern similar to that observed in the Bays, with proportionally fewer large individuals and more smaller plants at the oiled sites, especially in the shallower depth stratum (Figure 7). There were no differences among oil and control sites with respect to density, biomass, or cover by *Laminaria* (deep, P=0.26, 0.92, and 0.87; shallow, P=0.43, 0.37, and 0.64 respectively), or biomass of all algae (deep, P=0.79; shallow P=0.22; Appendix G).

Nereocystis habitats had a canopy of *Nereocystis leutkeana* with a diverse understory consisting primarily of *Agarum cribrosum*, *Pleurophycus gardneri*, and 3 *Laminaria* species (*L. saccharina*, *L. groenlandica*, and *L. yezoensis*). *Nereocystis* density was significantly greater at the oiled sites relative to the control (P<0.01, Table 4 and Figure 8). Also, there were proportionally more small plants and fewer large plants at the oiled sites (Figure 8).

The biomass of *Agarum* was significantly greater at the oiled sites relative to the control sites within the *Nereocystis* habitat (P<0.01). Mean biomass of *Agarum* was 284 g m^{-2} at oiled sites and only 32 g m^{-2} at the control sites. However, this was largely the result of a relatively high biomass of *Agarum* at 1 of the oiled sites (554 g m^{-2} at Little Smith Island). There were no other significant differences among oiled and control sites with regard to the percent cover, density, or biomass of any of the understory algae.

The total biomass of all understory algae (all algae excluding *Nereocystis*) tended to greater at control than at oiled sites. The biomass averaged 3,699 g m^{-2} at the oiled sites and 6,240 g m^{-2} at the control sites, but did not differ significantly among oiled and control sites (P=0.16).

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We measured the growth rate of *Agarum* at 2 oiled and 2 control sites for a period of between one and two months in the summer of 1990. The growth rate of the plants was relatively low, ranging from 3.8 to 9.4 cm per 30 days, and there was no consistent pattern with respect to the differences among oiled and control sites (Table 5). At one of the two pairs of oiled and control sites examined (Herring Bay and Lower Herring Bay) growth was better at the oiled than at the control. The pattern was the opposite at the other pair (Bay of Isles and Mummy Bay).

4.2 Infaunal and Epifaunal Invertebrates

4.2.1 Sediment Grain Size

The sediments within the eelgrass habitat were composed mostly of sand and mud (Figure 9, and Appendices H and I). The grain size composition of the sediments was generally similar among pairs of oiled and control sites within a given depth stratum. There were no significant differences among oiled and control sites in 8 of 12 pairs in 1990, and in 7 of 9 pairs in 1991 with respect to any of the 3 sediment parameters examined (Table 6). Differences in sediment composition were greatest at Bay of Isles and Drier Bay. The percent mud was consistently greater, and the percent sand lower, at Bay of Isles (an oiled site). For example, the percent mud averaged 81 and 69% in the deep stratum (6-20 m) and within the eelgrass bed, respectively at Bay of Isles. Mud comprised only 31 and 42% of the substratum at these same depth strata at Drier Bay. Higher percentages of sand, (and associated lower percentages of mud) were occasionally observed at control *vs.* oiled sites.

Within the Herring Bay fjord, the sediments were comprised mostly of muds (Appendix J). The proportion of the sediments at 20 m that were mud decreased from 98% in 1990 to 43% in 1991.

4.2.2 Infauna and Small Epifauna in Stratified Sampling

Eelgrass Habitats

The benthic community in soft sediments within and adjacent to eelgrass beds consisted of a diverse assemblage of invertebrates dominated by polychaetes, bivalve and gastropod mollusks, and crustaceans (Table 1 and Appendix K). We examined differences among oiled and control sites with respect to community parameters (Shannon diversity [H'], Simpson's dominance [D], species richness, total number of taxa, total abundance, and total biomass), as well as the abundance and biomass of dominant taxa.

1990 Results - In 1990, the benthic community offshore of eelgrass beds, at depths of 6-20 m, differed among oiled and control sites (Table 7). Analyses conducted for taxa collected by suction dredge revealed that dominance was lower and total abundance was greater at control sites (Table 7, Figure 10, and Appendix L). Furthermore, five dominant taxa (sigalionid polychaetes, caecid and lepetid snails, venerid clams, and all amphipods) were more abundant and/or had greater biomass at the control sites, while only one family (maldanid polychaetes) was more abundant at the oiled sites (Figures 11, and 12, and Appendix M).

A similar pattern was observed at the shallow (3-6 m) depth stratum. Species richness was greater at control sites (Table 7, Figure 13, and Appendix M) and, five taxa (rissoid snails, venerid and tellinid clams.

phoxocephalid amphipods, and all amphipods) were significantly more abundant or had greater biomass at control sites. Only one family (opheliid polychaetes) was more abundant at oiled sites (Table 7 and Figures 14 and 15).

The pattern displayed within the eelgrass bed was very different than in the deeper portions of the habitat just offshore of the beds. Within the bed, total abundance and total biomass were significantly greater at the oiled sites (Table 7, Figure 16, and Appendix L). The greater abundance at oiled sites was largely attributable to a greater abundance of epifauna (Figure 17 and Appendix M). These included mytilid mussels, spionid and spirorbid polychaetes, and lacunid snails. These taxa, along with one other family (venerid clams), were more abundant or had greater biomass at the oiled sites (Figure 17 and Appendix M). Only two families (trochid snails and phoxocephalid amphipods) were more abundant at the control sites.

Additional analyses performed on the data collected by dropnet in the eelgrass bed revealed that onchidorid nudibranchs were more abundant and had greater biomass at oiled sites, while species richness, the abundance of syllid and nereid polychaetes, and the abundance of amphipods were greater at control sites (Table 7, Figures 18-20, and Appendices N and O).

1991 Results - Fewer differences were observed between oiled and control sites in 1991 than in 1990. There were no differences among oiled and control sites (both deep and eelgrass bed strata) with respect to any of the community parameters (Table 7, Figure 10, and Appendix L). Within the deep stratum, there were 37% more individuals at the control sites than at the oiled in 1990, and by 1991, there were 21% more individuals at the control sites. Within the eelgrass bed, there were 93% more individuals at the oiled sites in 1990, and by 1991, we found 27% more at control sites. Furthermore, there were relatively few differences with respect to the abundance and biomass of dominant taxa, especially in the deeper portion of the habitat. At the 6-20 m depth stratum, one family (orbiniid polychaetes) had greater biomass at control sites and two polychaete families (Maldanidae and Spionidae) had greater biomass or were more abundant at oiled sites (Table 7, Figure 11, and Appendix M).

Within the eelgrass bed, five of the dominant taxa (lumbrinerid and phyllodocid polychaetes, Rhynchocoela ribbon worms, and trochid and lacunid snails) were more prevalent (abundance and/or biomass) at control sites, while nereid polychaetes and venerid clams were more prevalent at oiled sites (Table 7, Figure 17, and Appendix M). The higher abundance of epifaunal taxa observed at oiled sites in 1990 had largely disappeared by 1991. While there were generally higher abundances of some epifauna in 1991 (e.g., Mytilidae, Table 7) none of these differences were significant.

We did not sample using dropnets in 1991. However, we did obtain an independent estimate of mytilid abundance by sampling individual blades of eelgrass and counting the number of mussels attached. For these samples, the abundance of *Musculus* spp. (the only mytilid present) was significantly greater at oiled sites ($P = 0.06$, Figure 21).

We also examined the size distribution of *Musculus* sp. at one oiled site (Clammy Bay, Site #25) and one control site (Puffin Bay, Site #26) twice in 1990 in order to estimate the growth rate of these mussels, and to determine if there were differences in growth between oiled and control sites. The size distributions of the mussels were similar at the oiled and control sites, and increased from a mean of approximately 3 mm in length in July to about 6 mm in August (Figure 22).

1990 and 1991 Results - In the two-way analyses, in which data from both 1990 and 1991 were compared in a single analysis, comparisons among oiled and control sites indicated that there was significantly higher diversity (H') and lower dominance at control sites relative to oiled sites at both the 6-20 m and eelgrass bed strata (Table 8 and Appendix P). There was greater total abundance and biomass at oiled sites within the eelgrass bed.

Further analyses of abundance of the dominant taxa revealed that, within the 6-20 m stratum, more taxa had significantly greater abundance or biomass at oiled sites than control sites (Table 8 and Appendix Q). Four taxa (maldanid and nephtyid polychaetes, caecid snails and mytilid mussels) had greater abundance and/or biomass at oiled sites and only two taxa (capitellid and opheliid polychaetes) had greater abundance at control sites. Within the eelgrass bed, trochid snails and all amphipods, as well as phoxocephalid amphipods, had greater abundance and/or biomass at control sites, while spirorbid and spionid polychaetes had greater abundance at oiled sites.

There were dramatic increases in abundance, and the total number of taxa at both oiled and control sites from 1990 to 1991, at both the deep stratum and within the eelgrass bed (Table 8 and Appendix P). Average abundance increased 69% within the deep stratum and 127% within the bed. Seven of the dominant taxa within this depth stratum (sigalionid, maldanid, and syllid polychaetes, rissoid and caecid snails, all amphipods, and ophiuroid brittle stars) were significantly more abundant in 1991 (Appendix P). Six individual taxa (opheliid and capitellid polychaetes, mytilid mussels, trochid snails, caprellid amphipods, and all amphipods) were more abundant in 1991 (Appendix Q). Only amphictenid polychaetes displayed significantly greater abundance in 1990 than 1991.

Laminaria/Agarum Bays

1990 Results - The benthic community, inclusive of infauna and small epifauna, within *Laminaria/Agarum* bays was dominated by polychaetes, bivalves, gastropods and crustaceans (Table 1 and Appendix K). In 1990, we noted generally higher diversity at the oiled sites (Table 9, Figure 23, and Appendix R). Within the deep (11-20 m) stratum, Shannon diversity (H') was significantly higher and Simpson dominance (D) was significantly lower at the oiled than at control sites. Two families (cirratulid polychaetes and mytilid mussels) had greater abundance or biomass at oiled sites, while four families (serpulid and spionid polychaetes, caecid snails, and tellinid clams) had greater abundance or biomass at control sites (Figure 24 and Appendix S.

Within the shallower (2-11 m) depth stratum in 1990, species richness, total biomass, and total number of taxa were significantly greater at oiled sites (Figure 25) and Appendix R. Comparisons on the dominant taxa revealed that eight families had greater abundance or biomass at oiled sites, while none were greater at the control sites. Families greater at oiled sites included five polychaetes (Amphictenidae, Polynoidae,

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Serpulidae, Lumbrineridae, and Capitellidae), two snails (Cylichnidae and Nassariidae) and one clam (Lucinidae) (Figure 26 and Appendix S).

1991 Results - Far fewer differences among oiled and control sites were noted in 1991. At the deeper (11-20 m) stratum, diversity (H') was still higher and dominance was still lower at oiled sites, but the differences were not as great as observed in 1990 (Table 9, Figure 23, and Appendix R). Comparisons for the dominant taxa from the deep stratum indicated that opheliid and lumbrinerid polychaetes had greater abundance ($p < 0.1$) in oiled sites, while serpulid polychaetes were more prevalent at control sites (Figure 24 and Appendix S).

Within the shallow, 2-11 m depth zone there were no differences with respect to community parameters between oiled and control sites in 1991 (Figure 25 and Appendix R). Furthermore, only 2 taxa (dorvilleid polychaetes and small, unidentified gastropods) were more abundant at oiled sites, compared with 8 taxa in 1990. Spionid polychaetes were more abundant at control sites in 1991 (Table 9, Figure 26, and Appendix S).

1990 and 1991 Results - Analysis of the 1990 and 1991 data in a two way (oil code by year) analysis confirmed the results of the analyses done separately by year with respect to differences among oiled and control sites. A subset of those parameters that differed in the analyses by year also differed in the analyses for both years combined. Within the deep stratum, diversity (H') and species richness were significantly greater and dominance (D) was less at the oiled sites (Table 10 and Appendix T). Four families had greater abundance or biomass at control sites, while 2 had greater abundance at oiled sites (Table 10 and Appendix U). In the shallow stratum, the abundance or biomass of 4 taxa were greater at the oiled sites.

There were dramatic increases in diversity, abundance, and biomass at both oiled and control sites from 1990 to 1991, especially within the shallow depth stratum (Table 10 and Appendix T). Total abundance for all organisms increased significantly in the deep stratum, as did the abundance or biomass of 8 of the dominant taxa (Table 10 and Appendices T and U). These included 5 polychaetes and 3 bivalves. Only one family, serpulid polychaetes, was greater in 1990. In the shallow stratum, 5 community parameters (diversity, species richness, total number of taxa, total abundance, and total biomass) as well as the abundance or biomass of 16 of the dominant taxa all increased from 1990 to 1991. The taxa included 6 polychaetes, 4 snails, 3 bivalves, 2 amphipods, and one brittle star. No taxa were more prevalent in 1990.

In addition, we noted a significant interaction between oil code and year with respect to dominance (Table 10). In the deep stratum, dominance increased at the oiled sites relative to the control, while the opposite pattern was observed in the shallow depth stratum.

4.2.3 Infauna in Fjords

During the initial visit to Herring Bay fjord in October 1989, we noted a number of dead and dying organisms on the bottom, primarily in the deeper portions (> 11 m) of the fjord (See Section 4.3.2 below). In addition to the dead organisms, the mud substrate had a patchy, cobweb-like layer of the bacterium, *Beggiatoa*. This colorless, sulfur-dependent, hemolithotrophic bacteria is associated with enrichment of labile organic matter and low dissolved oxygen (Jorgensen, 1980).

The benthic community in Herring Bay fjord in 1989 was characterized not only by the presence of dead animals, but also a moderately low Shannon diversity (H') (1.7), a moderately high Simpson dominance index (0.4), and a near absence of sensitive burrowing amphipods (Amphithoidae: 16 individuals m^{-2}). The high dominance was mainly attributed to an abundance of stress-resistant taxa such as the bivalves *Lucina tenuisculpta* (Lucinidae) and *Mysella tumida* (Montacutidae) and the polychaetes *Nephtys cornuta* (Nephtyidae) and *Polydora socialis* (Spionidae) (Table 11; Figure 27). In spite of this, the community still maintained a relatively rich assemblage of infauna (e.g., 24 taxa at the family level or higher) (Table 11).

Similar surveys at Herring Bay fjord in 1990 revealed that the diversity and number of taxa were extremely low in both spring and fall surveys (Table 11). The H' diversity was less than 0.1 and there were only 6 taxa present by the fall. Furthermore, several taxa that were abundant in the Fall of 1989, including *Lucina*, *Mysella*, and *Polydora* were absent, and the community was almost totally dominated by *Nephtys cornuta* (Table 11). Dissolved oxygen values 0.5 m above the bottom averaged 3.6 mg l^{-1} in May, but were near zero in October.

By mid August 1991, the community in Herring Bay fjord demonstrated dramatic signs of recovery. Diver surveys revealed no dead organisms, although *Beggiatoa* was still evident on the bottom. Almost all infaunal community parameters had recovered to or near levels observed in 1989

(Table 11). *Nephtys cornuta* still dominated; however, *Lucina* and *Polydora* were now present again, but in low density. Many of the more sensitive species began to appear in moderate densities. These included burrowing amphipods (132 individuals m^{-2}) of the families Ischyroceridae, Isaeidae, Dexaminidae, Phoxocephalidae, and Lysianassidae.

Surficial sediment samples from the 20 m depth contour revealed coarser substrate than previously found at this site, 43% mud in 1991 compared with over 98% mud in 1990 (Appendix H). The dissolved oxygen during the August sampling (one month earlier than 1989 and 1990 fall samplings) averaged 9.7 mg l^{-1} 0.5 m above the bottom.

Four other fjords were examined during late September 1990. These included one heavily oiled (Inner Bay of Isles), one moderately to lightly oiled site (Disk Lagoon) and two control sites (Inner Lucky Bay and Humpback Cove). All of these sites had low bottom-water dissolved oxygen values of < 1 mg l^{-1} and the sulfur-dependent bacteria, *Beggiatoa* present. All sites had relatively low diversity and high dominance, and were dominated by *Nephtys cornuta* (Table 11).

Only one of the four other fjords, Inner Lucky Bay, was visited again in August 1991. As was the case in Herring Bay fjord, there were dramatic changes that took place since the sampling in Fall of 1990. *Nephtys* abundance was drastically reduced and diversity (both H' and the total number of taxa) increased.

4.3 Large Epibenthic Invertebrates

4.3.1 Patterns of Abundance at Oiled and Control Pairs

Three species of large epibenthic invertebrates were common in eelgrass beds: The helmet crab, *Telmessus cheiragonus*; the sunflower sea star, *Pycnopodia helianthoides*; and the leather star, *Dermasterias imbricata*. (A complete listing of large epibenthic species encountered is given in Appendix Y). *Telmessus* was significantly more abundant at the control relative to oiled sites in 1990 (Figure 28, Table 12, and Appendix W). Average densities were more than 3 m^{-2} at control sites, but only 0.4 m^{-2} at oiled sites, and in each of the four site pairs, average abundance was greater at the controls. There were no significant differences for the sea star species (Table 12, Figures 29 and 30, and Appendix W).

These species, along with 3 other sea stars (*Evasterias troschelii*, *Orthasterias koehleri*, and *Henricia leviuscula*) were abundant on hard substrate in bays, on points, and in *Nereocystis* habitats. In 1990, in the deeper stratum of the bays and in both shallow and deep strata on the points, *Telmessus* abundance was significantly greater at the control sites than at the oiled sites (Table 12, Figure 28, and Appendix W). Average abundances were 1.1 m^{-2} at control sites and less than 0.2 m^{-2} at the oiled sites. In addition, the 2 sea star species were generally more abundant at control sites. *Dermasterias* density was significantly greater at controls in the shallower stratum of both bay and point habitats, and *Evasterias* was more abundant at controls in the shallow stratum at points and in *Nereocystis* habitats (Figure 31). *Pycnopodia* was significantly more abundant at oiled sites in the shallow depth stratum in bays (Figure 30), and was generally more abundant at oiled sites in other habitats, but not

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significantly so. None of the other species showed significant differences at any of the other sites (Appendix W).

Unlike most other components of the PWS subtidal system, many of the large epibenthic species (*Telmessus*, *Dermasterias*, and *Pycnopodia*) were common to most or all habitats. Therefore, we were able to examine effects of oiling on these species over all habitats combined. It is clear from these results that the densities of *Telmessus* and *Dermasterias* were lower at oiled sites than at control sites in 1990 ($P<0.01$ and $P=0.03$ respectively, Table 12). Of the 12 pairs of sites in which *Telmessus* was present in at least one of the sites in the pair, 11 of these had higher *Telmessus* abundance at the control site, and the overall average abundance of *Telmessus* was about 4 times greater at the controls (Figure 28 and Appendix W). *Dermasterias* abundance was greater at the control in 10 and greater at the oiled in 3 pairs of sites, and average abundance was almost twice as great at control sites (Figure 29 and Appendix W).

In the two habitats sampled in 1991 (eelgrass beds and shallow portions of bays) recovery of populations of *Telmessus* was indicated by a lack of significant differences among oiled and control sites (Table 12, Figure 32, and Appendix W), and by a significant oilcode by year interaction within the eelgrass bed (Table 13). However, when both 1990 and 1991 data were considered together, there were still indications of a possible effect of oil, as mean densities were significantly greater in control than in oiled sites (Table 13, Figure 33, and Appendix Y.) $P<0.01$ in eelgrass and $P<0.10$ in bays). Furthermore, there was a significant decrease in the density of *Telmessus* at bay sites between 1990 and 1991.

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There was also a continuing effect of oil noted for populations of *Dermasterias* in 1991. The population density of *Dermasterias* was greater at control than at oiled sites in eelgrass habitats in 1991 (Table 12, Figure 34, and Appendix W), and when both years' data were considered together, there was a significant effect of oil in both habitats sampled (P=0.01 for eelgrass and P=0.03 for bays, Figure 35 and Appendix X). Only a significant increase in density between 1990 and 1991 in eelgrass habitats suggests possible recovery.

There was a general decline in the abundance of adult *Pycnopodia* between 1990 and 1991, and this decline was significant within *Laminaria/Agarum* bay habitats (Figure 36 and Appendix X). In the eelgrass habitat, there were no differences among oiled and control sites in 1990 (Table 12, Figure 30, and Appendix W), but in 1991, there were significantly more adult *Pycnopodia* at the control sites (Table 12, Figure 37, and Appendix W). Furthermore, density of adult sunstars was greater at oiled sites in shallow bay habitats in 1990 (Table 12 and Figure 30), but did not differ significantly among oiled and control sites in 1991 (Table 12 and Figure 37).

One surprising result of the 1991 survey was the extremely large number of juvenile (young-of-year) *Pycnopodia* present. There were highly significant (P<0.01) increases in the density of juvenile *Pycnopodia* between 1990 and 1991 in both eelgrass and bay habitats (Figure 38 and Appendix X). The density of these newly settled individuals was greater at oiled sites in the bay habitats, and tended to be higher, albeit not significantly so (P=0.12), at oiled sites in eelgrass habitats Figure 39 and Appendix W).

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4.3.2 Large Epifauna in Fjords

In 1989, we observed numerous dead animals in deeper portions (> 11 m) of the Herring Bay fjord. In one area surveyed (approximately 70 m^2) at Herring Bay, we observed over 40 dead animals laying on the bottom including 23 polychaete worms and 11 *Pycnopodia*. Also encountered were dead fish (cod), shrimp, squid, naticid snails, and brittle stars. These were in varying states of decay and were not enumerated.

Similar surveys at this site in 1990 and 1991 revealed fewer dead animals. In video transect surveys conducted in the spring 1990 we saw only one dead *Pycnopodia* over a 90 m^2 area. In fall 1990 only one dead cod and 3 dead worms were observed over an equal 90 m^2 survey area. More extensive visual searches in fall 1990 revealed some dead fish, but there were no concentrated pockets of dead organisms as observed in 1989.

Similar surveys and searches at 4 other fjords in Prince William Sound in 1990 and 1991 found some dead organisms in both oiled and control sites. These organisms included one Pacific herring, and several unidentified worms. However, none of these surveys found the concentration of dead organisms that we observed in Herring Bay Fjord in 1989.

4.3.3 Reproductive success in *Dermasterias*

Experiments conducted on *Dermasterias* revealed no significant differences among animals collected from oiled and control sites with respect to gonad index or spawning success. The mean gonad indices were 6.79 for the animals collected from oiled sites and 7.15 for the animals from control sites (P=0.75, t-test). Spawning success was measured in two experiments.

In the first, 75% of the females from both oiled and control sites spawned, in the second, 67% of the females from oiled sites spawned while 72% of the females from control sites spawned (P=0.66, chi-square).

One surprising result from our studies of *Dermasterias* was that nearly 30% of the population of animals collected in 1990 were parasitized by an internal barnacle parasite, *Dendrogaster* sp. This barnacle invaded the gonad tissue of the sea stars and parasitized stars had a significantly lower rate of spawning success (Table 14). There was no apparent difference in the infection rate among animals collected from oiled *vs.* control sites in 1990 (Table 15). However, we did note a significant decline in the infection rate, from 29% in 1990 to 10% in 1991 (Table 16).

4.4 Fishes

Over fifteen species of fish were found in eelgrass habitat in 1990. Pacific cod (especially young-of-year) were by far the most abundant species, comprising over 90% of the total number of fishes. A variety of demersal species made up the remainder of the fish community within this habitat (Appendix Y).

In 1990, the abundance of both adult and young-of-year cod was greater at oiled than at control sites (P<0.01 for both, Table 17, Figure 40, and Appendix Z). There was an average of 4 times as many young-of-year cod at oiled sites as controls, and adults were about 5 times as abundant at the oiled sites. The abundance of all other fishes in the eelgrass beds was very similar at oiled and control sites, and did not differ significantly.

The guts of young-of-year Pacific cod were examined to determine their diets. Diets were comprised primarily of molluscan larvae and small crustaceans (harpacticoid copepods, calanoid copepods, and amphipods). The diets of fish differed at the oiled and control sites. Fish at the oiled sites generally had fuller guts (Figure 41). Young-of-year cod from oiled sites also had generally higher proportions of molluscan larvae, although differences among all pairs of sites did not differ significantly (Figure 41). Young-of-year cod at the control sites had more crustaceans in their guts.

The fish community in *Laminaria/Agarum* habitats in bays and on points was dominated by Arctic shanny and a mixed group of sculpins. For the purposes of our analysis, we have divided the sculpins into 2 functional groups: smaller sculpin species and larger sculpin species. Other fishes found within these sites included various greenlings and ronquils. The point habitats tended to have somewhat greater abundances and a higher diversity of fishes than the bays, but the fish assemblages in these two habitats were otherwise similar.

Within the bay habitat in 1990, only the abundance of greenlings (Hexagrammidae) differed significantly at oiled *vs*. control sites (Table 17, Figure 42 and Appendix Z). The greenlings were more abundant at oiled sites.

In the point habitats, a relatively diverse group of fishes including small sculpins and searchers (Bathymasteridae) (in shallow waters); and greenlings, ronquils, and young-of-year Arctic shanny (in deeper waters) were found in greater abundance at oiled sites (Table 17 and Appendix Z). Juvenile cod were more abundant at control sites in both the deep and shallow strata (Table 17). However, these differences were due to one large school of fish noted at one of the control sites, and may not be representative of the more general pattern for this species. Pholids were also noted to be more abundant at deeper control sites.

Because of the similarity of the fish assemblages in bay and point habitats, we were also able to test for differences among control and oiled sites within the combined depths and habitats. In these analyses, both greenlings (Hexagrammidae, Figure 42) and small sculpins (Small Cottidae, Figure 43) were found to be more abundant at oiled sites (P=0.03 and P=0.07 respectively; Table 17 and Appendix Z).

The fish community within the *Nereocystis* habitat was dominated by schooling fishes (eg. herring and sandlance). The schools were uncommon, but there were large numbers of fish within each school. Because of this high spatial and temporal variability, we were unable to adequately sample densities of these schooling fish and have not analyzed these data statistically. Other species of non-schooling fish were found in relatively low density, and the only significant difference observed was a greater abundance of greenlings (Hexagrammidae) at oiled sites (P=0.08 Appendix Z).

Only a limited number of fish species were counted in our 1991 survey. These included cod (both young-of-year and adults) in both eelgrass and shallow bay habitats, and Arctic shanny and small sculpins in shallow bay habitats. Within the eelgrass habitat, there were significantly greater numbers of young-of-year cod at the oiled sites, as in 1990 (Table 17, Figure 40 and Appendix Z). This trend is further emphasized in the two-way analyses for effects of oiling and year, that also indicated that there

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were significantly more juvenile cod at oiled sites (Table 18, Figure 44 and Appendix Z). In addition, the density of both young-of-year cod and adult cod increased significantly from 1990 to 1991 ($P < 0.10$ and $P < 0.05$ respectively, Table 18 and Appendix Z).

Within the bay habitats in 1991, there were significantly greater numbers of adult Arctic shanny and small sculpins at control sites relative to oiled sites ($P=0.06$ and $P=0.02$ respectively, Table 17 and Appendix Z). This is in contrast to 1990, when no significant differences were observed for these taxa. In the two-way analyses for effects of oiling and year, there was a significant decrease in the density of adult Arctic shanny from 1990 to 1991, but there were no significant differences among oiled and control sites (Table 18, Figure 44 and Appendix AA).

4.5 Results from Hydrocarbon Analyses

1990 - Eelgrass habitat

Three sediment samples were collected from each depth stratum within each habitat for the evaluation of hydrocarbon levels. However, only samples collected from the eelgrass habitat, the *Laminaria/Agarum* bay habitat, and one silled fjord site were analyzed in total. Only one or two samples were analyzed for other habitats (*Laminaria/Agarum* points, *Nereocystis*, and other fjords). We rely on the mean concentration of EXXON VALDEZ PAHs from these samples to indicate the degree of oiling. Analytes that comprise the EXXON VALDEZ PAHs are given in Appendix BB and mean concentrations are given in Appendix CC.

In shallower portions of the eelgrass habitat, average concentrations of EXXON VALDEZ PAHs were higher in oiled than control sites (Table 19 and

Figure 45). The average concentration was more than twice as high at oiled than at control sites within the eelgrass bed, and about 1.6 times higher at oiled sites in the shallow stratum. Differences were significant ($P=0.04$) in the eelgrass bed, but not in the shallow stratum ($P=0.53$) where variability among sites was greater.

Somewhat surprising was the relatively high concentration of oil present at some control sites that were adjacent to unoiled shorelines, especially within the deeper stratum of the eelgrass habitat. Three of four control sites had oil concentrations higher than 500 ng g^{-1} sediment. The average concentration of EXXON VALDEZ PAHs was similar ($P = 0.92$) between control (546 ng g^{-1}) and oiled sites (490 ng g^{-1}) (Appendix CC).

1990 - *Laminaria/Agarum* bay habitat

At the sites sampled in *Laminaria/Agarum* bay habitats, there were also striking differences among oiled and control sites with respect to concentrations of oil. Oil concentrations were nearly three times higher at oiled than control sites in the shallow portions of the habitat, and were nearly five times higher at oiled than control sites in the deeper stratum. Statistically significant differences ($P < 0.1$) were noted in both strata (Table 19 and Figure 46).

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1990 - Point and *Nereocystis* habitats

There are very few hydrocarbon data available for point or *Nereocystis* habitats (Figure 46; Appendix CC) and no statistical analyses were performed for these habitats. The general trend of somewhat higher levels of oil at oiled sites, with occasionally high levels of oil at some control sites, was also evident from these data.

1991 - Eelgrass habitat

Sediment samples collected in bay habitats in 1991 have not been analyzed for hydrocarbon levels. As a result, we present only the data from eelgrass habitats for this year.

EXXON VALDEZ PAH concentrations were lower in both oil and control sites in 1991 than in 1990 (Figure 45 and Appendix CC). Comparisons between years indicate that there was a significant ($P<0.01$) decline in oil concentrations in both depth strata examined (Table 19). Mean concentrations of PAHs were higher at the oiled sites within both strata sampled, but differences were statistically significant in only the deeper stratum (Figure 45 and Table 19).

Differences among depths

There were few differences in the concentrations of EXXON VALDEZ PAHs among depths within the eelgrass habitat. The only exception was at control sites in 1990, where concentrations were 2.5 times higher within the deeper stratum than in the eelgrass bed ($P<0.10$).

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In contrast, oil concentrations were significantly greater in the shallow stratum for both oiled and control sites within the *Laminaria/Agarum* bay habitat in 1990. Mean concentrations were about 3 times greater at the shallower depth at oiled sites ($P<0.10$), and were more than 5 times higher in shallower portions of the control sites ($P<0.01$).

1989, 1990, and 1991 data from fjords

Concentrations of EXXON VALDEZ PAHs in subtidal sediments from a heavily oiled fjord within Herring Bay averaged 1185 ng g^{-1} sediment in 1989 (Figure 47). In 1990, these levels dropped to about 1,000 ng g^{-1} sediment, and in 1991, PAHs were reduced to near background levels of 41 ng g^{-1} sediment.

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5.0 DISCUSSION

5.1 Interpretation of Statistical Tests and the Assessment of Injury

In assessing the injury to subtidal populations of plants and animals caused by the EVOS, we rely primarily on the comparison of population parameters in oiled *vs.* control sites in 1990 and 1991. There are few pre-spill data available, and we were unable to make pre- vs. post- spill comparisons except in a very broad sense. Also, we have not attempted to link changes in biological variates with hydrocarbon concentrations in any statistical sense. Given the high degree of spatial variability in both hydrocarbon concentrations and biological variates, the relatively high degree of error in the measurement of hydrocarbon concentrations and biological variates, and the relatively small sample sizes for both, such an analysis would probably not be very enlightening.

Our comparison of oiled and control sites in 1990 and 1991 suggest that the EVOS resulted in changes to at least some species within each of the components (plants, infaunal invertebrate, epibenthic invertebrate and fish) of the shallow subtidal ecosystem in Prince William Sound. The following provides a brief discussion of the differences between pre- and post-spill surveys as well as a summary of the statistical differences observed between oiled and control sites in 1990 and 1991, and our interpretation of the statistical tests with respect to the effects of the EVOS.

As with all assessments of the effects of a disturbance on ecological systems, the final decision as to whether an impact has occurred generally rests on "weight of evidence". When one examines a host of biological

5.3 Effects of the EVOS Based on Comparisons of Oiled and Control Sites

5.3.1 Effects on Plants

Eelgrass appears to have been adversely affected by the EVOS. Densities were higher at the control site in three of the four site pairs, and the mean density of turions was roughly 33% greater at control sites relative to oiled sites. These differences were significant at P=0.06. Also, the density of flowering plants was higher at the control sites. All control sites had mean densities of flowering plants that were greater than their paired control, and the overall differences were significant at P=0.08.

While the statistical tests of the effects of oil on eelgrass were only marginally significant, the argument for an effect, with respect to flowering, is strongly supported by similar evidence presented in a second, independent study. An evaluation of the effects of the EVOS on eelgrass in Prince William Sound by Teas et al. (1991) also demonstrated that there was a reduced density of flowering stalks of eelgrass at oiled sites. However, Teas et al. (1991) noted no differences with respect to the density of plants.

We suspect that the reduction in the density of turions at oiled sites was probably the result of some physical disturbance (e.g. boat traffic) while the inhibition of flowering may have been a result of physiological stress caused by the toxic effects of oil. Previous laboratory studies suggest that relatively low levels of kerosene and toluene can reduce rates of carbon uptake by *Zostera* (McRoy and Williams, 1977). However, these same authors suggest that eelgrass is less sensitive than associated animals to the effects of oil. Studies of effects of the AMOCO CADIZ and other previous oil spills also suggest there was little impact of oil on population density of *Zostera marina* (den Hartog and Jacobs, 1980) or other sea grasses (reviewed in Cairns and Buikema, 1984).

This apparent injury to the eelgrass population was short lived. There was an almost complete recovery of eelgrass by 1991, as indicated by a lack of significant differences in both turion and flower density among oiled and control sites in that year.

In each of the three habitats on hard substrate (*Nereocystis*, *Laminaria/Agarum* in bays, and *Laminaria/Agarum* on points) we observed differences in the size distribution of the dominant alga at oiled and control sites. In all cases, there were proportionally more small algae (*Nereocystis* and *Agarum* in the *Nereocystis* habitat and *Agarum* at the other two habitats) at the oiled sites. In addition, we observed higher mean densities of one of the dominant algal species at oiled sites in each habitat: *Nereocystis* in the *Nereocystis* habitat, *Laminaria saccharina* in the bays, and small *Agarum cribrosum* at points.

The differences in size distribution may have been the result of slower growth of plants at oiled sites, or loss of larger plants coupled with recent recruitment at the oiled sites. The existing growth information indicates that there was no consistent difference in growth rate at oiled and control sites. However, we measured growth at only 2 pairs of sites, and only during a time of year when growth is expected to be slow (Vadas, 1968).

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While we can not rule out the possibility that differences in growth may have caused differences in size distribution, we feel that it is more likely that the differences in size distribution were the result of differences in survival and recruitment. We suspect that larger plants were lost at the oiled sites as a result of the spill, that this loss made space available on the bottom, and that this space was quickly colonized by new algal recruits in spring 1990.

We do not know the mechanism that may have been responsible for the presumed loss of older algae at oiled sites, but suspect that it was the result of cleanup activities rather than toxicity of oil. Previous laboratory studies indicate that oil may adversely affect reproduction in some brown algae (Steele, 1977) and injuries to intertidal populations of algae have been demonstrated in previous spills (e.g. Smith, 1968; Thomas, 1973, 1978; Floc'h and Diouris, 1980, 1981; Rolan and Gallagher, 1991). However, subtidal populations of algae appear to have been relatively unaffected in previous spills (North et al., 1964; Foster et al., 1971). We suspect that increased boating activity and the associated losses caused by the pulling of anchors may have been a primary cause of loss of algae.

5.3.2 Effects on Infaunal and Smaller Epifaunal Invertebrates

Effects in the Eelgrass Habitat

The response of the benthos at oiled eelgrass sites differed according to depth. Outside the eelgrass bed, total abundance and species richness were greater and species dominance was lower at control sites. In addition, the abundance of dominant taxa tended to be greater at the control sites. In the deeper portions of the habitat, 6 taxa were more abundant at control sites while only 1 was more abundant at oiled sites. Similarly, at the

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shallower sites just offshore of the eelgrass bed, 5 taxa were more abundant at controls while 1 was more abundant at oiled sites.

The infaunal community outside of the eelgrass beds in Prince William Sound in 1990 was characteristic of disturbed communities that typically have lower species diversity or richness and higher species dominance (Pielou, 1974; Pearson and Rosenberg, 1978). The results are what one would expect in the case of severe petroleum hydrocarbon contamination in subtidal soft bottom communities. Results from previous oil spills indicate that benthic communities generally represent good *in situ* monitors for measuring effects of oil fluxing to the bottom, and that moderate amounts of oil in sediments cause impacts comparable to those we observed. For example, following the AMOCO CADIZ oil spill on the Brittany coast of France, Glémarec and Hussenot (1981) noted a variety of changes in the abundance and structure of the fauna within nearshore benthic communities. Similar observations were made by Sanders et al. (1980) following the Buzzard's Bay spill, and by Hyland et al. (1989) following the sinking of a tanker off the coast of California.

The greater abundance of amphipods at control sites in 1990, at both depths outside the eelgrass bed, was perhaps the greatest single indicator of injury caused by oiling. Amphipods are important prey to a variety of sea birds and fishes (see Feder and Jewett, 1987 for review). Benthic amphipods are notoriously sensitive to petroleum hydrocarbons (e.g., Busdosh and Atlas, 1977; Lee et al., 1977; Percy, 1976, 1977; Lee and Nicol, 1978a,b), and massive declines in benthic amphipods were observed following the AMOCO CADIZ oil spill (Cabioch et al., 1978; Chassé, 1978; den Hartog and Jacobs, 1980; Dauvin, 1982).

Among the other taxa found to be more abundant at control sites, at both depths outside the eelgrass bed, were the families, Veneridae and Tellinidae. The principal members of these families are the suspension- or deposit-feeding clams, *Saxidomus*, *Protothaca*, *Macoma*, and *Tellina*. Little information is available on the response of these bivalves to petroleum. However, Chassé (1978) observed from the AMOCO CADIZ oil spill that subtidal populations of burrowing macrofauna, like bivalves, were more severely damaged than intertidal populations. Studies (*in vitro and in situ*) have shown that intertidal *Macoma balthica* were adversely affected by various exposures of Prudhoe Bay crude oil (Feder, et al, 1979; Shaw, et al, 1976; Taylor and Karinen, 1977; Stekoll, et al, 1980). The implication in this study is that subtidal *Macoma*, and perhaps other clams, were adversely affected by petroleum from the EVOS.

Two taxa that increased at the oiled sites, maldanids and opheliids, are representative of species that are typically characterized as either opportunistic or stress-tolerant. Spies and DesMarais (1983) presented data that showed that petroleum was utilized by the maldanid *Praxillella* as a carbon source in a natural petroleum seep in the Santa Barbara Channel. They suggested the petroleum was used in sufficient amounts to account for greater density of organisms observed in the seep than in a similar nonseep environment. Intertidal representatives of the family Opheliidae were observed to be very resistant to oil from the AMOCO CADIZ oil spill (Chassé, 1978). This family was mainly represented in the Prince William Sound eelgrass habitat by the subsurface deposit feeder, *Armandia brevis*.

Within the eelgrass bed in 1990, we also observed a greater abundance within control sites for 4 of the dominant taxa, as well as for amphipods.

However, overall abundance and biomass were greater at the oiled sites. This was primarily attributable to the greater abundance of small epifaunal species at the oiled sites. These included suspension feeding spirorbid polychaetes and mytilid mussels (*Musculus* spp.), and small lacunid snails that primarily live attached to eelgrass blades.

We do not know why there was an increase in epifaunal species at oiled sites. One hypothesis is that increased abundances of these epifauna resulted from decreased abundances of predators at the oiled sites. The helmet crab, *Telmessus*, and the leather star, *Dermasterias*, were found in greater abundance at control than at oiled sites. These are known predators of *Musculus* (personal observations) and are likely predators of other epifauna on eelgrass. In a similar vein, O'Clair and Rice (1985) predicted that an oil spill in Prince William Sound might lead to the reduction in the abundance of another sea star species, *Evasterias troschelii*, and that this in turn may lead to increased abundance of its principal prey, *Mytilus edulis*.

Another explanation for the increase in epifauna at oiled sites is that oiled sites tend to be areas where prevailing currents and winds concentrate both oil and larvae, leading to higher abundances of newly settled epifauna at the oiled sites. Alternatively, epifauna may have been more abundant at oiled sites as the result of increased food availability from degrading oil or from chemical fertilizers being sprayed on adjacent beaches for the purpose of bioremediation.

The other taxa that were more abundant at oiled sites within the eelgrass bed included onchidorid nudibranchs and surface deposit-feeding spionid

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polychaetes. Both of these taxa can be classified as classic secondary opportunists that thrive in polluted regions. Beyers (1968) found nudibranchs to thrive in polluted areas of low oxygen in Oslofjord, Norway. Spionids have been observed in numerous investigations (e.g., Sanders et al., 1972; Grassle and Grassle, 1974; Pearson and Rosenberg, 1978; Gray, 1979) as being abundant in organically enriched environments. A member of this family, *Polydora*, flourished in shallow waters immediately following the spill of #2 fuel oil (Sanders et al., 1980). There were at least eight species of spionids, including the genus *Polydora*, that dominated the oiled eelgrass sites in Prince William Sound.

Effects in the *Laminaria/Agarum* Bay Habitat

The effects of oil were much less pronounced in the *Laminaria/Agarum* bay habitats than in the eelgrass habitat. Within the deeper portion of this habitat in 1990, there were some adverse impacts on the benthic community, as indicated by the greater abundance or biomass for 4 taxa at control sites. However, diversity, as well as the abundance and biomass of 2 of the dominant species, were greater at oiled sites. There was even less evidence of adverse impacts within the shallow portion of the habitat, as the only differences observed were greater abundances of eight taxa at oiled sites.

We suspect that the differences in the effects of oil within eelgrass and bay habitats largely result from differences in sediment composition and wave action within the two habitats. Unlike the eelgrass beds, the *Laminaria/Agarum* bay habitat is dominated by hard substrata, with only small pockets of rather shallow veneers of soft sediments intermixed.

These sediments are often resuspended, and less likely to accumulate and maintain as high a level of hydrocarbons as observed in eelgrass beds. This is suggested by the generally lower concentrations of oil noted at *Laminaria/Agarum* bay sites relative to eelgrass sites (Figures 44 and 45).

Recovery in Eelgrass and *Laminaria/Agarum* Bay Habitats

By 1991, approximately 27 months after the EVOS, there were strong indications of recovery of the benthic community in the eelgrass habitat. Within each of the depth strata sampled in 1991, community parameters (H', D, total abundance, etc.) as well as the abundance of amphipods did not differ at control and oiled sites. In addition, there were significant increases in the total abundance of organisms, the number of taxa, and the abundance of a number of dominant taxa between 1990 and 1991, at both oiled and control sites. This suggests that populations throughout the Sound may have been adversely affected by the EVOS and were recovering in 1991. However, we noted a number of taxa, especially within the eelgrass bed, that were still more abundant at control sites in 1991, suggesting that recovery was not complete.

Recovery was also evident in the *Laminaria/Agarum* Bay habitat. There were very few significant differences in either community parameters or in the abundance or biomass of dominant taxa in 1991, in either the deep or shallow depth strata. Furthermore, there were very marked increases in abundance in this habitat from 1990 to 1991. In the deeper stratum, the abundance or biomass of 8 taxa increased significantly between 1990 and 1991, and a total of 16 taxa had significant increases in the shallow stratum. As in the eelgrass habitat, this suggest recovery from possible Sound-wide injury as a result of the spill.

This recovery process is fairly typical of what has been observed in benthic infaunal communities following other oil spills. The general sequence of events after a catastrophic oil spill is 1) a toxic effect with considerable mortality; 2) an organically enriched period in which opportunistic taxa become extremely abundant; and 3) a period in which opportunists decrease in importance and fauna begin to return to conditions similar to adjacent unoiled areas and/or to a community characteristic of relatively undisturbed conditions (Pearson and Rosenberg, 1978; Glémarec and Hily, 1981; Glémarec and Hussenot, 1981, 1982; Spies et al., 1988). It is difficult to categorize any of the shallow subtidal habitats we studied in Prince William Sound as simply resembling one or more of the successional stages noted above. While the community as a whole may not reflect a particular stage, a disruptive response and later recovery was evident in some faunal groups, e.g., amphipods.

Effects in Fjords

The infaunal community in Herring Bay fjord underwent marked changes between 1989 and 1991. In 1989, there was a relatively rich assemblage of infauna, including amphipods, snails, small bivalves, and several polychaete species. However, the community was obviously stressed, as indicated by the many dead or dying organisms. By 1990, the community was extremely impoverished, and was almost totally dominated by a single genus of polychaete, *Nephtys cornuta*. By 1991, the community had recovered, as the diversity of taxa and number of organisms increased.

The almost total collapse of the benthic community in the Herring Bay fjord between 1989 and 1990 was probably at least in part the result of the effects of oiling. However, it is difficult to distinguish the effects of oil from naturally occurring disturbances that result from seasonal oxygen depletion. Fjords with shallow sills, similar to the Herring Bay fjord, typically have reduced benthic assemblages because the sills prevent or reduce exchange with water outside the fjord. During late summer, stratification in temperature and/or salinity causes poor exchange of bottom and surface waters, and results in the depletion of oxygen near the bottom. A seasonal cycle of oxygen depletion and associated declines in benthic fauna have been observed in Scandinavian and Scottish fjords (e.g., Jorgenson, 1980; Rosenberg, 1980; also see review by Pearson, 1980) and documented as the "August Effect" in New England estuaries (Rhoads and Germano, 1982).

In 1990, our hope was that we could help distinguish naturally occurring dysoxic events from the effects of oil by sampling in Herring Bay as well as in unoiled "control" fjords. Several sites were sampled that were presumably unoiled, and this sampling revealed the occurrence of seasonal oxygen depletion and impoverished benthic communities in other nearby fjords. However, examination of hydrocarbon data suggests that our "control" sites in fact had relatively high concentrations of oil. The lack of additional controls makes it impossible to clearly distinguish the effects of oil from natural events that may vary from one year to the next, such as plankton blooms; however, the decline in benthic communities in Herring Bay as well as other fjords in 1990, followed by a recovery in

1991, suggests that oil <u>may</u> have had an impact on these fjordic benthic communities.

Seasonal hypoxia ($O_2 < 2$ mg/l^{-1}) or anoxic (O_2= 0 mg/l^{-1}) conditions often result in dominance by stress-tolerant taxa (Jorgensen, 1980; Rosenberg, 1980) such as observed in the fjordic portion of Herring Bay and in the other fjords in the Sound. *Lucina*, *Polydora*, and *Nephtys* that were common in fjords in the Sound are often associated with stressed environments. However, changes with respect to the relative abundance of these species in Herring Bay in 1989 through 1990 suggest possible impacts of oiling. For example, *Lucina* and other lucinids appear to be able to live where conditions are extreme and oxygen and food are limited (Yonge and Thompson, 1976). *Lucina* is of the same order as the stress`tolerant *Thyasira* genus, and several species of *Thyasira* (*T. flexuosa*, *T. sarsi*, *T. mtokanagai*, *T. miyadii*) have been reported from organically enriched and polluted substrates (see Table 1 in Pearson and Rosenberg, 1978). Apparently, the *Lucina* population that dominated at Herring Bay fjord in 1989 (61% of faunal abundance) was well established in this impoverished fjordic environment, since the individuals sampled were mainly older than one year; many were more than three years old. The absence of live *Lucina* and the presence of empty shells in 1990 provides evidence of mortality due to hydrocarbon toxicity or to prolonged oxygen depravation.

Dominance by *Nephtys cornuta* in 1990 also suggests possible impacts by oil. Lizaraga-Partida (1974) reported *Nephtys cornuta* in semi-polluted substrates in Ensenada Bay, Mexico, in areas enriched with organic material derived from sewage`fish waste. Pearson and Rosenberg (1978) give several other examples of *Nephtys* (*N. incisa*, *N. hombergi*, *N. ciliata*, *N.*

longosetosa, and N. faneiscona) appearing in organically enriched and polluted areas, often low in dissolved oxygen. Busdosh (1978) found *Nephtys* only in association with oiled substrates; it alone preferred oiled to clean sediment. While *Nephtys* is primarily a predator, it also can utilize the high organic loads associated with the decay of dead organisms through deposit feeding. The dominance of *Nephtys cornuta* in Herring Bay fjord in 1990 was presumably the result of the additional food from organisms that died there, the decrease in the number of competitors and predators, and the tolerance (or perhaps preference for) oiled substrates.

There were few amphipods present in the Herring Bay fjord in 1989, and no amphipods were present in 1990. However, by 1991 amphipods began to reappear in relatively high densities. Amphipods are known to be extremely sensitive to oil, and we suspect that their decline was caused by high hydrocarbon concentrations. Presumably the decrease of toxic fractions coupled with the oxic conditions observed in 1991 created an environment more conducive to recovery of amphipod populations.

5.3.3 Effects on Larger Epibenthic Invertebrates

We observed reduced abundances of two numerically dominant epibenthic invertebrates at the oiled sites; the helmet crab, *Telmessus cheiragonus* and the leather star, *Dermasterias imbricata*. *Telmessus* was consistently found in lower abundance at oiled sites in each of the 3 habitats in which it occurred (eelgrass, *Laminaria/Agarum* bays, and *Laminaria/Agarum* points). There is strong evidence from prior oil spill studies suggesting that arthropods are especially sensitive to the toxic effects of oil (Capuzzo,

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1987) and we suspect that at least some *Telmessus* in oiled sites were either killed or fled from oiled areas.

There was some evidence of moderate recovery of *Telmessus* populations in 1991, as no significant differences were noted at oiled *vs*. control sites. However, the lack of differences resulted largely from a decline in abundance at the control sites, and may have been the result of emigration from control sites to previously oiled areas. In fact, there was little evidence of recruitment for these crabs, and a significant decline in abundance was noted from 1990 to 1991 in shallow bay habitats. If in fact the EVOS caused the death of crabs, then true recovery can only be accomplished through recruitment.

Dermasterias abundance was also lower at oiled sites, especially in shallower portions of the habitats. Unlike many of the species that are common in the subtidal, *Dermasterias* also can be found intertidally. These sea stars migrate into the lower intertidal areas as the tide rises, become exposed on steeper rock faces as the tide falls, and then release themselves from the rocks falling into deeper water as the tide recedes further. As a result of this behavior, *Dermasterias* were probably exposed to large amounts of oil as well as to harm from cleanup activities (especially high pressure hot water cleaning). We suspect that the lower population density of *Dermasterias* at oiled sites was the result of mortality caused by either oil toxicity or cleanup activities.

A surprising result of our studies with *Dermasterias* was the extremely high incidence of internal barnacle parasites. In 1990, approximately 30% of the *Dermasterias* population was infected with this parasite that impairs reproductive effort by castrating its host. In summer 1991, the rate of infection by the parasite had declined markedly. However, there were no differences in the incidence of parasitism among oiled and control sites, and do not know if the high rate of parasitism in 1990 was the result of the EVOS.

5.3.4 Effects on Fishes

Increased abundances in young-of-year fishes were noted at oiled sites in both eelgrass and in *Laminaria/Agarum* habitats. In the eelgrass habitat, we noted a greater abundance of young-of-year Pacific cod, and in the *Laminaria/Agarum* habitats, we noted greater abundances of juvenile Arctic shanny at the oiled sites. Ebeling et al. (1972) also found greater numbers of larval and young-of-year fishes in oiled sites relative to control sites in the Santa Barbara Channel immediately following the very large oil spill there in 1969.

The increase in the abundance of Pacific cod at oiled sites within the eelgrass habitat was likely a direct result of the increase in mussels that we observed at those sites. The fish at the oiled sites had fuller guts with proportionally more mollusk larvae than those at the control sites.

Gut content analyses of young-of-year Pacific cod in the eelgrass habitat also indicated that fewer crustaceans were being taken as food in the oiled sites relative to the controls. The lack of crustaceans in the guts of fish from oiled sites may have been because there were fewer crustaceans at the oiled sites. Evidence from dredge and dropnet samples in the eelgrass sites suggest that amphipods were less abundant at the oiled sites, and

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these as well as other crustaceans may have been negatively impacted by oil.

The general pattern of higher abundances of fish at oiled sites was also observed in other habitats. We do not know the cause for this, but suspect that it too may be the result of increased availability of food.

5.4 Hydrocarbon Levels and Their Relation to Observed Biological Results

Hydrocarbon data indicate that sites that we have classified as oiled were in fact oiled, and that there were generally higher levels of oiling at oiled *vs.* control sites. However, the data also suggest that oil was present in many (if not all) of our control sites. This means that differences in biological variates that we have observed between oiled and control sites are possibly conservative estimates of the effects of oil. It appears that the effects of oil may not have been restricted to our "oiled" sites, but may have occurred to a lesser degree throughout the Sound. This is supported by the correlation of reduced levels of oil in 1991 and the increase in abundance of many taxa, especially among the benthic infauna. However, sound-wide increases in abundance from 1990 to 1991 may also have been the result of natural temporal variability.

Hydrocarbon levels within the Sound were greatly reduced in the summer of 1991, a little over two years after the EVOS. This is comparable to the pattern observed in other spills that have occurred in comparable habitats. While aromatic petroleum hydrocarbons can persist in sediments for periods in excess of six years (Neff and Anderson, 1981), evidence from prior spills suggest that hydrocarbon levels in relatively exposed habitats generally approach background levels after a period of several years. Five months following the AMOCO CADIZ oil spill along the coastal waters off France, hydrocarbons were present in the muddy fine sand sediments of the Bay of Morlaix in high concentrations, 515,000 $\nu g\ g^{-1}$. These sharply declined to 31,000 $\nu g\ g^{-1}$ within two years (Dauvin, 1982). Within the coastal inlets, hydrocarbon concentrations 12 months after the spill were < 100,000 $\nu g\ g^{-1}$ in well oxygenated sands, but between 1,000,000 to 10,000,000 $\nu g\ g^{-1}$ in finer sediments. Contamination dropped drastically in the second year (Glémarec and Hussenot, 1982).

5.5 Causes for Observed Effects

The biological effects summarized above can largely be attributed to the EVOS. The available evidence suggests that there were differences among oiled and control sites for given taxa within each component of the subtidal ecosystem in Prince William Sound (plants, infaunal invertebrates, epibenthic invertebrates, and fish) and that oil was present within the sediments at our oiled sites. Furthermore, our findings largely agree with historical evidence of the effects of oil.

The differences that we observed among oiled and control sites may have occurred as the result of the direct (first order) effects of oiling, or as an indirect (second or higher order) effects. The direct effects include chemical toxicity of aromatic derivatives; asphyxiation or entanglement due to direct physical coating; and a variety of reproductive, behavioral, and other sublethal disorders that ultimately may lead to long-term population changes. They may also include the effects of cleanup activities such as physical cleaning methods, bioremediation, and increased boating activity relating to the cleanup effort. Second order effects include changes in a prey species abundance as the result of the direct effect of oil on its predator, changes in predator abundance as the result of direct effects of oil on prey abundance, or changes in habitat abundance as the result of direct effects of oil.

We suspect that many of the differences that we observed were attributable to the direct effects of oil. These include the lower abundances of amphipods and other benthic infauna in silled fjords and in eelgrass beds, and the lower densities of *Telmessus*. However, it is unlikely that the changes were the result of acute toxicity. Studies of the hydrocarbon concentrations in subtidal sediments in Prince William Sound (O'Clair et al., 1993) suggest that concentrations peaked in 1990 at most sites, but never reached levels that were expected to be acutely toxic. Also, direct measures of toxicity of sediments in 1990 and 1991 (Wolfe et al., 1993) failed to demonstrate any significant mortality of either amphipods or oyster larvae in sediments collected form oiled sites relative to sediments collected from unoiled reference sites. The differences that we observed were more likely the result of morality that resulted from chronic exposure to hydrocarbons, or to sublethal effects, such as changes in behavior that may result a higher risk to predation.

An alternative hypothesis for the differences in species abundances at oiled and control sites is that these sites were inherently different regardless of the effects of oil. It may be, for example, that predominant current patterns that resulted in the oiling of certain sites are also responsible for the concentration of planktonic larvae and food sources at those oiled sites. Such a hypothesis may explain why certain species, e.g., larval fishes, were more abundant at the oiled sites. However, this hypothesis relies on the unlikely assumption that current patterns are not variable. Furthermore, such a hypothesis cannot easily explain why we observed lower abundances of many of the species at oiled sites in 1990, or why differences observed in 1990 did not persist into 1991.

We have not attempted to distinguish between the different types of direct effects of the EVOS. The sampling program was not designed to test for the effects of different cleanup activities, and in most cases bioremediation and shoreline cleanup of some sort were carried out near our oiled sites (Table 21). Even though we have records of shoreline cleanup activities for many of our study sites, it is difficult to extrapolate from activities along the shoreline to effects in the subtidal. For example, even though shorelines adjacent to our sites may not have been cleaned, the subtidal habitat may have been affected by the anchoring of vessels involved in the cleanup effort at nearby sites.

5.6 Possible Implications of Effects on Higher Trophic Levels

We have little direct evidence of the effects of observed changes in the subtidal organisms that we have studied on higher trophic levels. However, in a general sense, we know that changes in composition of benthic fauna can have serious trophic implications. Many of the species affected in Prince William Sound were of special significance to higher trophic levels. For example, significant declines in the biomass of the bivalve families, including Veneridae and Tellinidae, were noted in soft sediments outside of eelgrass beds. These families include the suspension and deposit-feeding clams, *Saxidomus*, *Protothaca*, *Macoma*, and *Tellina*. All are important prey to the large sea otter population within Alaska (Calkins, 1978; Green and Brueggeman, 1991) as well as to sea ducks. In addition, *Telmessus* were

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adversely impacted by the EVOS, and these also serve as valuable food for otters (Green and Brueggeman, 1991).

Many subtidal benthic invertebrates and small fish are important food resources for bottom-feeding species such as pandalid shrimps, crabs, larger bottom fishes such as halibut, sea ducks, and sea otters (see review in Feder and Jewett, 1981, 1987; Hogan and Irons, 1988; McRoy, 1988). Furthermore, the larvae of most benthic organisms in Prince William Sound are released into the water column and are utilized as food by large zooplankters and juvenile stages of pelagic fishes such as salmon and herring. Thus, damage to the benthic system by hydrocarbon contamination could affect feeding interactions of important species on the bottom as well as in the water column.

Wertheimer et al. (1993) reported that juvenile pink and chum salmon in the nearshore waters of Prince William Sound were contaminated by exposure to EVOS crude oil in 1989, but not in 1990. Although there were no observable negative effects to chum salmon, pink salmon grew significantly slower and were significantly smaller in oiled areas than in non-oiled areas in 1989. While they found no evidence of a reduction in available prey organisms of these juvenile salmon, they determined that epibenthic prey biomass, which was primarily harpacticoid copepods, was higher in oiled locations than non-oiled locations in 1989.

Growth and survival rates were significantly lower in Dolly Varden and cutthroat trout populations that emigrated to the sea through oil-contaminated nearshore waters than uncontaminated waters (Hepler et al. 1993). Bioaccumulation of petrogenic hydrocarbons in the food chain or

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chronic starvation were hypothesized as the pathways that spilled crude oil had slowed growth and accelerated mortality of these two species.

5.7. Recovery of the Subtidal Communities in Prince William Sound

Rates of recovery for oil-impacted benthic communities have ranged from weeks on rocky shores at Santa Barbara (Straughan, 1971) to a decade in muddy fine sand of the Bay of Morlaix (N. France) (Ibanez and Dauvin, 1988). Teal and Howarth (1984) suggested that a century may be needed in salt marshes.

The recovery rate of the subtidal community in Prince William Sound seems dependent on the component in question. Subtidal algae and eelgrass appeared to have completely recovered within one to two years. Based upon the changes observed in 1991, it is likely that the benthic infaunal community will return to pre-spill conditions and equilibrate within 3 to 4 years after the spill. However, based on the lengthy recovery in fine sediments (low-energy areas) after the AMOCO CADIZ spill (Ibanez and Dauvin, 1988), it may take as long as a decade to see normality return to the oiled eelgrass benthic community of Prince William Sound.

One problem in predicting recovery within this community is that we do not have a very good picture of what the pre-spill conditions were like. As a result, full evaluation of recovery will depend on several more years of post-spill monitoring.

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Table 1. List of the 15 dominant infaunal and epifauanl taxa sampled by suction dredge and by dropnet within each habitat, depth stratum, and year. Separate rankings are given for abundance and biomass.

Dredge Samples - Eelgrass - Abundance

	Deep (6-20m)		Shallow (3-6m)		Bed (<3m)	
	1990	1991	1990	1991	1990	1991
RANK	TAXA NAME	TAXA NAME	TAXA NAME	TAXA NAME	TAXA NAME	TAXA NAME
1	SPIONIDAE	SPIONIDAE	SPIONIDAE		SPIONIDAE	MYTILIDAE
2	LUCINIDAE	OPHELIIDAE	OPHELIIDAE		SPIRORBIDAE	OPHELIIDAE
3	TELLINIDAE	LUCINIDAE	SPIRORBIDAE		MYTILIDAE	CAPRELLIDEA
4	OPHELIIDAE	SYLLIDAE	MONTACUTIDAE		GASTROPODA	SPIRORBIDAE
5	THYASIRIDAE	SPIRORBIDAE	MYTILIDAE		CAPRELLIDEA	SPIONIDAE
6	NEPHTYIDAE	THYASIRIDAE	GASTROPODA	NO	OPHELIIDAE	GASTROPODA
7	MYTILIDAE	TELLINIDAE	LACUNIDAE	DATA	LACUNIDAE	MONTACUTIDAE
8	SPIRORBIDAE	CAPITELLIDAE	LUCUNIDAE		TELLINIDAE	SYLLIDAE
9	SYLLIDAE	AMPHICTENIDAE	TELLINIDAE		MONTACUTIDAE	LACUNIDAE
10	BIVALVIA	SIGALIONIDAE	BIVALVIA		AMPHICTENIDAE	BIVALVIA
11	AMPHICTENIDAE	RISSOIDAE	AMPHICTENIDAE		BIVALVIA	CAPITELLIDAE
12	CAPITELLIDAE	CAECIDAE	CAPRELLIDEA		CAPITELLIDAE	RISSOIDAE
13	CAECIDAE	AMPHARETIDAE	RISSOIDAE		SYLLIDAE	POLYNOIDAE
14	MALDANIDAE	NEPHTYIDAE	BALANIDAE		PHOXOCEPHALIDAE	TELLINIDAE
15	OPHIUROIDEA	BIVALVIA	SYLLIDAE		POLYNOIDAE	TROCHIDAE

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Table 1. (Continued)

Dredge Samples - Eelgrass - Biomass

	Deep (6-20m)		Shallow (3-6m)		Bed (<3m)	
	1990	1991	1990	1991	1990	1991
RANK	TAXA NAME	TAXA NAME	TAXA NAME	TAXA NAME	TAXA NAME	TAXA NAME
1	LUCINIDAE	TELLINIDAE	LUCINIDAE		VENERIDAE	MYTILIDAE
2	VENERIDAE	LUCINIDAE	CHAETOPTERIDAE		MYTILIDAE	VENERIDAE
3	OLIVIDAE	OLIVIDAE	ECHINARACHNIDAE		TELLINIDAE	TELLINIDAE
4	BIVALVIA	BIVALVIA	TELLINIDAE		MYIDAE	ATELECYCLIDAE
5	TELLINIDAE	NEPHTYIDAE	RHYNCHOCOELA		LUCINIDAE	MYIDAE
6	RHYNCHOCOELA	MYTILIDAE	MYTILIDAE	NO	NEREIDAE	RHYNCHOCOELA
7	LUMBRINERIDAE	RHYNCHOCOELA	VENERIDAE	DATA	PHYLLODOCIDAE	LUCINIDAE
8	CARDIIDAE	CARDIIDAE	OLIVIDAE		SPIONIDAE	SPIONIDAE
9	MYTILIDAE	THYASIRIDAE	OPHELIIDAE		ATELECYCLIDAE	OPHELIIDAE
10	THYASIRIDAE	UNGULINIDAE	OPHIUROIDEA		GLYCERIDAE	ORBINIIDAE
11	GLYCERIDAE	MPHICTENIDAE	ORBINIIDAE		GONIADIDAE	POLYNOIDAE
12	CAECIDAE	CAECIDAE	OWENIIDAE		OPHELIIDAE	NEREIDAE
13	OPHIUROIDEA	CHAETOPTERIDAE	NEPHTYIDAE		LACUNIDAE	LUMBRINERIDAE
14	ORBINIIDAE	LEPETIDAE	LYONSIIDAE		LUMBRINERIDAE	BIVALVIA
15	SPIONIDAE	GLYCYMERIDAE	SPIONIDAE		AMPHICTENIDAE	MONTACUTIDAE

Table 1. (Continued)

Dropnet Samples - Eelgrass

	Abundance 1990	Biomass 1990
RANK	TAXA NAME	TAXA NAME
1	MYTILIDAE	MYTILIDAE
2	LACUNIDAE	LACUNIDAE
3	SPIRORBIDAE	HIPPOLYTIDAE
4	TROCHIDAE	TROCHIDAE
5	CAPRELLIDEA	PLEUSTIDAE
6	POLYNOIDAE	BRYOZOAN
7	MONTACUTIDAE	MONTACUTIDAE
8	BIVALVIA	POLYNOIDAE
9	GASTROPODA	NEREIDAE
10	ISCHYROCERIDAE	SPIRORBIDAE
11	ONCHIDORIDIDAE	CAPRELLIDEA
12	RISSOIDAE	ONCHIDORIDIDAE
13	HIPPOLYTIDAE	RISSOIDAE
14	NEREIDAE	GASTROPODA
15	SYLLIDAE	ISCHYROCERIDAE

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Table 6. Comparisons of surficial sediment grain size data between oiled and unoiled site-depth transect pairs in eelgrass habitat in Prince William Sound, 1990 and 1991. Comparisons were made using unpaired t-tests on percent (arcsin transformed) grain size. Substrate pairs significantly different at $p < 0.05$ are underlined.

1990 Site-Depth Transect Paired Comparisons / **P-VALUES**

Oiled	versus	Unoiled	Mud	Sand	Gravel
13-1	vs.	14-1	<u><0.001</u>	<u>0.011</u>	0.374
16-1	vs.	15-1	0.785	0.117	0.733
17-1	vs.	18-1	<u>0.008</u>	<u>0.008</u>	*
25-1	vs.	26-1	0.454	0.212	0.374
13-2	vs.	14-2	<u>0.017</u>	<u>0.013</u>	0.137
16-2	vs.	15-2	0.467	0.108	0.171
17-2	vs.	18-2	0.093	0.060	0.420
25-2	vs.	26-2	0.195	0.236	0.306
13-3	vs.	14-3	0.056	0.054	0.374
16-3	vs.	15-3	<u>0.002</u>	<u>0.001</u>	0.788
17-3	vs.	18-3	0.229	0.160	0.513
25-3	vs.	26-3	0.681	0.676	0.374

1991 Site-Depth Transect Paired Comparisons / **P-VALUES**

Oiled	versus	Unoiled	Mud	Sand	Gravel
13-1	vs.	14-1	<u>0.009</u>	<u>0.040</u>	0.213
16-1	vs.	15-1	0.999	0.115	0.338
17-1	vs.	18-1	0.548	0.063	0.459
25-1	vs.	26-1	0.893	0.392	0.310
13-3	vs.	14-3	0.056	0.070	0.082
16-3	vs.	15-3	0.311	0.156	0.885
17-3	vs.	18-3	0.251	0.108	0.374
25-3	vs.	26-3	0.167	0.066	0.165
34-3	vs.	35-3	<u>0.023</u>	<u>0.030</u>	0.374

* no comparison was made since gravel was absent from both site-transects.

Table 7. Summary of test results on benthic invertebrate population parameters and dominant taxa (in abundance and biomass) in paired (oiled vs control) eelgrass habitat site comparisons, 1990 and 1991. a = abundance; b = biomass; +, a, b = P ≤ 0.1; ++, aa, bb = P ≤ 0.05; +++, aaa, bbb = P ≤ 0.01.

	DEEP 6-20 M (T1)				SHALLOW 3-6 M (T2)				EELGRASS BED < 3 M (T3)			
YEAR	> @ OILED		> @ CONTROL		> @ OILED		> @ CONTROL		> @ OILED		> @ CONTROL	
1990	Dominance	++	Abundance	+			Richness	+	Abundance	+++	Richness[1]	++
									Biomass	+++		
	Maldanidae	aa	Sigalionidae	a	Opheliidae	bb	Rissoidae	a	Spionidae	a,bbb	Syllidae[1]	aaa
			Caecidae	aa,bb			Veneridae	b	Spirorbidae	aa	Nereidae[1]	a,bb
			Lepetidae	bbb			Tellinidae	bb	Mytilidae	aaa,bbb	Trochidae	aaa
			Veneridae	bb			Phoxocephalidae	a	Veneridae	b	Phoxocephalidae	aaa
			Unid.Bivalvia	bb			Amphipoda	a	Lacunidae	bb	Amphipoda[1]	b
			Amphipoda	aaa					Unid. Bivalvia	a		
									Onchidorididae	aaa,b[1]		
1991	Maldanidae	a	Orbiniidae	b	-----------NOT SAMPLED-----------				Veneridae	bb	Lumbrineridae	bbb
	Spionidae	a,b							Nereidae	bb	Phyllodocidae	b
											Rhynchocoela	bb
											Trochidae	aaa
											Lacunidae	bb

[1] Collected by Dropnet

Table 8. Summary of test results for community parameters, and abundance and biomass of dominant taxa in two-way analyses of (A) treatment (oiled vs control), (B) year (1990 vs 1991) and (C) treatment and year interactions in eelgrass habitats. a = abundance; b = biomass; +, a, b = $P \leq 0.1$; ++, aa, bb = $P \leq 0.05$; +++, aaa, bbb = $P \leq 0.01$.

A.

DEEP 6-20 M (T1)				EELGRASS BED < 3 M (T3)			
> @ OILED		> @ CONTROL		> @ OILED		> @ CONTROL	
Dominance	++	Diversity	+	Dominance	++	Diversity	+
		Biomass	+	Abundance	+		
				Biomass	+		
Maldanidae	aaa	Capitellidae	aa	Spirorbidae	aa	Trochidae	a
Nephtyidae	a	Opheliidae	a	Spionidae	a	Phoxocephalidae	aaa
Caecidae	aa					Amphipoda	aaa,bb
Mytilidae	aa,bb						

B.

DEEP 6-20 M (T1)				EELGRASS BED < 3 M (T3)			
> @ 1990		> @ 1991		> @ 1990		> @ 1991	
		Abundance	+++	Amphictenidae	aa	Abundance	+++
		No. Taxa	++			No. Taxa	++
		Sigalionidae	a			Opheliidae	aaa
		Maldanidae	a			Capitellidae	a
		Syllidae	a			Mytilidae	aa
		Rissoidae	aaa			Trochidae	aaa
		Caecidae	a			Caprellidea	aa
		Amphipoda	a			Amphipoda	aa
		Ophiuroidea	aa				

C.

DEEP 6-20 M (T1)				EELGRASS BED < 3 M (T3)			
↓ C & ↑ O 90 to 91		↑ C & ↓ O 90 to 91		↓ C & ↑ O 90 to 91		↑ C & ↓ O 90 to 91	
Bivalvia	bbb					Rissoidae	aa
Amphipoda	b					Lacunidae	a

Table 9. Summary of test results on benthic invertebrate population parameters and dominant taxa (in abundance and biomass) in paired (oiled vs control) *Laminaria/Agarum* bay habitat site comparisons, 1990 and 1991. a = abundance; b = biomass; +, a, b = $P \leq 0.1$; ++, aa, bb = $P \leq 0.05$; +++, aaa, bbb = $P \leq 0.01$.

	DEEP 11-20 M (T1)				SHALLOW 2-11 M (T2)			
YEAR	> @ OILED		> @ CONTROL		> @ OILED		> @ CONTROL	
1990	Diversity	++	Dominance	+++	Richness	++		
					Biomass	++		
					No. Taxa	++		
	Cirratulidae	a	Serpulidae	aa	Amphictenidae	a		
	Mytilidae	b	Spionidae	a	Polynoidae	a		
			Caecidae	a	Serpulidae	bb		
			Tellinidae	bbb	Lumbrineridae	b		
					Capitellidae	bb		
					Cylichnidae	bb		
					Nassariidae	bbb		
					Lucinidae	bb		
1991	Diversity	+	Dominance	+				
	Opheliidae	aa	Serpulidae	a,b	Dorvilleidae	a	Spionidae	a,b
	Lumbrineridae	a			Unid. Gastropoda	a		

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Table 10. Summary of test results for community parameters, and abundance and biomass of dominant taxa in two-way analyses of (A) treatment (oiled vs control), (B) year (1990 vs 1991), and (C) treatment and year interactions in *Laminaria/Agarum* bay habitats. a = abundance; b = biomass; +, a, b = $P \leq 0.1$; ++, aa, bb = $P \leq 0.05$; +++, aaa, bbb = $P \leq 0.01$.

A.

DEEP 11-20 M (T1)				SHALLOW 2-11 M (T2)			
> @ OILED		> @ CONTROL		> @ OILED		> @ CONTROL	
Diversity	+++	Dominance	+++				
Richness	+						
Cirratulidae	aa	Serpulidae	aaa	Dorvilleidae	aa		
Opheliidae	a	Caecidae	a	Polynoidae	a		
		Lucinidae	bb	Capitellidae	b		
		Tellinidae	b	Unid. Gastropoda	a		

B.

DEEP 11-20 M (T1)				SHALLOW 2-11 M (T2)			
> @ 1990		> @ 1991		> @ 1990		> @ 1991	
		Abundance	+++			Diversity	+++
						Richness	+++
						No. Taxa	+++
						Abundance	+++
						Biomass	+++
Serpulidae	b	Amphictenidae	aaa			Ampharetidae	aaa
		Opheliidae	aaa			Sigalionidae	a
		Ampharetidae	aaa			Spirorbidae	aaa
		Sigalionidae	aa			Amphictenidae	aaa
		Spionidae	aa,bbb			Syllidae	aa
		Tellinidae	bb			Opheliidae	aaa,bbb
		Hiatellidae	bb			Nassariidae	bbb
		Myidae	bbb			Rissoidae	aaa,bbb
						Cylichnidae	bb
						Unid. Gastropoda	a
						Hiatellidae	aaa
						Lyonsiidae	b
						Anomiidae	bb
						Aoridae	aa
						Amphipoda	aaa,bb
						Ophiuroidea	bb

C.

DEEP 11-20 M (T1)				SHALLOW 2-11 M (T2)			
↓ C & ↑ O 90 to 91		↑ C & ↓ O 90 to 91		↓ C & ↑ O 90 to 91		↑ C & ↓ O 90 to 91	
Dominance	+	Rhynchocoela	b			Dominance	+
		Mytilidae	bb			Spionidae	aa,b
						Serpulidae	bb

Table 11. Population parameters for benthic invertebrates and dominant (in terms of abundance) invertebrate taxa, bottom oxygen, and *Exxon Valdez* PAHs in oiled (Herring Bay, inner Bay of Isles, and Disk Lagoon) and unoiled silled fjords (inner Lucky Bay and Humpback Cove) in Prince William Sound.

HERRING BAY (SITE 28-601)	10/18/89	5/28/90	10/1/90	8/14/91
Area Sampled (m^2):	0.50	0.60	0.60	0.60
Total Abundance (indiv m^{-2}):	4192.00	4863.00	3487.00	4393.00
Total Biomass (g m^{-2}):	79.44	19.02	16.20	17.80
Total Taxa Family Level & Higher:	24.00	8.00	6.00	32.00
Shannon Diversity (H′):	1.66	0.03	0.10	1.64
Simpson Dominance (D):	0.39	0.99	0.97	0.41
Species Richness (SR):	2.76	0.82	0.61	3.70
Bottom Oxygen (mg l^{-1}):	---	2.2 -5.0	0.0-0.1	8.7-11.2
$\bar{X}$ *Exxon Valdez* PAHs (ng g^{-1}):	1185.00	1075.00	---	41.00

10/18/89

TAXON	# m^{-2}	CUMUL.%
Lucinidae	2544	60.69
Spionidae	368	69.47
Nephtyidae	336	77.48
Montacutidae	256	83.59
Rissoidae	80	85.50
Ampharetidae	64	87.02
Gastropoda (unid.)	64	88.55
Myidae	48	89.69
Goniadidae	48	90.84
Polyodontidae	48	91.98
Hiatellidae	32	92.75
Phyllodocidae	32	93.51
Balanidae	32	94.27
Caecidae	32	95.04
Sigalionidae	32	95.80
Pyrenidae	32	96.56
Thyasiridae	32	97.33
Ampithoidae	16	97.71

5/28/90

TAXON	# m^{-2}	CUMUL.%
Nephtyidae	4848	99.69

10/1/90

TAXON	# m^{-2}	CUMUL.%
Nephtyidae	3432	98.42

8/14/91

TAXON	# m^{-2}	CUMUL.%
Nephtyidae	2737	62.30
Capitellidae	442	72.37
Diastylidae	238	77.78
Ampharetidae	145	81.08
Opheliidae	133	84.11
Spirorbidae	133	87.14
Bivalvia (unid.)	82	89.01
Munnidae	80	90.83
Caprellidea	67	92.35
Amphipoda (unid.)	55	93.60
Syllidae	40	94.51
Hesionidae	27	95.13
Ischyroceridae	23	95.65
Isaeidae	13	95.95
Dexaminidae	13	96.24
Cardiidae	13	96.54
Phoxocephalidae	13	96.84
Lucinidae	13	97.13

Table 11. Continued.

INNER LUCKY BAY (Site 29)	6/6/90	9/28/90	8/13/91
Area Sampled (m^2):	0.20	0.20	0.20
Total Abundance (indiv m^{-2}):	740.00	725.00	90.00
Total Biomass (g m^{-2}):	1.11	2.98	0.04
Total Taxa Family Level & Higher:	4.00	2.00	6.00
Shannon Diversity (H´):	0.85	0.04	1.43
Simpson Dominance (D):	0.46	0.99	0.31
Species Richness (SR):	0.45	0.15	1.11
Bottom Oxygen (mg l^{-1}):	0.40	0.1-0.9	0.30
$\overline{X}$ *Exxon Valdez* PAHs (ng g^{-1}):	442.00	---	---

6/6/90			9/28/90			8/13/91		
TAXON	# m^{-2}	CUMUL.%	TAXON	# m^{-2}	CUMUL.%	TAXON	# m^{-2}	CUMUL.%
Decapoda (unid.)	370	50.00	Nephtyidae	720	99.31	Opheliidae	45	50.00
Nephtyidae	340	95.95				Bivalvia (unid.)	15	66.67
Amphipoda (unid.)	25	99.33				Mytilidae	15	83.34
						Rissoidae	5	88.90
						Lumbrineridae	5	94.46
						Corophiidae	5	100.00

Table 11. Continued.

INNER BAY OF ISLES (Site 30)	6/10/90	9/29/90
Area Sampled (m^2):	0.20	0.40
Total Abundance (indiv m^{-2}):	2800.00	3667.00
Total Biomass (g m^{-2}):	22.82	19.88
Total Taxa Family Level & Higher:	18.00	10.00
Shannon Diversity (H´):	2.11	1.34
Simpson Dominance (D):	0.17	0.34
Species Richness (SR):	2.14	1.10
Bottom Oxygen (mg l^{-1}):	11.80	0.30-0.40
$\overline{X}$ *Exxon Valdez* PAHs (ng g^{-1}):	451.00	---

6/10/90		
TAXON	# m^{-2}	CUMUL.%
Nephtyidae	725	25.89
Gastropoda (unid.)	700	50.89
Decapoda (unid.)	360	63.75
Lucinidae	325	75.36
Opheliidae	160	81.07
Bivalvia (unid.)	120	85.36
Ascidiacea	85	88.40
Polynoidae	85	91.44
Balanidae	45	93.05
Montacutidae	40	94.48
Caprellidea	40	95.91
Goniadidae	30	96.98

9/29/90		
TAXON	# m^{-2}	CUMUL.%
Montacutidae	1692	46.14
Nephtyidae	1255	80.37
Haminoeidae	292	88.33
Rissoidae	182	93.29
Bivalvia (unid.)	115	96.43

Table 11. Continued.

	DISK LAGOON (SITE 32) 9/26/90	HUMPBACK COVE (SITE 33) 9/30/90
Area Sampled (m^2):	0.60	0.60
Total Abundance (indiv m^{-2}):	3735.00	1668.33
Total Biomass (g m^{-2}):	121.98	11.12
Total Taxa Family Level & Higher:	13.00	5.00
Shannon Diversity (H´):	1.10	0.11
Simpson Dominance (D):	0.56	0.96
Species Richness (SR):	1.46	0.54
Bottom Oxygen (mg l^{-1}):	0.3-1.0	<0.10
$\bar{X}$ *Exxon Valdez* PAHs (ng g^{-1}):	---	---

9/26/90

TAXON	# m^{-2}	CUMUL.%
Nephtyidae	2777	74.35
Balanidae	208	79.92
Lucinidae	165	84.34
Balanomorpha	153	88.44
Tellinidae	133	92.00
Bivalvia (unid.)	105	94.81
Ampharetidae	92	97.27

9/30/90

TAXON	# m^{-2}	CUMUL.%
Nephtyidae	1638	98.20

Table 12. Summary of results for tests of differences in abundance of large epibenthic invertebrates at oiled *vs.* control sites. 000 or XXX = P<0.01; 00 or XX = P<0.05; 0 or X = <0.1; 0 = > at control sites; X = > at oiled sites. ND = no data, habitat not sampled in 1991.

Eelgrass Bed

	Bed	
	90	91
Telmessus cheiragonus	000	-
Dermasterias imbricata	-	00

Laminaria/Agarum Bays

	Deep 11-20 m		Shallow 2-11 m	
	90	91	90	91
Telmessus cheiragonus	000	ND	-	-
Dermasterias imbricata	-	ND	00	-
Pycnopodia helianthoides	-	ND	XX	X
P. helianthoides - adult	-	ND	X	-
P. helianthoides - juvenile	-	ND	-	XXX

Laminaria/Agarum Points

	Deep 11-20 m		Shallow 2-11 m	
	90	91	90	91
Telmessus cheiragonus	000	ND	00	ND
Dermasterias imbricata	-	ND	0	ND
Evasterias troschelii	-	ND	0	ND
Pycnopodia helianthoides	-	ND	-	ND
P. helianthoides - adult	-	ND	X	ND
P. helianthoides - juvenile	-	ND	-	ND

Nereocystis

	Bed 1990
Evasterias troschelii	0

All Habitats Combined

	All Depths Combined 1990
Telmessus cheiragonus	000
Dermasterias imbricata	00

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Table 13. Test results for the density of large benthic invertebrates in two-way analyses of the effects of oil (oiled *vs*. control), year (1990 *vs*. 1991), and their interaction in eelgrass and shallow *Laminaria/Agarum* bay habitats. 000 or XXX = P<0.01; 00 or XX = P<0.05; 0 or X = <0.1; 0 = > at control sites or > in 1990.; X = > at oiled sites or > in 1991. For the interaction, 0 indicates a decline at control sites relative to oiled sites between 1990 and 1991, while X indicates the opposite.

	Eelgrass Bed			Bays 2-11 m		
	Oil	Year	Int.	Oil	Year	Int.
Telmessus cheiragonus	000	-	0	0	XX	-
Dermasterias imbricata	00	0	-	00	-	-
Evasterias troschelii	-	-	-	-	-	-
Pycnopodia helianthoides	-	000	-	XXX	-	-
P. helianthoides adult	-	-	-	-	XXX	-
P. helianthoides juvenile	-	000	-	-	XXX	-

ACE 30236853

Table 14. Results of a Chi-square test examining differences in the spawning success of *Dermasterias imbricata* parasitized by the barnacle *Dendrogaster* sp. The starfish were collected from Northwest and Cabin Bays in 1990.

No. of Rays Parasitized	Spawn	No Spawn	% Spawn
0	48	11	81
1	9	3	75
2	2	3	40
3	0	4	0
4	1	1	50
5	2	5	29

$x^2 = 21.2$, df=5, $P<0.01$

Table 15. Results of a Chi-square test examining differences in the infection rate of *Dermasterias imbricata* by the barnacle *Dendrogaster* sp. at oiled *vs.* control sites.

Herring Bay (Oiled) and Lower Herring Bay (Control)

Parasitized

Site	Yes	No	%
Oiled	5	18	22%
Control	3	20	13%
Total	8	38	Mean=17%

$x^2 = 1.36$, df=1, P=0.24

Northwest Bay (Oiled) and Cabin Bay (Control)

Site	Yes	No	%
Oiled	12	31	28%
Control	18	28	39%
Total	30	59	Mean=34%

$x^2 = 1.25$, df=1, P=0.26

Bay of Isles(Oiled) and Mummy Bay (Control)

Parasitized

Site	Yes	No	%
Oiled	10	34	22.7%
Control	14	28	33.3%
Total	24	62	Mean=28.0%

$x^2 = 1.20$, df=1, P=0.27

ACE 30286855

Table 16. Results of a Chi-square test examining differences in the proportion of *Dermasterias imbricata* parasitized by the barnacle, *Dendrogaster* sp., in 1990 and 1991.

Site	1990			1991		
	With	W/out	% With	With	W/out	% With
Northwest Bay	12	31	28%	-	-	-
Cabin Bay	18	28	39%	-	-	-
Herring Bay	8	18	31%	-	-	-
Lower Herring Bay	4	20	17%	2	14	13%
Bay of Isles	10	34	23%	0	5	0%
Mummy Bay	14	28	28%	3	17	15%
Sleepy Bay	-	-	-	0	11	0%
Total	66	159	29%	5	47	10%

$x^2 = 16.8$, df=1, $P<0.01$

ACE 30286856

Table 17. Summary of results for tests of differences in the abundance of fishes at oiled *vs.* control sites. 000 or XXX = P<0.01; 00 or XX = P<0.05; 0 or X = <0.1; 0 = > at control sites; X = > at oiled sites.

Eelgrass Bed

	Bed 90	Bed 91
Juvenile Cod	XXX	XX
Adult Cod	XXX	-

Laminaria/Agarum Bays

	Deep 11-20 m		Shallow 2-11 m	
	90	91	90	91
Greenlings	-	ND	X	-
Adult Arctic Shanny	-	ND	-	0
Small Sculpins	-	ND	-	0

Laminaria/Agarum Points

	Deep 11-20 m		Shallow 2-11 m	
	90	91	90	91
Greenlings	X	ND	-	ND
Ronquils	X	ND	-	ND
Juvenile Arctic Shanny	X	ND	-	ND
Juvenile Cod	00	ND	00	ND
Pholids	0	ND	-	ND
Small Sculpins	-	ND	XXX	ND
Searchers	-	ND	X	ND

Nereocystis

	Bed 1990
Greenlings	0

Bays and Points Combined

	All Depths Combined 1990
Greenlings	XX
Small sculpins	X

ACE 30286857

Table 18. Test results for the density of fishes in two-way analyses of the effects of oil (oiled *vs*. control), year (1990 *vs*. 1991), and their interaction in eelgrass and shallow *Laminaria/Agarum* habitats. 000 or XXX = P<0.01; 00 or XX = P<0.05; 0 or X = <0.1; 0 = > at control sites or > in 1990.; X = > at oiled sites or > in 1991. For the interaction, 0 indicates a decline at control sites relative to oiled sites between 1990 and 1991, while X indicates the opposite.

	Eelgrass Bed			Bays 2-11 m		
	Oil	Year	Int.	Oil	Year	Int.
Adult Arctic Shanny	ND	ND	ND	-	X	-
Juvenile Cod	XX	X	-	ND	ND	ND
Adult Cod	-	XX	-	ND	ND	ND

ACE 30286258

Table 19. Summary of tests of differences in concentrations of EXXON VALDEZ PAHs at oiled *vs.* control sites. Results of both one-way analyses (testing for differences among oiled and control sites within a given year) and two-way analyses (testing for the effects of oil code, year, and their interaction) are given. ND = no data, habitat not sampled in 1991.

One-Way Analyses - Eelgrass and Bay Habitats

		P Values	
		90	91
Eelgrass	Deep (6 to 20 m)	0.92	0.03
	Shallow (3 to 6)	0.53	ND
	Eelgrass Bed	0.04	0.26
Bays	Deep (11 to 20 m)	0.02	ND
	Shallow (2 to 11 m)	0.08	ND

Two-Way Analyses - Eelgrass Habitat

	P Values		
	Oil	Year	Int.
Deep (6 to 20 m)	0.94	<0.01	0.43
Bed	0.08	<0.01	0.60

ACE 30286859

Table 20. Comparison of mean densities of dominant macroalgae at Latouche Point prior to (June 1976) and after (July 1990) the EXXON VALDEZ oil spill. Data from 1976 are from Rosenthal et al., 1977. The 1976 data are means from depths of 3.5 to 6 m. The 1990 data are from depths of 3 m to 6 m.

Taxa	Mean Density ($No.m^2$)	
	1975	1990
Nereocystis luetkaena	1.2	0.3
Laminaria groenlandica(1)	6.8	38.0
Laminaria yezoensis	1.5	0.3
Agarum cribrosum	0.3	0.3
Pleurophycus gardneri	3.1	3.3

[1] Rosenthal et al. (1977) identified this species as *L. dentigera*.

ACE 30286860

Table 21. Shallow subtidal study sites within ADEC shoreline segments, Prince William Sound, 1990. EVOS cleanup activity. Note the EVOS cleanup activity that occurred adjacent to many of the oiled study sites.

Site Name	Site #	Oil Code[1]	Habitat Code[2]	Lat.	Long.	ADEC Segment #	EVOS Cleanup Activity[3]	Survey Date
Cabin Bay	1	C	B	60°39.5	147°27.0	NA024	No Activity	
Northwest Bay	2	O	B	60 33.3	147 34.6	EL056-D	Manual removal; Bioremediation	Summer 1990
Herring Bay	3	O	B	60 26.8	147 47.1	KN0132A	Manual removal	5/29/90
L. Herring Bay	4	C	B	60 26.8	147 48.4	KN0551-A	No Activity	
Mummy Bay	5	C	B	60 13.8	147 49.0	KN0601	No Activity	
Bay of Isles	6	O	B	60 23.1	147 42.6	KN0136-A;KN0004-A	No Activity	
Bay of Isles	13	O	E	60 23.2	147 44.5	KN0202-A	No Activity	
Drier Bay	14	C	E	60 19.2	147 44.2	KN0575-A	No Activity	
L. Herring Bay	15	C	E	60 24.2	147 48.1	KN0551-A	No Activity	
Herring Bay	16	O	E	60 26.7	147 47.2	KN0132B	Rake/till; manual removal; Bioremed.; mechanical treat.	Summer 90-91
Sleepy Bay	17	O	E	60 04.0	147 50.1	LA017-A - LA018-A	Rake/till; manual removal; Bioremed.; mechanical treat.	Summer 90-91
Moose Lips Bay	18	C	E	60 12.7	147 18.5	No Segment #	No Activity	
Clammy Bay	25	O	E	60 39.1	147 22.5	NA006-D	No Activity	
Puffin Bay	26	C	E	60 44.0	147 25.0	PT001	No Activity	
Lucky Bay	27	C	F	60 13.7	147 52.0	KN0600-A	No Activity	
Herring Bay	28	O	F	60 28.1	147 42.4	KN0118-A	Manual removal; bioremed.	5/6/90
Bay of Isles	30	O	F	60 23.0	147 45.3	KN0200-A - KN0201-A	Rake/till; manual removal;	5/14/90
Lucky Bay	29	C	F	60 13.9	147 51.5	KN0600-A	No Activity	
Bay of Isles	31	O	F	60 23.2	147 39.6	KN0202-3-A;KN0009-A	Manual removal; bioremed.	6/7-9/91
Disk Lagoon	32	C	F	60 39.6	147 39.6	DI065-A	No Activity	
Humpback Cove	33	C	F	60 12.5	148 17.5	WH504	No Activity	

[1]Oil Codes O = Oiled
C = Control

[2]Habitat Codes B = Laminaria/Agarum - Island Bays
E = Zostera (eelgrass)
F = Silled Fjords

[3]EVOS cleanup activity: information provided by ADEC Oil Spill Response Center, Anchorage, AK.

FIGURES

Figure 1. Locations of subtidal study sites in Prince William Sound. Lettered boxes represent inset maps A through N that detail study site locations. Number and letter codes represent the site number and indicate the habitat type. For example, in Map A, 33F is site #33, a silled fjord.

Habitat code:
B = *Laminaria/Agarum* - Island Bay
P = *Laminaria/Agarum* - Island Points
E = Eelgrass
N = *Nereocystis*
F = Silled Fjord

The key below indicates site numbers, site names, and inset map locations.

Habitat Type	Site #	Name	Oil Code	Inset Map Location
Eelgrass	13	Bay of Isles	O	H
	14	Drier Bay	C	F
	15	Lower Herring Bay	C	G
	16	Herring Bay	O	I
	17	Sleepy Bay	O	D
	18	Moose Lips Bay	C	M
	25	Clammy Bay	O	K
	26	Puffin Bay	C	K
	34	Short Arm	O	H
	35	Mallard Bay	C	F
Laminaria/Agarum Island Bays	01	Cabin Bay	C	K
	02	Northwest Bay	O	J
	03	Herring Bay	O	I
	04	Lower Herring Bay	C	G
	05	Mummy Bay	C	E
	06	Bay of Isles	O	H
Laminaria/Agarum Island Points	19	Discovery Point	O	E
	20	Lucky Bay	C	E
	21	Outer L.H. Bay	C	G
	22	Outer Herring Bay	O	I
	23	Ingot Point	O	J
	24	Peak Point	C	K
Nereocystis	07	Latouche Point	C	C
	08	Procession Rocks	C	B
	11	Naked Island	C	K
	12	Little Smith Is.	C	L
	09	Zaikof Point	C	N
Silled Fjords	27	Outer Lucky Bay	C	E
	28	Herring Bay	C	I
	29	Inner Lucky Bay	C	E
	30	Inner Bay of Isles	C	H
	31	Outer Bay of Isles	C	H
	32	Disk Lagoon	C	J
	33	Humpback Cove	C	A

ACE 30286863

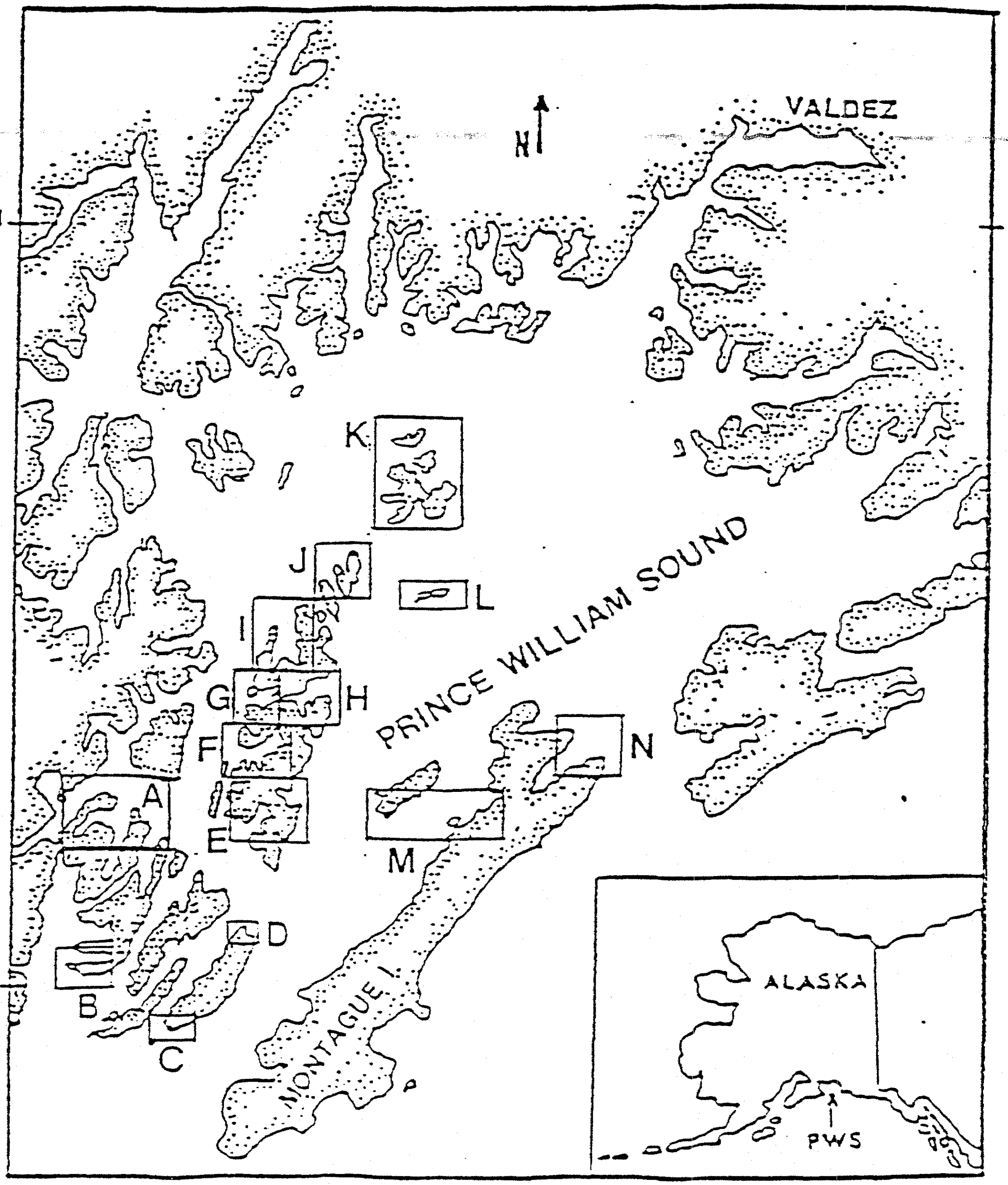


Figure 1. (continued)

ACE 30286864

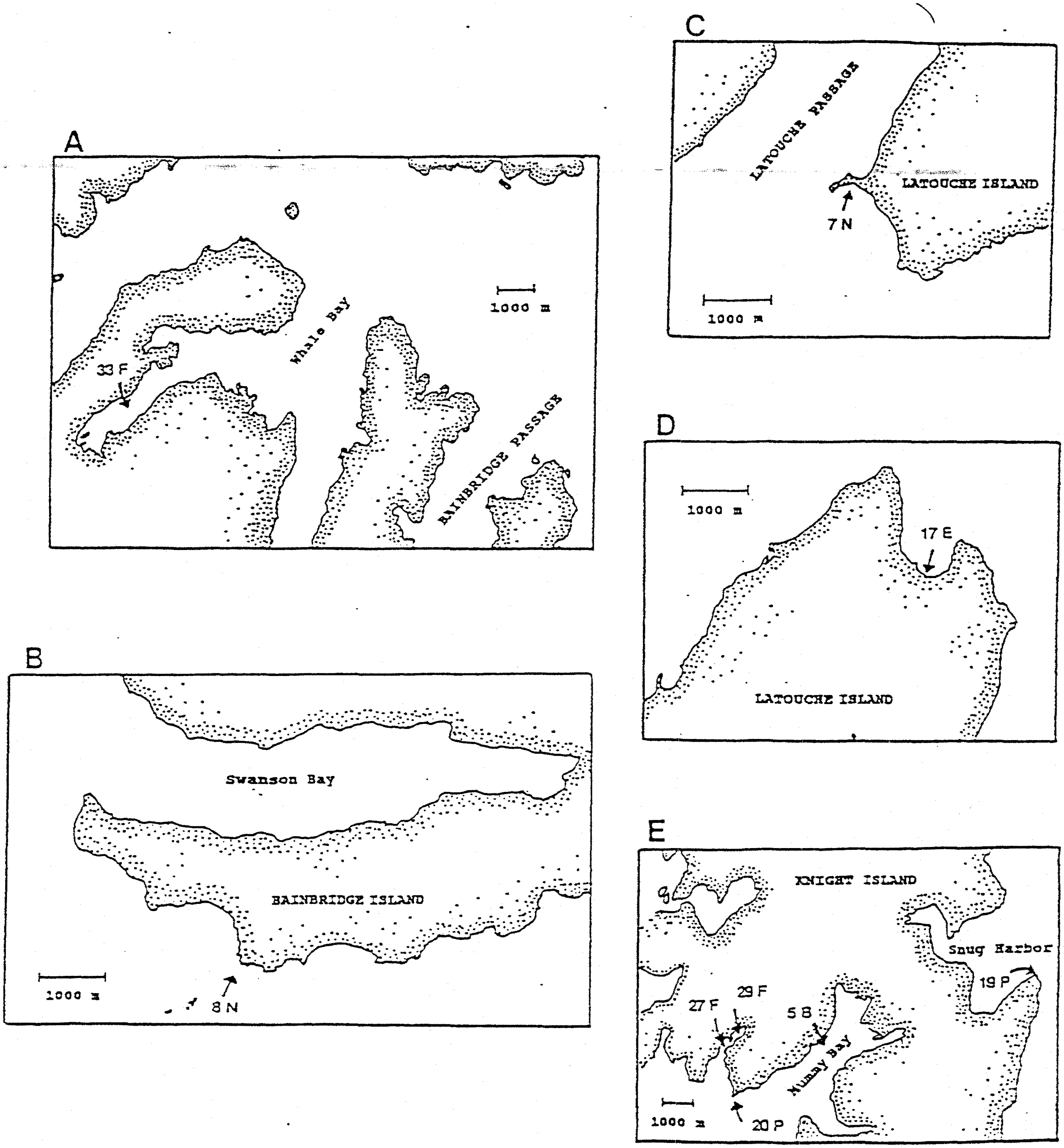


Figure 1. (continued)

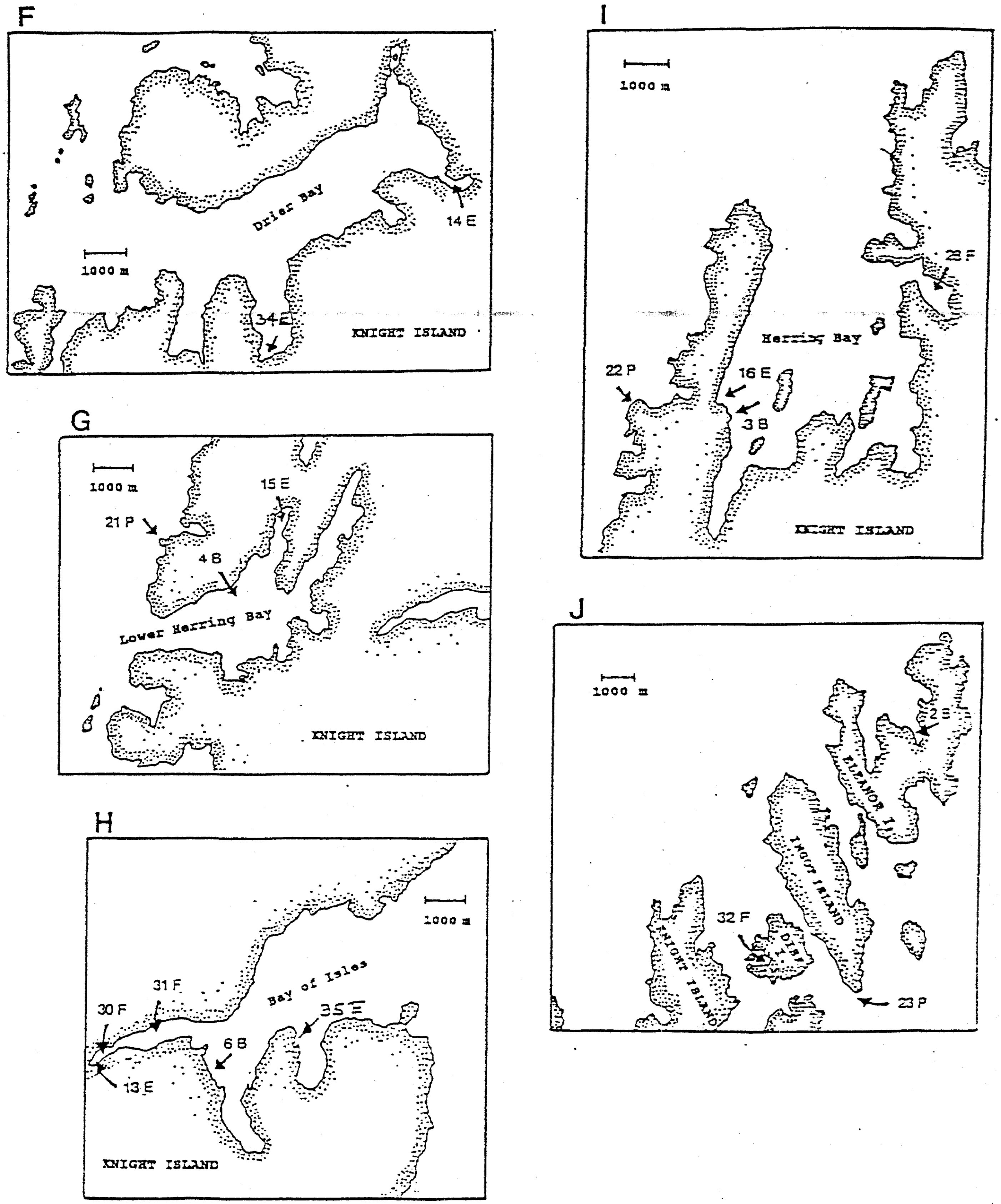
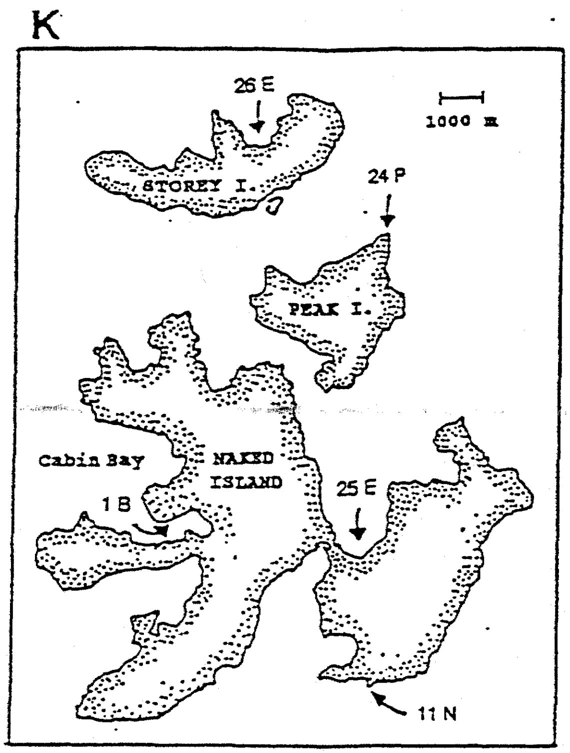
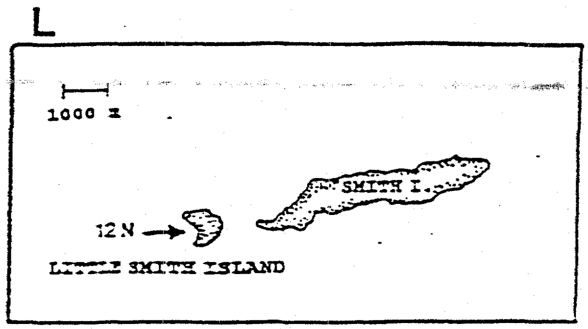
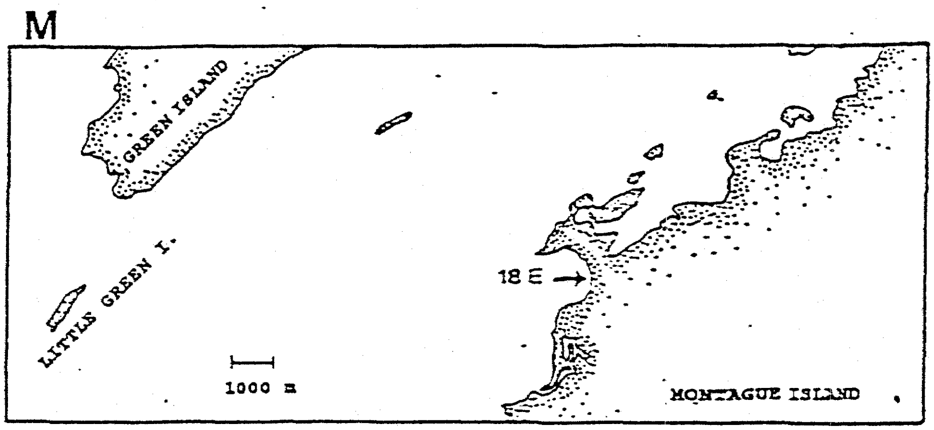


Figure 1. (continued)







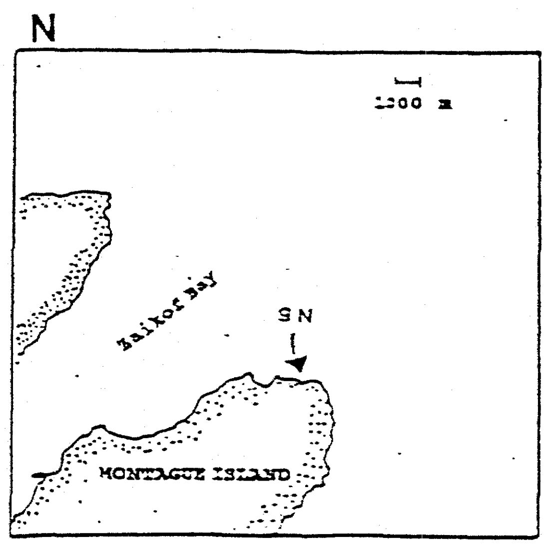


Figure 1. (continued)

ACE 30286867

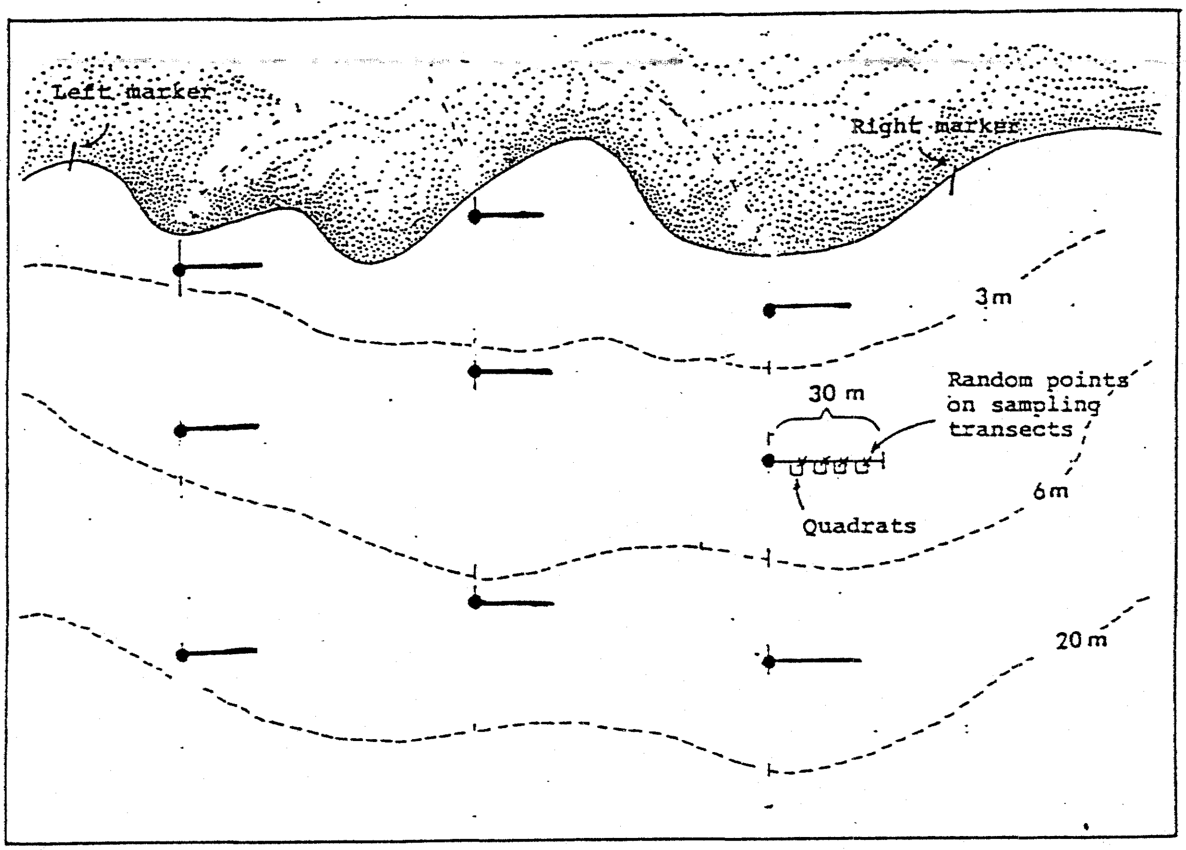


Figure 2. Schematic showing the layout of sampling transects and quadrats at eelgrass sampling sites. Positions of transects within the eelgrass bed were selected independent of depth, and are shown here at depths less than 3 meters. Depths of the transects in other strata (3 to 6 and 6 to 20 m) were selcted at random. Samples taken in other habitats (*Laminaria/Agarum* and *Nereocystis*) used a similar site layout, but with differing depth strata.

ACE 30286868

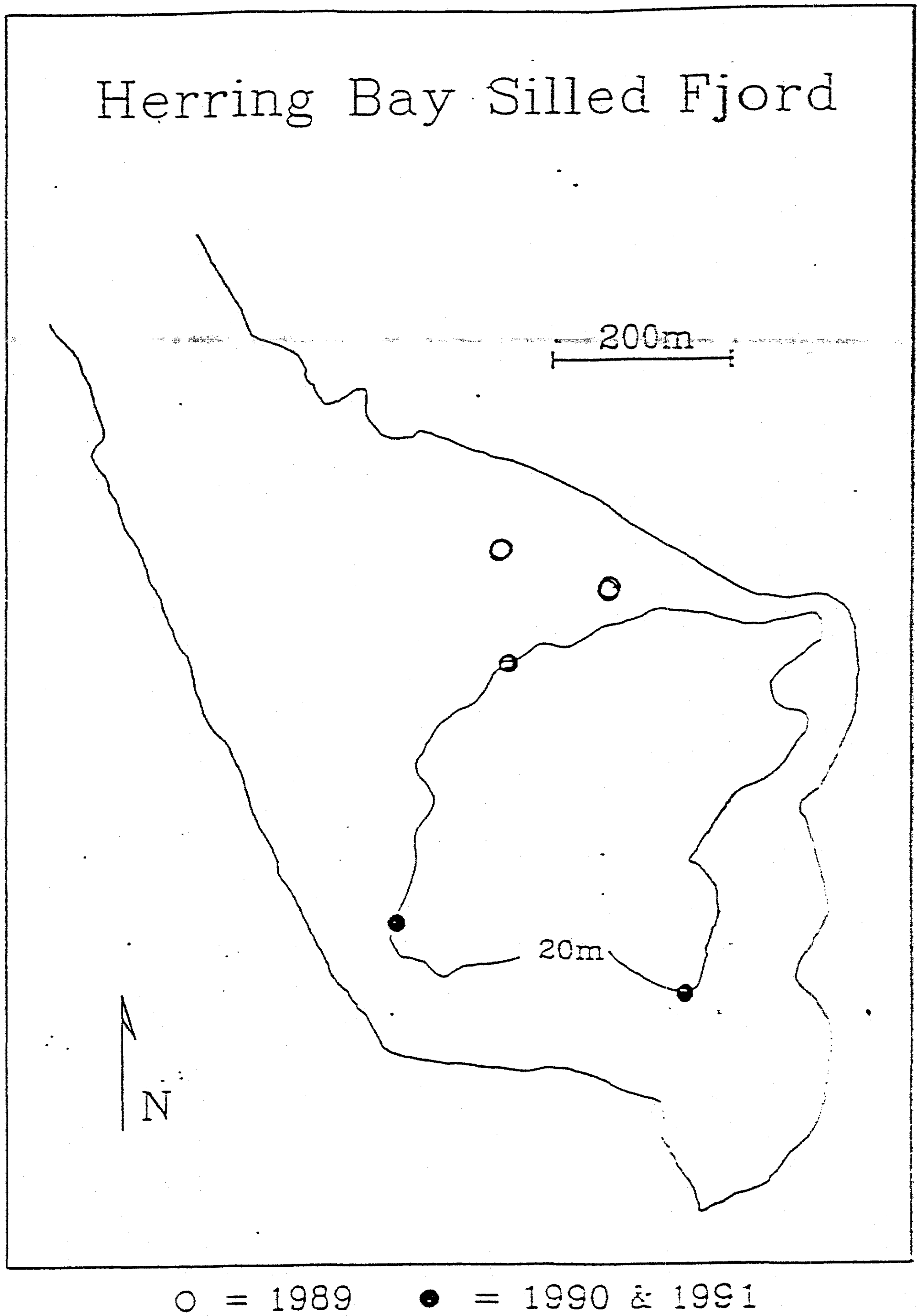


Figure 3. Detail showing the approximate sampling locations of sampling sites within the Herring Bay silled fjord in 1989, 1990, and 1991.

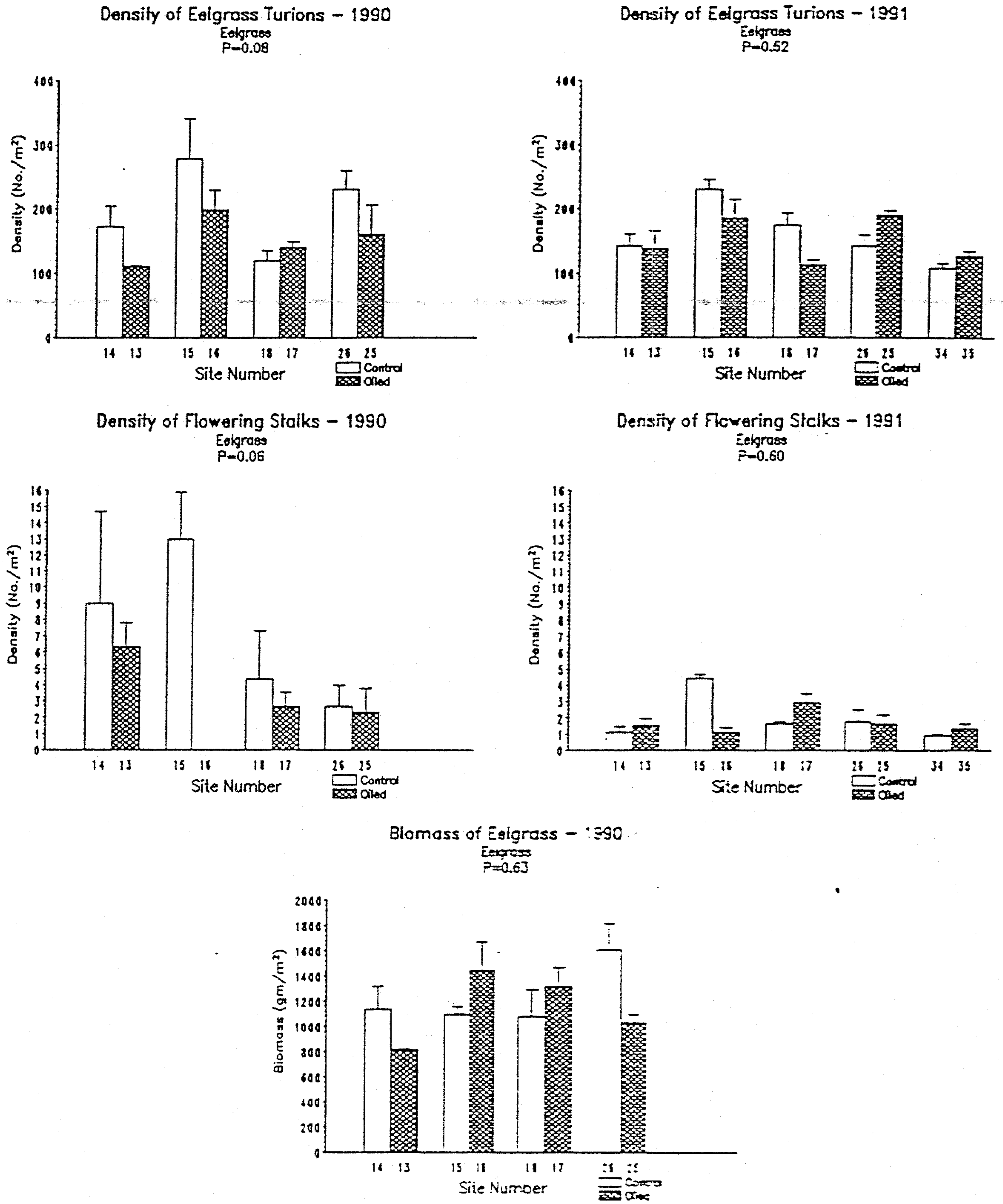


Figure 4. Density of turions, density of flowers and biomass of eelgrass at oiled and control sites in Prince William Sound. Error bars are +/- 1 standard error.

ACE 30236870

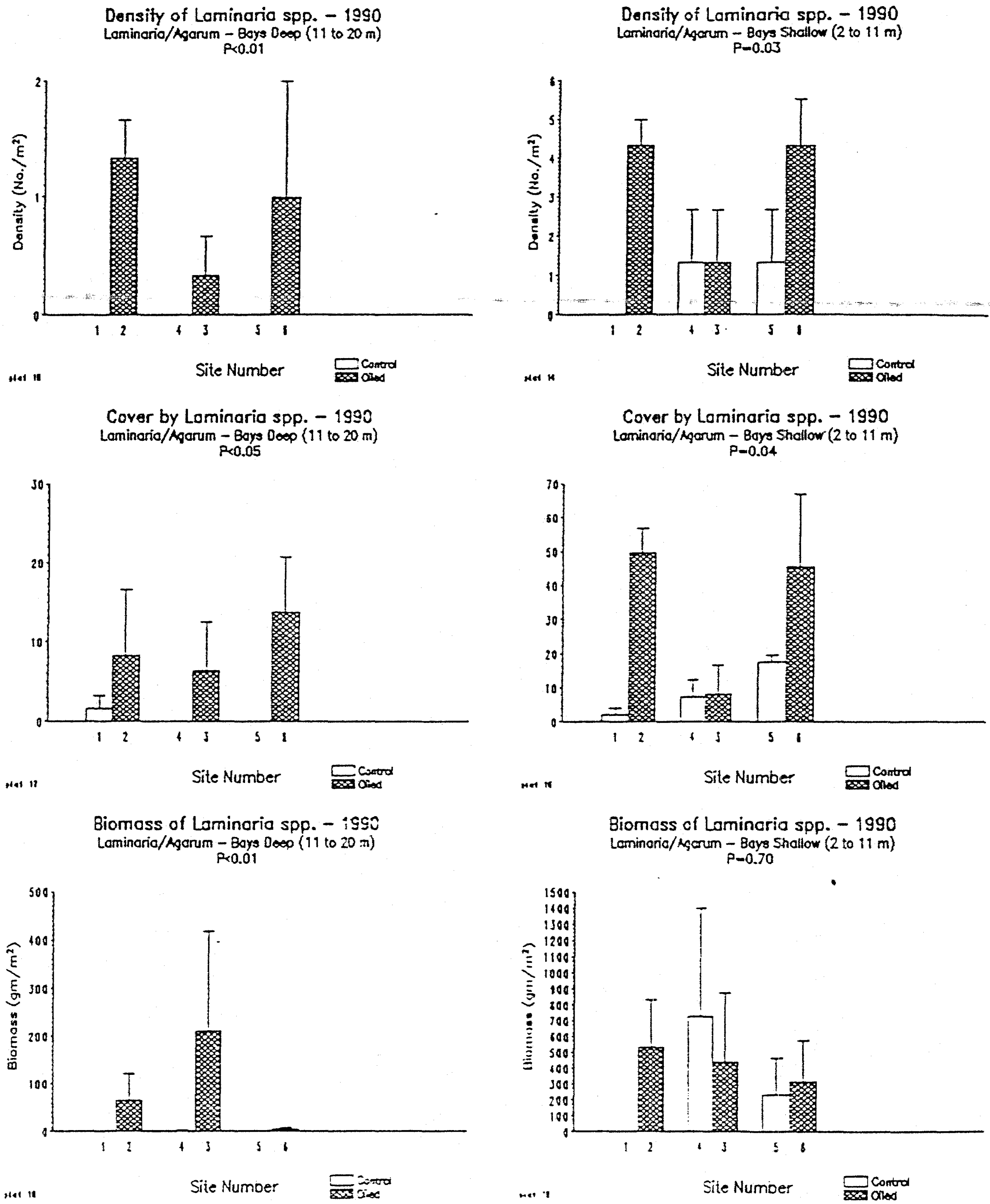


Figure 5. Density, percent cover, and biomass of *Laminaria spp.* at oiled and control sites in the *Laminaria/Agarum* habitat in island bays. Error bars are +/- 1 standard error.

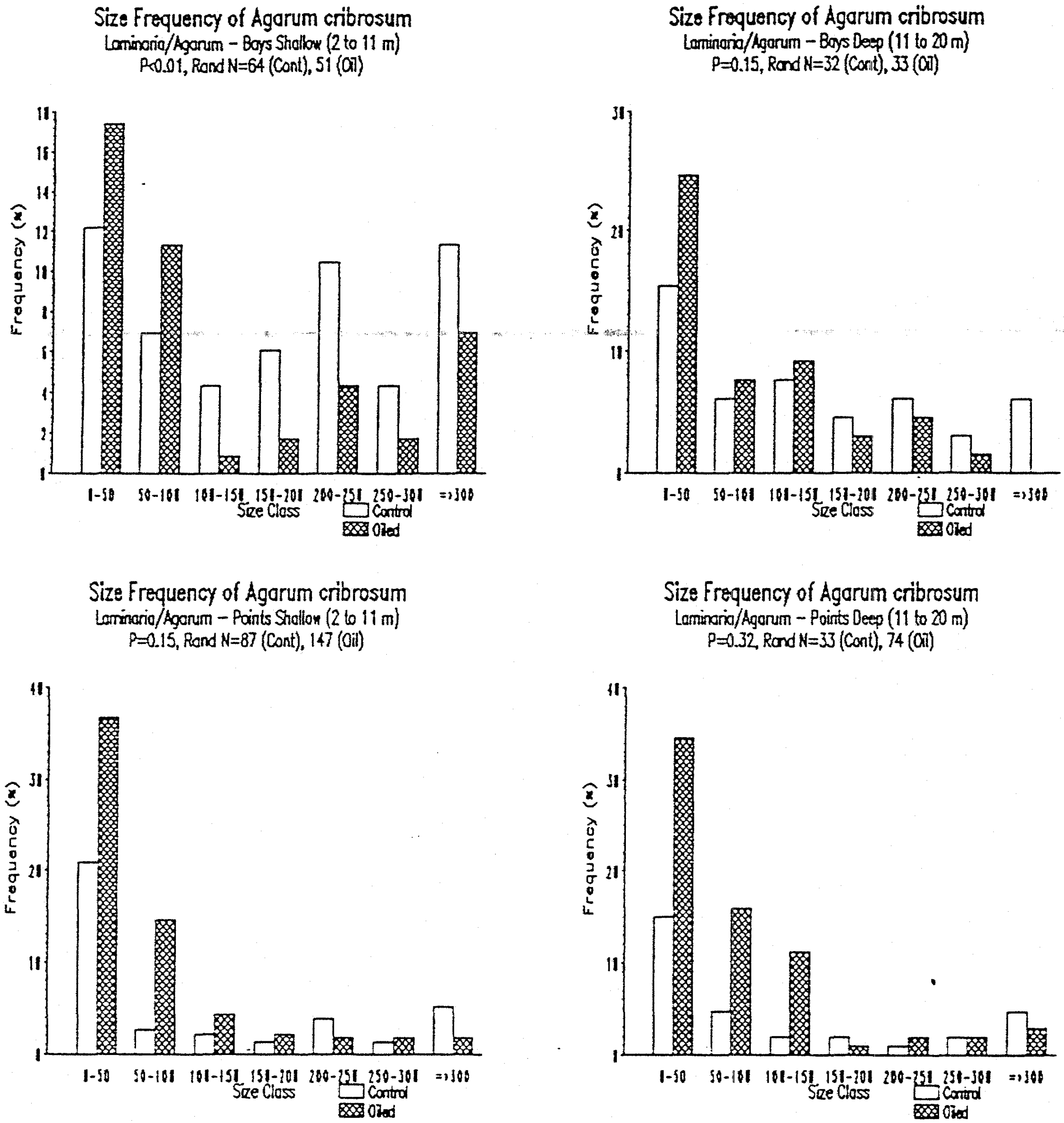


Figure 6. Size frequency of *Agarum cribrosum* at oiled and control sites in the *Laminaria/Agarum* habitat in Prince William Sound in 1990. Size classes are given as wet weights (gms).

ACE 30286872

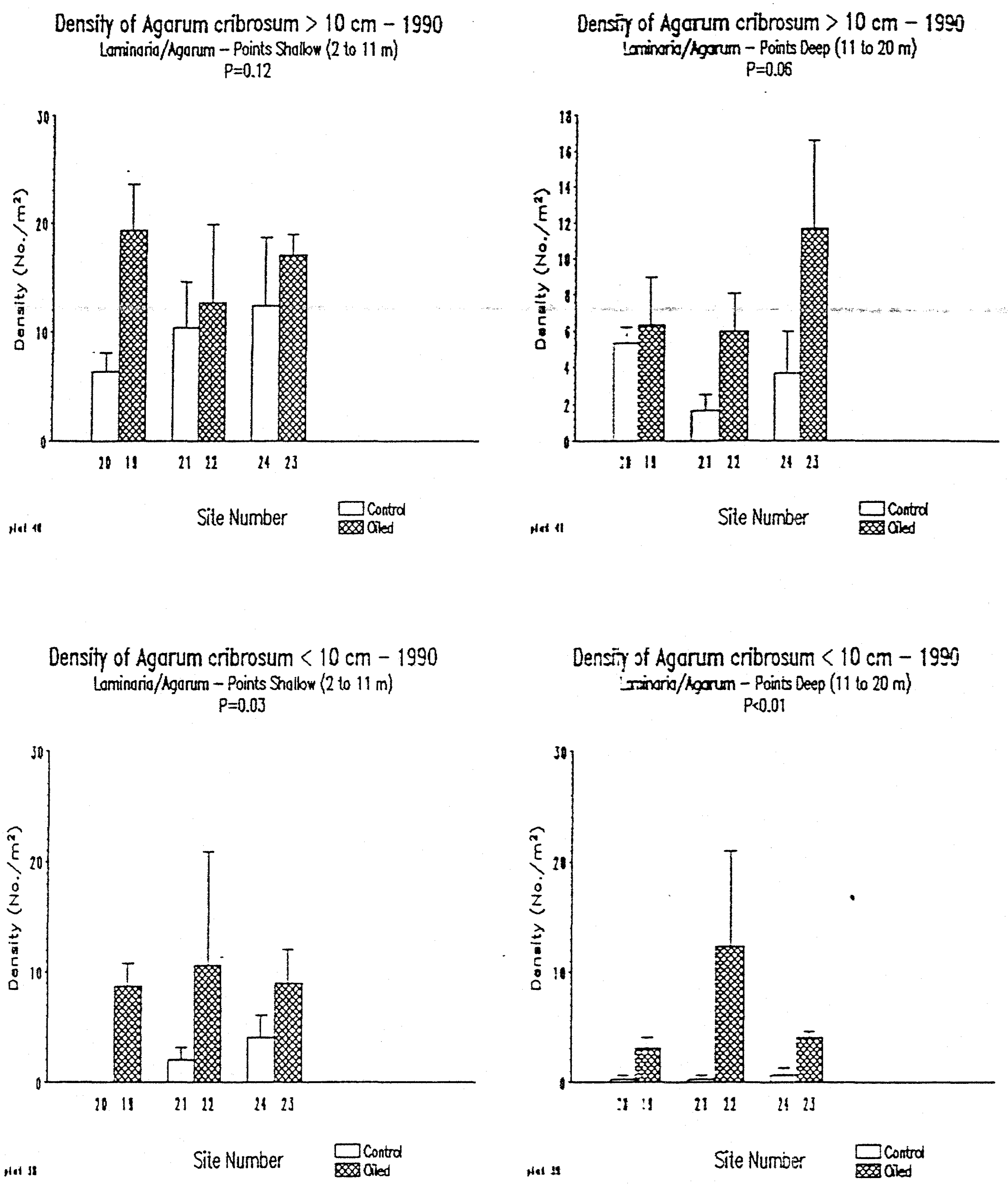
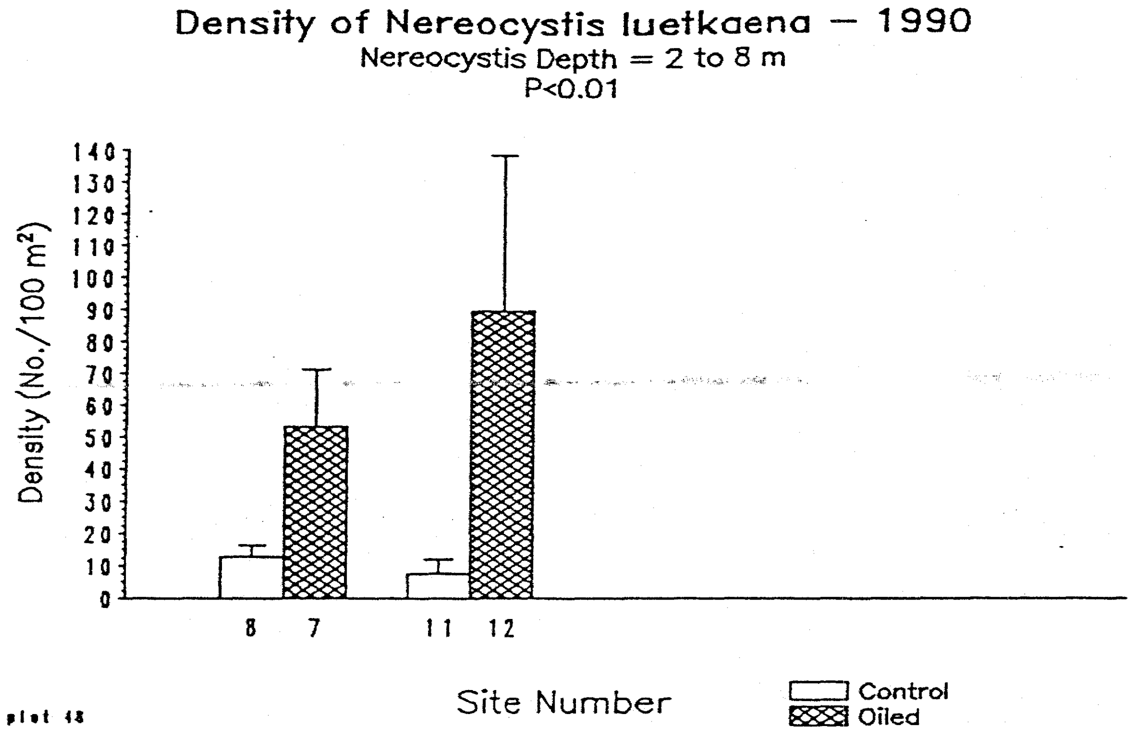


Figure 7. Density of large (>=10 cm) and small (< 10cm) *Agarum cribrosum* at oiled and control sites in the *Laminaria/Agarum* habitat on island points in Prince William Sound. Error bars are +/- 1 standard error.

ACE 30286873



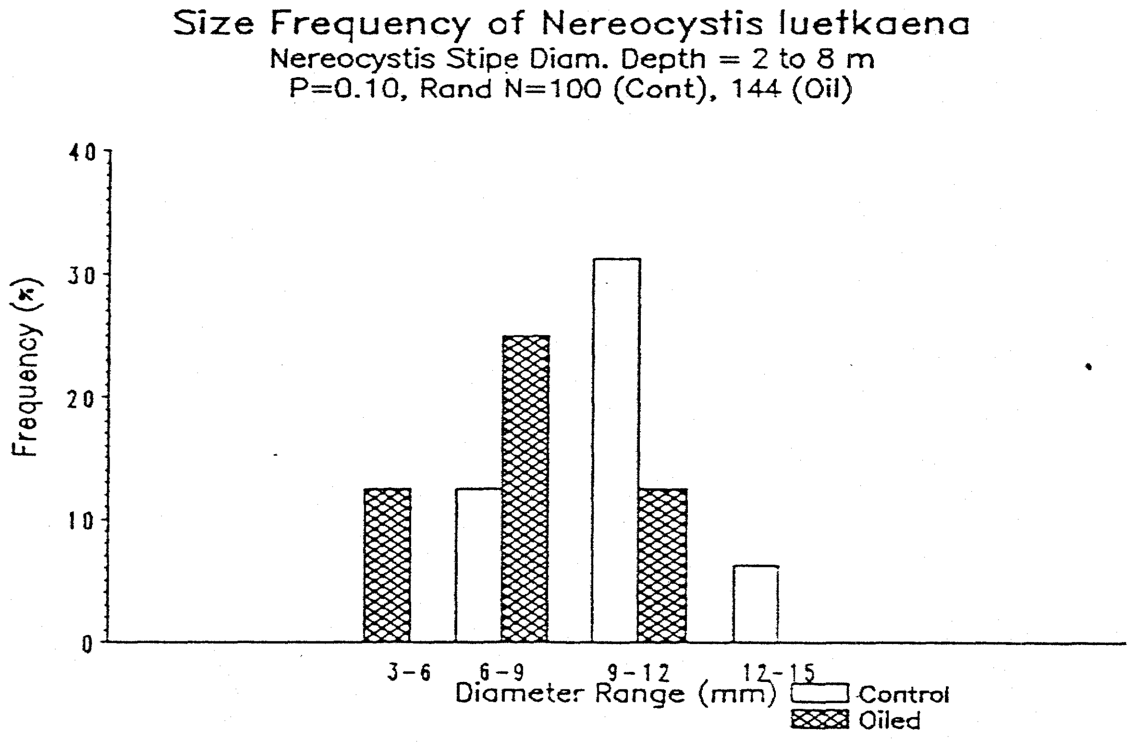


Figure 8. Density and size frequency of *Nereocystis luetkeana* at oiled and control sites in Prince William Sound. Error bars are +/- 1 standard error.

ACE 30286874

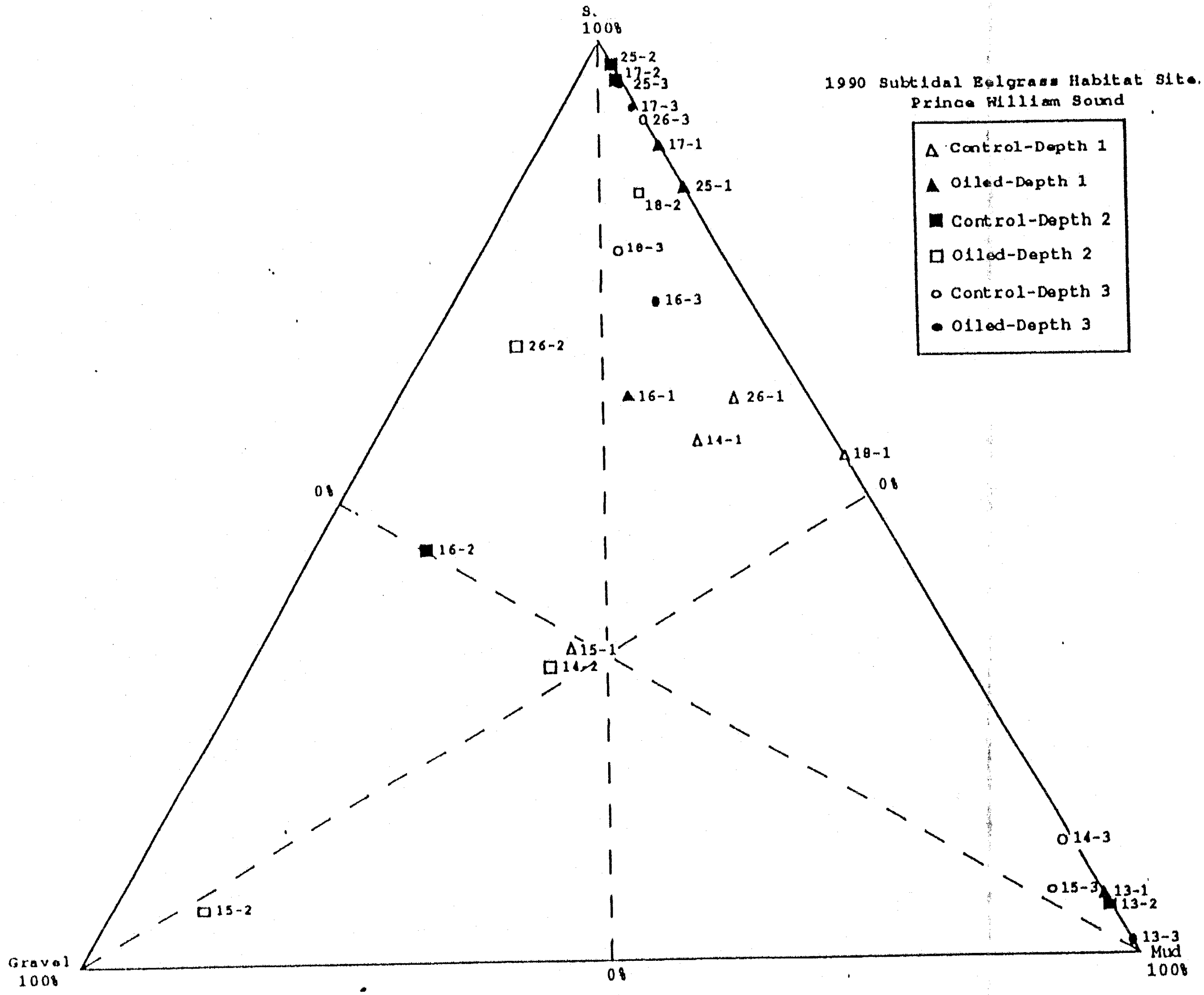


Figure 9. Ternary diagrams of granlometric composition of sediments at sites within eelgrass habitats in Prince William Sound in 1990 and 1991. Paired oiled and control sites and corresponding site numbers are: Bay of Isles (13) - Drier Bay (14); Herring Bay (16) - Lower Herring Bay (15); Sleepy Bay (17) - Moose Lips Bay (18); and Clammy Bay (25) - Puffin Bay (26); and Short Arm of Bay of Isles (35) - Mallard Bay (34).

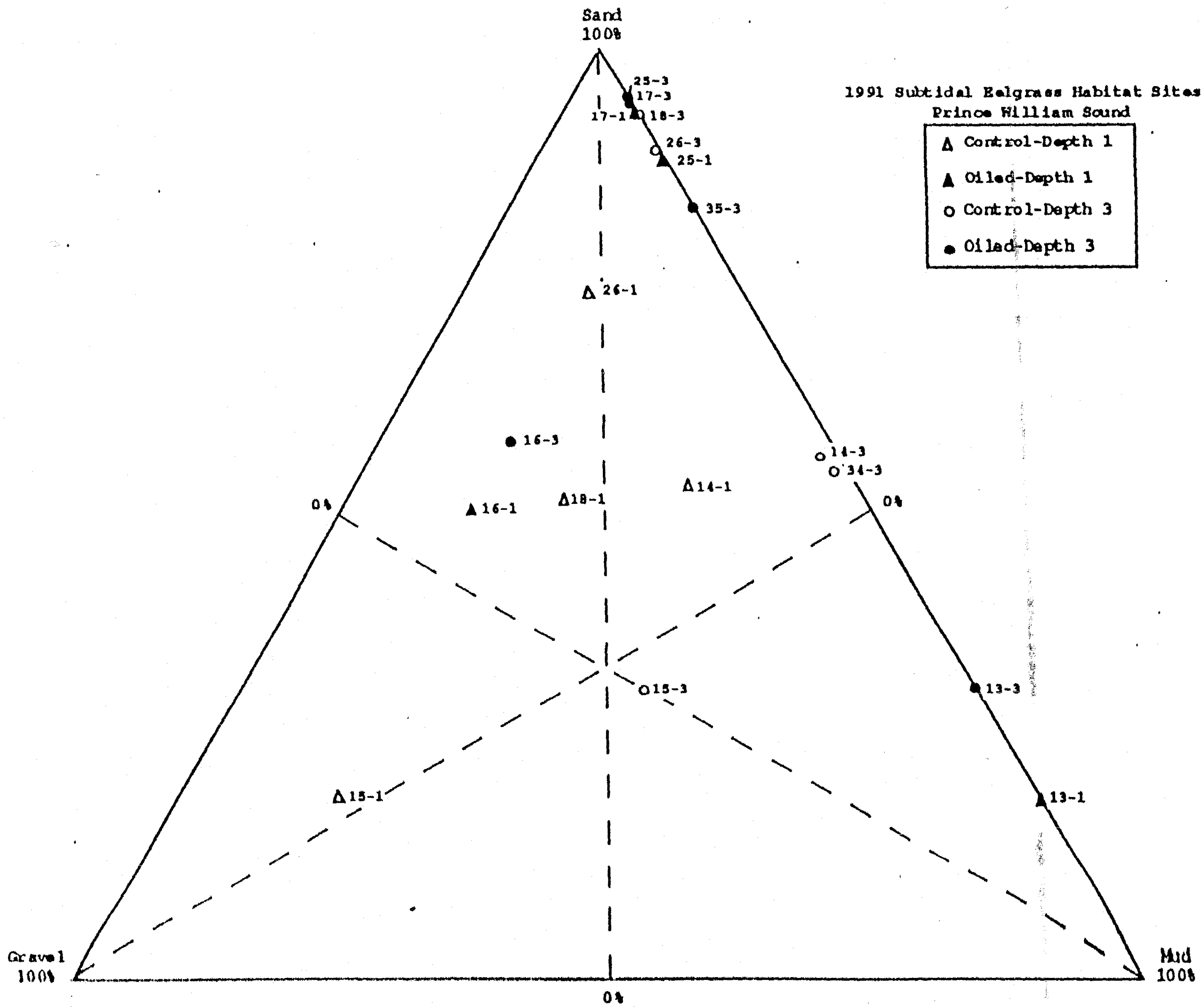


Figure 9. Continued.

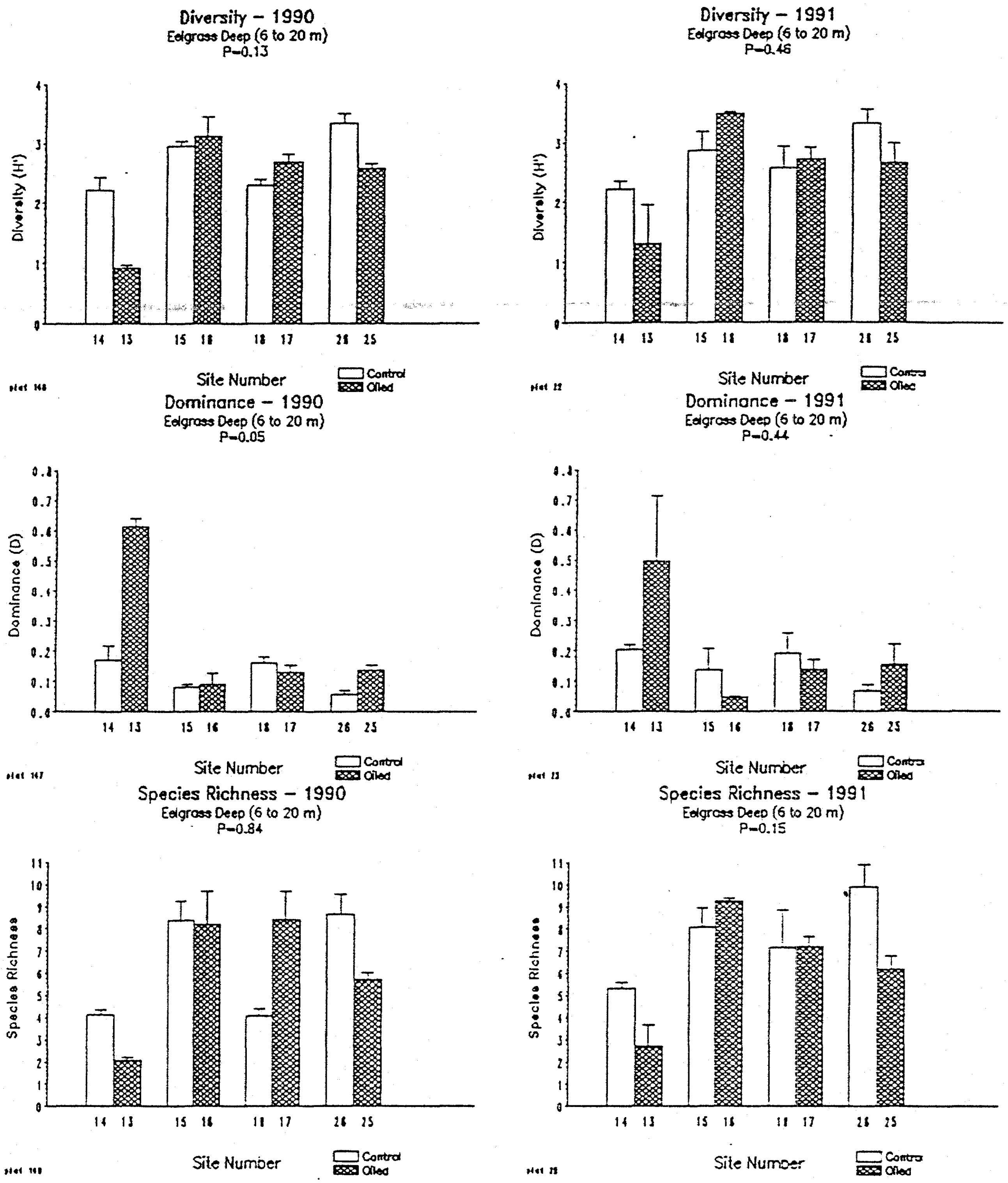


Figure 10. Diversity, dominance, species richness, total abundance, total biomass, and number of taxa for infaunal invertebrates from dredge samples in the deep stratum within the eelgrass habitat in Prince William Sound in 1990 and 1991. Error bars are +/- 1 standard error.

ACE 30286877

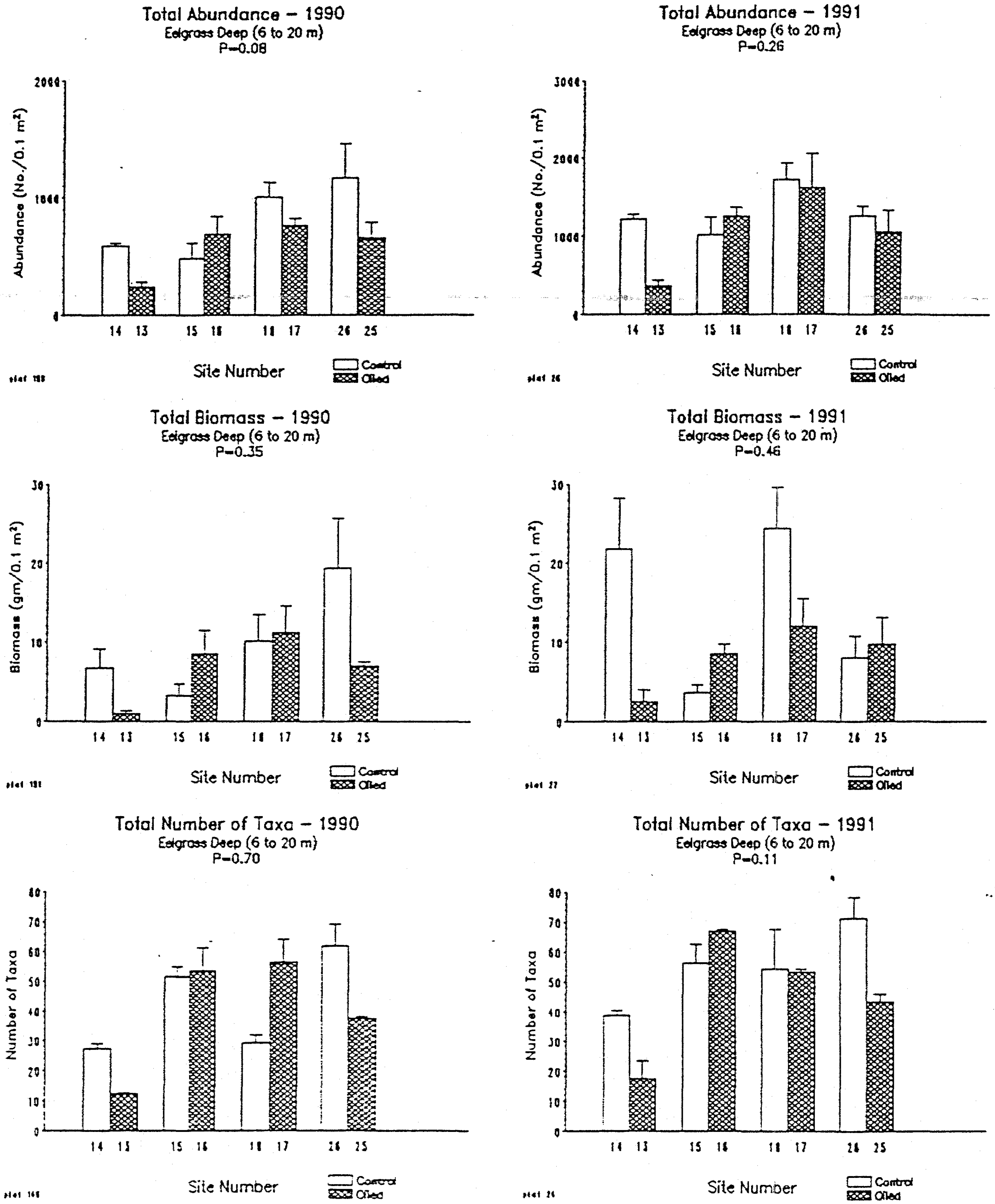


Figure 10. (Continued)

ACE 30286878

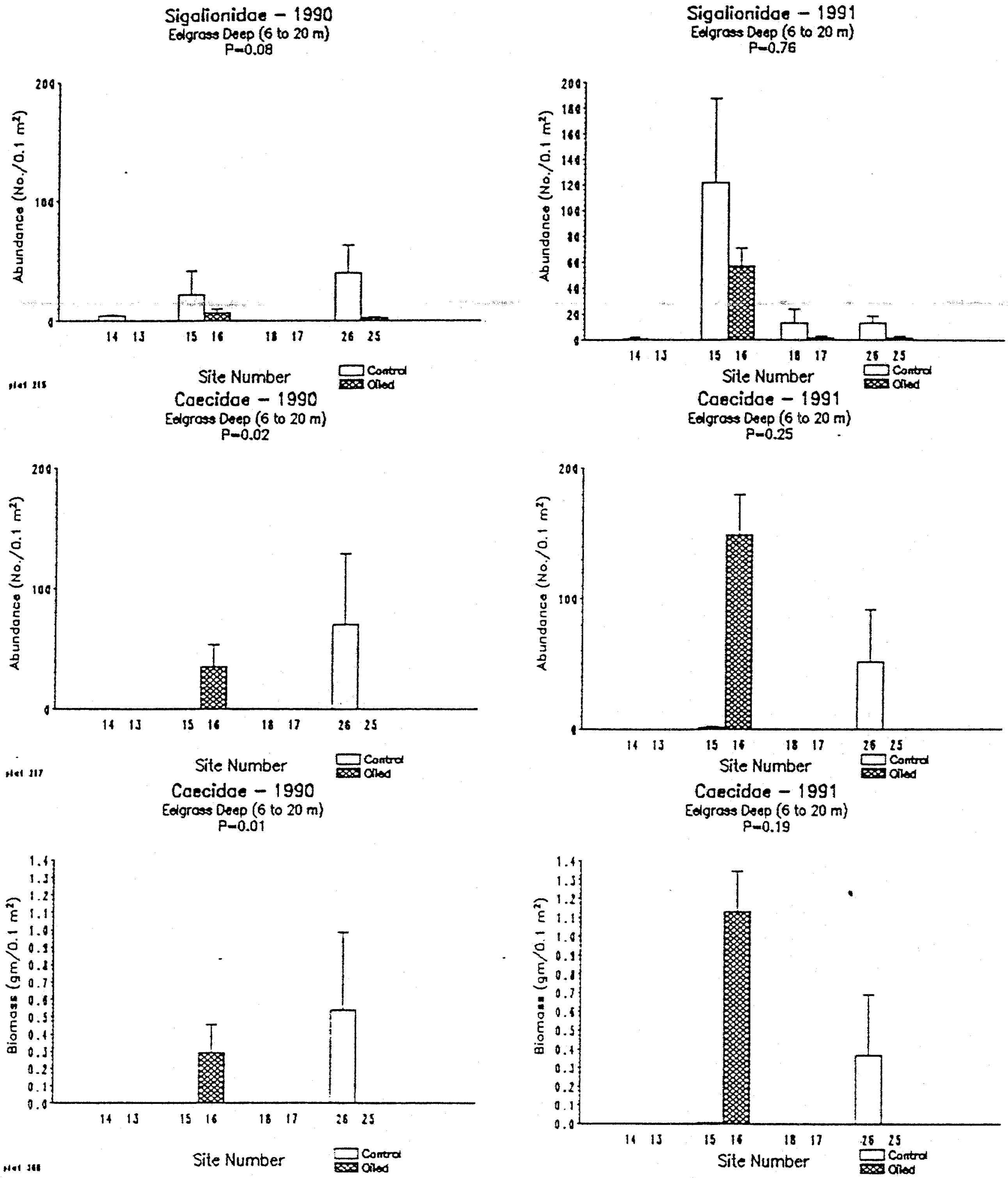


Figure 11. Abundance and biomass of dominant taxa in dredge samples that differed significantly at oiled and control sites in the deep stratum within the eelgrass habitat in Prince William Sound in 1990 and 1991. Error bars are +/- 1 standard error.

ACE 30286879

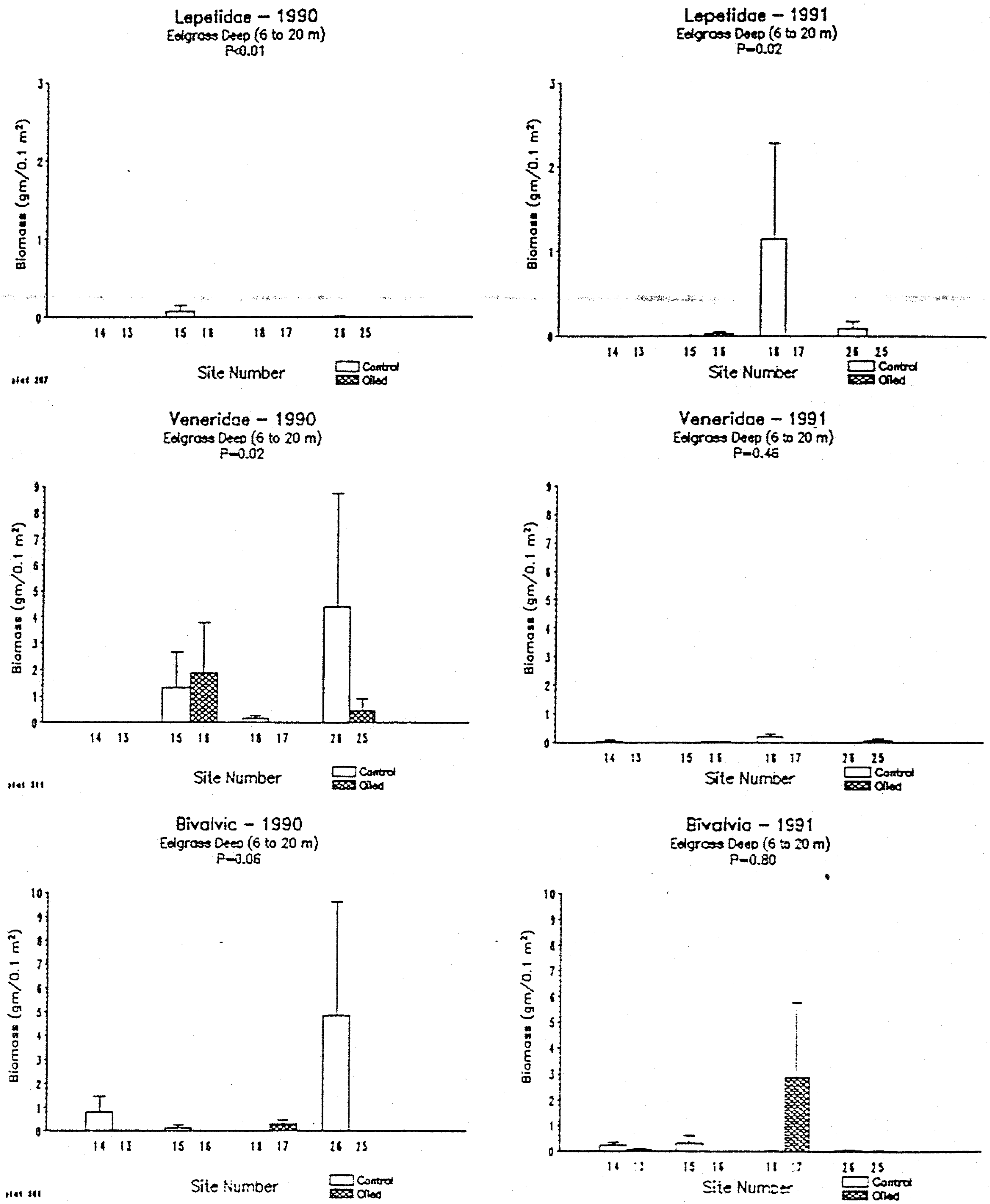


Figure 11. (Continued)

ACE 30286880

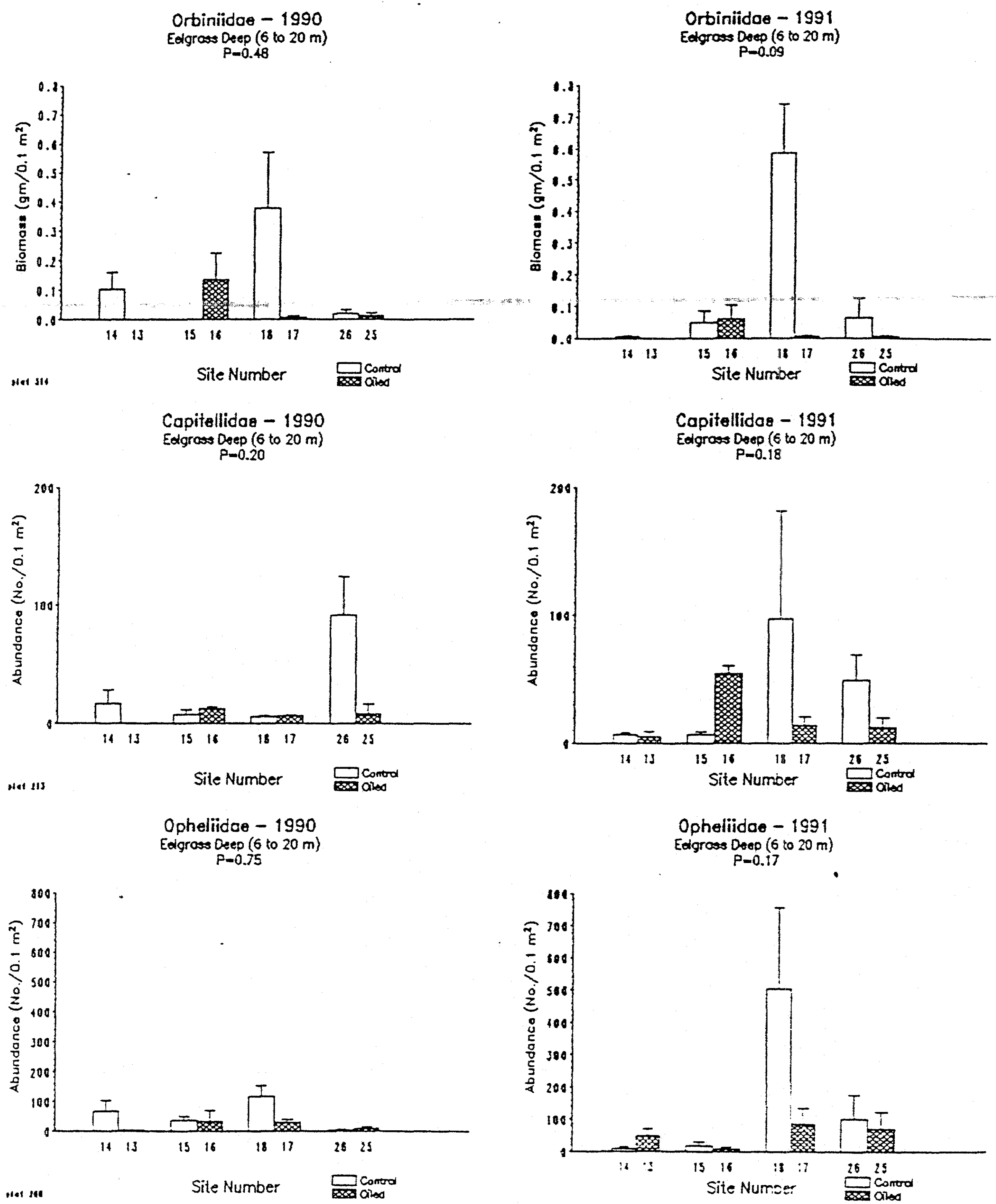


Figure 11. (Continued)

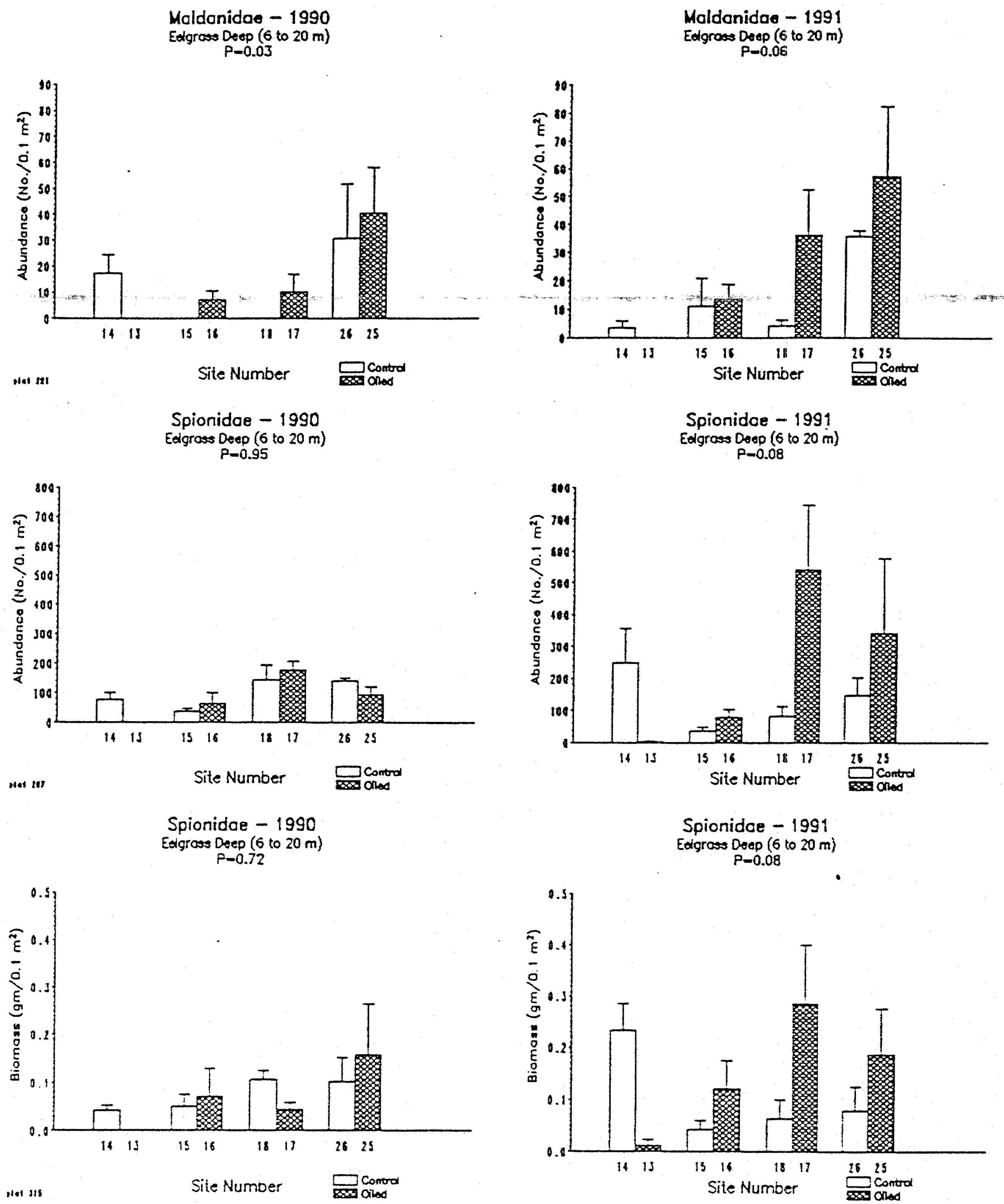


Figure 11. (Continued)

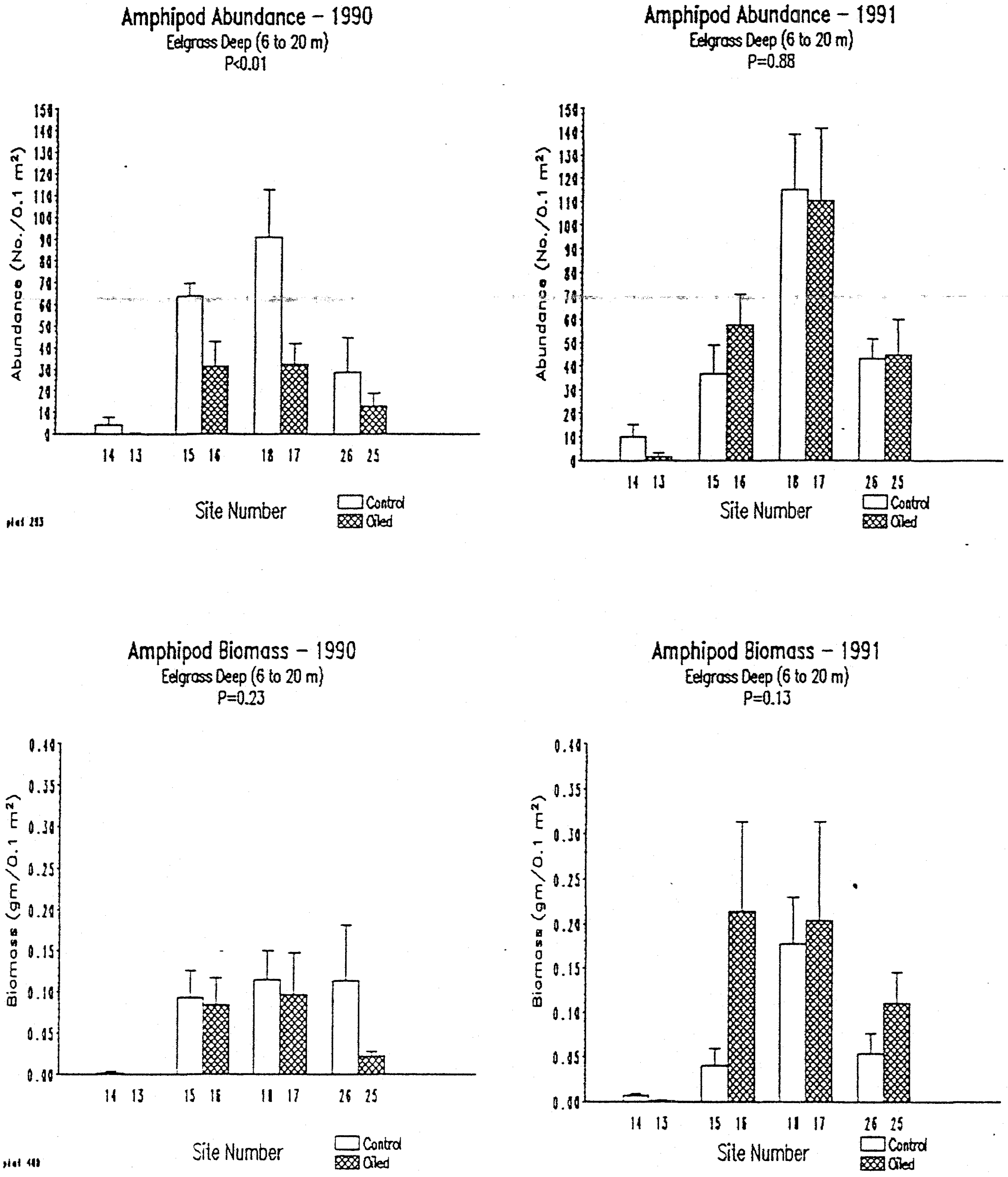


Figure 12. Abundance and biomass of amphipods in dredge samples at oiled and control sites in the deep stratum within the eelgrass habitat in Prince William Sound in 1990. Error bars are +/- 1 standard error.

ACE 30286383

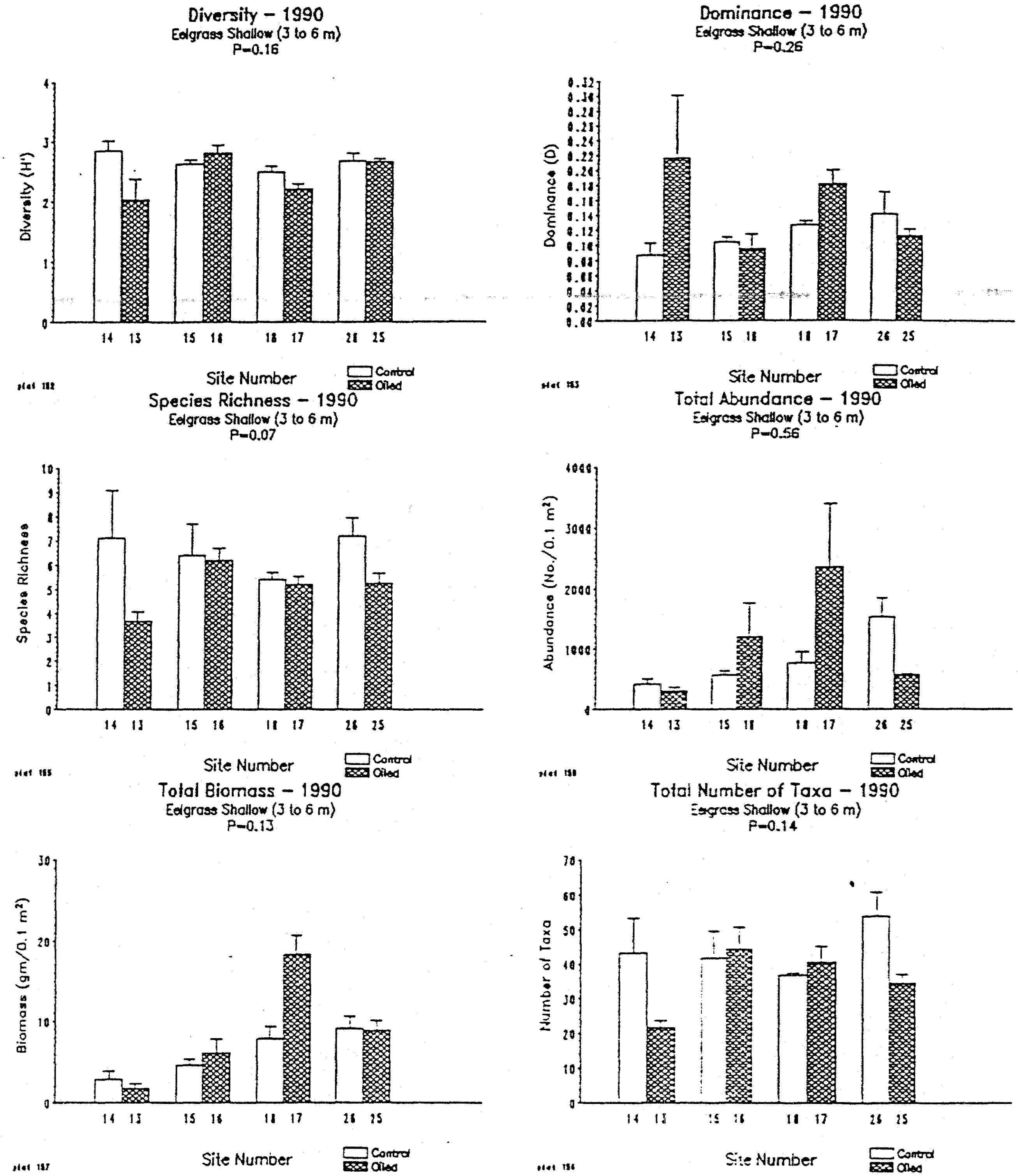


Figure 13. Diversity, dominance, species richness, total abundance, total biomass, and number of taxa for infaunal invertebrates from dredge samples in the shallow stratum within the eelgrass habitat in Prince William Sound in 1990. Error bars are +/- 1 standard error.

ACE 30286884

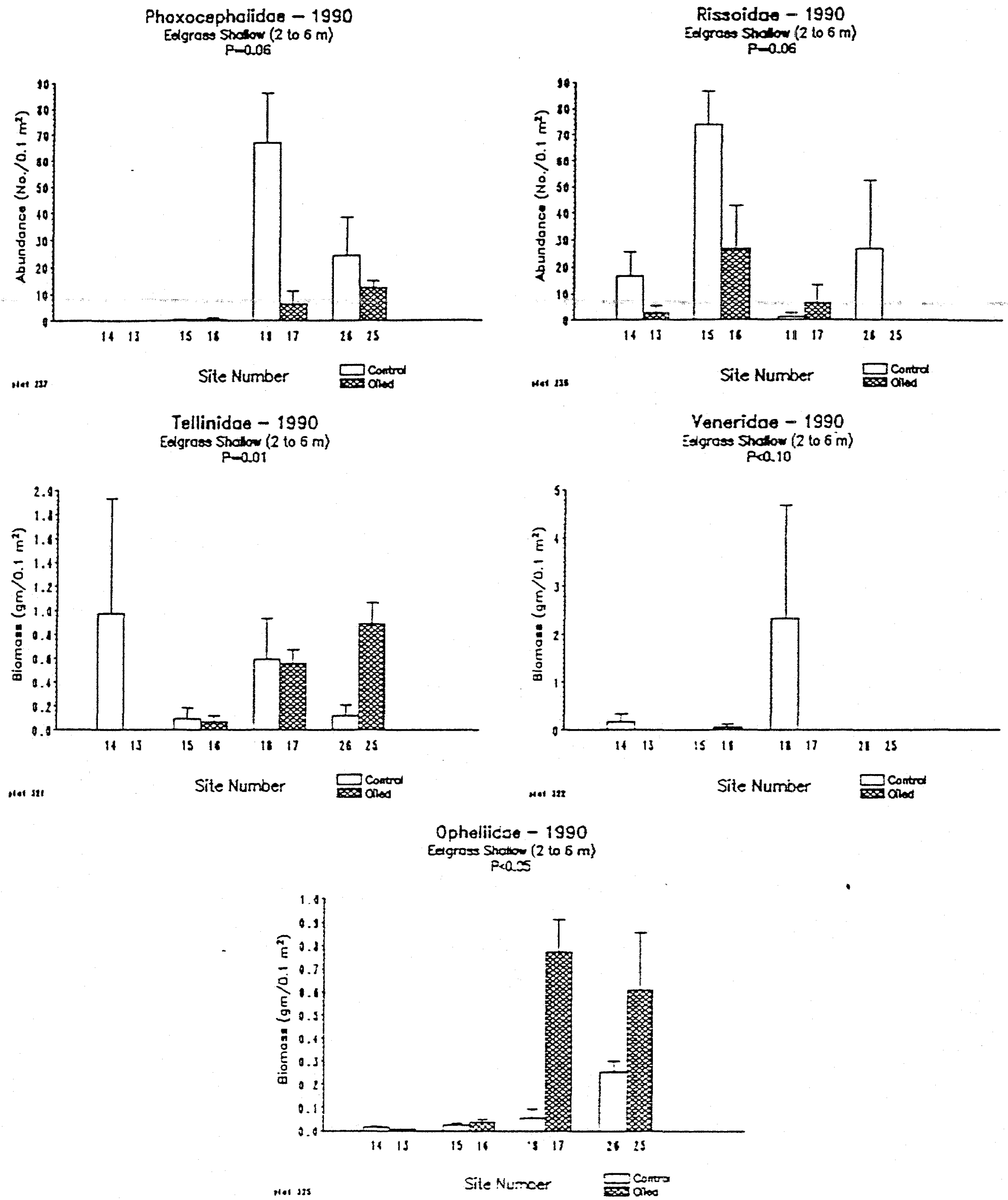


Figure 14. Abundance and biomass of dominant taxa in dredge samples that differed significantly at oiled and control sites in the shallow stratum within the eelgrass habitat in Prince William Sound in 1990. Error bars are +/- 1 standard error.

ACE 30286885

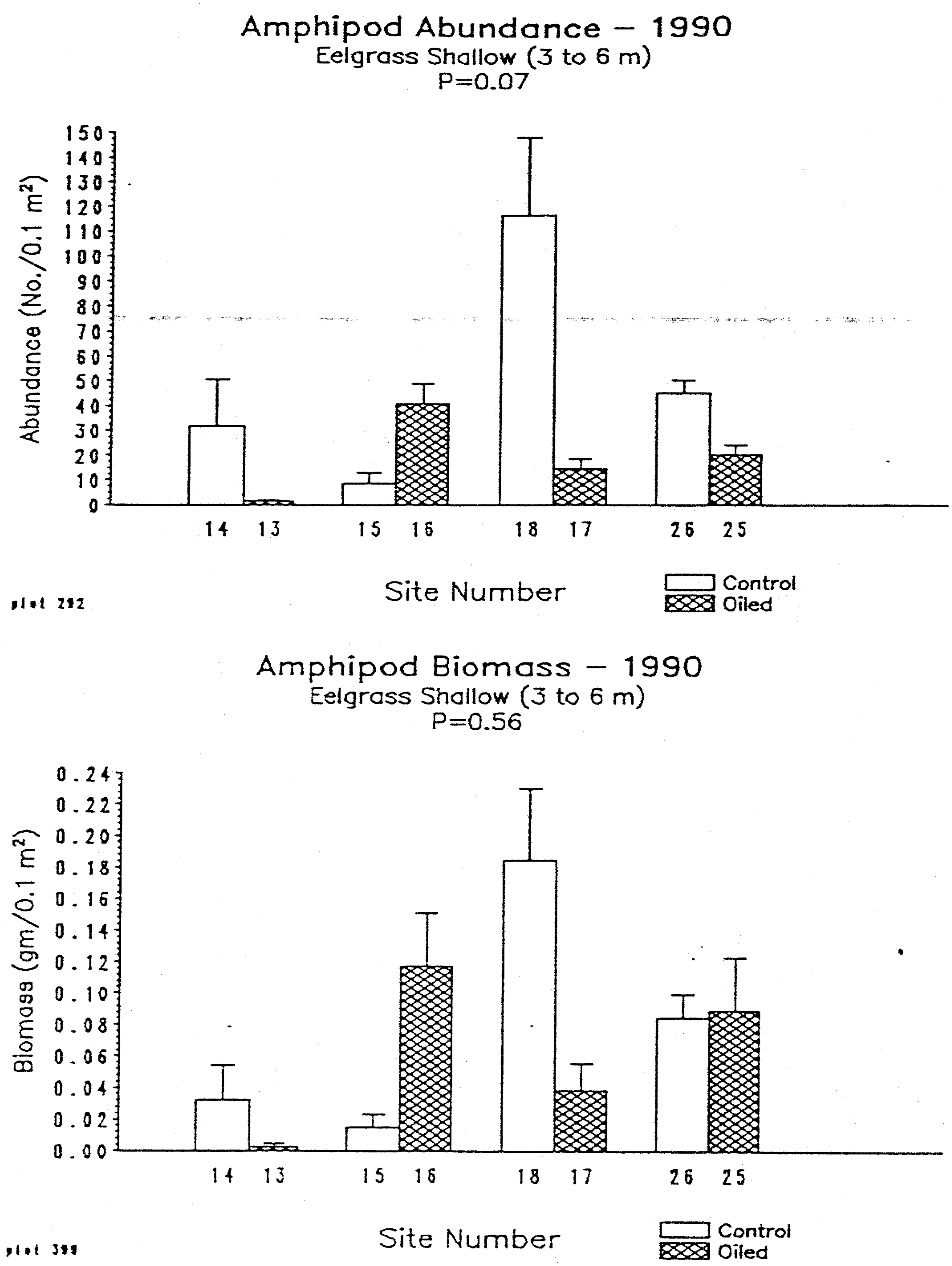


Figure 15. Abundance and biomass of amphipods in dredge samples at oiled and control sites in the shallow stratum within the eelgrass habitat in Prince William Sound in 1990. Error bars are +/- 1 standard error.

ACE 30286886

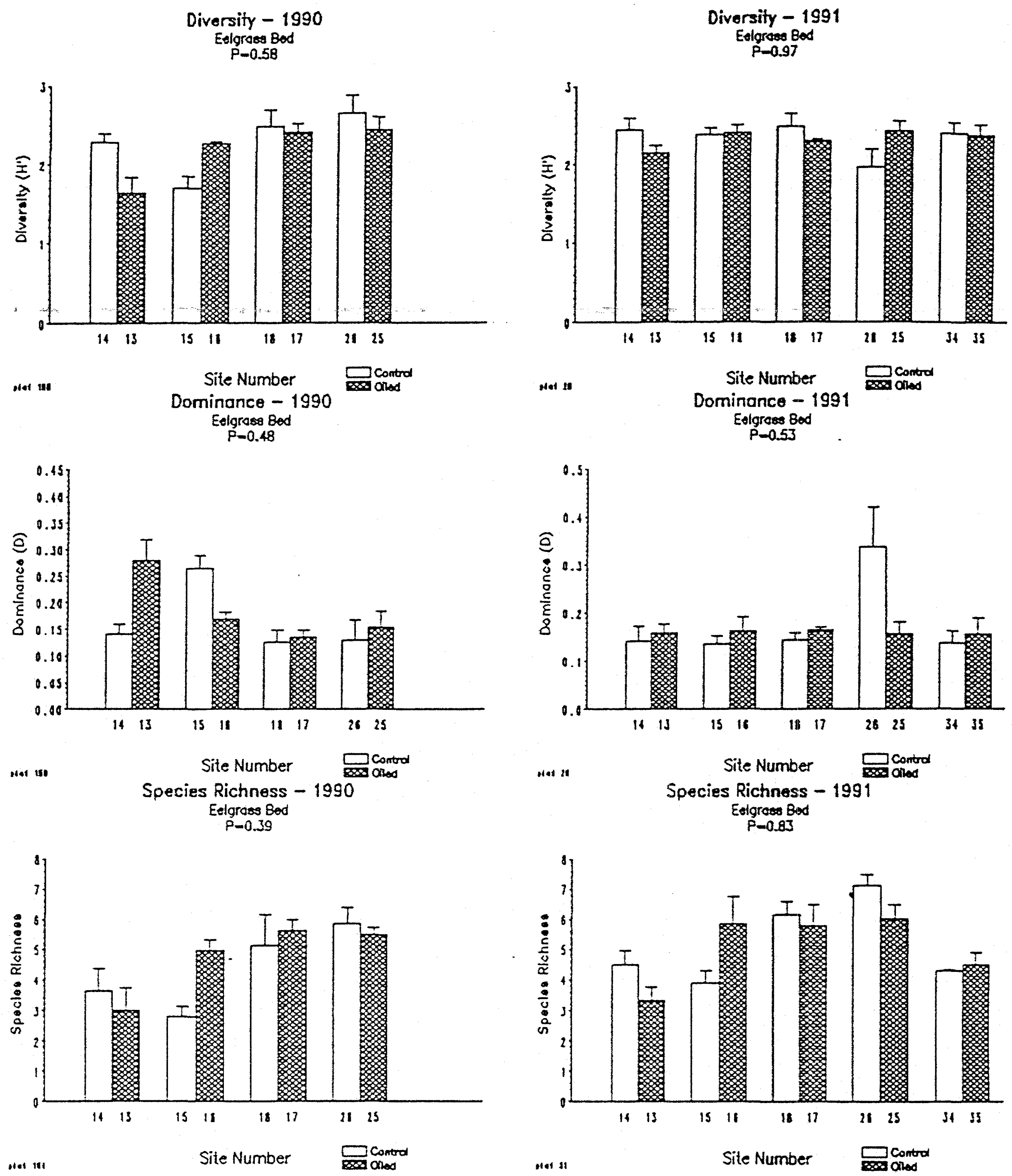


Figure 16. Diversity, dominance, species richness, total abundance, total biomass, and number of taxa for infaunal invertebrates from dredge samples in the eelgrass bed within the eelgrass habitat in Prince William Sound in 1990 and 1991 . Error bars are +/- 1 standard error.

ACE 30286887

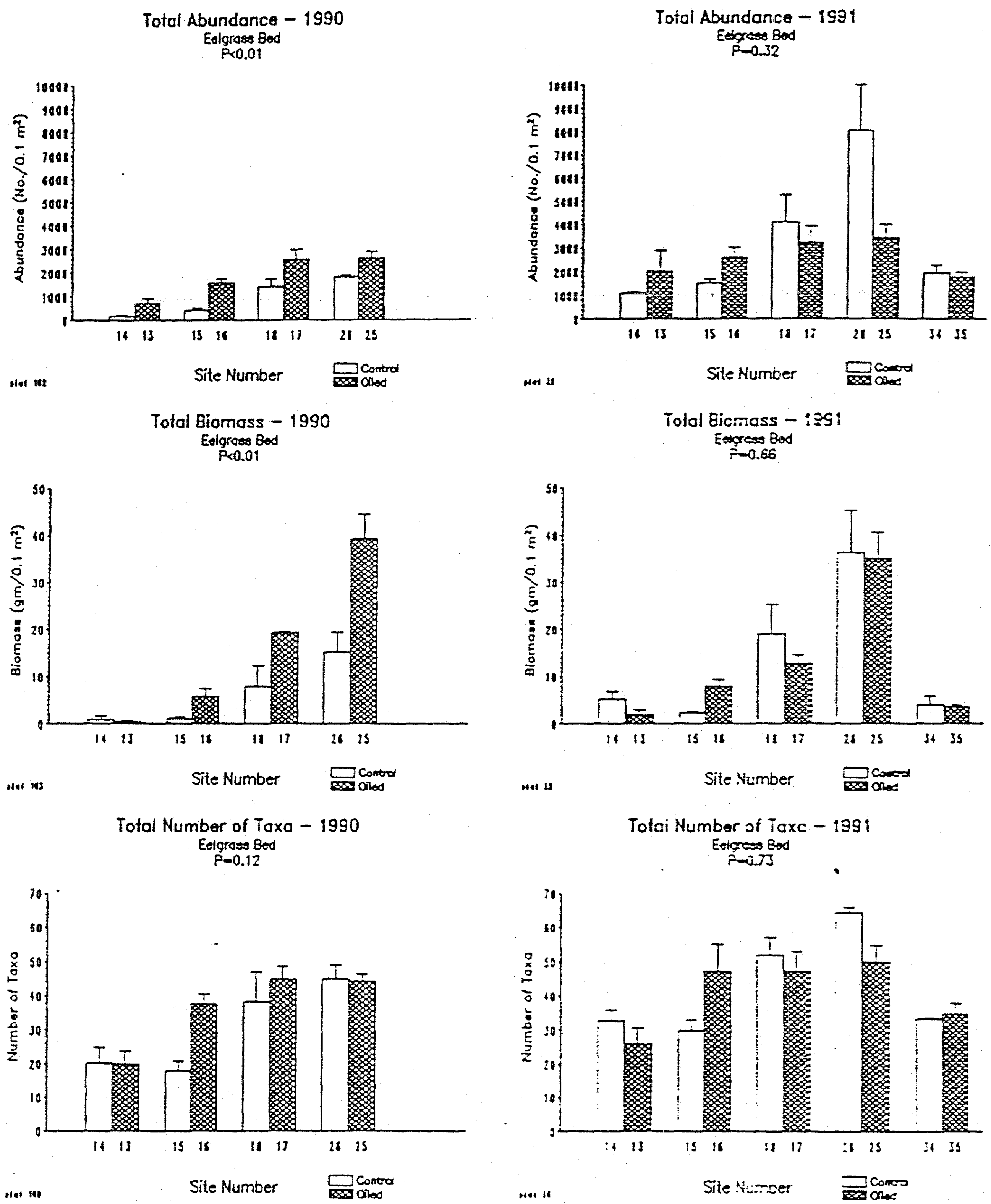


Figure 16. (Continued)

ACE 30286888

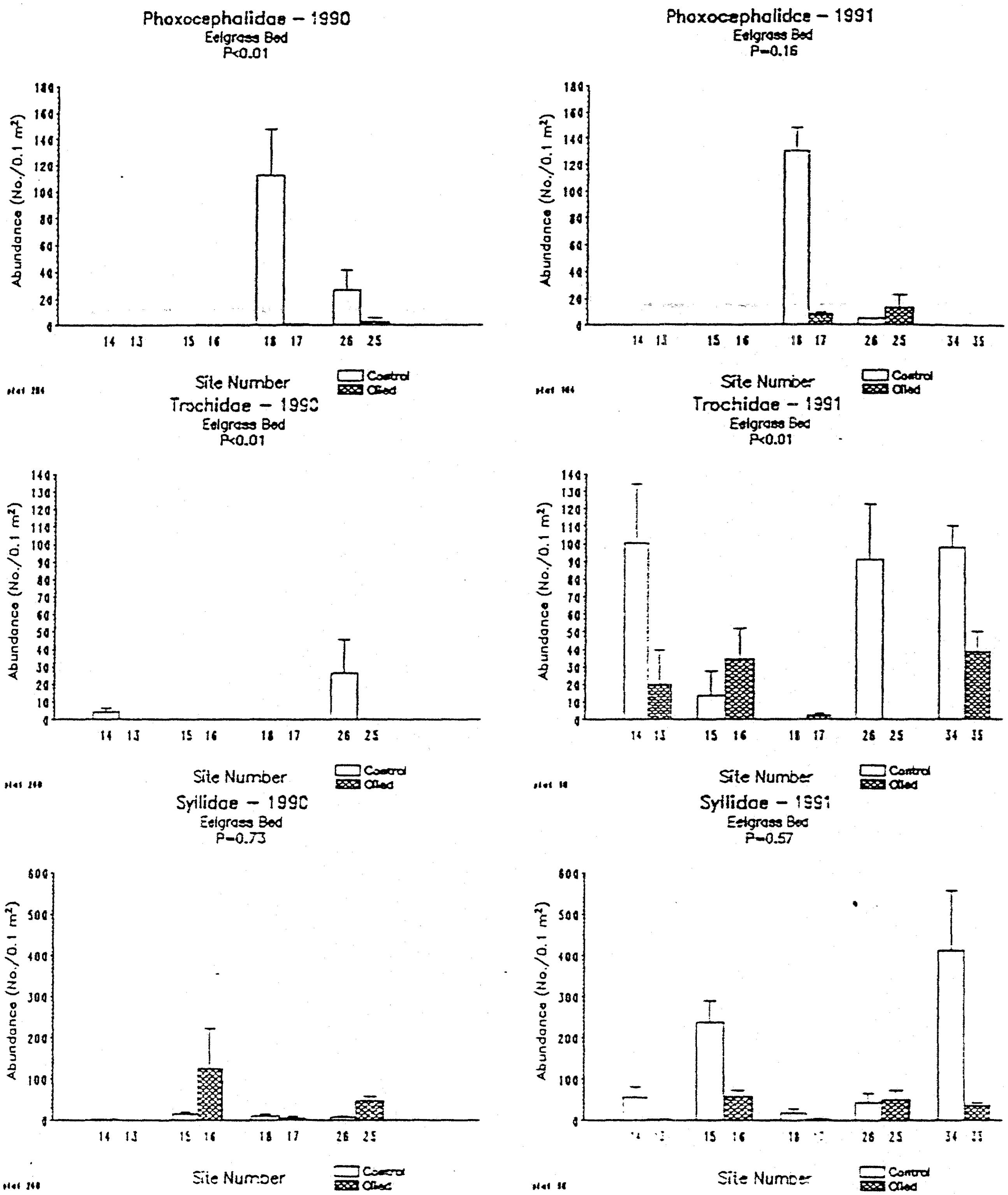


Figure 17. Abundance and biomass of dominant taxa in dredge samples that differed significantly at oiled and control sites in the eelgrass bed within the eelgrass habitat in Prince William Sound in 1990 and 1991. Error bars are +/- 1 standard error.

ACE 30286839

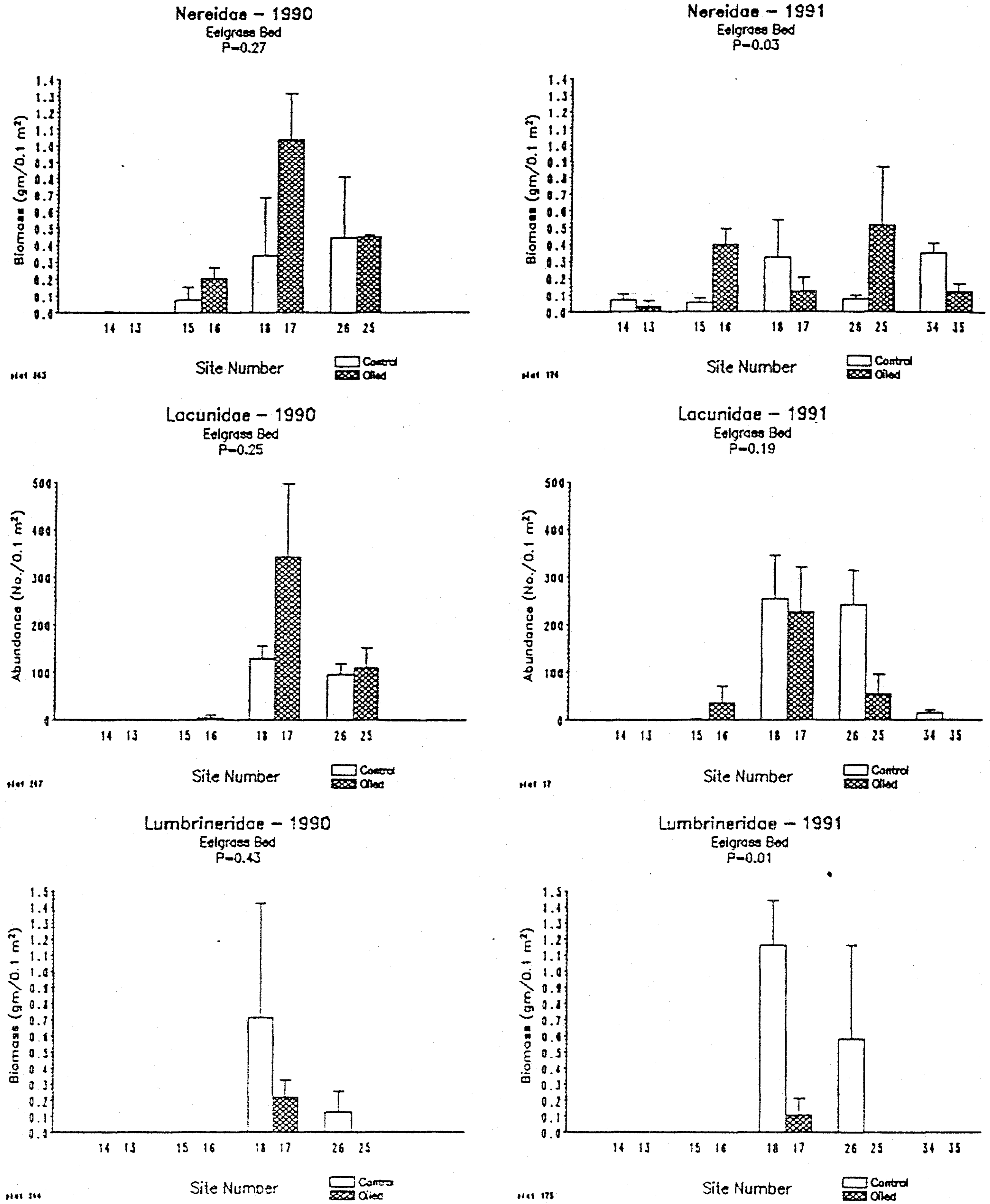
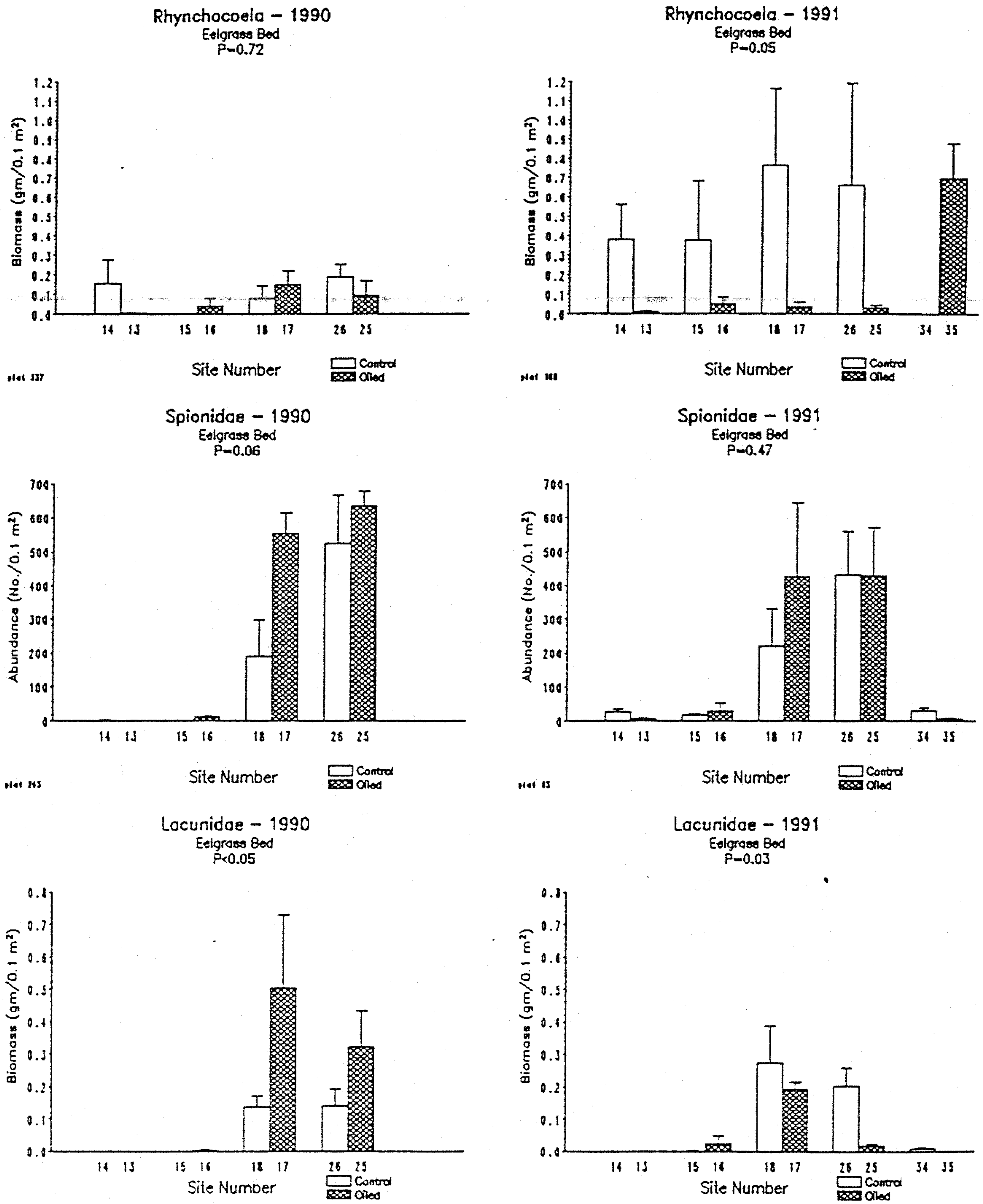


Figure 17. (Continued)

ACE 30286890



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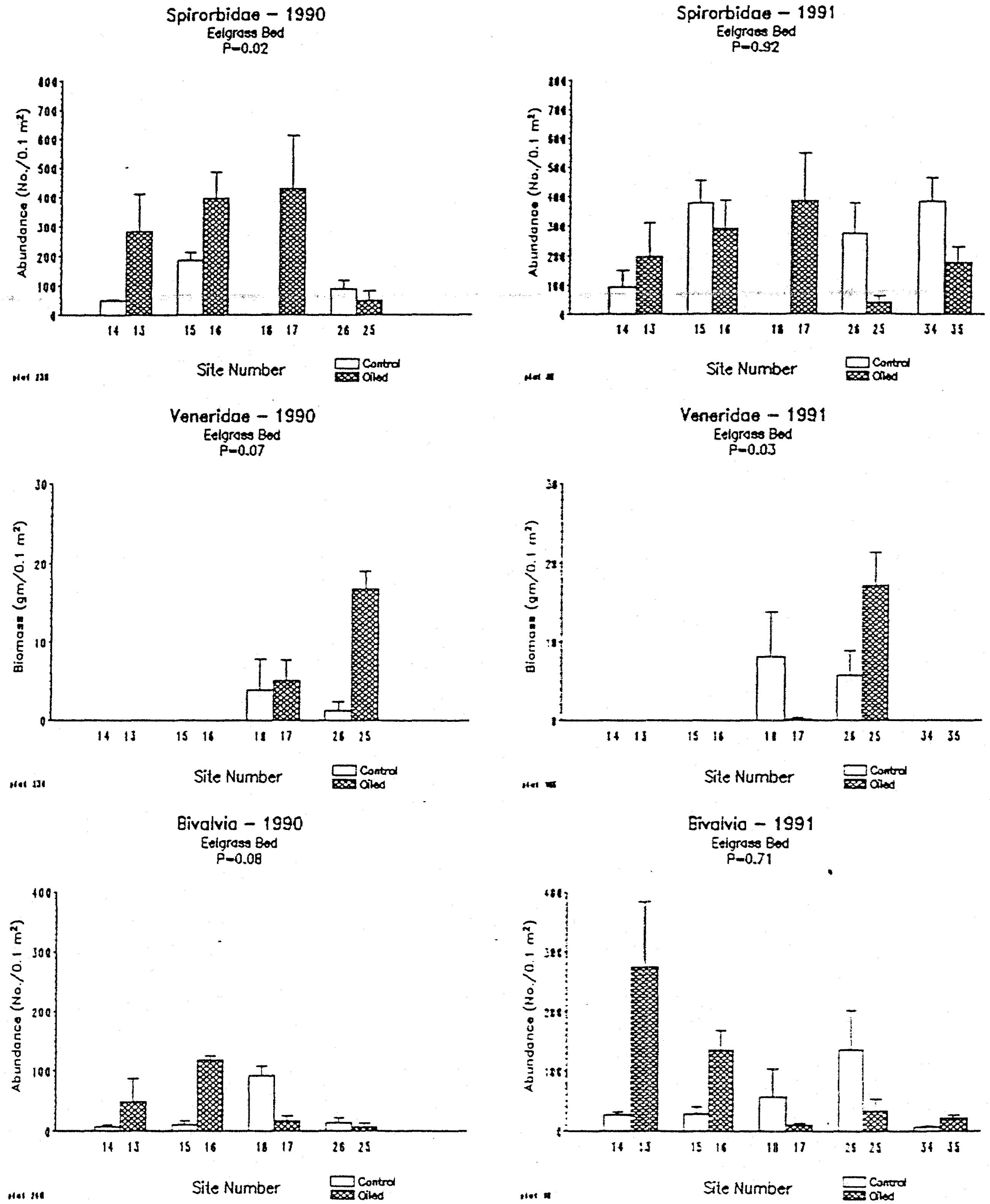
ACE 30286891



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ACE 30236892

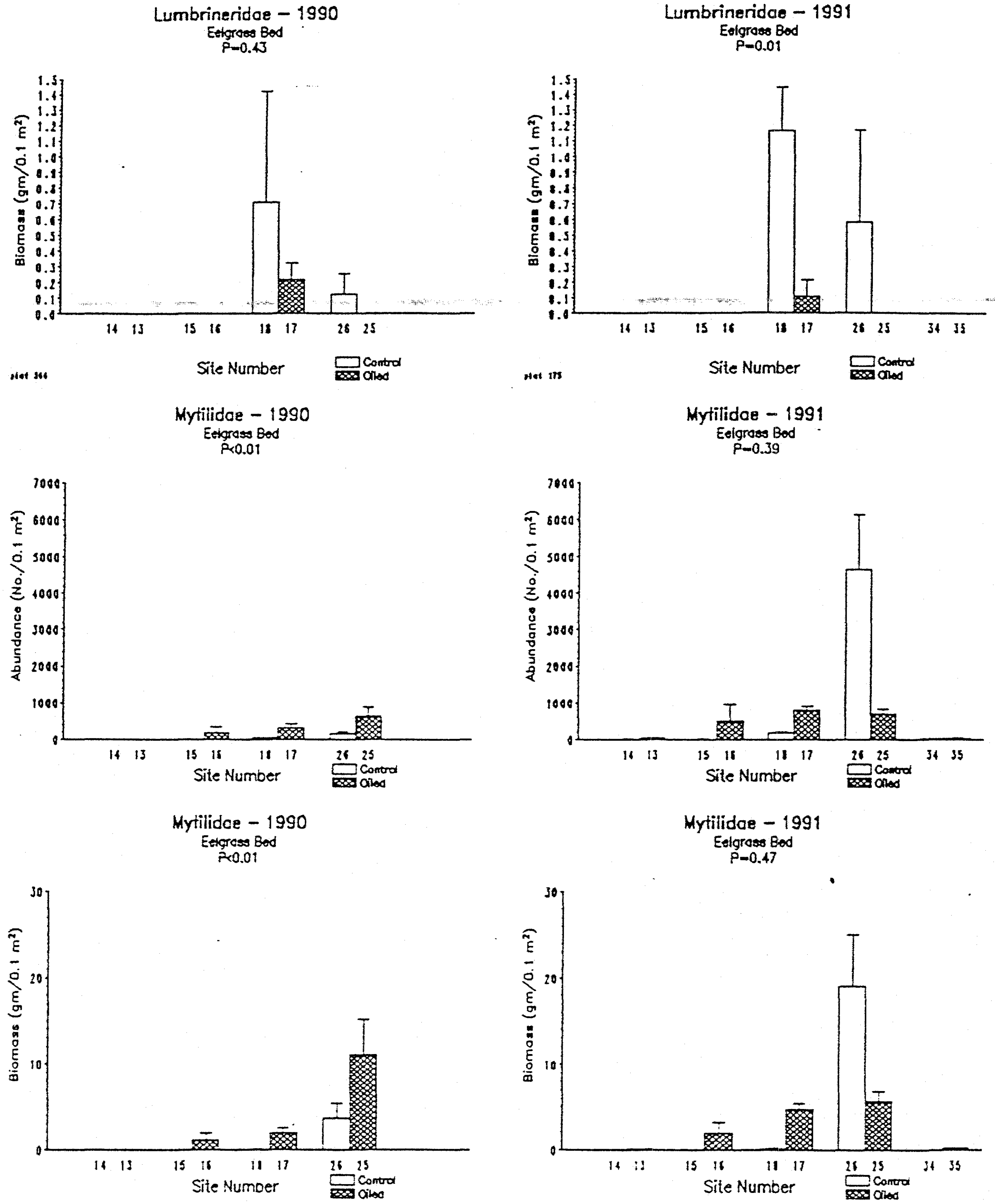


Figure 17. (Continued)

ACE 30286893

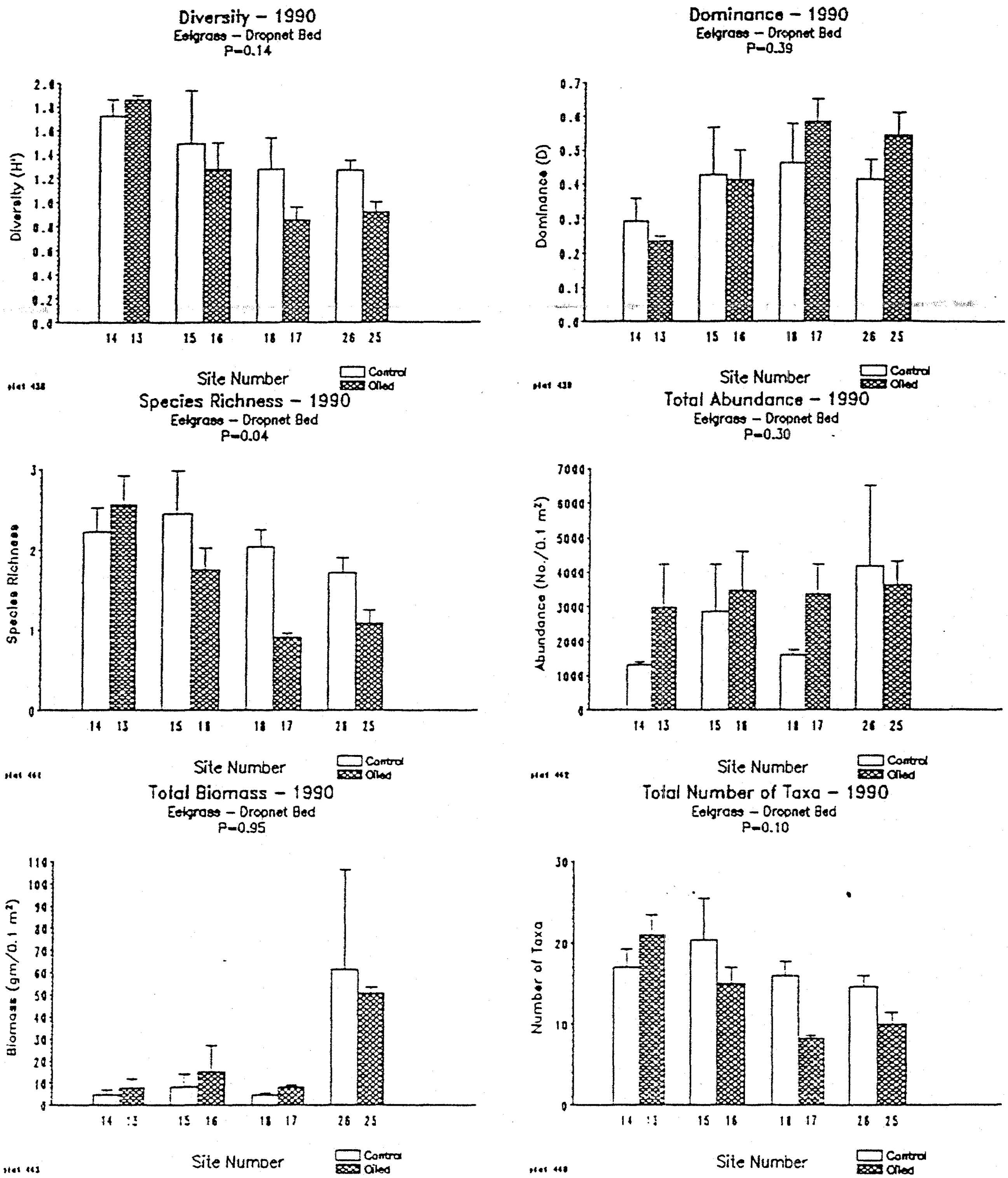


Figure 18. Diversity, dominance, species richness, total abundance, total biomass, and total number of taxa for infaunal invertebrates from dropnet samples in eelgrass beds within the eelgrass habitat in Prince William Sound. Error bars are +/- 1 standard error.

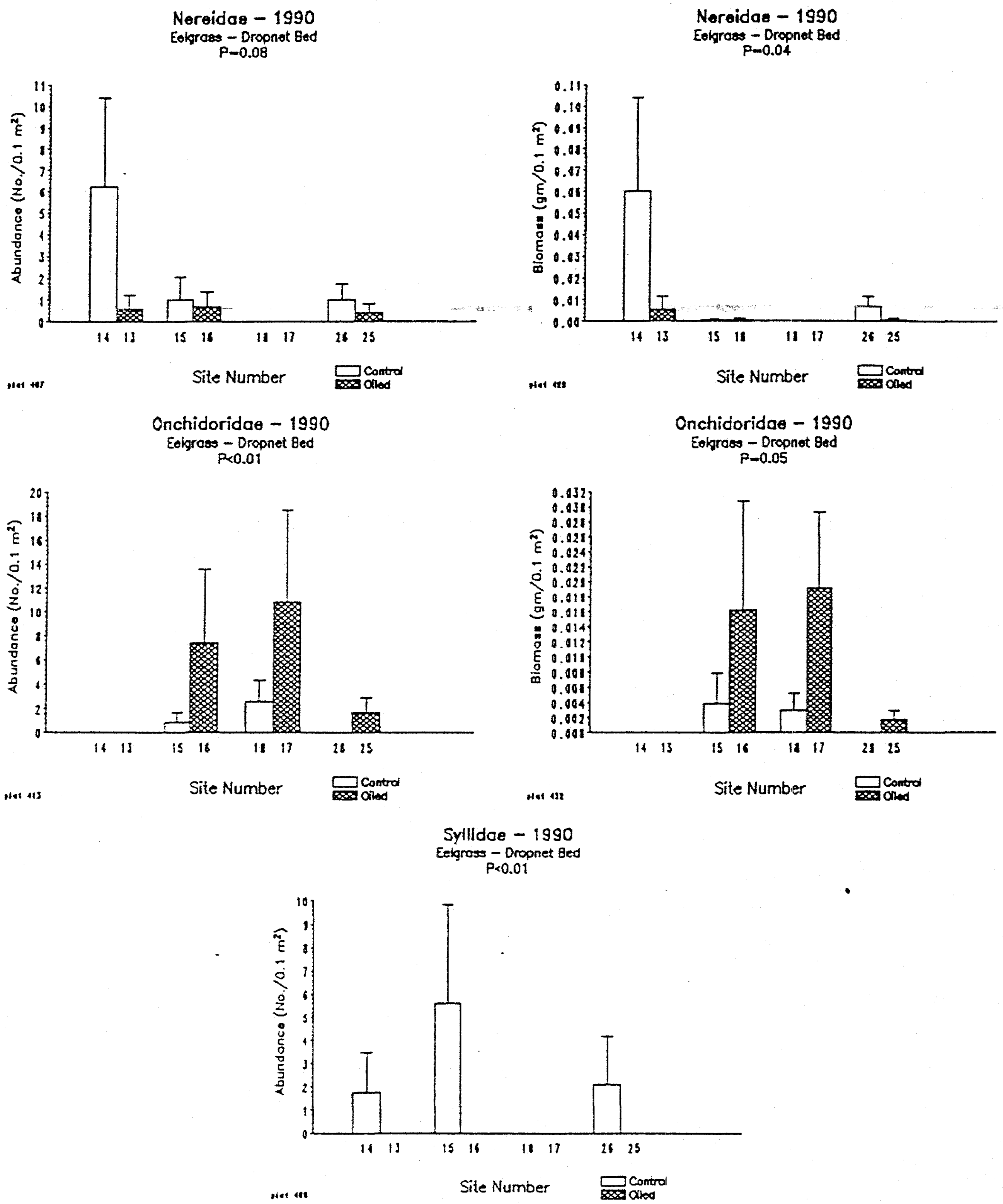
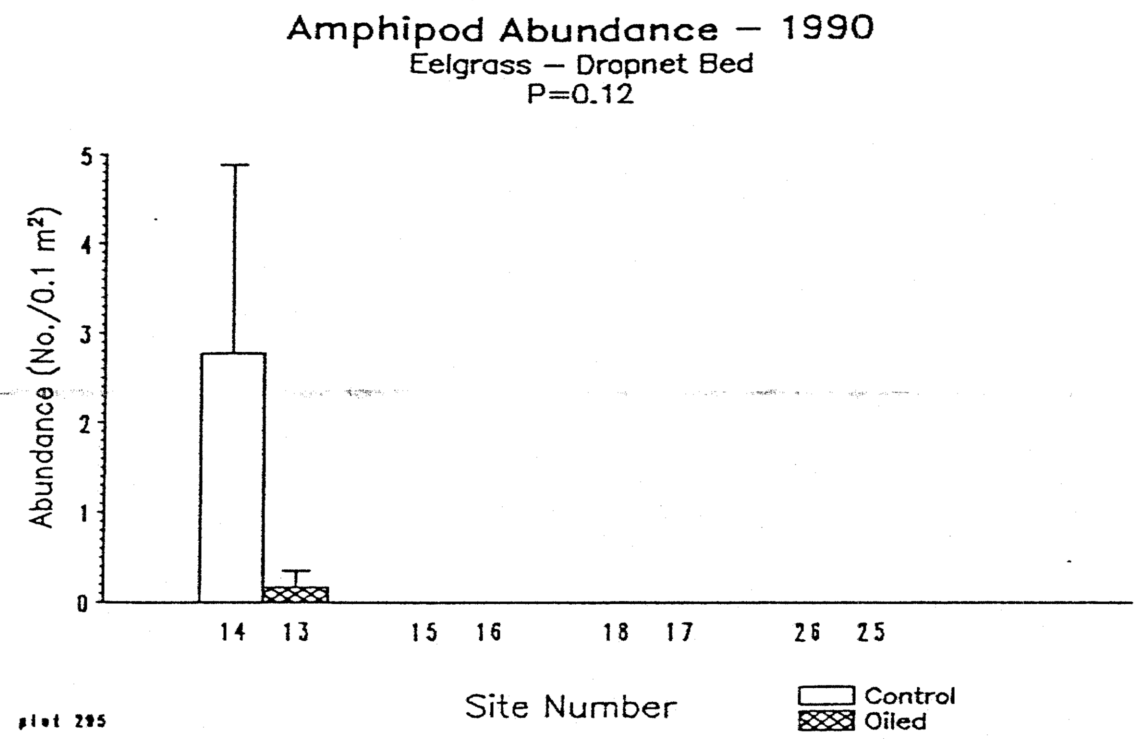


Figure 19. Abundance and biomass of dominant taxa in dropnet samples that differed significantly at oiled and control sites in the eelgrass bed within the eelgrass habitat in Prince William Sound in 1990. Error bars are +/- 1 standard error.

ACE 30286895



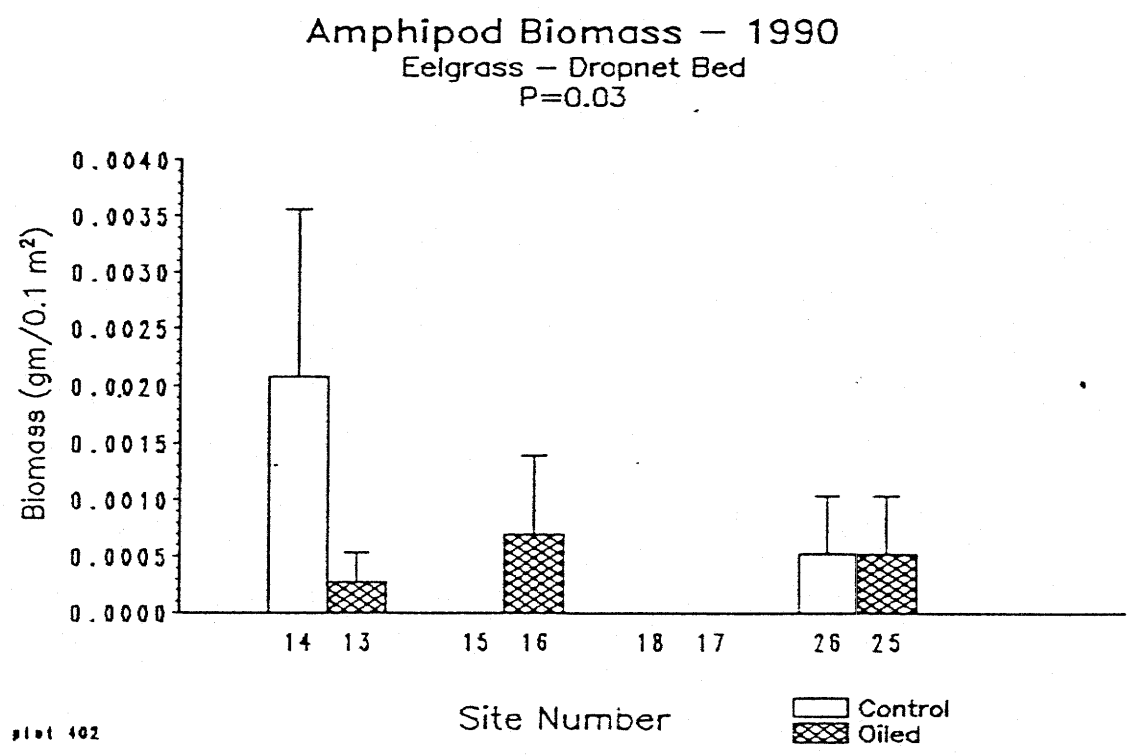


Figure 20. Abundance and biomass of amphipods in dropnet samples at oiled and control sites in eelgrass beds within the eelgrass habitat in Prince William Sound in 1990. Error bars are +/- 1 standard error.

ACE 30286896

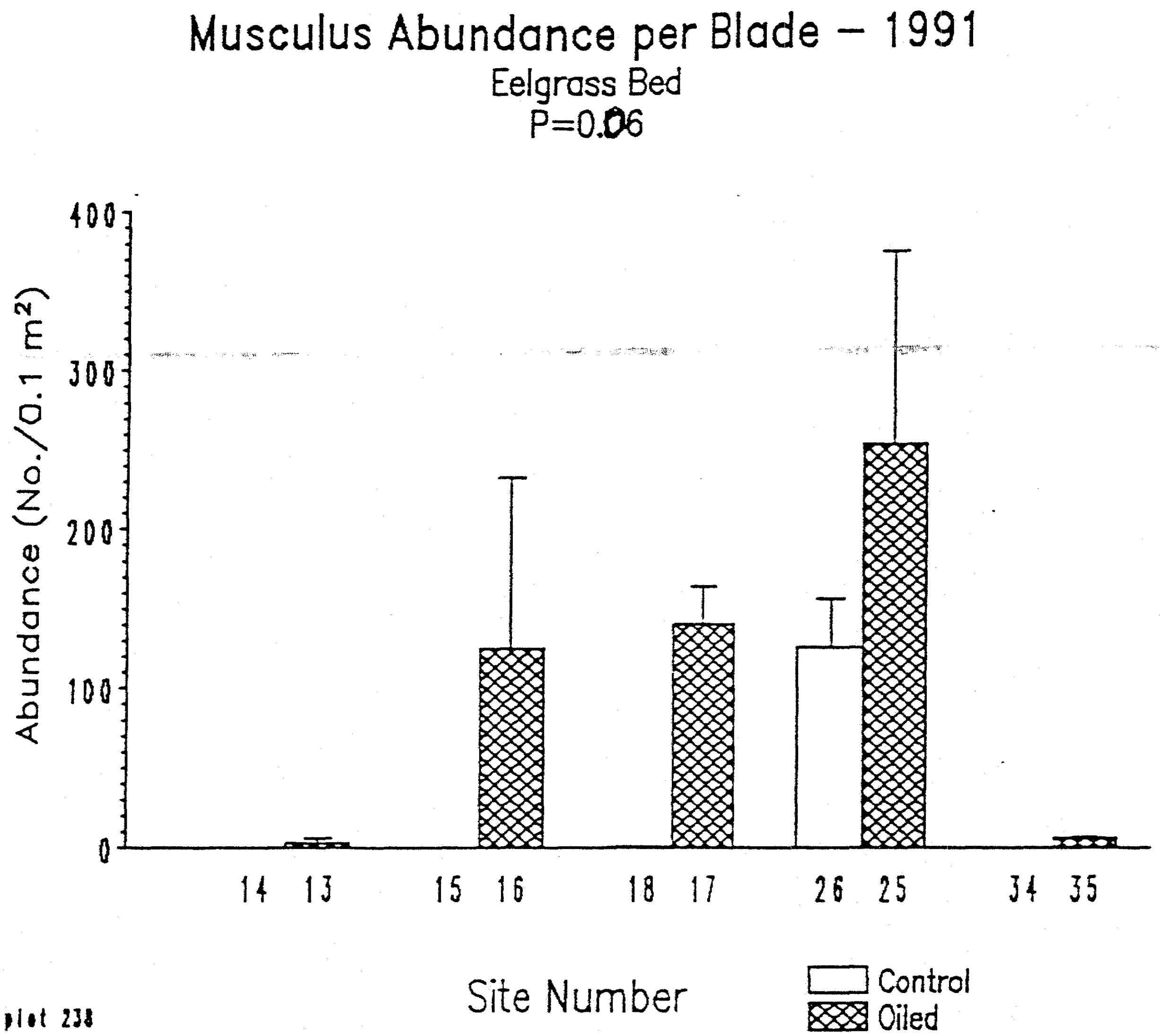
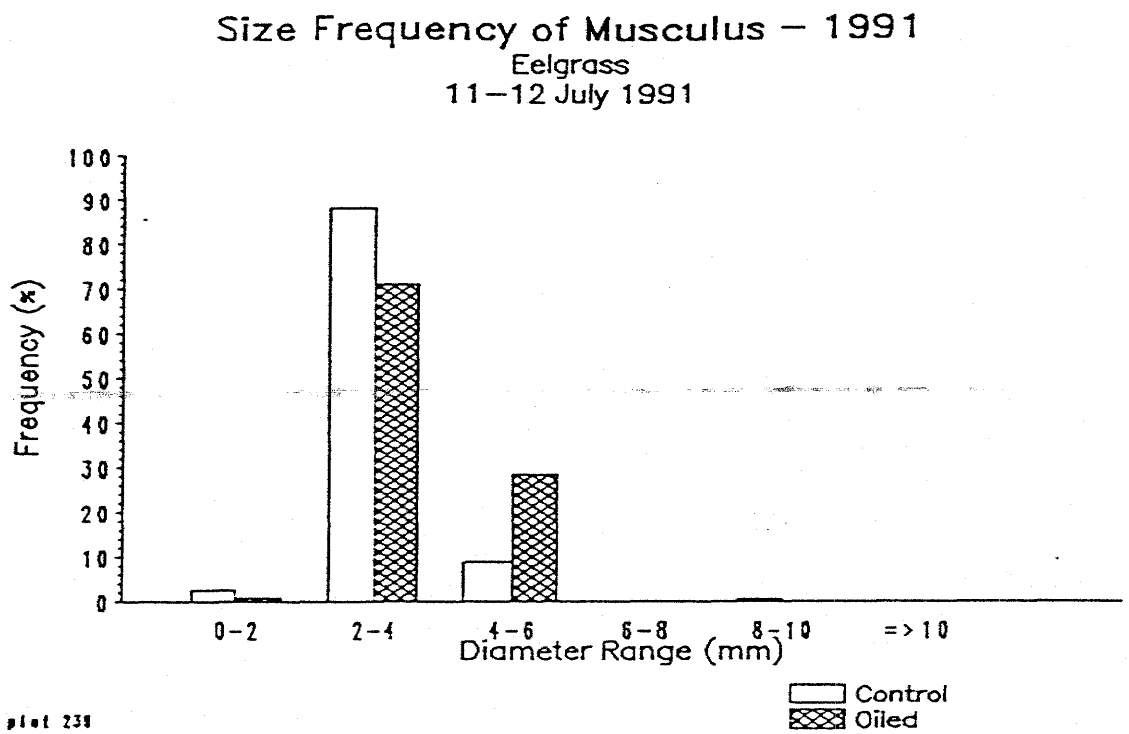


Figure 21. Abundance of *Musculus* spp. per eelgrass turion at oiled and control sites in the eelgrass habitat in Prince William Sound in 1991. Error bars are +/- 1 standard error.

ACE 30236897



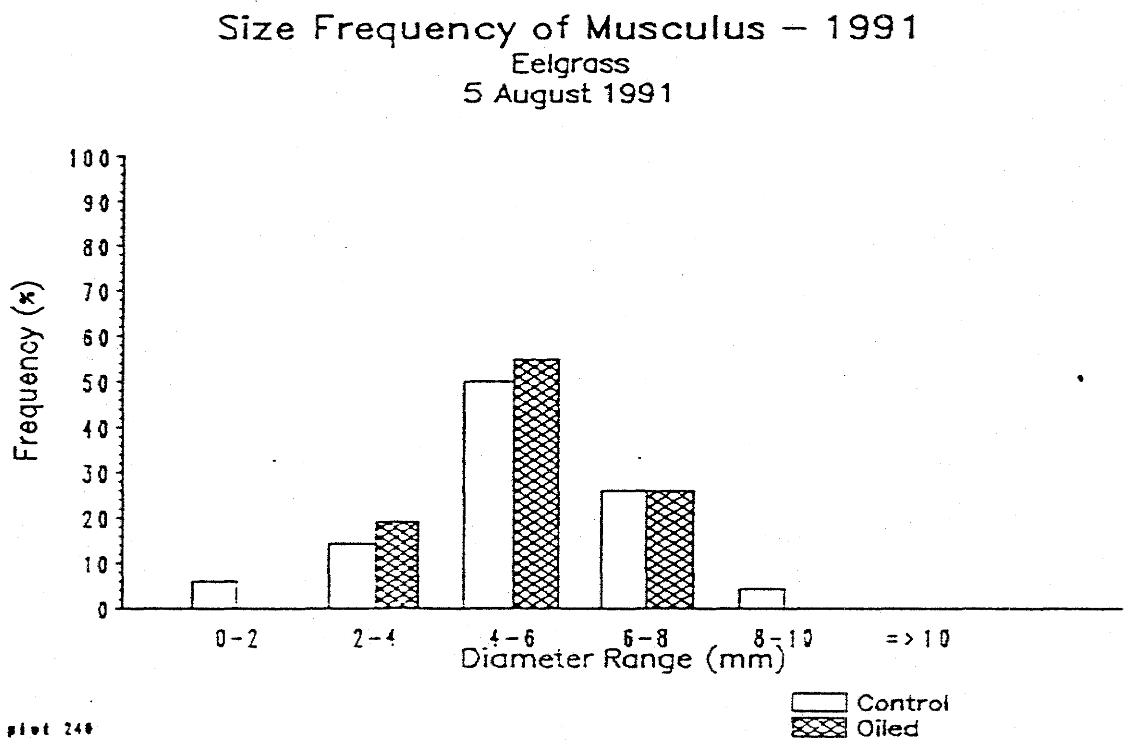


Figure 22. Size frequency of *Musculus* spp. at oiled (Clammy Bay-Site #25) and control sites (Puffin Bay-Site #26) in the eelgrass habitat in Prince William Sound during two visits in 1991.

ACE 30286898

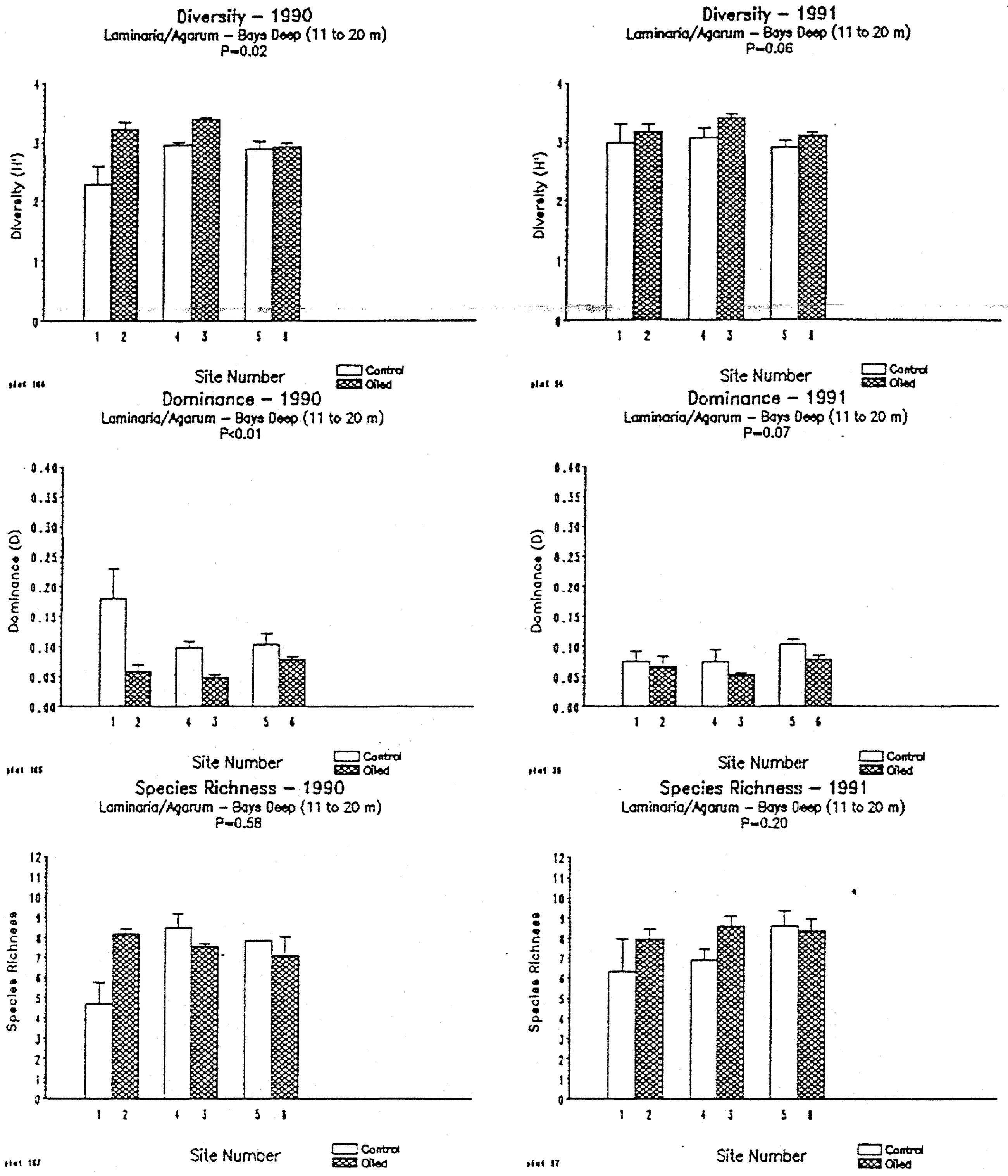


Figure 23. Diversity, dominance, species richness, total abundance, total biomass, and number of taxa for infaunal invertebrates from dredge samples in the deep stratum within the *Laminaria/Agarum* Bay habitat in Prince William Sound in 1990 and 1991. Error bars are +/- 1 standard error.

ACE 30286899

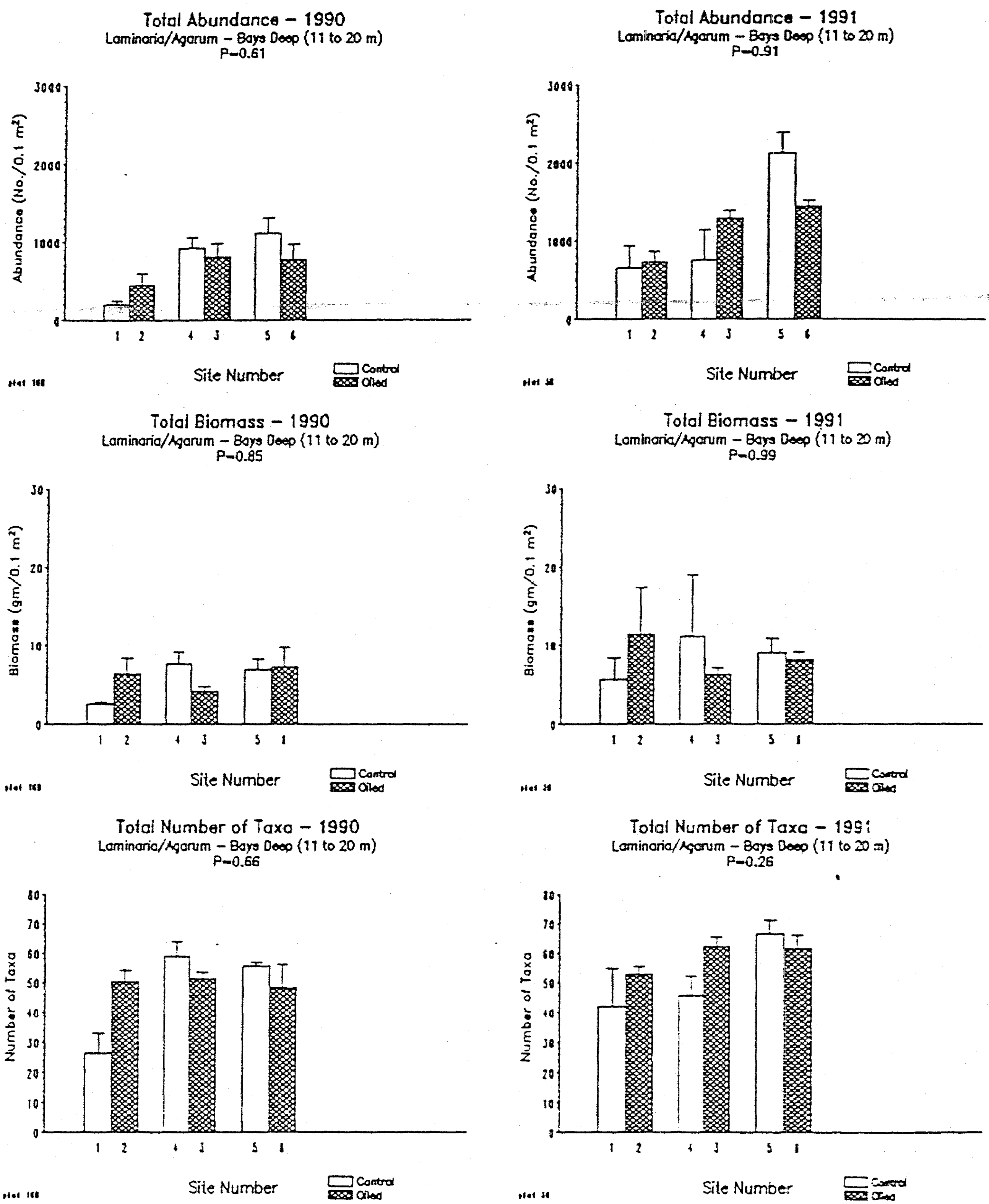


Figure 23. (Continued)

ACE 30286900

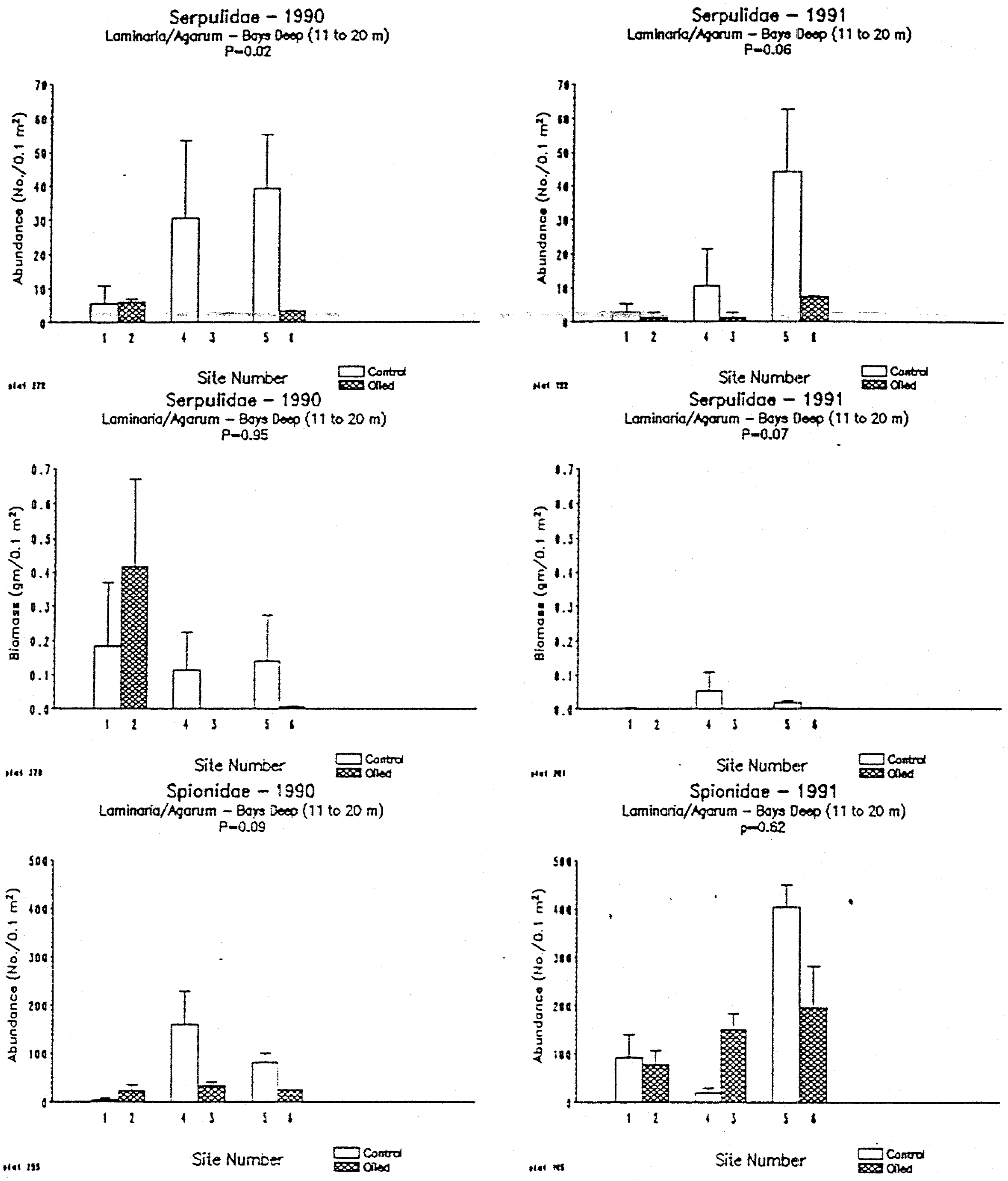


Figure 24. Abundance and biomass of dominant taxa in dredge samples that differed significantly at oiled and control sites in the deep stratum in the *Laminaria/Agarum* Bay habitat in Prince William Sound in 1990 and 1991. Error bars are +/- 1 standard error.

ACE 30286901

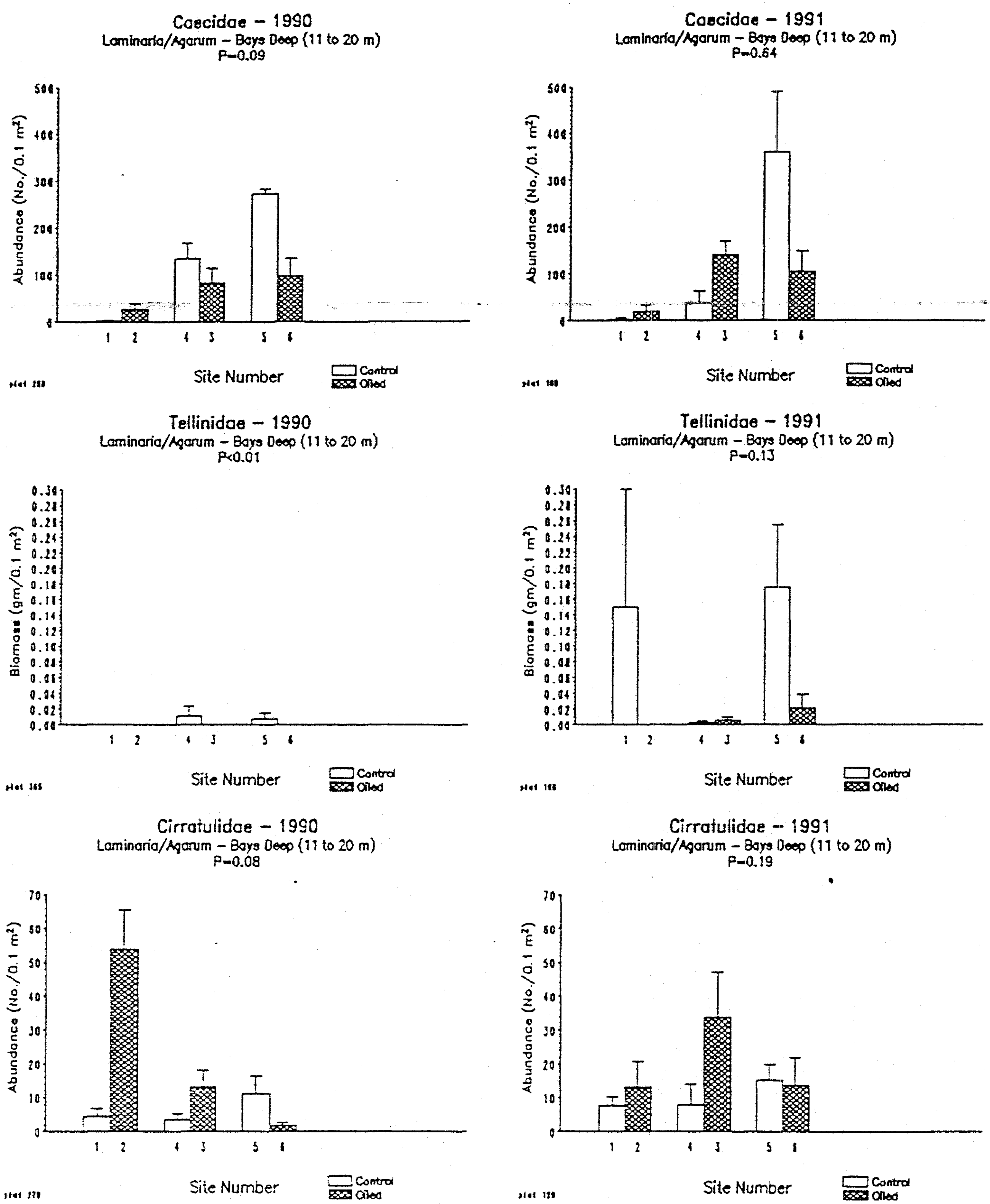


Figure 24. (Continued)

ACE 30286902

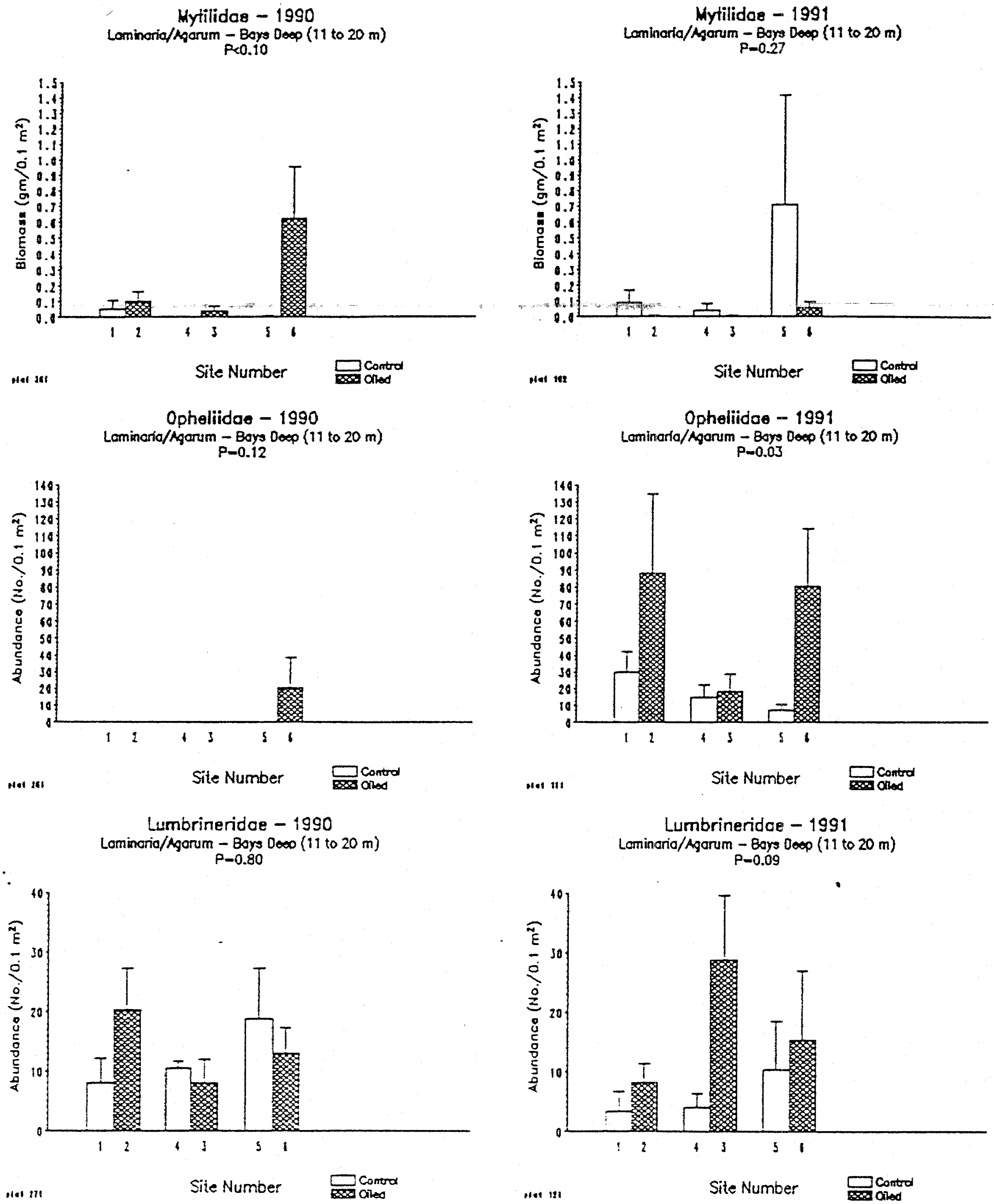


Figure 24. (Continued)

ACE 30286903

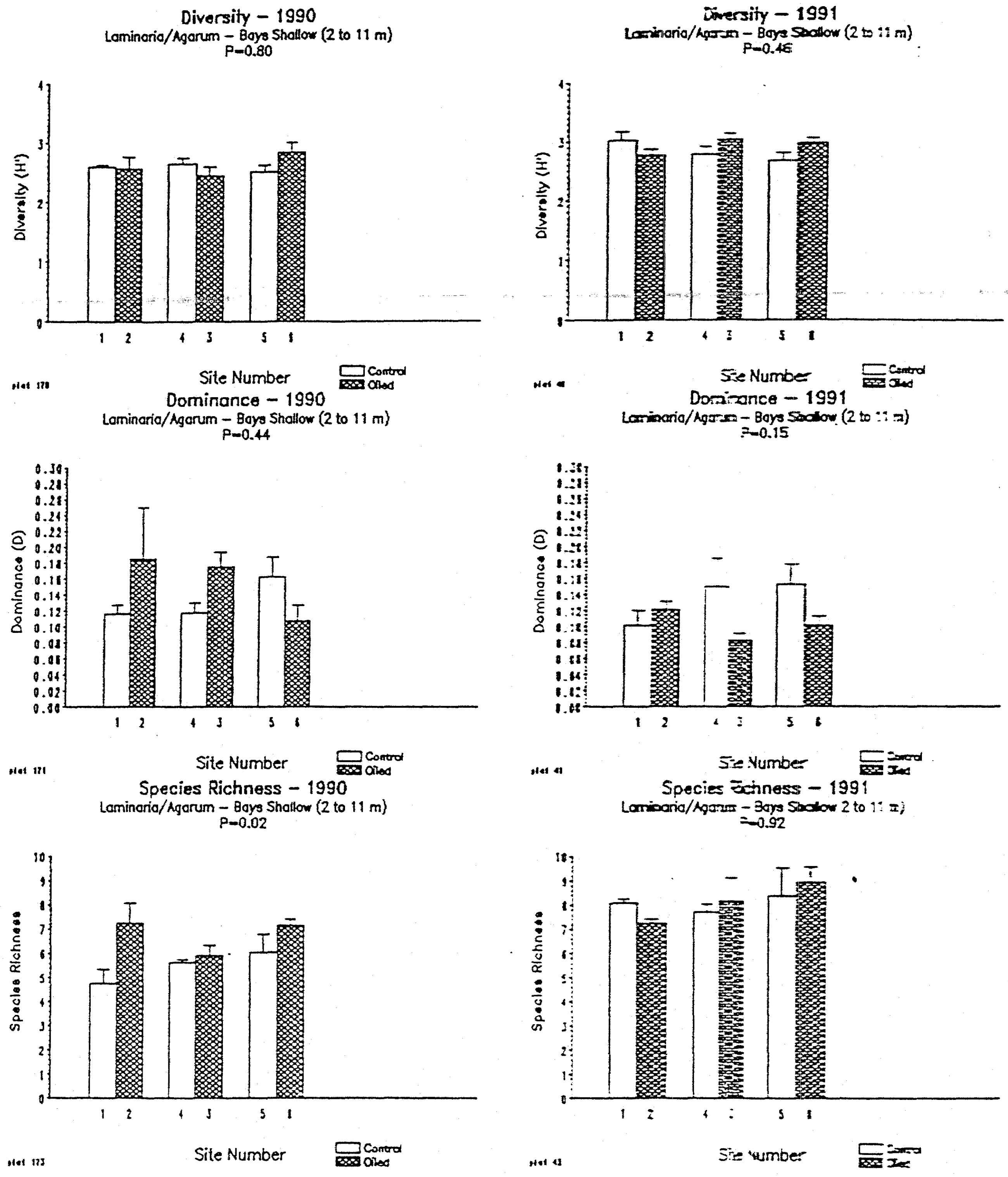


Figure 25. Diversity, dominance, species richness, total abundance, total biomass, and number of taxa for infaunal invertebrates from dredge samples in the shallow stratum within the *Laminaria/Agarum* Bay habitat in Prince William Sound in 1990 and 1991. Error bars are +/- 1 standard error.

ACE 30236904

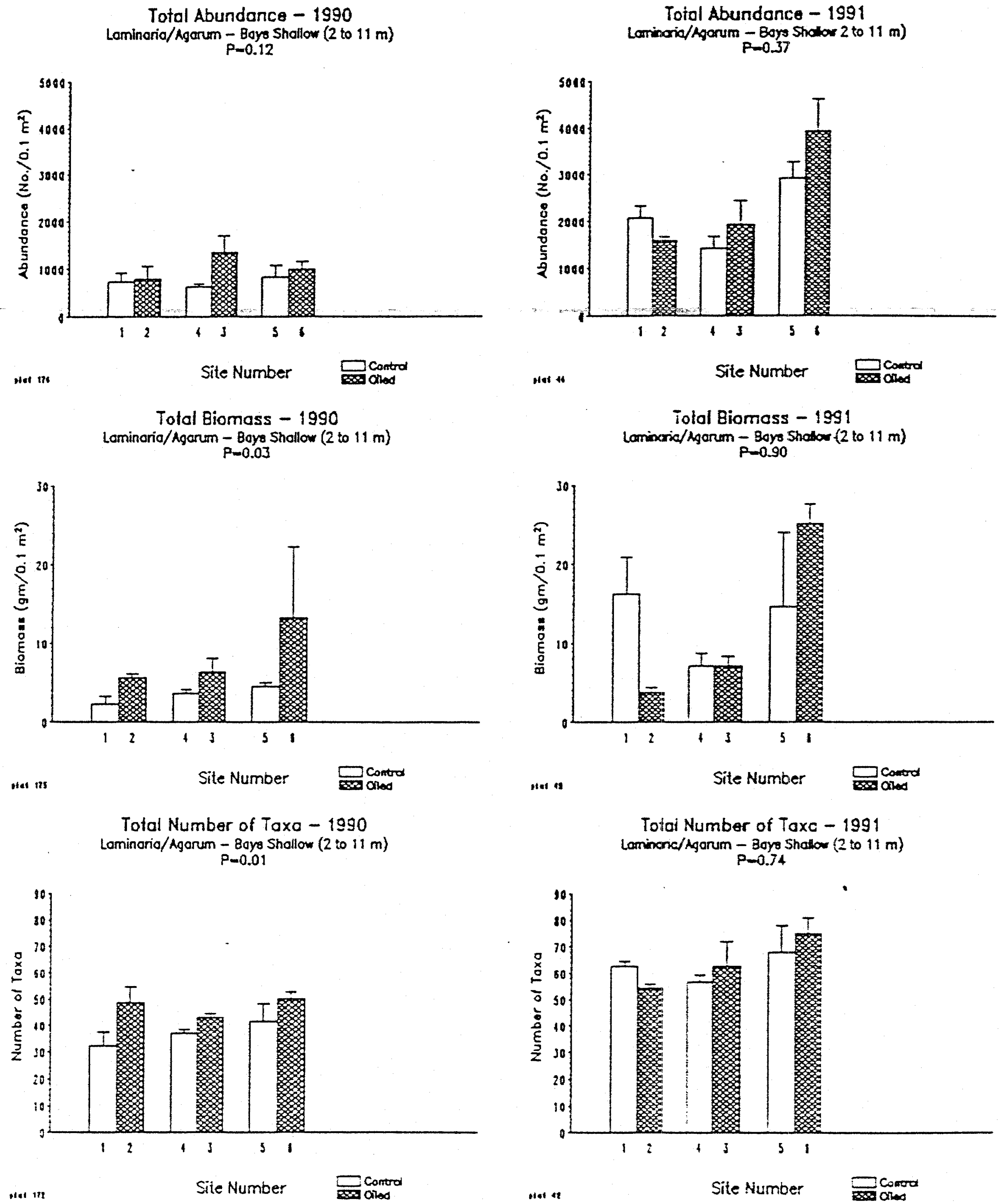


Figure 25. (Continued)

ACE 30236905

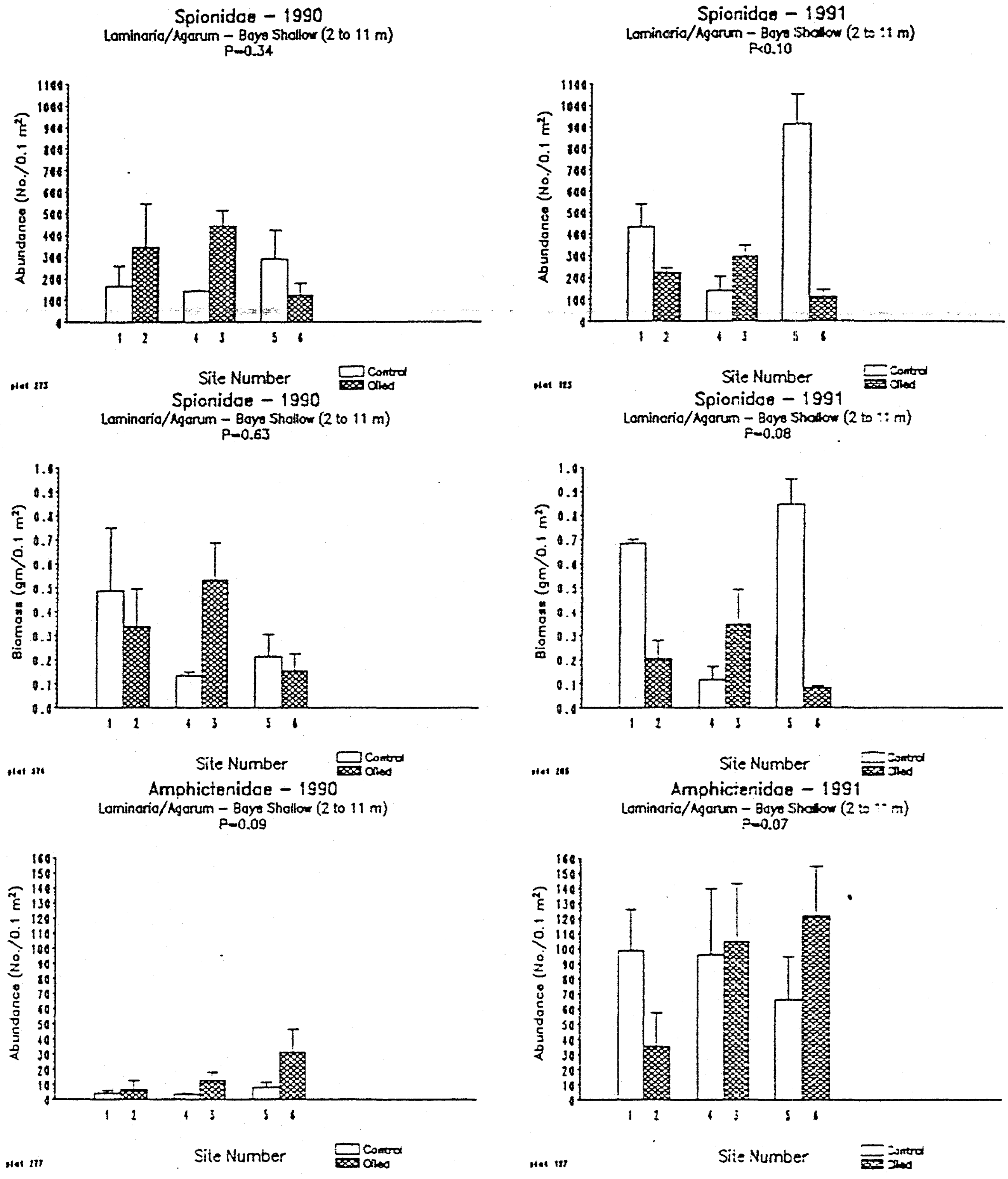


Figure 26. Abundance and biomass of dominant taxa in dredge samples that differed significantly at oiled and control sites in the shallow stratum in the *Laminaria/Agarum* Bay habitat in Prince William Sound in 1990 and 1991. Error bars are +/- 1 standard error.

ACE 30236906

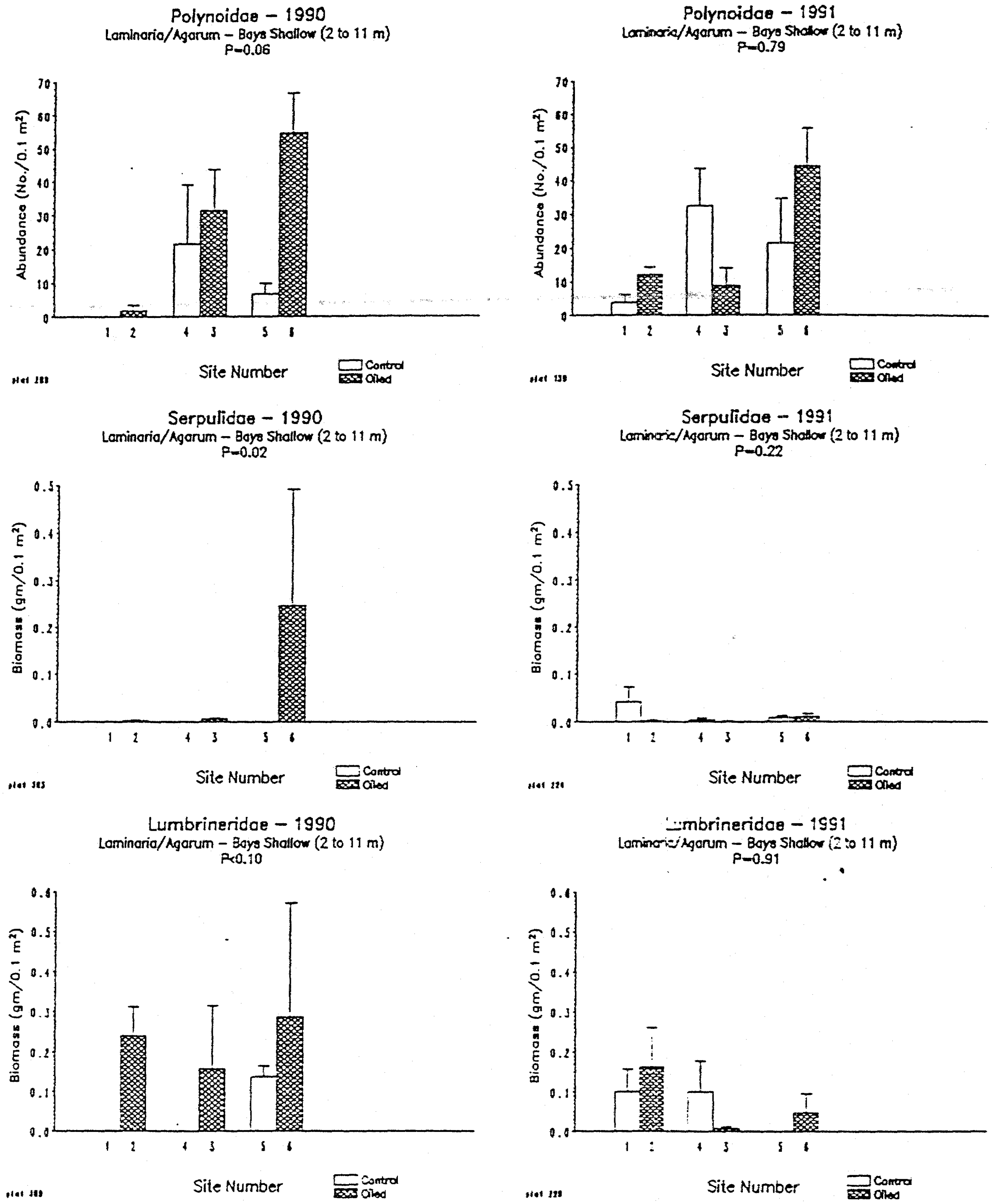


Figure 26. (Continued)

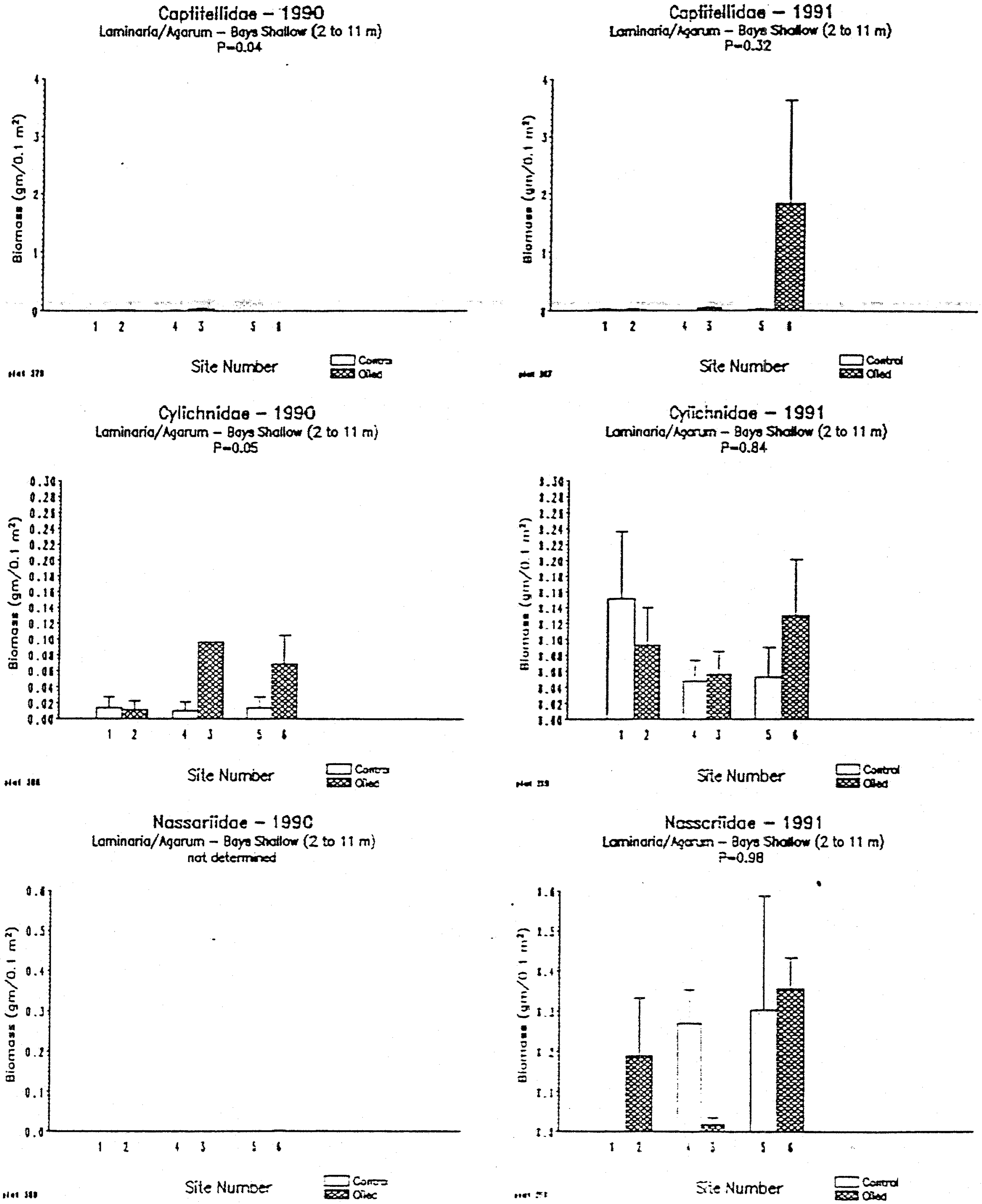


Figure 26. (Continued)

ACE 30236908

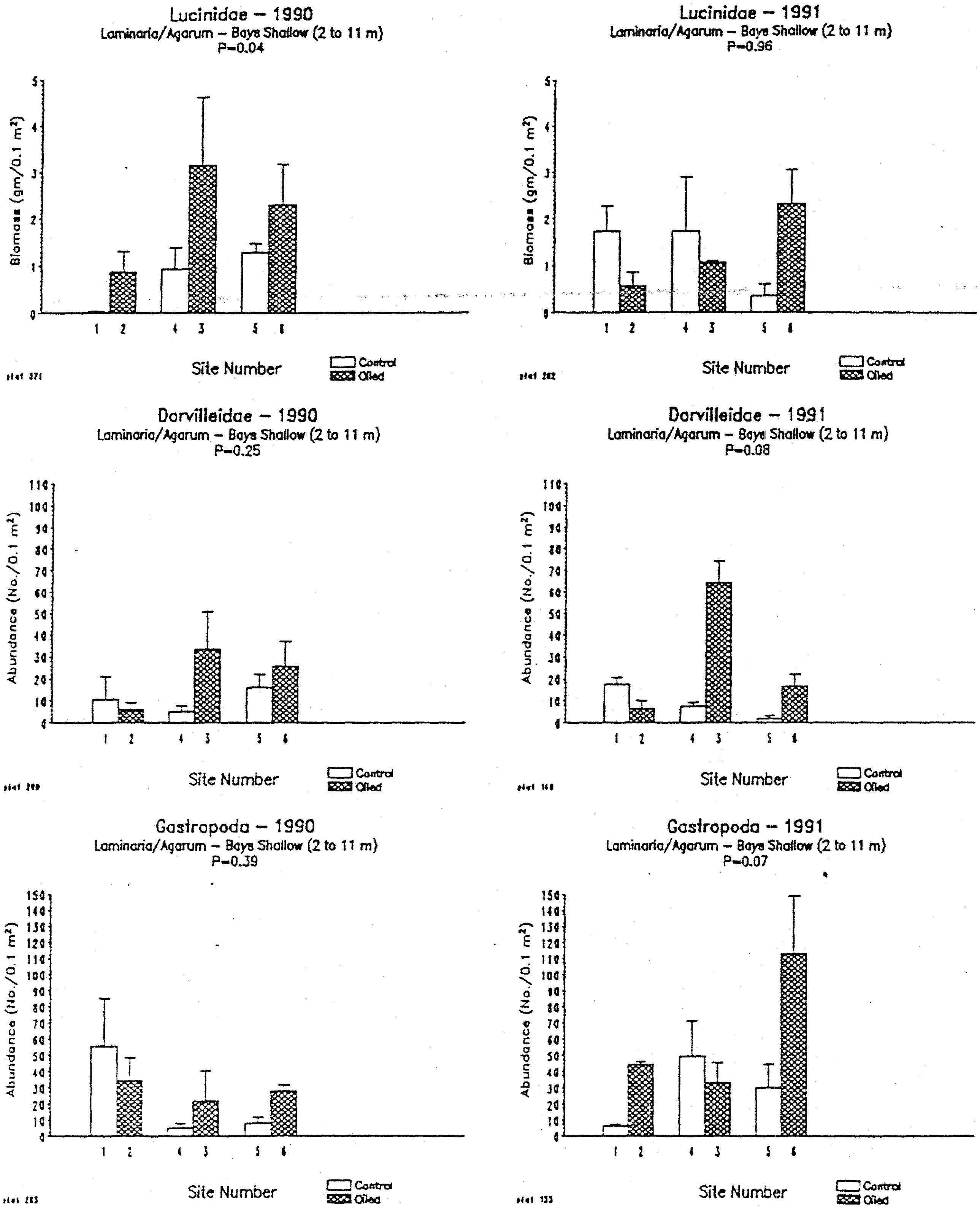


Figure 26. (Continued)

ACE 30286909

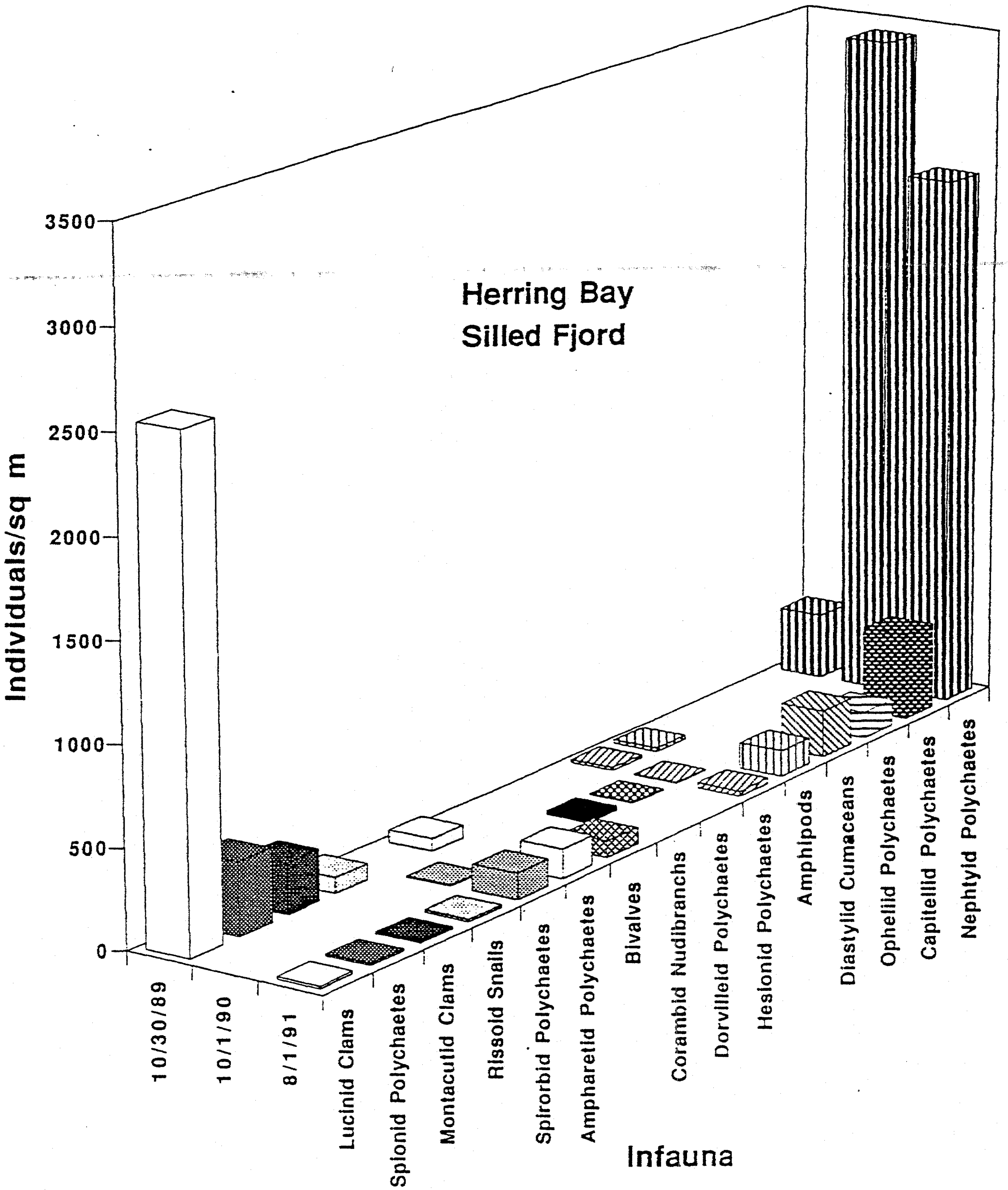


Figure 27. Abundances (individuals/sq m) of benthic invertebrate taxa collected by suction dredge from Herring Bay silled fjord, 1989-91.

ACE 30286910

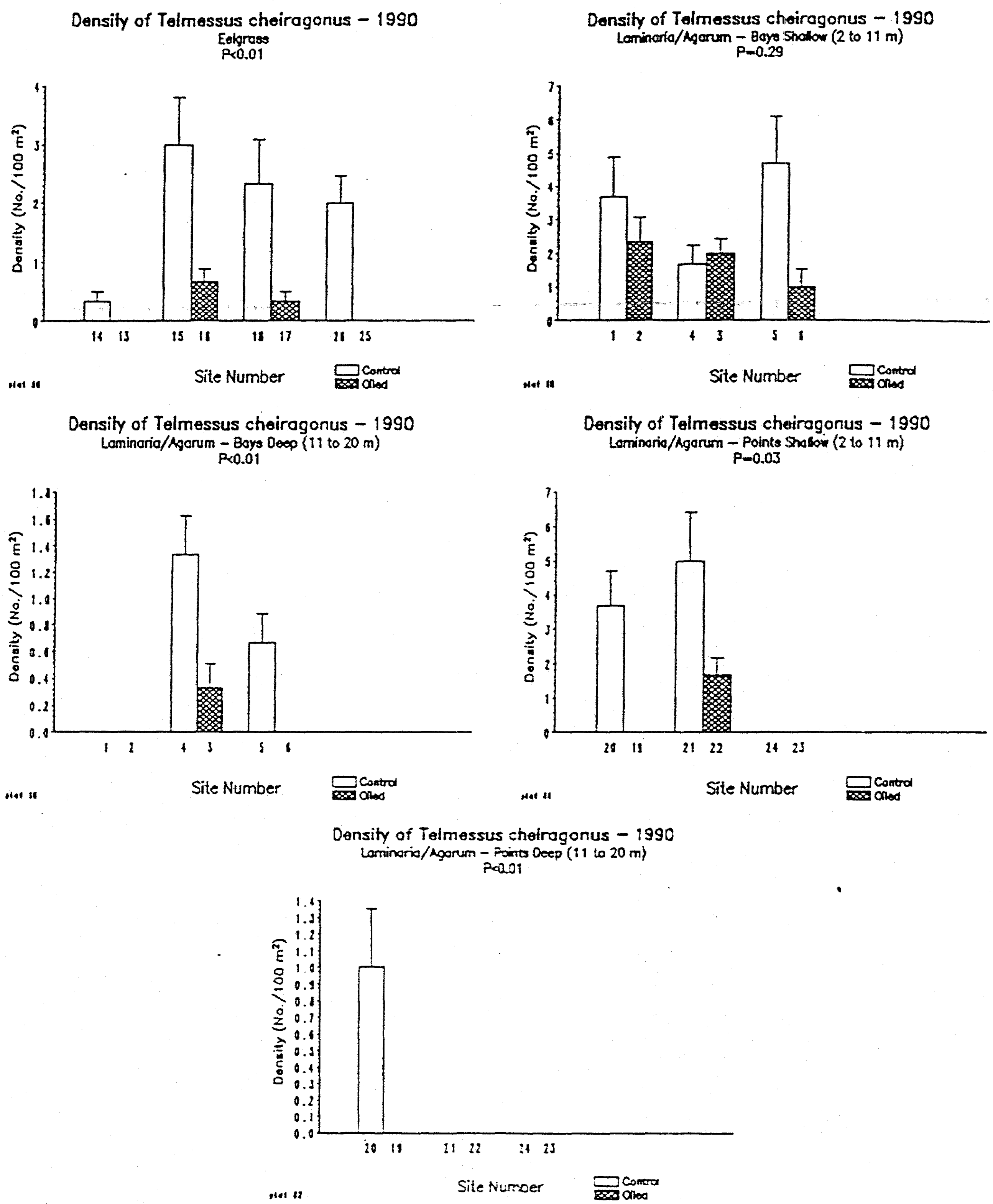


Figure 28. The abundance of *Telmessus cheiragonus* at oiled and control sites within the eelgrass and *Laminaria/Agarum* habitats in Prince William Sound in 1990. Error bars are +/- 1 standard error.

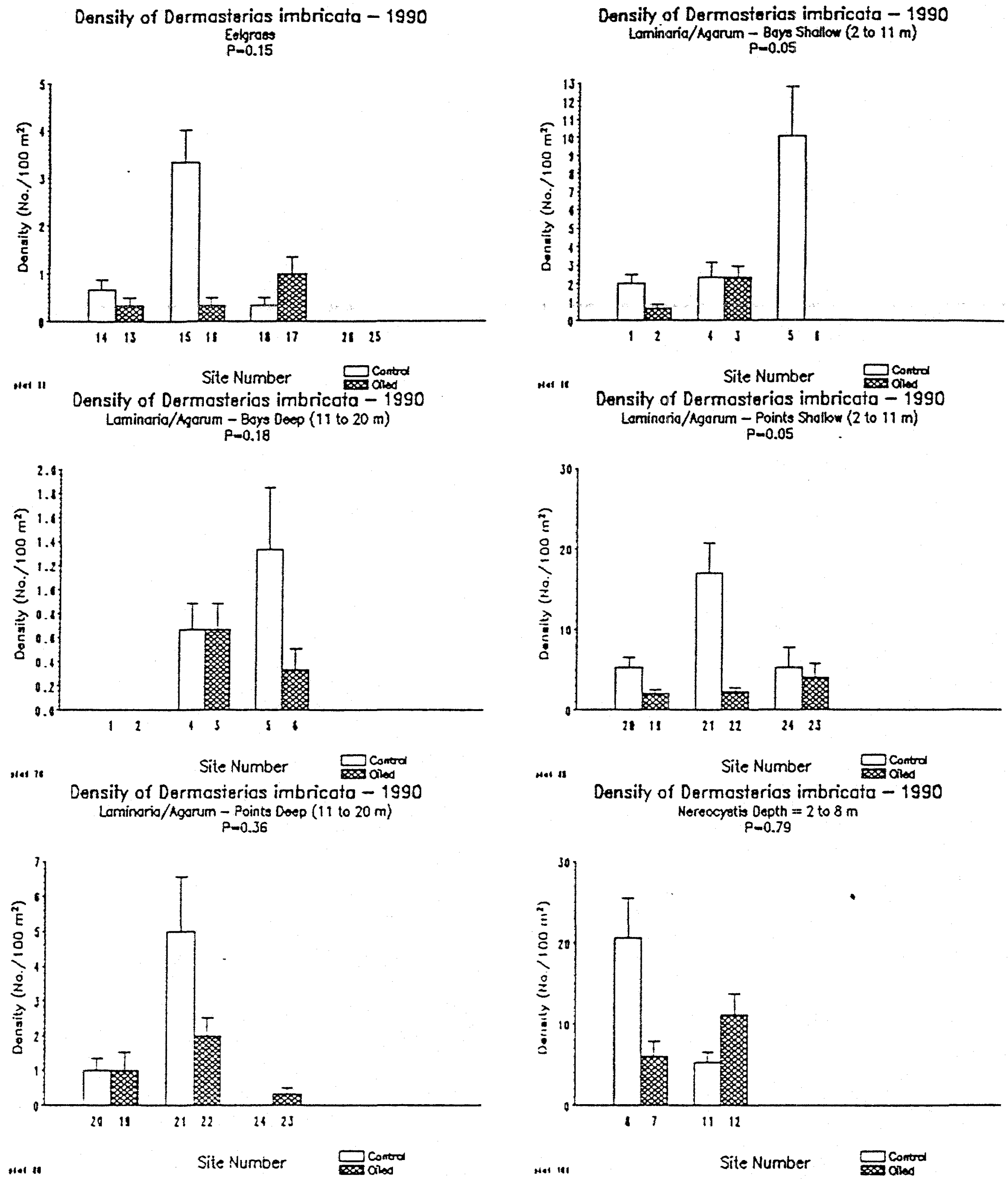


Figure 29. The abundance of *Dermasterias imbricata* at oiled and control sites within eelgrass, *Laminaria/Agarum*, and *Nereocystis* habitats in Prince William Sound in 1990. Error bars are +/- 1 standard error.

ACE 30286912

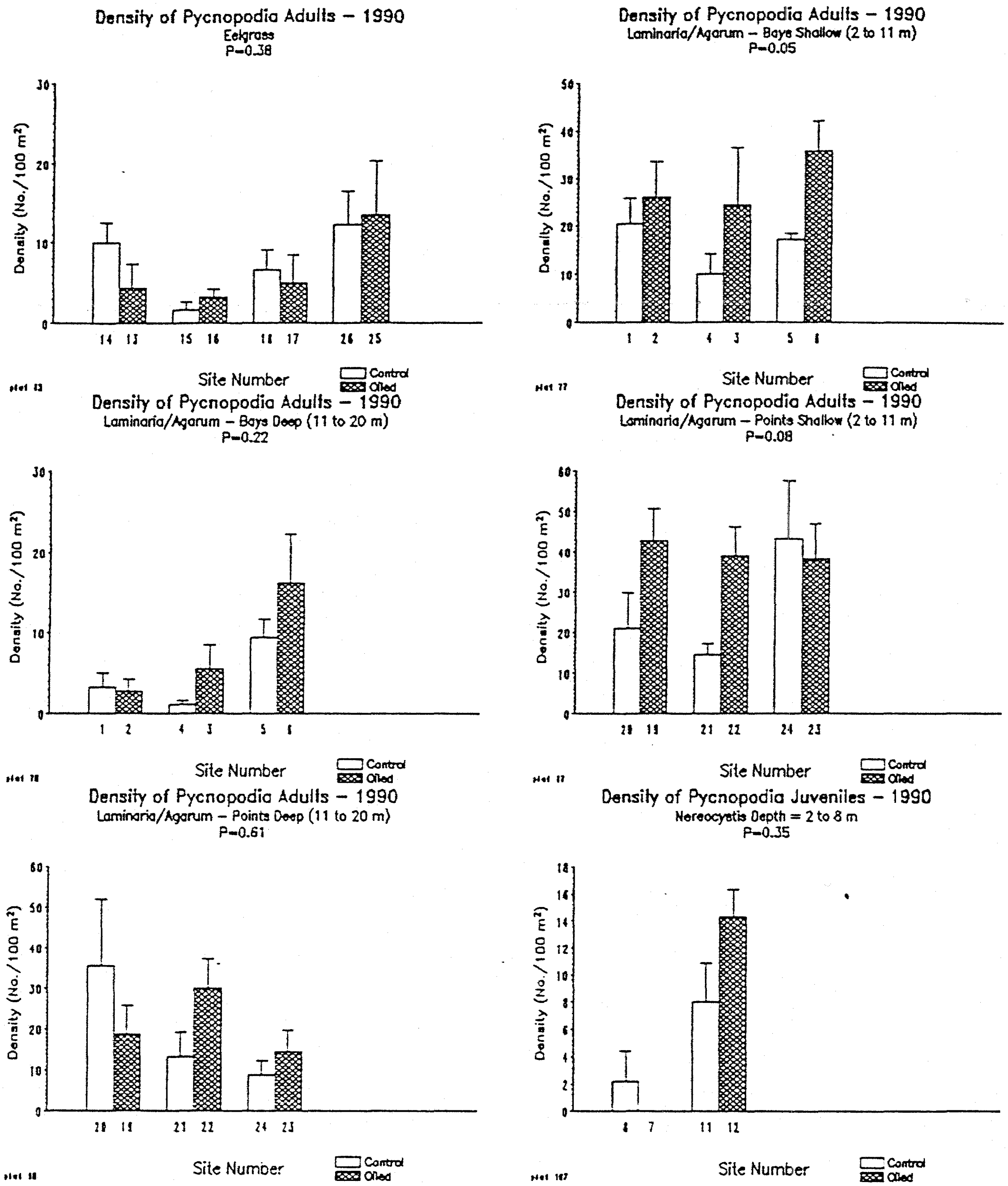


Figure 30. The abundance of adult *Pycnopodia helianthoides* at oiled and control sites within eelgrass, *Laminaria/Agarum*, and *Nereocystis* habitats in Prince William Sound in 1990. Error bars are +/- 1 standard error.

ACE 30286913

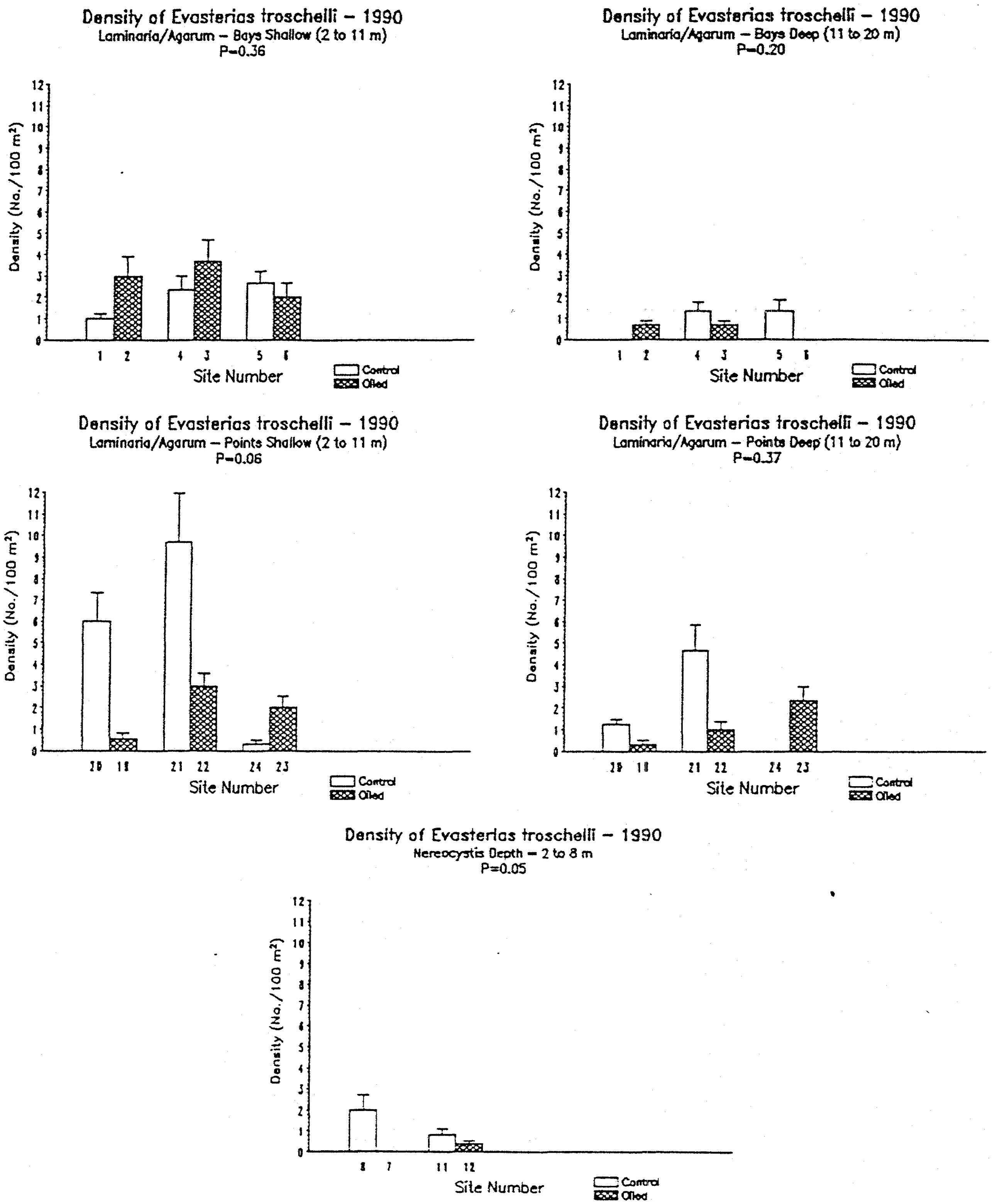
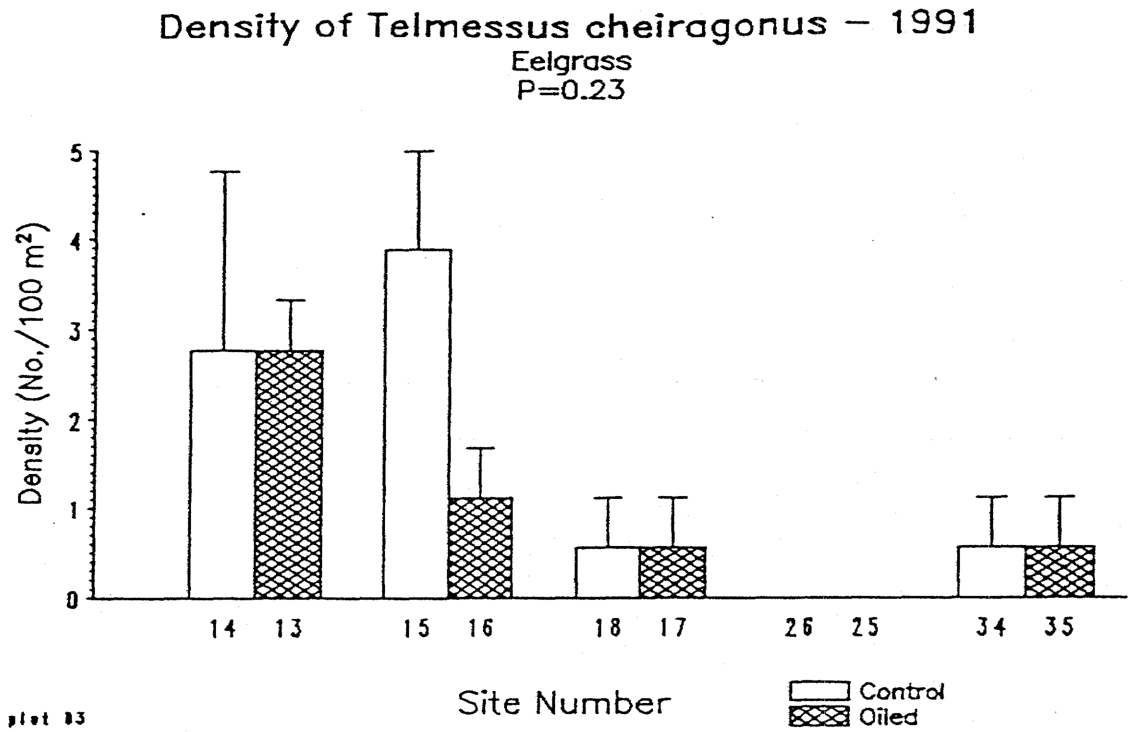


Figure 31. The abundance of *Evasterias troschelii* at oiled and control sites within the *Laminaria/Agarum* and *Nereocystis* habitats in Prince William Sound in 1990. Error bars are +/- 1 standard error.

ACE 30286914



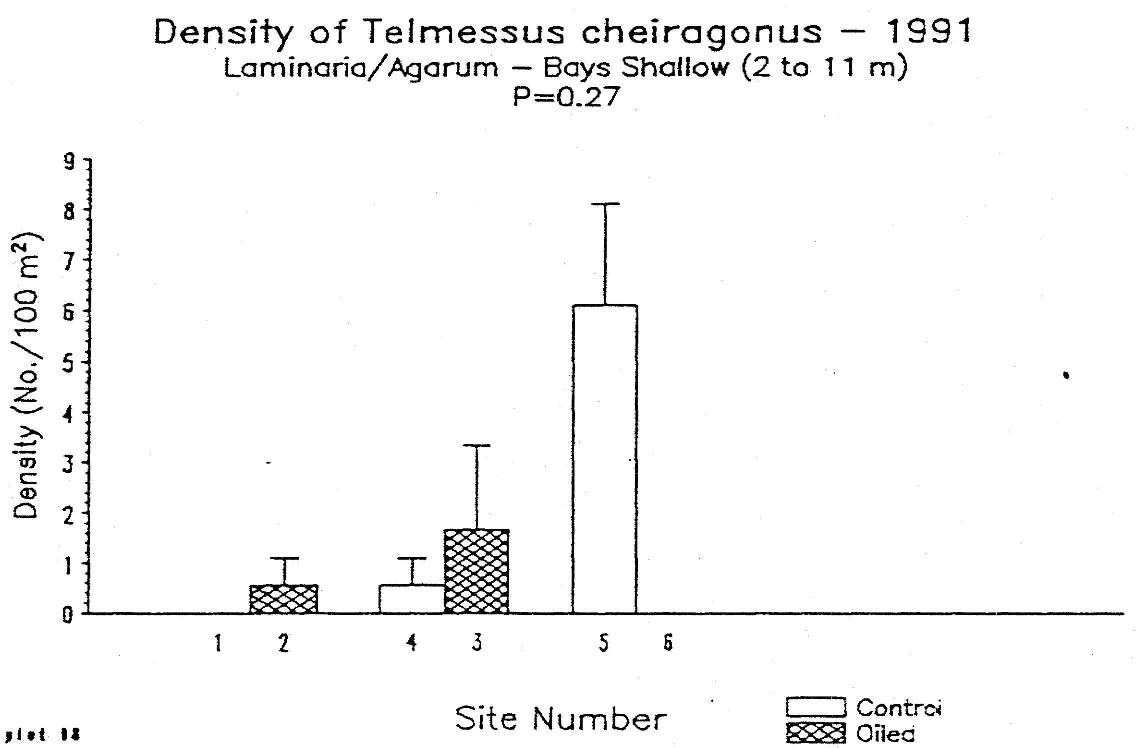
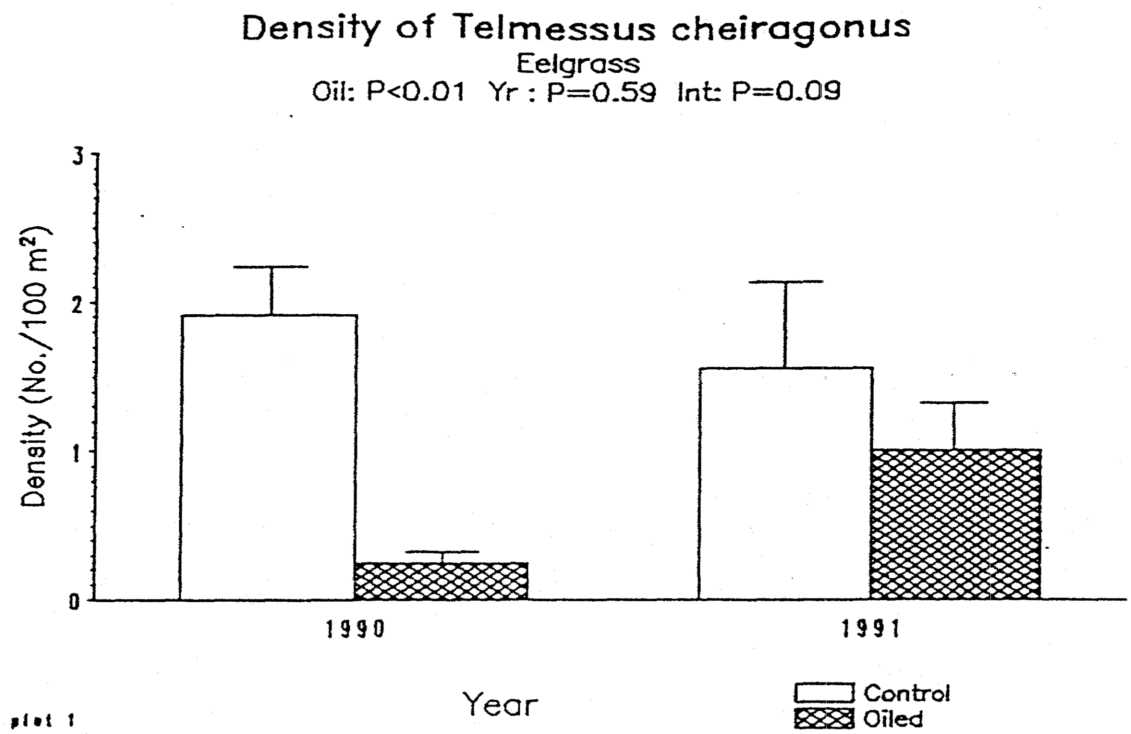


Figure 32. The abundance of *Telmessus cheiragonus* at oiled and control sites within eelgrass and *Laminaria/Agarum* habitats in Prince William Sound in 1991. Error bars are +/- 1 standard error.

ACE 30286915



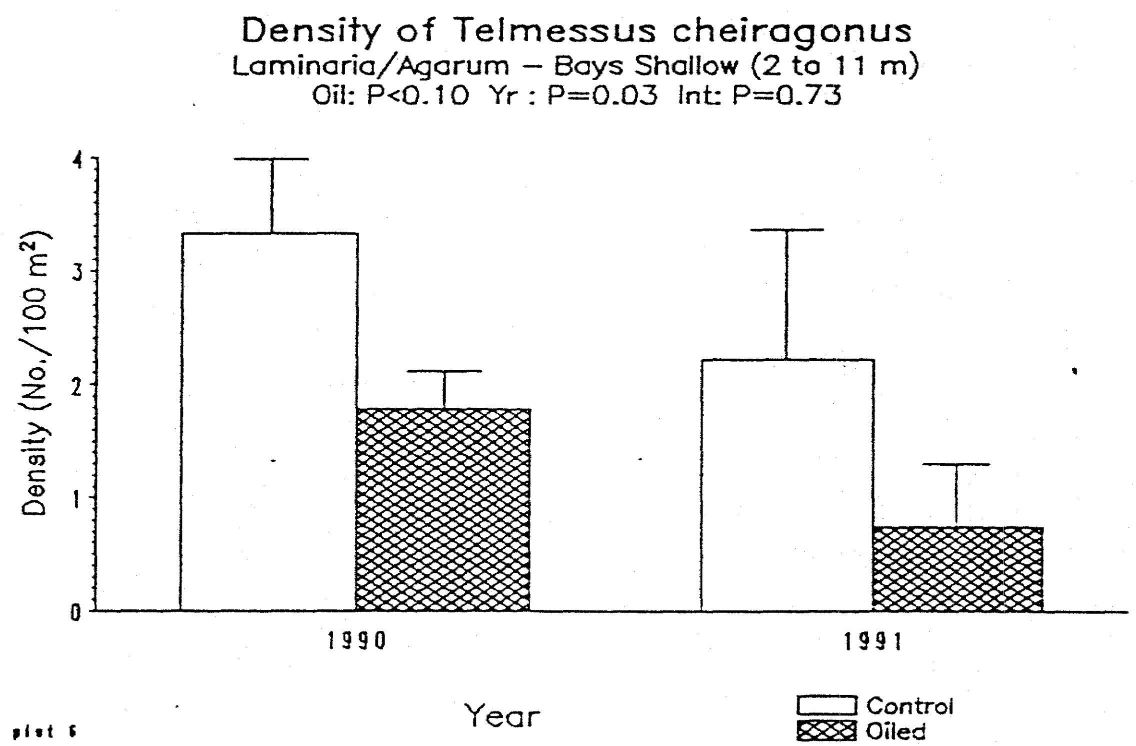
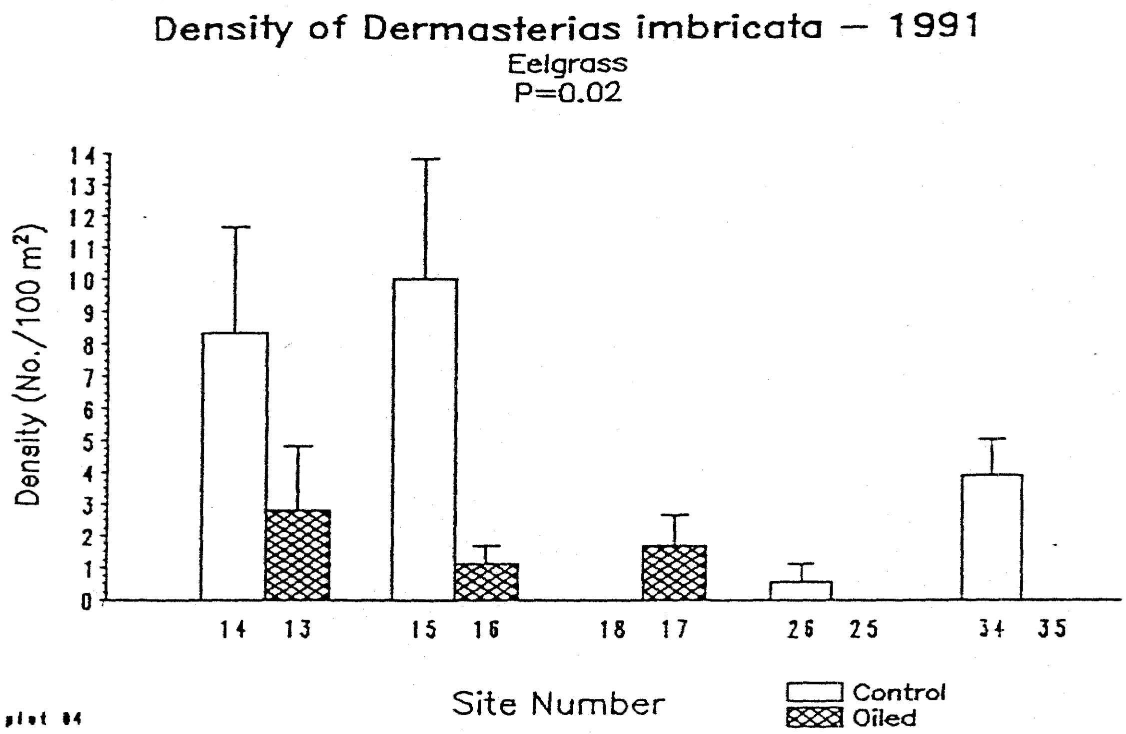


Figure 33. The abundance of *Telmessus cheiragonus* at oiled and control sites within eelgrass and *Laminaria/Agarum* habitats in Prince William Sound in 1990 and 1991. Error bars are +/- 1 standard error.

ACE 30286916



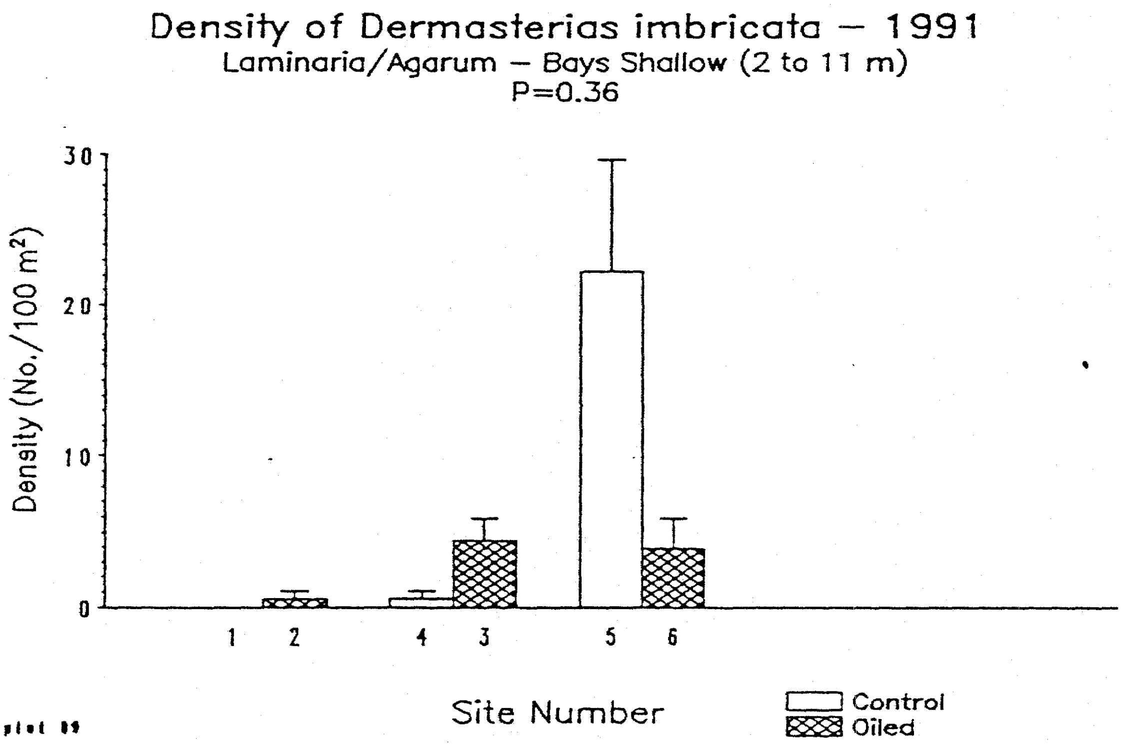
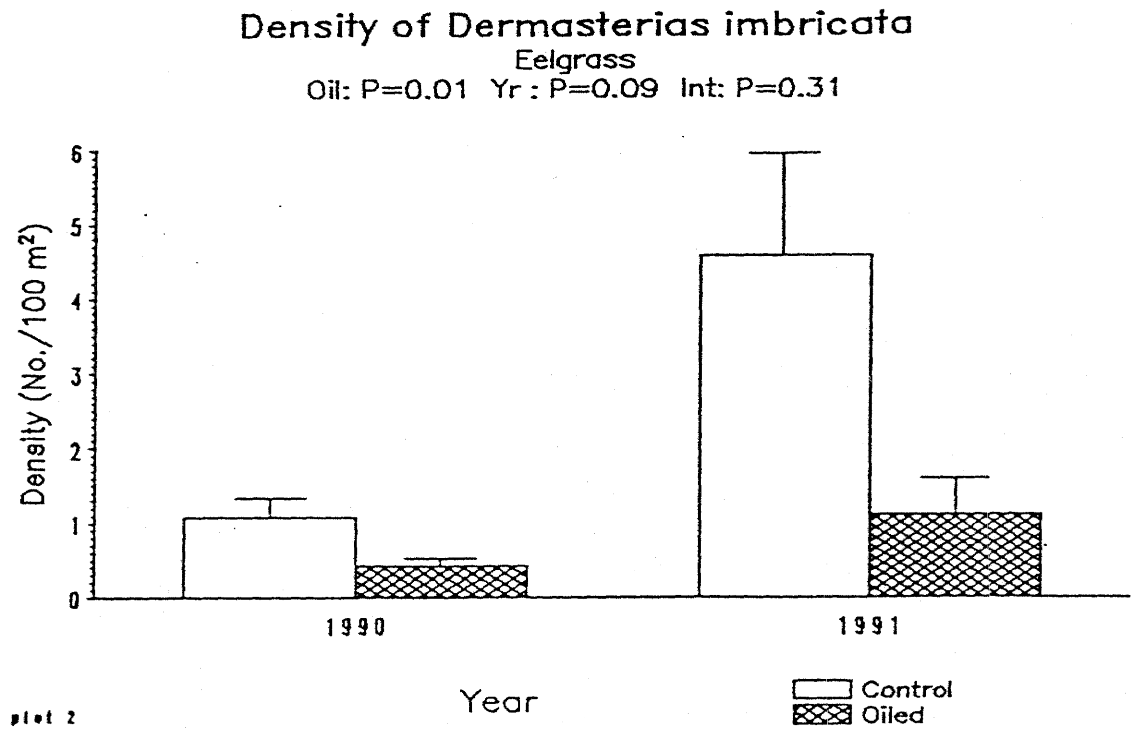


Figure 34. The abundance of *Dermasterias imbricata* at oiled and control sites within eelgrass and *Laminaria/Agarum* habitats in Prince William Sound in 1991. Error bars are +/- 1 standard error.

ACE 30286917



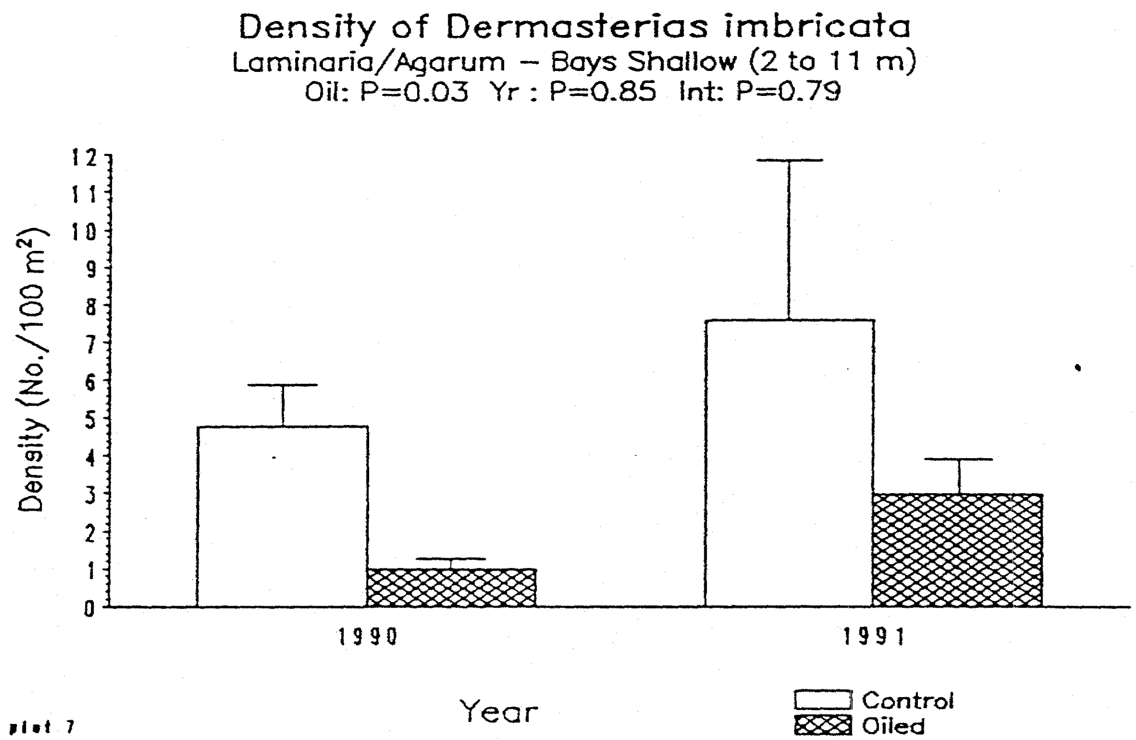
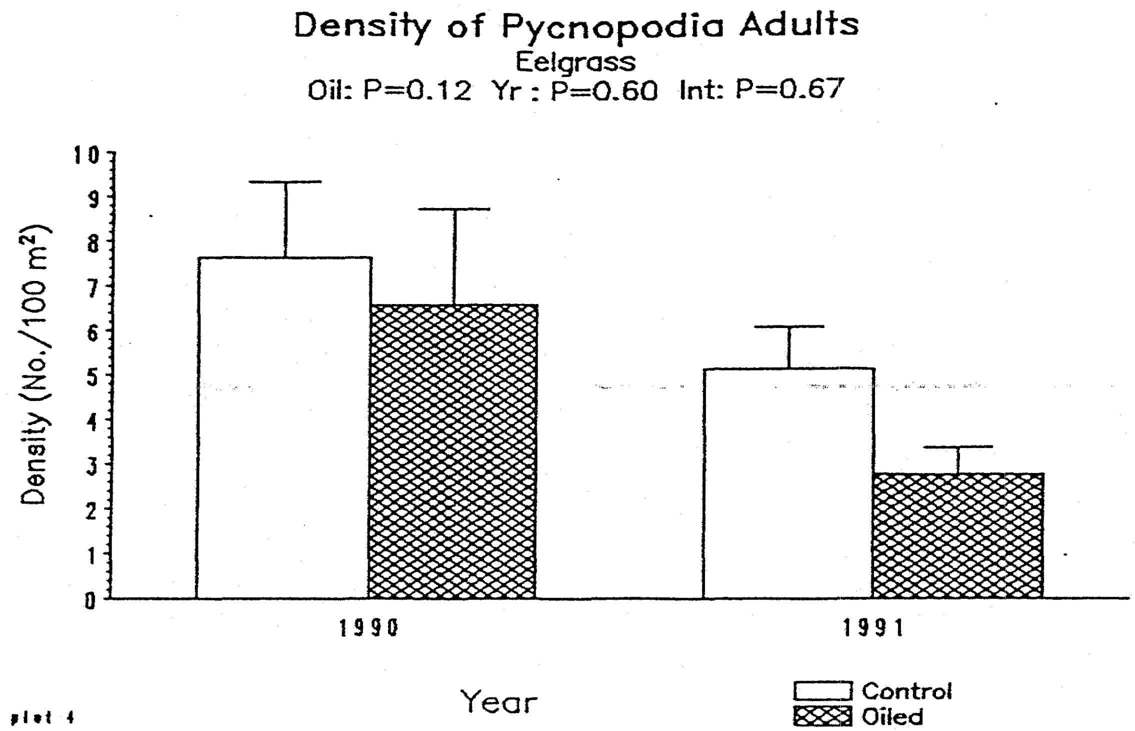


Figure 35. The abundance of *Dermasterias imbricata* at oiled and control sites within eelgrass and *Laminaria/Agarum* habitats in Prince William Sound in 1990 and 1991. Error bars are +/- 1 standard error.

ACE 30286918



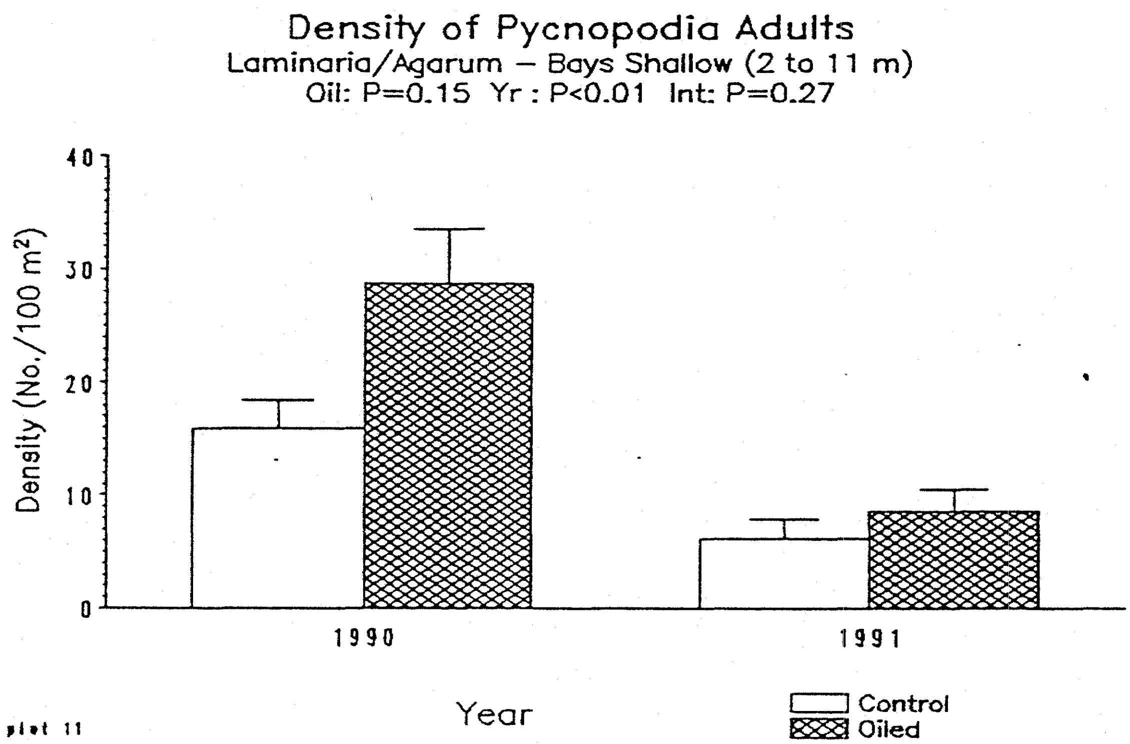
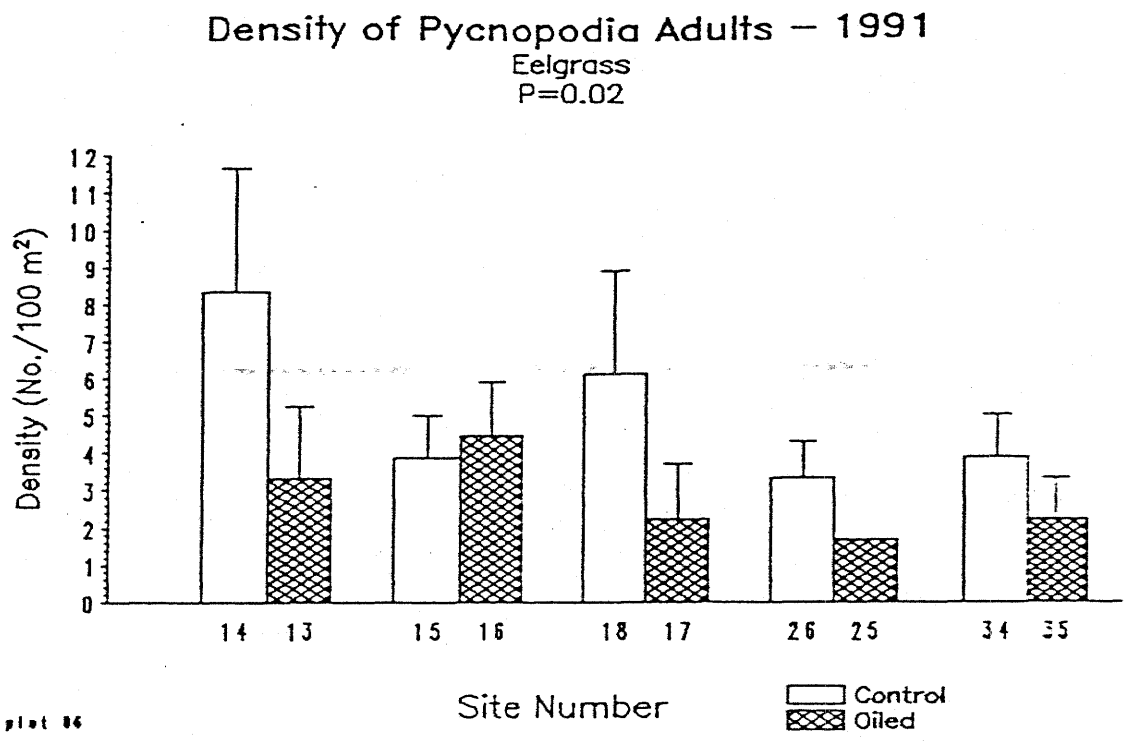


Figure 36. The abundance of adult *Pycnopodia helianthoides* at oiled and control sites within eelgrass and *Laminaria/Agarum* habitats in Prince William Sound in 1990 and 1991. Error bars are +/- 1 standard error.

ACE 30286919



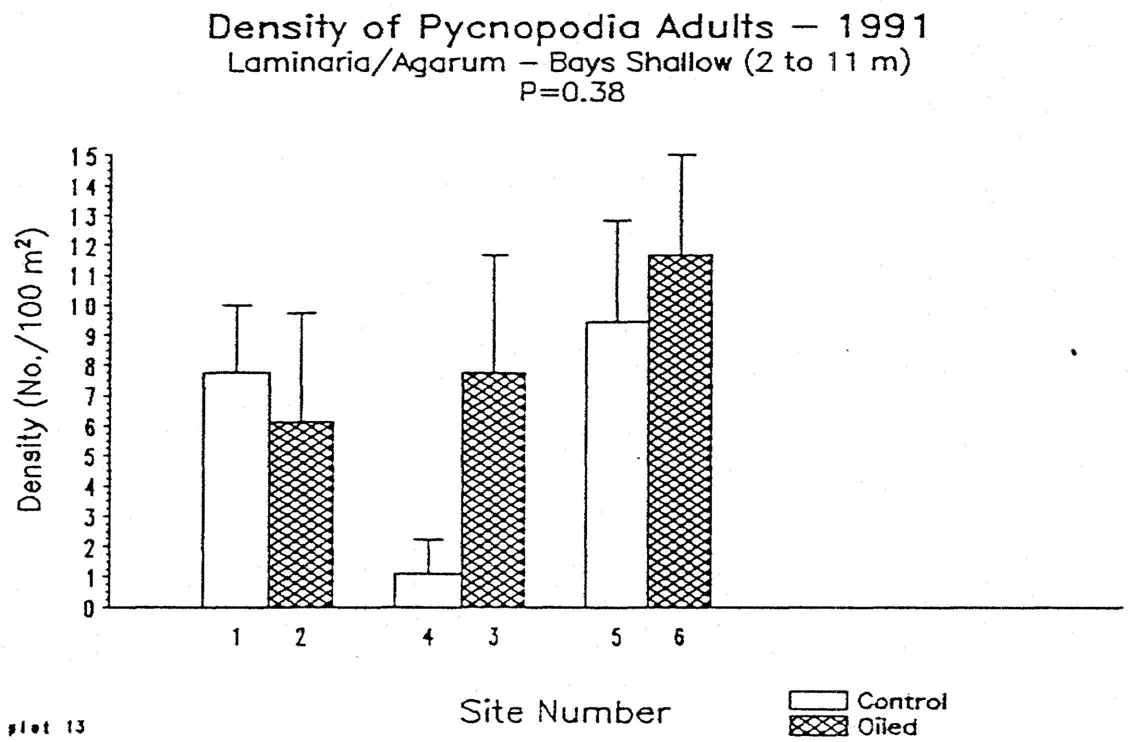
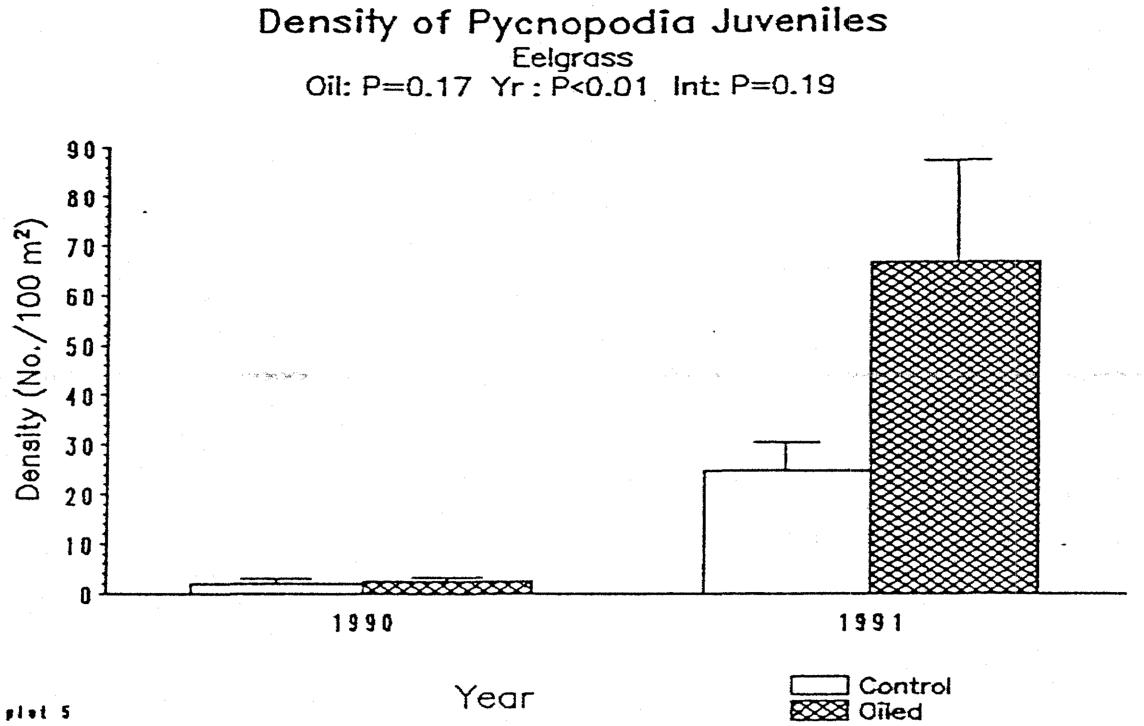


Figure 37. The abundance of adult *Pycnopodia helianthoides* at oiled and control sites within eelgrass and *Laminaria/Agarum* habitats in Prince William Sound in 1991. Error bars are +/- 1 standard error.

ACE 30286920



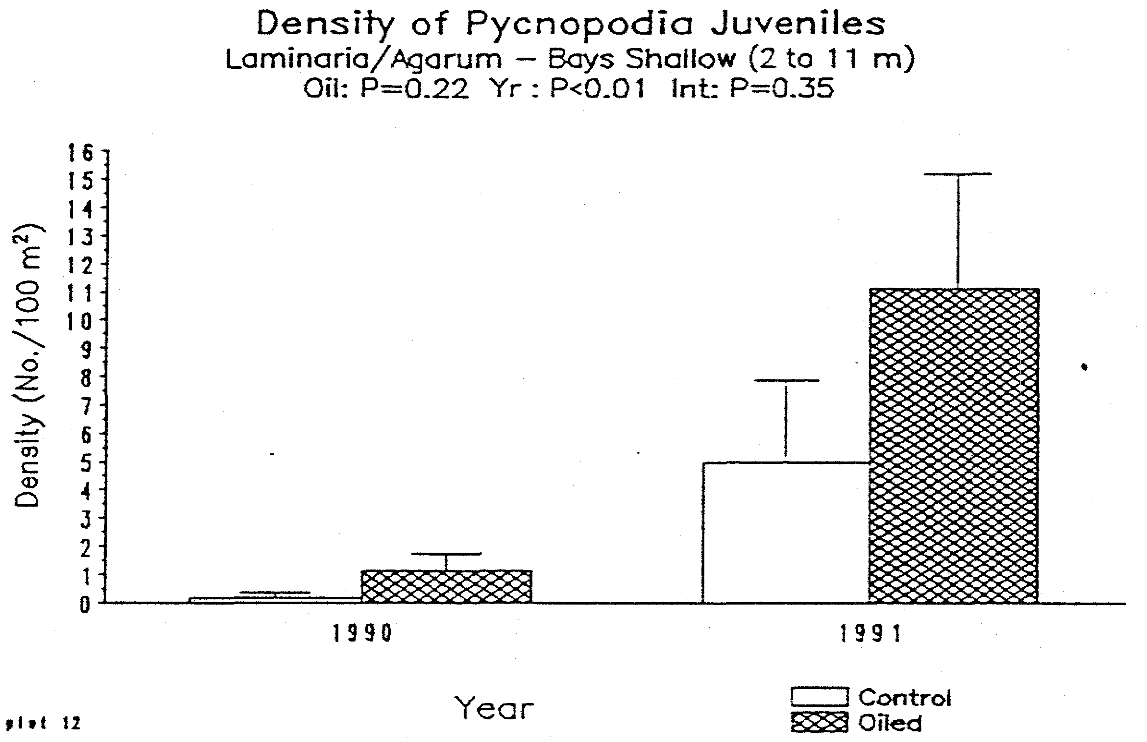
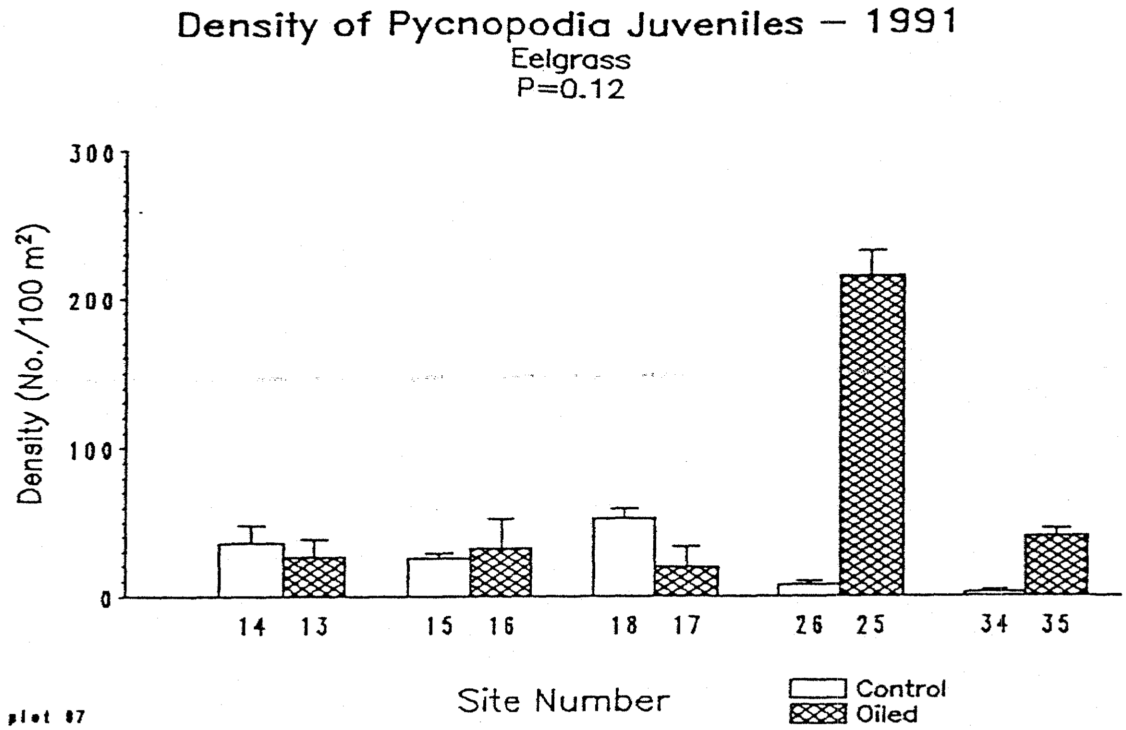


Figure 38. The abundance of juvenile *Pycnopodia helianthoides* at oiled and control sites within eelgrass and *Laminaria/Agarum* habitats in Prince William Sound in 1990 and 1991. Error bars are +/- 1 standard error.

ACE 30286921



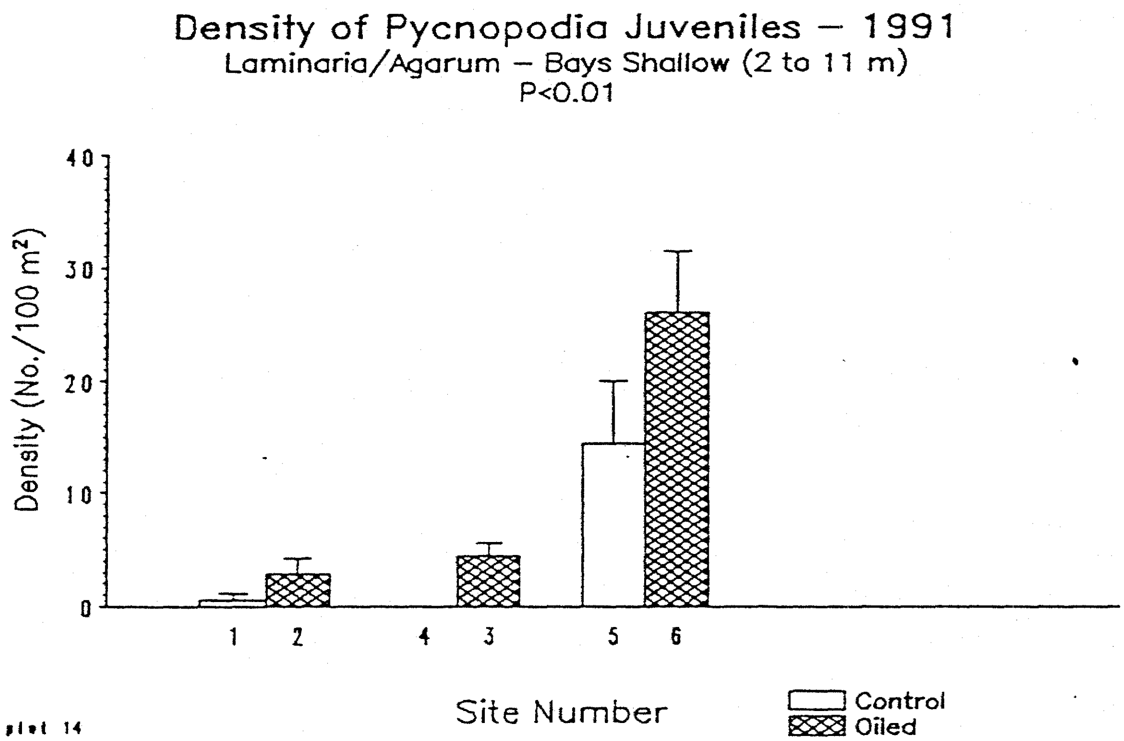


Figure 39. The abundance of juvenile *Pycnopodia helianthoides* at oiled and control sites within eelgrass and *Laminaria/Agarum* habitats in Prince William Sound in 1991. Error bars are +/- 1 standard error.

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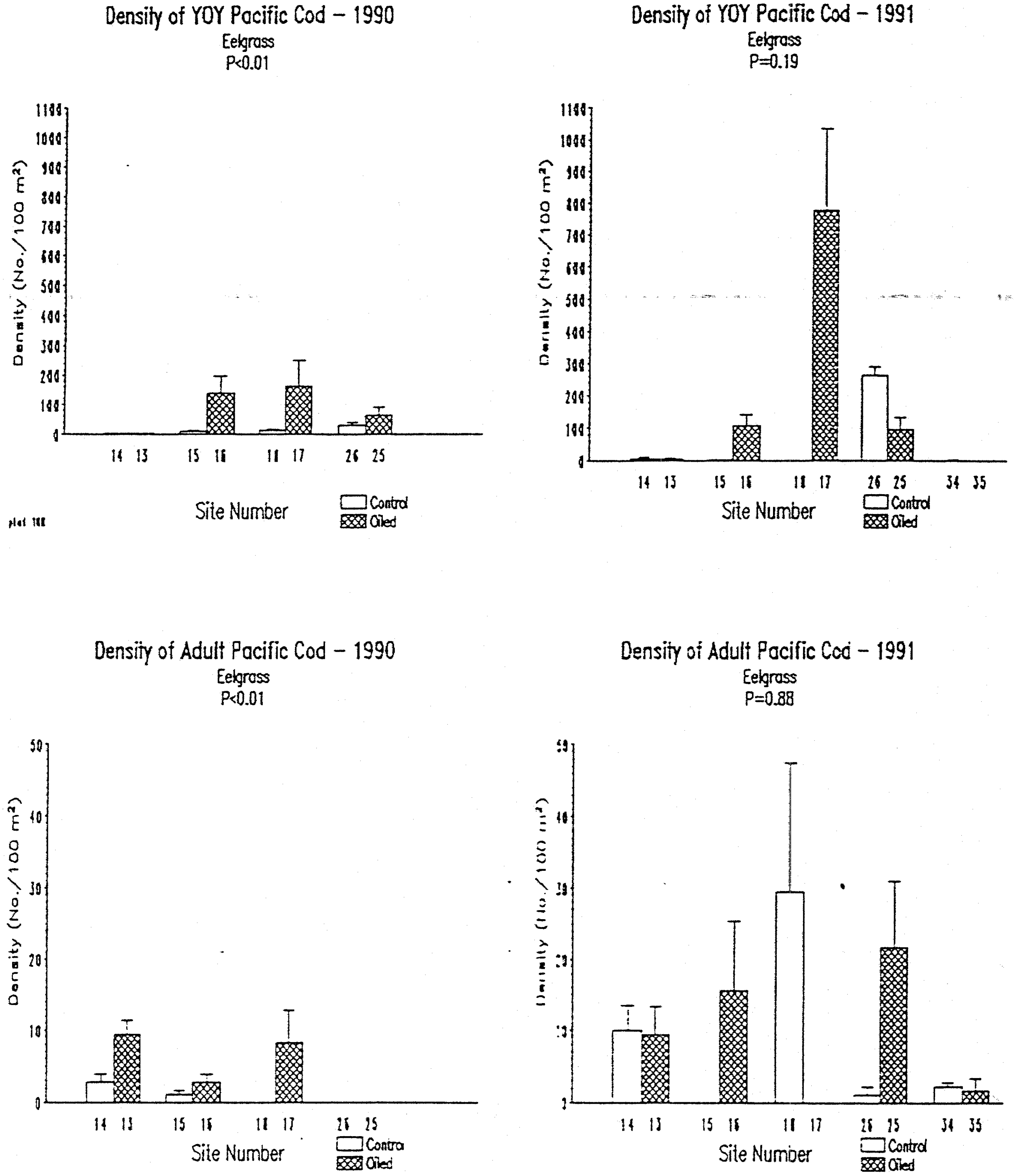

Figure 40. The abundance of young of year Pacific Cod at oiled and control sites within the eelgrass habitat in Prince William Sound in 1990 and 1991. Error bars are +/- 1 standard error.

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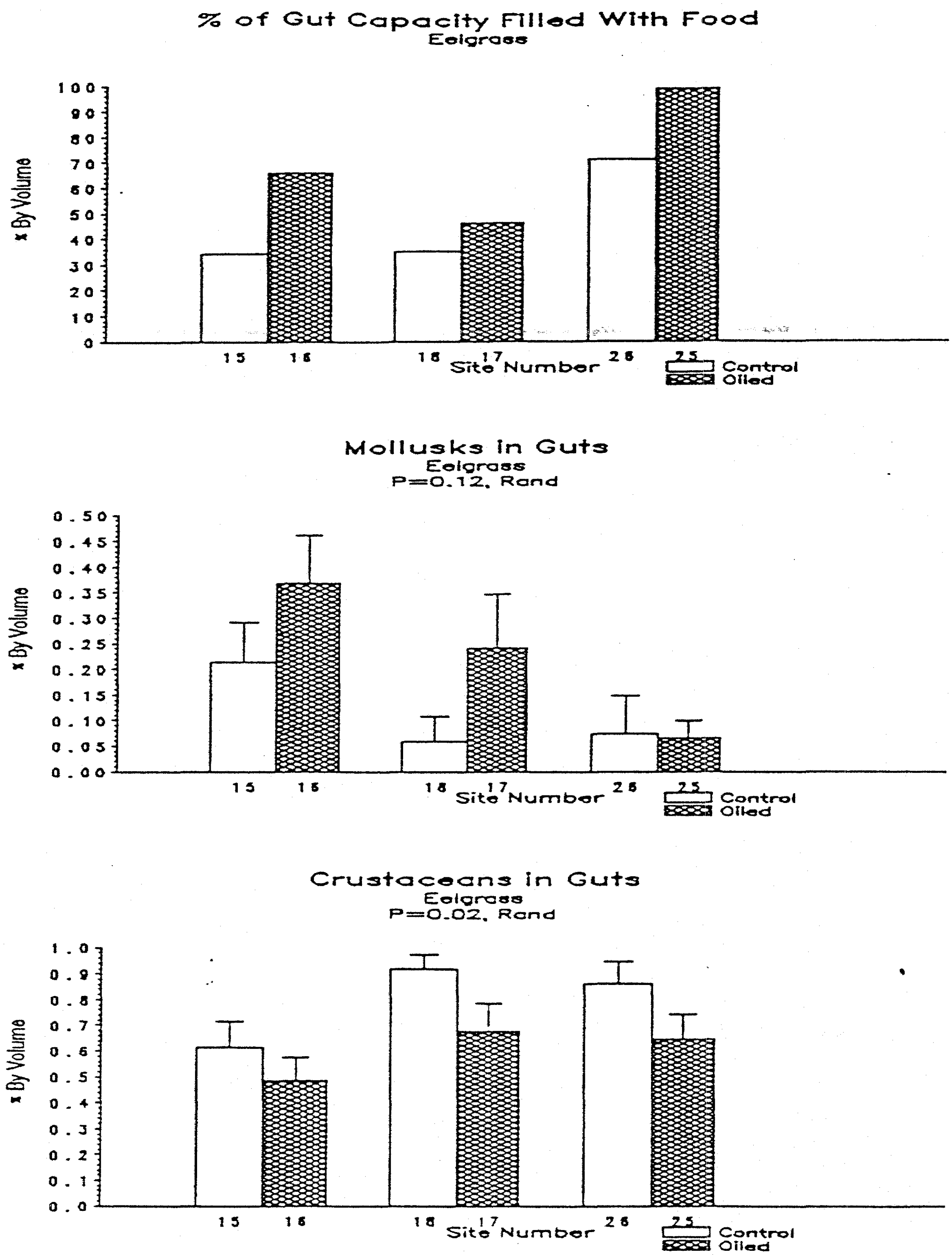

Figure 41. Percent fullness, and the percent occurrence of mollusks and crustaceans in the guts of young-of-year Pacific Cod from oiled and control sites in the eelgrass habitat in Prince William Sound in 1990.

ACE 30286924

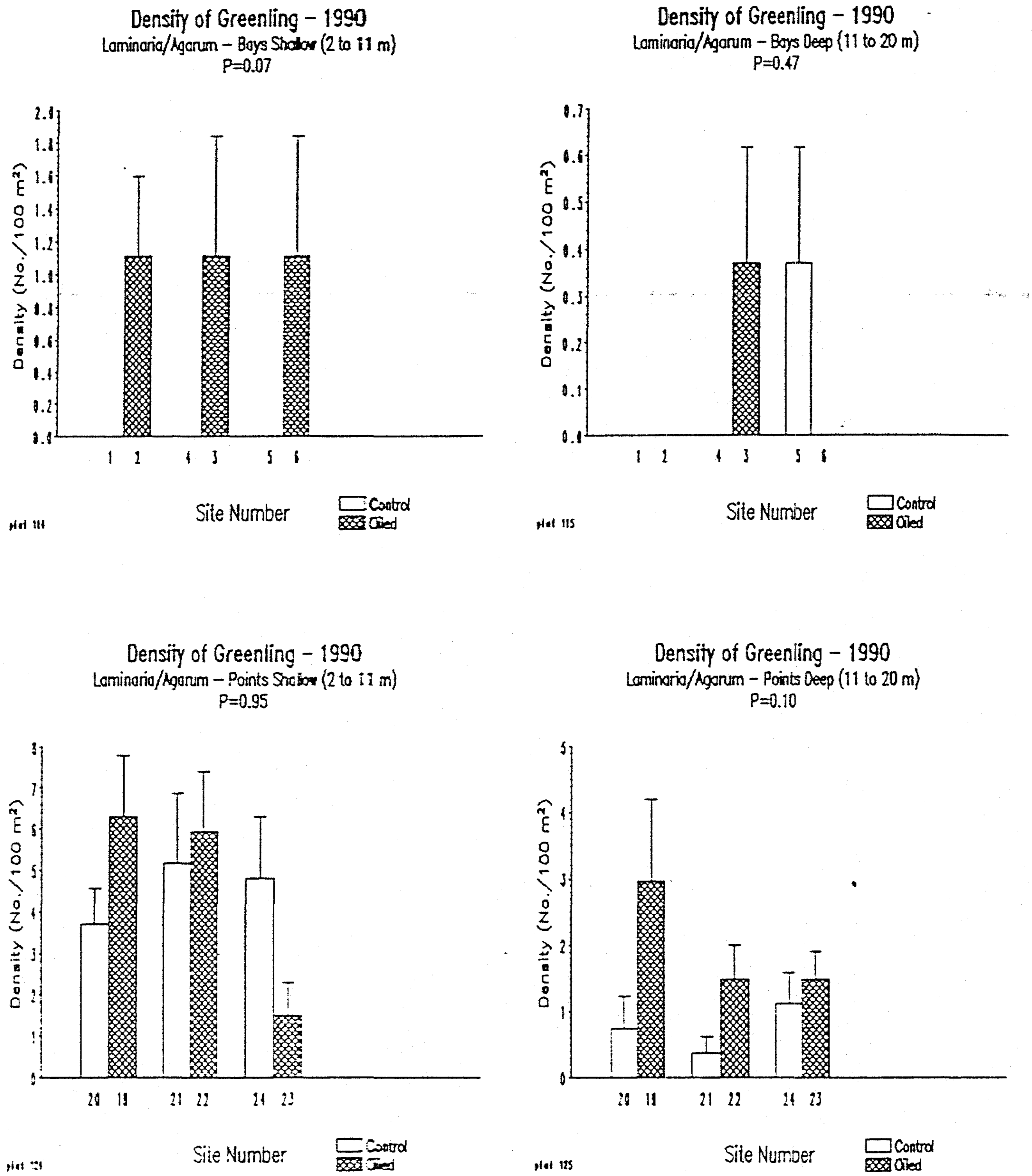

Figure 42. Abundance of Hexagrammidae (Greenlings) at oiled and control sites in *Laminaria/Agarum* habitats in Prince William Sound in 1990. Error bars are +/- 1 standard error.

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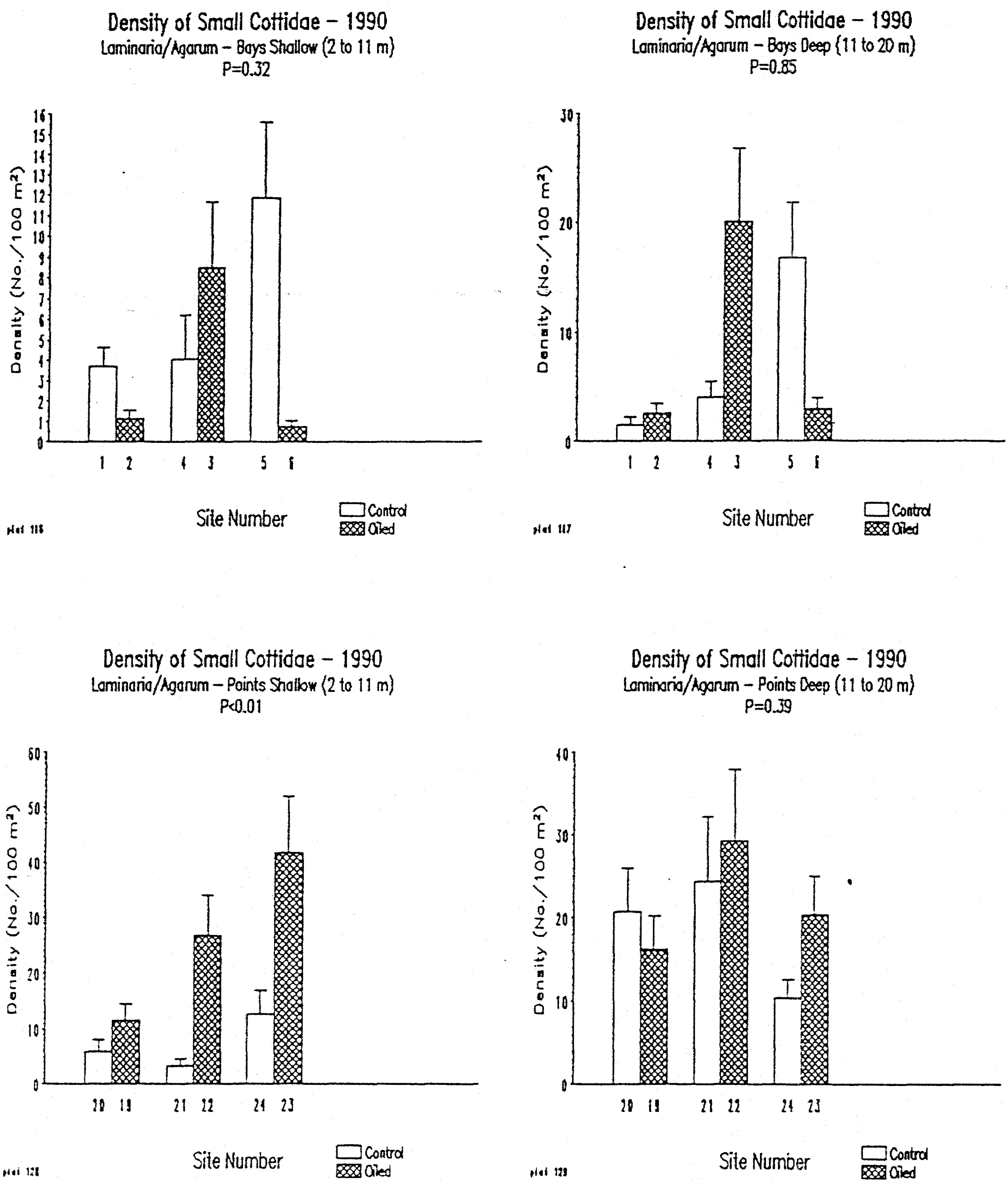

Figure 43. Abundance of small sculpins (cottidae) at oiled and control sites in *Laminaria/Agarum* habitats in Prince William Sound in 1990. Error bars are +/- 1 standard error.

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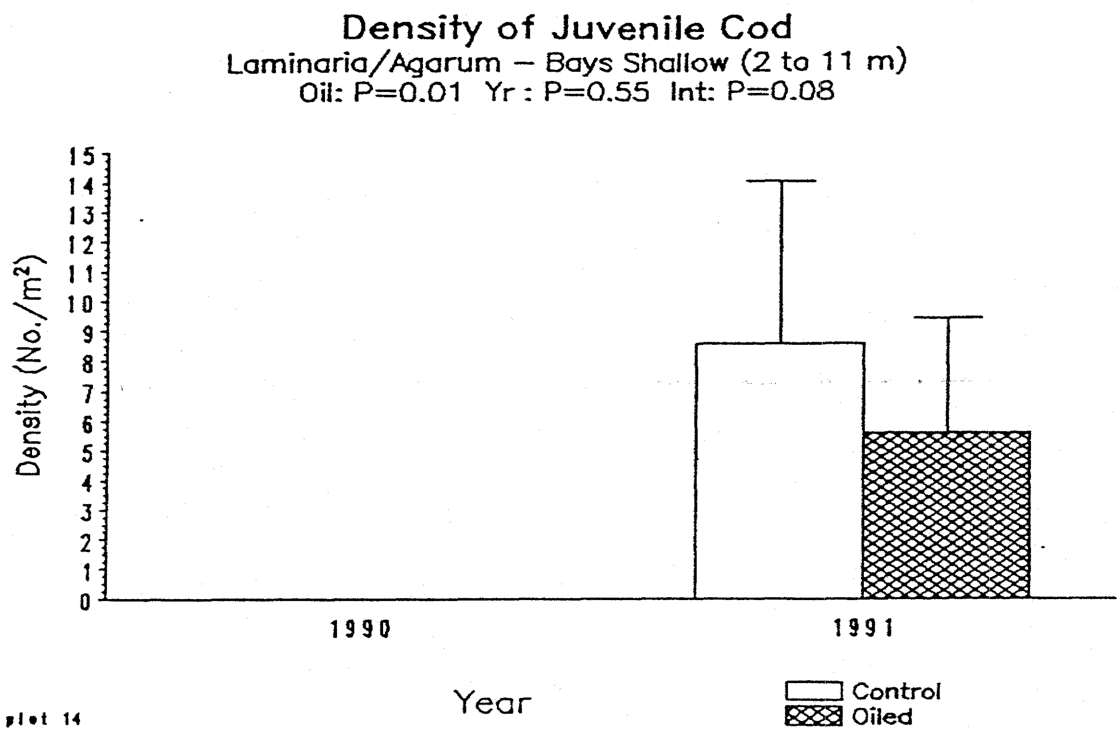

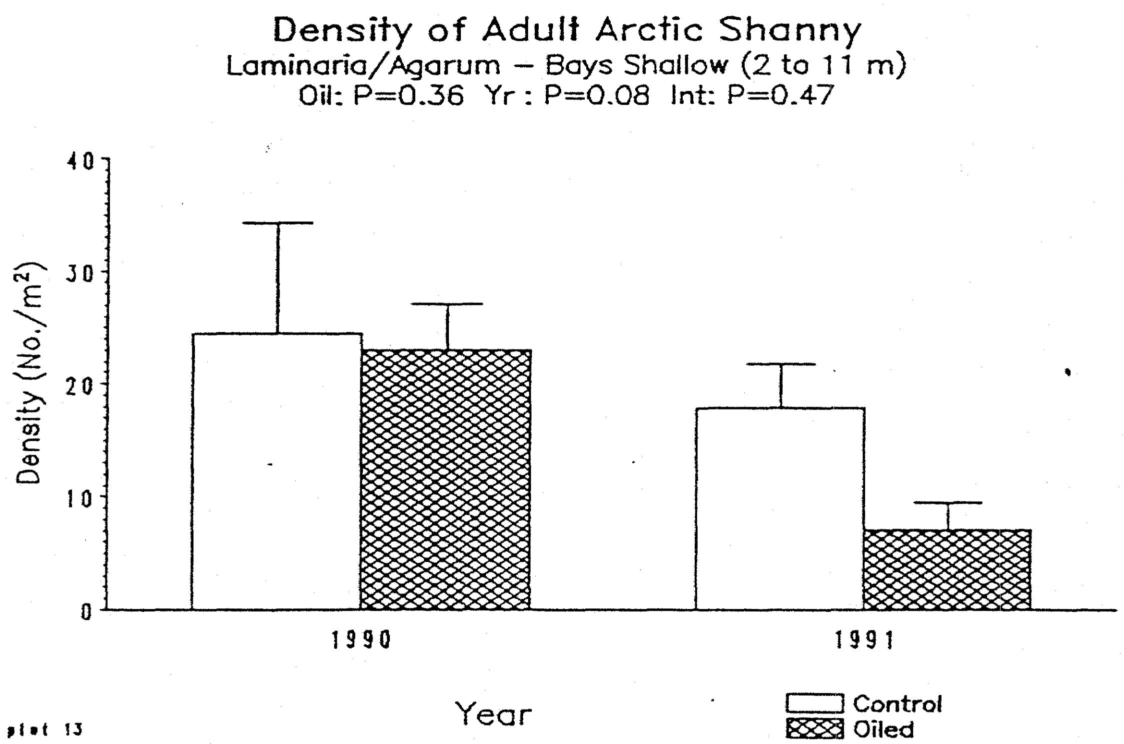

Figure 44. Abundance of juvenile cod and adult *Stichaeus* (arctic shanny) at oiled and control sites in *Laminaria/Agarum* habitats in Prince William Sound in 1990 and 1991. Error bars are +/- 1 standard error.

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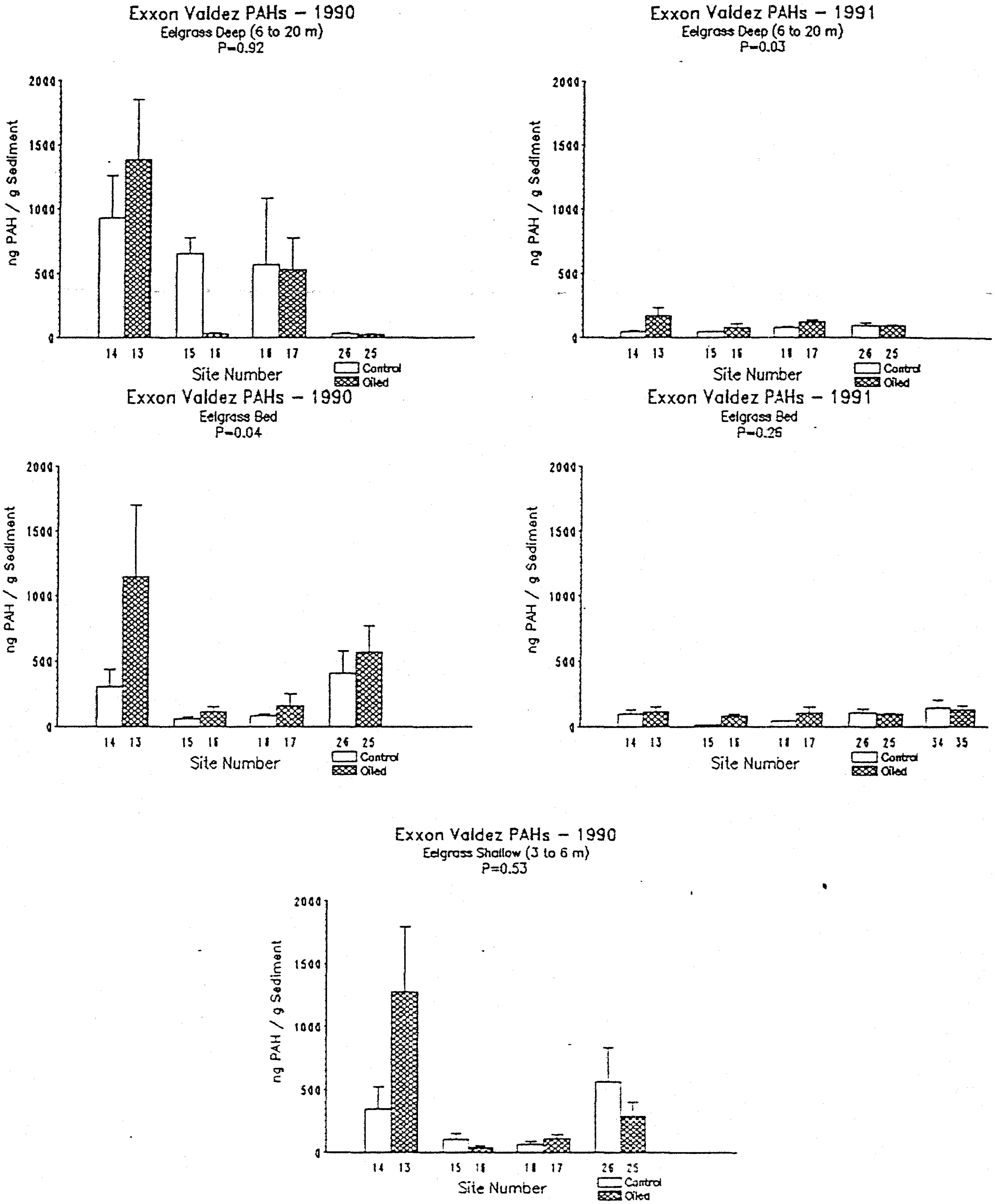

Figure 45. Concentrations of EXXON VALDEZ PAHs in the eelgrass habitat in Prince William Sound in 1990 and 1991.

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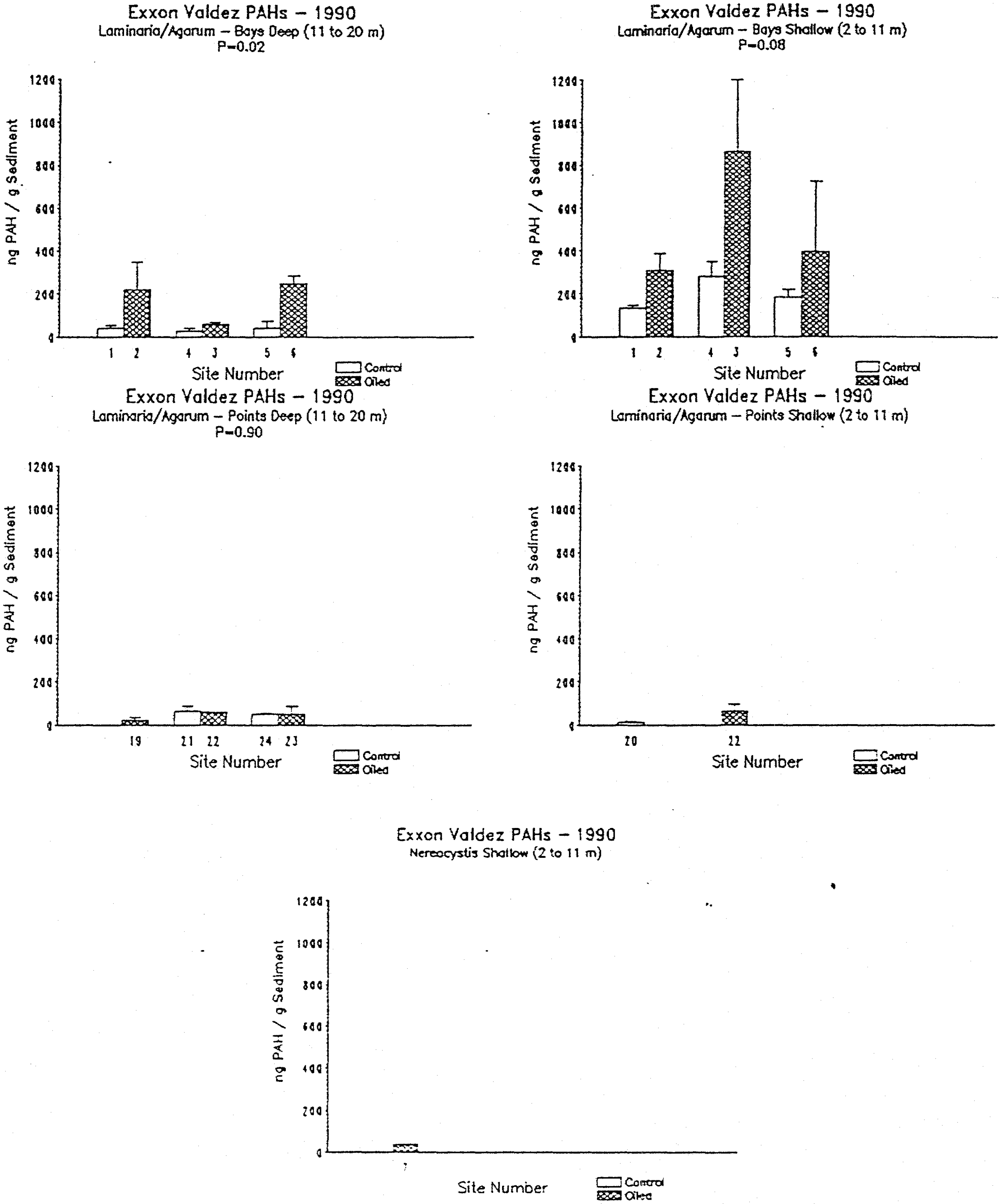

Figure 46. Concentrations of EXXON VALDEZ PAHs in the *Laminaria/Agarum* and *Nereocystis* habitats in Prince William Sound in 1990 and 1991.

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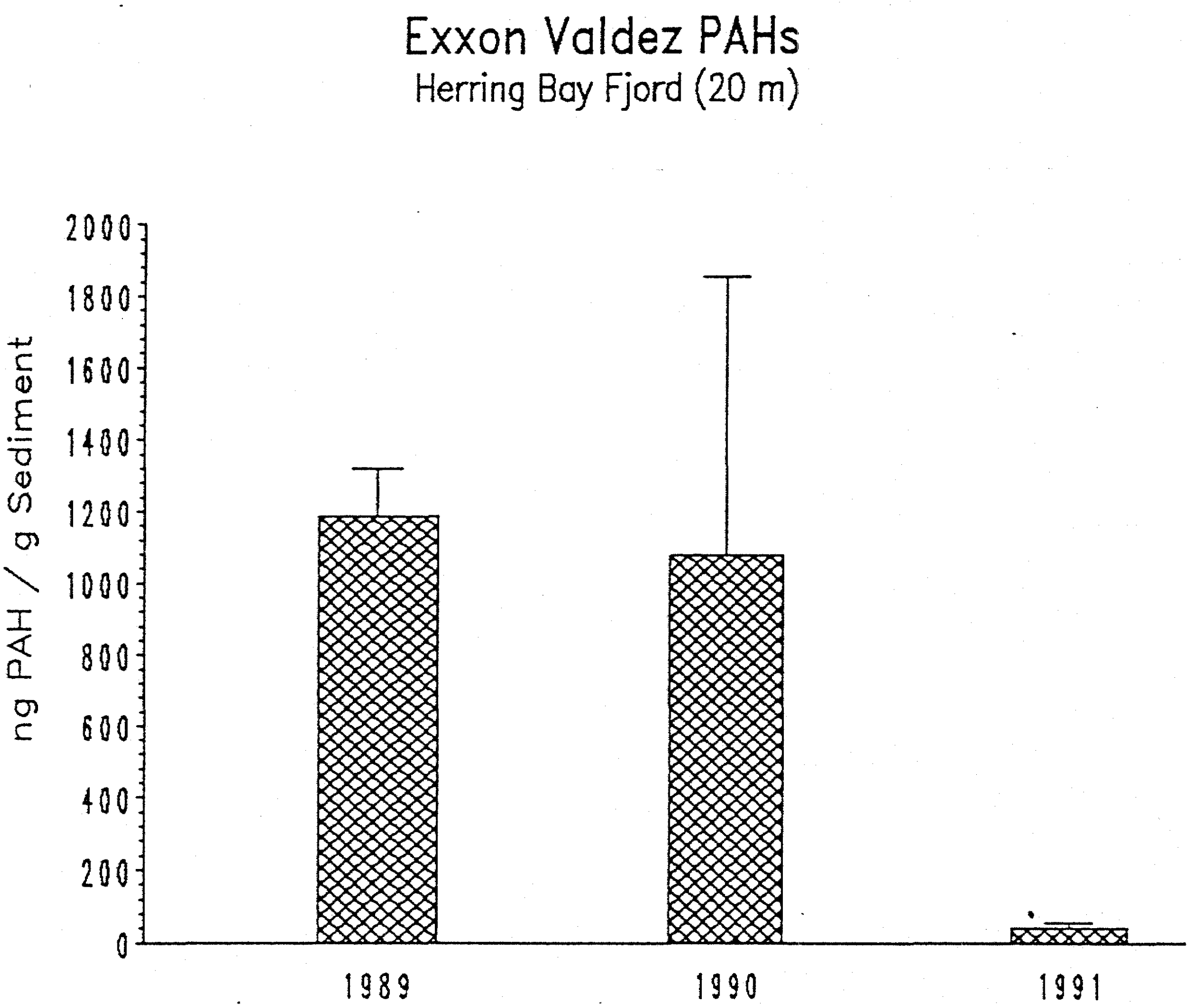

Figure 47. Concentrations of EXXON VALDEZ PAHs in Herring Bay fjord in 1989, 1990, and 1991.

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APPENDIX A.

Standard operating procedure for field activities in shallow subtidal habitats in Prince William Sound, Alaska, 1990.

APPENDIX A. Standard operating procedure for field activities in shallow subtidal habitats in Prince William Sound, Alaska, 1990.

1.0. Definitions

Habitat type - One of the four habitat types mainly defined by the dominant plants present: *Laminaria/Agarum*, *Nereocystis*, or *Zostera*. The *Laminaria/Agarum* habitat is further subdivided in Island Bays and Island Points. The fourth habitat, silled fjord, was not characterized by plants but by the presence of a shallow sill at the fjord entrance.

Study site - An area of coastline to be sampled; within each habitat type study sites may be defined as moderate-heavily oiled, unoiled (control).

Site baseline - A line connecting the endpoints of the study site, approximately 200 m long.

Station transect - A line perpendicular to the site baseline extending from the 0 tide depth out to a depth of 20 m, at locations selected randomly within a study site. There are three station transects along a site baseline.

Depth strata - Subsets of the site in various depth ranges.

Sampling depth - Randomly selected points in the depth strata on a station transect.

Sampling transect - A 30-m line following the contour to the right of a station transect along which subtidal sampling is conducted.

Quadrat - A 0.25 m^2 (0.5 m by 0.5 m) plot for photography and plant studies randomly located along a sampling transect; also, a 0.1 m^2 plot for infaunal studies randomly located along a sampling transect.

2.0. Preliminary Study Site Selection

Silled Fjords - A total of eight potential study sites were initially selected: 2 heavily oiled sites (Arm of Herring Bay and the West arm of the Bay of Isles), 2 moderately oiled sites (Disk Lagoon and Marsha Bay), one lightly oiled site (Louis Bay) and 3 control sites (Northwest arm of Lower Herring Bay, Johnson Bay, and Copper Bay). Additional sites considered in the field were Lucky Bay and Humpback Cove in Whale Bay. We choose most sites within the Knight Island group that were similar in geomorphology to the Herring Bay site where we observed a "Dead Zone" in 1989. All had restricted entrances with an apparent sill, based on examination of hydrographic charts Heavily oiled sites had over 50% of their shoreline classified as moderately to heavily oiled on the map indicating cumulative impact of oiling through July 1, 1989 (the July map) and had at least 10% of the shoreline moderately to heavily oiled in September, as per the September "walkathon" data (the

September map). The control sites had no oil indicated on either map. We anticipated sampling at all sites over a two week period.

Island Points - Island Points were selected according to the following process. All potential sites were marked on a map. We first drew an outside polygon around the island groups, one around Naked, Storey, and Peak Islands and another around the islands from the northern tip of Eleanor Island to the southern tip of Knight Island. (Smith, Little Smith, Green, Montague, and Latouche Islands were considered part of the outer sound group because of the strong influence of oceanic currents). The polygons were drawn such that any two interior points that were separated by less than 4 km were contained within the polygon. Islands less than 1/2 km in the longest dimension were not considered. The verticies of the polygon were considered as points if the angle formed by lines drawn along the shoreline to 1/2 km in either direction from the vertex was less than 60#.

Points were classified as oiled if there was moderate to heavy oil present within 100 m to either side of the point as indicated in both the cumulative oiling map as of July and the September map. There were 11 such oiled points identified.

We selected 3 oiled sampling sites from these 11 sites. The sites were placed into three groups based on location: four sites in the northwestern quadrant (1, 2, 3, and 4), four sites in the southeastern (6,7,8, and 9), and three miscellaneous sites (site 5 on the southwestern side of Knight Island and sites 10 and 11 in the northeastern quadrant).

We then examined the September walkathon data in more detail and gave preference to sites with heavy to moderate oil within 100 m to either side of the point. On this basis, Point # 10 was the selected over points 11 and 5. The remaining sites within each group were ranked using a random process. Final ranking are as follows:

Area	Selected	Alter. 1	Alter. 2	Alter. 3
NW	4	2	3	1
SE	7	9	6	8
Other	10	11	5	-

Control sites were selected that were not oiled on both the July and September oil map, and that most closely matched the oiled sites with regard to location.

Island Bays - All bays were examined within the island group from Storey Island south to Knight Island. A bay was defined as a body that was longer (distance from the mouth to the uppermost reaches) than the mouth was wide and that had a length greater than or equal to 2 km. Bays were classified as oiled if at least half of their shorelines were moderately to heavily oiled on the July map and at least 20 % was heavily to moderately oiled on the September map. Five potential oiled bays were identified: Northwest Bay, Herring Bay, Horn Bay, Snug Harbor, and Bay of Isles. We selected Herring Bay as one of our sites to be sampled because it is being used as a base for intertidal and

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subtidal experiments. We then selected two other sites from a simple random sample of the remaining 4. The 2 selected sites were Northwest Bay and Snug Harbor. Alternate sites , in order of preference, as chosen through a random process, were Bay of Isles and Horn Bay.

Sites within bays were selected based on the presence of moderate to heavy oil in the September walkathon (along at least 1/2 km of shoreline), and on the existence of previously established NOAA/DEC sampling sites, at which samples were collected for hydrocarbon analysis in 1989. These generally represent shoreline segments of approximately 500 to 1000 m. Actual sites within these segments will be selected based on physical characteristics of substratum type and slope in a reconnaissance cruise in April, 1990.

Control bays were selected that most closely resembled the oiled bays and that were not oiled in both the July and September oil maps. These were as follows:

Oiled Site	Control	Alter. 1
Herring Bay	Lower Herring Bay	Drier Bay
Snug Harbor	Mummy Bay	
Northwest Bay	Cabin Bay	
Bay of Isles	Mummy Bay	
Horn Bay	Mummy Bay	

Eelgrass - Sites where eelgrass is present within the PWS area were identified by Kim Sundberg, Rick Rosenthal, and the NOAA staff of Chuck O'Clair and Stanley Rice. Oiled eelgrass beds were selected that were indicated as moderately to heavily oiled on both July and September oil maps. This resulted in 9 potential sites. One of these (Perry Island) was eliminated from consideration because there was no adequate control. The other 8 were placed into 3 groups: Group 1 are bowls on the eastern side of the islands, with mouths facing North (site # 2 on Naked Island, site # 3 on Latouche Island, and site # 7 in Snug Harbor). Group 2 is in the northwest quadrant of the Knight Island group (#3 on Disk Island and #'s 4 and 5 in Herring Bay). Group 3 are sites within Bay of Isles (8 and 9). Order of preference for sampling of sites within groups was determined based on the presence of DEC/NOAA sampling sites used in 1989. If hydrocarbon samples were taken at all sites within a group, then sites were selected at random. These were as follows:

Area	Selected	Alter. 1	Alter. 2
Bowls	6	7	2
NW	5	3	4
Bay of Isles	9	8	

Control sites were selected that were not oiled on both the July and September oil maps, that were in the same geographic region, and were of similar aspect and exposure. The control site for Herring Bay (#5) was within Lower Herring Bay, for the Latouche Island site was in Sawmill Bay on Evans Island, and for the Bay of Isles site was in Drier Bay.

Nereocystis - Sites where *Nereocystis* is present within the PWS area were identified by Kim Sundberg and Rick Rosenthal. Oiled *Nereocystis* beds were selected that were indicated as moderately to heavily oiled in both July and

September oil maps. This resulted in 5 potential sites: Danger Island, Latouche Pt., Green Island, Smith Island, and Little Smith Island. The sites were placed into 3 groups based on location: Group 1 is Danger and Latouche, group 2 is Green Island, and group 3 is Smith and Little Smith. Danger Island and Smith Island sites were randomly selected as priority sites among groups 1 and 3.

Control sites were selected that were not oiled on both the July and September oil maps, that were in the same geographic region, and were of similar aspect and exposure. The control site for Danger Island was Pt. Elrington, for Smith Island was Zaikof Pt., and for Smith Island was Pt. Montague.

3.0. Study Site Confirmation and Site Descriptions

Site confirmation - An aerial and ship based survey of all potential study sites was made in April, 1990. Tom Dean, Rick Rosenthal, and Dave Laur flew the Sound, examined each site from the air to insure that habitat types were correctly defined and that control sites resemble oiled sites with regard to geomorphology. Sites accessible by float plane were visited. Some study sites were marked with a pink paint mark on the shore line. Other sites have distinguishing features that allow sites to be identified. Photographs and/or videos were taken of each site. Those sites inaccessible by plane were visited by Tom Dean and Troy Tirrell aboard a boat.

Sites Selected - The sites selected in the confirmatory survey, and their site codes are given in Table 1. The site numbers used here were reassigned after site conformation visits and do not necessarily correspond to numbers assigned to sites during the preliminary selection phase as described in section 2.0.

Silled Fjords - Several of the potential silled fjord sampling sites were visited in April 1990. Most were found to be inadequate because they were too large and did not have sills. The only sites found to fit the prescribed characteristics were the previously sampled site in Herring Bay and the western arm of Bay of Isles. An additional control site was located in Port Audrey Cove, Drier Bay. The uppermost part of Lucky Bay may also be an adequate control.

Several sites and their alternatives were not adequate and new sites were selected. For example, the *Nereocystis* sites at Green Island and Pt. Elrington were deleted because of a lack of *Nereocystis* (on Green Island) or because the site was more exposed than the oiled site (Pt. Elrington). New sites were selected based on previously established criteria.

Site Descriptions - A description of each site follows.

Site # 01 - Cabin Bay - Naked Island. This is a *Laminaria/Agarum* control site. It is located within ADEC segment # NA024. Site is on northern shore of the southern arm, near the point between the northern and southern arms of the bay. A paint mark was placed on a rock above the high tide mark. The substrate is large cobble and boulder. (Note - there is a cobble beach to the east that may be a good collecting spot for clams.)

Site # 02 - Northwest Bay - Eleanor Island. This is a *Laminaria/Agarum* oiled site. It is located within ADEC segment # EL056-D. Site is on the eastern shore of the eastern arm, near a stream in the southern most portion of the bay. A paint mark was placed on a rock above the high tide mark. The substrate is large cobble and boulder. (Note - The site may need to be moved toward the mouth of the bay in order to match the Cabin Bay site better).

Site # 03. - Herring Bay. This is a *Laminaria/Agarum* oiled site. It is located within ADEC segment # KN0132A. Site is on the western shore, about 2/3 down the bay, just south of a salmon stream. The site is marked by a regulatory stream marker, 2 points south of the stream. The middle of the site is to be in the middle of the run just south of the 3rd point south of the stream. The substrate is rock outcrop with some boulders.

Site # 04. - Lower Herring Bay. This is a *Laminaria/Agarum* control site. It is located within ADEC segment # KN0551-A. Site is on the western shore near the start of the western arm of the Bay. The site is marked with a paint mark just to the south of a waterfall. Our site is to be centered 2 points (about 300 m) to the south of the mark. The substrate is rock outcrop.

Site # 05 - Mummy Bay - This is a *Laminaria/Agarum* control site. It is located within ADEC segment # KN0601. Site is on the northwestern shore of Mummy Bay, about 2/3 up the bay. The site is centered in the middle of a plateau that sticks out into the bay, with water falls on either side. The substrate is mostly cobble and boulder. No marks were made.

Site # 06 - Bay of Isles. This is a *Laminaria/Agarum* oiled site. It is located within ADEC segment #'s KN0136-A and KN0004-A. Site is on the southern shore of the bay, near the juncture of the western and southern arms. Center of site is on an outcropping of the eastern most of 2 points, just to the east of a small (30 m long) cobble beach. The substrate at the site is rock bluffs with boulder and cobble. No site marks were made.

Site # 07 - Latouche Pt. This is an oiled *Nereocystis* site. Site is on the southwestern tip of Latouche Island. Site center is about 100 m to the west of a small hooked tip off this point. No site mark was made.

Site # 08 - Procession Rocks, Bainbridge Island. This is a control *Nereocystis* site. Site is near the southern most tip of Bainbridge Island, between the island and Procession rocks. No site mark was made. An on site evaluation and determination of the best match for Latouche needs to be made.

Site # 09 - Zaikof Bay, Montague island. This is a control *Nereocystis* site. Site is on a Pt. on the southern shore of Zaikof Bay, about 2 km from Zaikof Pt. Site center is on the middle of 3 reefs that run offshore about 200 m southeast of a regulatory stream marker next to a large white rock on the bluff. No site mark was made. Substrate at the site is reef outcrop with large boulders.

Site # 10 - Montague Pt., Montague Island. This is an oiled *Nereocystis* site. Site is on the northwest shore of Montague Island near Pt. Montague. The site is directly offshore of a high bluff, just where the bluff falls off the west into a wooded meadow. The site is marked with pink paint on the roots of a spruce tree that appears to be falling from the bluff into the meadow. The site center is 100 m to the west of a razor back reef directly offshore of the mark. Substrate at the site is reef outcrop.

Site # 11 - Dubois Pt., Naked Island. This is a control *Nereocystis* site. Site is a small southerly projection on the southeast shore of Naked Island. There are 2 small islands off the tip of the point. The site center is on the southern tip of the eastern most island. No site mark was made.

Site # 12 - Little Smith Point. This is an oiled *Nereocystis* site. Site is at the southern most tip of Little Smith Island. Site center is a western tip of a small island off the point. No site mark was made.

Site # 13 - Bay of Isles. This is an oiled *Zostera* (eelgrass) site. It is located within ADEC segment # KN0202-A. Site center is 100 m east of a salmon stream, along the southern shore of the western arm of the bay. The substrate is small cobble and silt. No site marks were made.

Site # 14 - Drier Bay (Northeast cove). This is a control *Zostera* (eelgrass) site. It is located within ADEC segment # KN0575-A. Site center is 100 m west of the western most of 2 salmon streams along the southern shore of the cove. Substrate is mixed cobble with softer silt sediment. No site marks were made.

Site # 15 - Lower Herring Bay. This is a control *Zostera* (eelgrass) site. It is located within ADEC segment # KN0551-A. Site is at the mouth of a salmon stream near the northern extreme of the western arm of the bay. No site mark was made. Site center is the salmon stream. The substrate is cobble with silt.

Site # 16 - Herring Bay. This is an oiled *Zostera* (eelgrass) site. It is located within ADEC segment # KN0132B. Site is at the mouth of a salmon stream about 2/3 of the way into the bay on the western shore. Rebar that are painted pink mark an ADEC underwater transect. A site marker (flashing) was placed on a fallen tree just to the north of the site. The substrate at the site is cobble with silt.

Site # 17 - Sleepy Bay, Latouche Island. This is an oiled *Zostera* (eelgrass) site. It is located within ADEC segment #'s LA017-A - LA018-A. Site is in the southern most part of the bay, at the mouth of a salmon stream. The site center is the mouth of the salmon stream. Rebar that are painted pink mark an ADEC underwater transect. No site marks were made.

Site # 18 - Moose Lips Bay - Northeast Montague Island. This is a control *Zostera* (eelgrass) site. Site is in a small embayment due east of the Northern tip of Little Green Island. There are 2 salmon streams at this site. The southern most is an active stream. The northern most dead ends in a marsh behind the cobble berm. The site center is marked with a small buoy placed off the northern most stream, about 200 m from shore. The substrate is mostly silt and sand with some cobble.

Site # 25 - Clammy Bay (Northeastern Naked Island). This is an oiled *Zostera* (eelgrass) site. It is located within ADEC segment # NA006-B."Clammy Bay" is the unofficial name given to this eelgrass site by the field crew. The site is located on the southeastern side of McPherson Passage. The shoreline is covered with unconsolidated cobble and boulders. No streams are in the vicinity, but there is much freshwater from the adjacent steep hillside. Bottom substrate is fine sand to black silt.

Site # 26 - Puffin Bay (Northeastern Storey Island). This is a control *Zostera* (eelgrass). It is located within ADEC segment # ST001."Puffin Bay" is the unofficial name given to this eelgrass site by the field crew. The site is bisected by a small rocky pinnacle outcropping. A cobble beach is present. The substrate is grey compact sand.

Site # 19 - Discovery Point This is an oiled *Laminaria/Agarum* island point site. Site is on the southern entrance to Snug harbor. Site center is on the northern most extension of the point. No site marks were made.

Site# 20 - Lucky Point (What's it called Pt.) This is a control *Laminaria/Agarum* island point site. The site is at the western side of the mouth of Lucky Bay. The island is identified by 2 spruce trees. The site center is on the northwestern most point on the island. No site marks were made.

Site# 21 - Outside Lower Herring Bay (Pt Lyman control). This is a control *Laminaria/Agarum* island point site. Site is centered on the southernmost island off the point. The site center is on the northwestern most point on the island. No site marks were made.

Site # 22 - Outside Herring Bay (Pt. Lyman). This is an oiled *Laminaria/Agarum* island point site. Site is on the western most island off the point, with the site center at the western point of the island. No site marks were made.

Site # 23 - Ingot Pt. This is an oiled *Laminaria/Agarum* island point site. Site is on the southern most point of Ingot Island. Site center is at the middle of the largest island off the point, just west of three smaller islands. No site marks were made.

Site # 24 - Peak Pt. This is a control *Laminaria/Agarum* island point site. Site is on the northern most point of Peak Island. Site center is at the center of the long axis of the largest of three island off the point. No site marks were made.

Site # 27 - Outer Lucky Bay (SW Knight Island). This is a control silled fjord site. It is located within ADEC segment # KN0600-A. This site is located west of Mummy Bay and south of the inner fjord. Rock outcroppings at the south end and submerged rocks at the north end delineate the outer fjord. The substrate is gray silt. The beaches are composed of cobble.

Site # 28 - Herring Bay (NW Knight Island). This is an oiled silled fjord site. It is located within ADEC segment # KN0118-A. This site is located on the east side of Herring Bay; nearly surrounded by high peaks. The substrate is a flocculant gray-black material over silt. The veach is composed of cobble and talus rock.

Site # 29 - Inner Lucky Bay (SW Knight Island). This is a control silled fjord site. It is located within ADEC segment # KN0600-A. This site is located north of Site 27 and only accessible at high tide due to the presence of exposed rocks and rapids at low tide. The substrate is gray silt. The beach is composed of talus from the surrounding peaks. Freshwater enters the fjord from a stream and waterfall.

Site # 30 - Inner Bay of Isles (east Knight Island). This is an oiled silled fjord site. It is located within ADEC segment #'s KN0200-A - KN0201-A. This site is located west of Site 31. The substrate is an admixture of coarse gravel and gray silt. The narrow slate shingle beach is surrounded by a stand of alder. A fresh water stream drains into the fjord from the west.

Site # 31 - Outer Bay of Isles (east Knight Island). This is an oiled silled fjord site. It is located within ADEC segment #'s KN0202-3-A; KN0009-A. The site is located east of Site 30 and separated from the remainder of the bay by a shallow sill and 17 m deep channel. The substrate is a mixture of coarse gravel and gray silt. The beach is composed of cobble and gravel.

Site # 32 - Disk Lagoon (west Disk Island). This is an oiled silled fjord site. It is located within ADEC segment # DI065-A. The site is a small embayment on the west side of Disk Island, connected by three narrow passages to Lower Passage.

Site # 33 - Humpback Cove (western Whale Bay on the mainland of SW Prince William Sound). This is a control silled fjord site. It is located within ADEC segment # WH504. The site is at the western extension of Whale Bay. The substrate is a flocculant dark brown material over silt-clay. "Humpback Cove" is the unofficial name given to the site by the field crew.

4.0 Sampling in Silled Fjords

An abbreviated survey of silled fjords will be conducted in May and June, 1990. Four sites will be visited and sampled (Herring Bay, Port Audrey Cove, Lucky Bay, and Bay of Isles). Estimates of density of infaunal invertebrates will be obtained from 6 benthic airlift samples (0.1 m^2) taken by divers at random positions along the 20 m depth contour in each of the 4 bays. A small boat with a fathometer will cruise the bay along three transects. The first will extend from the mouth of the bay, along its axis and to the uppermost reaches. A second will be run perpendicular to the first, and a third will be run that bisects the first two. A buoy will be placed at the first and last sounding of 20 m experienced on the transect. A diver will then go to the bottom and place a circular 0.1 m^2 frame 3 m from the buoy anchor in a predetermined random compass direction from anchor. The frame is pushed into the substrate until the frame handles are flush with the seafloor (i.e., 10 cm deep). The sediment within the frame is then vacuumed into a collecting bag attached to the suction device. The vacuum force needed for collection is obtained from a 70 GPM water pump and a 3.8 cm diameter Venturi jet dredge nozzle. The influent side of the dredge nozzle is connected to the pump and the effluent side to a 1.8 m length of 7.6 cm diameter flexible discharge hose, terminating in a 1.0 mm mesh collecting bag. A ball valve is used on the influent line to operate the suction system while the water pump is run at a constant rpm. The sample is considered complete when the sediment is removed to the lower lip of the collecting frame.

A second diver will characterize the bottom using a video. A 20 m transect will be videoed at each sampling site.

Two sediment samples will be taken at each station: one for hydrocarbon analysis and the other for grain size analysis. Each sample will be collected from within 3 m of the buoy anchor. A sample for hydrocarbons will be collected in a wide mouth jar (precleaned ICHEM) by scraping the top 5 cm from the surface of the substrate until the jar is half to three quarters filled. A sample for grain size analysis will taken in the same manner. In addition, at the second sampling station, a sample of the water 0.5 m above the bottom will be taken for hydrocarbon analysis.

A sample of any dead animals will be made (within the limits of safe diving - <20 meters) at each infaunal sampling station within the bay. An attempt will be made to sample at least 5 worms and 1 starfish (the most abundant dead organisms observed in 1989), and any dead fish observed at each sampling station. The invertebrates will be collected and frozen for hydrocarbon analysis. Fish will be dissected and preserved for histological/hydrocarbon analysis.

Upon return to the ship, lids to the hydrocarbon sample jars will be loosened and some water poured off, leaving a 2 cm headspace in order to prevent breakage upon freezing. A water sample will also be collected and analyzed for salinity.

A temperature, salinity, and dissolved oxygen profile will be made in each bay by lowering a temperature/dissolved oxygen probe into the water at the deepest part of the bay and measuring oxygen and salinity at every 1 m interval.

In the Fall, a more extensive survey will be conducted at these, and possibly 2 other sites. Upon arrival at the study site, a bathymetric survey of the bay will be made using a portable fathometer aboard a small inflatable boat and radar aboard the mother ship. Three survey lines will be run. The first will extend from the mouth of the bay, along its axisand to the uppermost reaches. A second will be run perpendicular to the first, and a third will be run that bisects the first two. Depth measurements will be made every 20 m along each line.

We will characterize the bottom using a diver held video camera. Three video transects will be made: One along the long axis of the bay, one along the short axis and through the deepest part of the bay, and one that bisects the short and long axis. The diver will swim along a compass course.

Sampling of sediments and infauna will be the same as in the Spring survey.

5.0. Stratified Sampling in *Laminaria* Habitats in Island Bays and on Island Points

5.1 Station setup

A. Locate the center of the study site. Drop buoys approximately 100 m to either side of the marker. (In cases where the habitat does not extend for 100 m on either side of the center, the distance may be reduced to 50 m). Drop the buoys so that a line connecting them is parallel to the site baseline. Start the skiff approximately 25 m to the right of right buoy and approach the buoy at a constant rate of speed. (Determine left versus right when facing the site from the sea). Record the time required to cover the distance from approximately 30 m from the right buoy to the left buoy. Do not vary the speed of the boat during this operation and maintain a constant distance from shore.

B. Divide the time by 3 (e.g., 7.2/3 = 2.4 Min). Select a random number on the calculator and multiply the two values (e.g., 2.4 X 0.8978 = 2.15 min). Add (Total Time)/3 to the result and 2 (Total Time)/3 to the result. For example, 2.15 min, 2.15+2.4 = 4.55 min, and 4.55+2.4 = 6.95 min are the random starting points at which to start the station transects when measured from the left hand side and traveling at the same speed. Buoys to mark the starting point of each station transect will be dropped at 2.15 min, 4.55 min, and 6.95 min when measured from the left hand side of the site.

C. At each station, a small boat will be driven seaward from nearshore along a course perpendicular to the site baseline, dropping marker buoys at randomly preselected depths in each of the depth strata. The original buoy marking the station transect will be retrieved after the marker buoy is dropped in the first depth stratum. The protocol for random selection of positions for the buoys is: (1) for each station transect select a random number (proportion) between 0.0 and 1.0, (2) multiply the range of depth in each strata by the proportion. For example, if the random proportion is 0.35, the depth (D) in the two depth strata would be:

2-11 m	$D = 0.35 \times 9\ m + 2\ m = 5.2\ m$
11-20 m	$D = 0.35 \times 9\ m + 11\ m = 16.2\ m$

All depths should be corrected to mean low low water using output from TIDE1 software for the region closest to the sampling site. A schematic of a hypothetical site layout is presented in Appendix Figure A-1.

5.2. Censusing Fish Populations

Two divers swim to the bottom at the deepest of the two marker buoys. Diver # 1 attaches a 30 m fiberglass transect tape to the anchor and swims a 30 m isobathyal sampling transect to the right (facing shore). The diver visually counts fish, by species, within 2 m of the transect line and within 3 m of the bottom. Non-cryptic specimens of echinoderms and crustaceans larger than 10 cm will also be counted in this 2 m by 30 m band.

Diver # 2 swims along the sampling transect from the buoy anchor recording a 2 m by 30 m video transect pointing the camera down toward the substrate.

After a 2 minute wait 3 m off the end of the transect, the divers swim side by side with the transect line between them, each diver counting the number of benthic fishes within a 1 m band on their side of the transect tape. An attempt will be made to count all individuals of length 5 cm or larger.

Following completion of the deepest transect the two divers will move up to the next shallowest marker buoy and repeat the procedure. Identical procedures as described above for the deepest sample transect will be followed at the sample stations in the shallower depth strata.

5.3. Sampling Plant and Epifaunal Invertebrate Populations

Following the fish subsampling at a sampling transect, two divers (#'s 3 and 4) swim down to the marker buoy anchor. At randomly preselected locations on the sampling transect, diver #3 places four large (0.25 m^2) quadrat frames, with the upper left hand corner of the frame on the specified random points.

The quadrats are place on the shoreward side of the sampling transect.

The random positions for the upper left corner of the large quadrats are determined by the following protocol. Multiple 7 m by a random number between 0.0 and 1.0 (proportion) to find the point for the upper left hand corner of the quadrat in the 7.5 m segments with the zero end of each section being closest to the marker buoy. The segment length is reduced from 7.5 m to 7 m before multiplying by the random proportion it insure that the resulting quadrats do not extend off the 30 m sampling transect. For example, if the random proportion is 0.26, the four quadrat locations on the 30 m sample transect would be 1.82, 9.32, 16.82, and 24.32 m.

Diver #3 estimates the amount of algal cover in each of the large quadrats. Diver #3 then clears all macroalgae from each large quadrat, placing the cut pieces in labeled mesh bags. The algae are to be clipped 5 cm above the substrate. *Laminarian* algae smaller than 5 cm are counted. The smaller algae (including small *Laminarians*, leafy reds, and encrusting forms) are to be collected from 1 quadrat at each sampling transect (see invertebrate sampling procedures below). Diver #4 photographs each quadrat using a camera with a 28 mm lens. Six frames are required in order to photograph the entire 50 by 50 cm area in each quadrat. The sequence of photographs in each quadrat is as reading a book, i.e. starting in the upper left hand corner and moving from left to right, when facing the 30 m end of the transect.

Aboard ship, algal samples are separated by species, counted, patted dry. Each plant is weighed individually and its weight recorded. The reproductive condition (either with or without evident sori) of each *Laminaria*n species is noted.

Samples of representatives of each canopy species are preserved by placing them in labeled jars with 5% formalin.

5.4. Estimation of Population Parameters for Infaunal Invertebrates

Following completion of the photographic quadrats and algal sampling, two divers (#5 and 6) will go to the sampling transect which still has the 30 m tape and the four large quadrat frames in place. Diver #5 swims the tape until reaching the first quadrat frame and continues to swim until reaching a patch of soft substrate (silt, sand, or small gravel with depth greater than 5 cm.) larger than 0.1 m^2. Diver #5 then vacuums all material within a 0.1 m^2 frame placed in the center of the patch, to a depth of 10 cm, using an airlift sampler. Diver #5 then swims to the second quadrat and repeats the procedure. (Only 2 small quadrats are sampled for benthic infauna at each station transect). Diver #6 collects sediment samples for hydrocarbon and grain size analyses and then rolles up the tape and collects the quadrats on the return swim. At one station per site (#2) Diver #6 also collects a water sample from 0.5 m above the bottom for hydrocarbon and salinity measurement. On board ship all airlift samples will be preserved in 10% buffered (sea water) formalin.

5.5. Physical Measurements

Salinity and temperature will be measured at the middle sampling transect within each depth stratum. Measurements will be made at depths of 0.5 m below the surface, 2 m below the surface, and 0.5 m above the bottom using a YSI temperature/salinity meter.

6.0. Stratified Sampling in *Nereocystis* Habitat

6.1 Station Setup

All *Nereocystis* sampling sites will be marked with a single paint mark on the shore at the center of the site. Set sampling locations as follows: Locate the center marker of the study site. Drop buoys approximately 100 m to either side of the marker. Drop the buoys so that an imaginary line connecting them is parallel to the site baseline, just offshore of any visible kelp canopy. Start the skiff approximately 25 m to the right of the right buoy and approach the buoy at a constant rate of speed. (Determine left versus right when facing the site from the sea). Record the time required to cover the distance from approximately 30 m from the right buoy to the left buoy. Do not vary the speed of the boat during this operation and maintain a constant distance from shore.

Repeat steps B and C as described in 5.1 above to establish 3 stations at each of 2 depth strata. See Appendix Figure A-1 for a hypothetical site layout.

Divers #1 and 2 enter at the buoy on the outer margin of the kelp canopy and drop to the buoy anchor. They then swim a tape from the buoy on a compass course perpendicular to shore until no more canopy forming kelps (*Nereocystis*) are observed. The distance from the buoy to the inner margin of distribution for kelp canopy species is recorded. The divers then swim back the tape to 1/2 the distance to the buoy and mark the station with a pop float. This process is repeated for each transect station, establishing 3 stations per site in the center of the distribution of *Nereocystis*.

6.2 Sampling Fish, Plants, and Invertebrates

Fish, plants, invertebrates, and sediments are sampled at each station as described for *Laminaria* habitats with the following additions.

Along the three station transects within the center of distribution of *Nereocystis*, divers #2 and 3 will count all *Nereocystis* within a 2 m wide band on either side of the transect, and will measure diameters of the stipes of the first 20 *Nereocystis* encountered on each transect. All plants will be measured at a height of 1 m above the bottom. Divers #5 and 6 will obtain an independent sample of 40 *Nereocystis* (at 1 oiled and 1 control site only), and these plants will be weighed and measured to establish a regression between stipe diameter, length, and weight of the plants. These are to be collected outside of the sampling transects, but within 100 m and at the same depths as the sampling transects.

Also, on each of the 3 sampling transects within the *Nereocystis* canopy, canopy fishes will be counted along a 2m x 30 m band at a depth of 2 m. An attempt will be made to count all fish in a 2 m by 3 m column parallel to the surface. Sampling for fishes will be conducted at least 1 hr. after all other survey work has been completed.

7.0 Stratified Sampling in Eelgrass Habitat

7.1 Station Setup

All eelgrass sampling sites will be marked with a single paint mark on the shore at the center of the site. Set sampling locations as follows: Locate the center marker of the study site. Drop buoys approximately 100 m to either side of the marker. Drop the buoys so that an imaginary line connecting them is parallel to the site baseline, just offshore of any visible eelgrass. Snorkeling may be required to identify the outer margin of the eelgrass bed. Start the skiff approximately 30 m to the right of the right buoy and approach the buoy at a constant rate of speed. (Determine left versus right when facing the site from the sea). Record the time required to cover the distance from approximately 30 m from the right buoy to the left buoy. Do not vary the speed of the boat during this operation and maintain a constant distance from shore.

Repeat steps B and C as described in 5.1 above to establish 3 stations at each of 2 depth strata, 3 to 6 m and 6 to 20 m. See Appendix Figure A-2 for a layout of a hypothetical eelgrass site.

Divers #1 and 2 enter at the buoy on the outer margin of the eelgrass bed and drop to the buoy anchor. They then swim a tape from the buoy on a compass course perpendicular to shore until no more eelgrass is observed. The distance from the buoy to the inner margin of distribution eelgrass is recorded. The divers then swim back the tape to 1/2 the distance to the buoy and mark the station with a pop float. This process is repeated for each transect station, establishing 3 stations per site in the center of the distribution of eelgrass.

7.2 Sampling Fish

Within each of the 3 strata on each transect, divers will establish three 30 m long transects running parallel to shore. Divers #1 and 2 enter the water, lay out the tape, and sample fish and large motile invertebrates as described in section 5.2. (Note - A video may be required only on transects within the eelgrass bed).

7.3 Sampling Epifaunal Invertebrate Populations

Epifaunal invertebrates associated with eelgrass will be sampled only along the three sampling transects that lie within the eelgrass zone. Two samples are taken along each of the sampling transects; therefore, six epifaunal samples are collected at each eelgrass site. A 0.5 m^2 drop net will be dropped from a small boat within three meters adjacent to the two random points where infauna is to be collected (see Section 7.5). Once the net is dropped it is pursed and retrieved to the boat. The contents of the net are rinsed into a sample jar, preserved with buffered formalin, and labeled.

7.4 Sampling Eelgrass

Eelgrass will be sampled only along the sampling transect that lies within the eelgrass zone. Divers #3 and 4 will harvest all eelgrass from each of the 4 quadrats per depth stratum. The turions of the plants will be cut approximately 1 cm above the sediment surface. The plants will be bagged underwater and returned to the boat. There, the number of turions per quadrat will be counted, and all turions in each quadrat weighed. In addition, we will note the number of flowering stalks per quadrat, and count the number of seeds per stalk in the first 10 seed stalks encountered per quadrat. (Note - no photographs will be required in the eelgrass habitat.

7.5. Sampling Infaunal Invertebrates

Infaunal invertebrates will be sampled in a 0.1 m^2 airlift sample from each of first two quadrats per station transect. Station transects to be sampled include both those within the eelgrass zone and those outside of the eelgrass. Two sediment samples will be taken to a depth of 5 cm at each sampling transect. One will be used to determine grain size and the other to determine hydrocarbon concentrations.

8.0. Special Notes on Sample Collection for Sediments, Water, and Fish

8.1. Collecting Fishes for Food Habits, Condition Factor and Hydrocarbon Concentration Studies

Following completion of the above sampling, a collection of fishes will be made to assess diets, condition factor, and maximize collection of two species: (1) a commonly occurring benthic feeding species (kelp or whitespotted greenling if possible) and (2) a commonly occurring midwater feeding species (dusky=planktivore or black=piscivore if possible). Twenty to 25 individuals of each species are desired from each site. Fish will be collected at sites at least 50 m from the nearest sampling transect if possible.

Techniques including diver spearing, hook and line fishing, and diver operated hand nets will be used in an attempt to collect fish.

Collected fishes will be measured (fork length) and weighed. Selected tissues and/or organs will be removed and treated as specified in the documents detailing collection and handling of samples for hydrocarbon analyses (State/Federal damage assessment plan, analytical chemistry, collection and handling of samples, August 9, 1989, Auk Bay Lab Attorney Work Product). Tissue samples and organ samples should consist of 1 g per fish for 15 fish. Their stomachs will then be excised and fixed in 10% formalin.

8.2. Collecting Sediment and Bottom Water Samples

Two samples of sediment will be collected at each station transect, 3 m to the right of the buoy anchor. One sample will be used to determine hydrocarbon levels and the other to determine grain size. The following protocol will be followed: Collect sediment by scooping directly into the opened sample container. Scoop to a 5 cm depth to obtain 10- 100 g of sediment (equivalently 4 oz. jars will be filled to just below the shoulder). If sediment is not readily available at the point then collect the closest available material, including small rocks and organic material, along the sampling transect avoiding the locations of study quadrats for plant and animal collections. After returning the jar to the surface, loosen the lid and pour off approximately 2 cm of water to allow room for expansion of the sample upon freezing.

A water sample will be taken at a depth of 0.5 m above the surface at the middle sampling transect within each depth stratum.

All sediment and water samples are to be numbered sequentially, tagged, logged, sealed with evidence tape, and frozen.

All samples collected in the procedures described above will be handled and documented as specified in the protocols for sample accountability and chain of custody.

9.0 Experiments Evaluating Reproductive Success

9.1. Site Selection

All experiments will be conducted at 1 oiled and 1 control site. These will be either in the *Laminaria* habitat within island bays or within eelgrass habitat. The oiled sites will be selected at random from the 3 oiled sites used in the stratified sampling program. The control site will be the location matched with that site.

9.2. Design

- Species and collection sites

Experiments will be conducted with 3 invertebrate species (The blue mussel, Mytilus edulis, one of two clam species, Protothaca, and the starfish Dermasterias) and two plant species (a kelp, *Laminaria* saccharina or Agarum cribrosum, and eelgrass, *Zostera* marina). Mussels, starfish, and kelp will be collected from sites used in stratified sampling for *Laminaria/Agarum* habitat in island bays. Clams and eelgrass will be collected from eelgrass habitat.

- Invertebrate experiments

Twenty individuals of each species will be collected from each of 3 stations per site. We will collect individuals of approximately equal size. Mussels and clams will be collected from 1 m below mean low low water and starfish from 10 m below mean low low water. All samples will be returned to the University of Alaska Marine Laboratory in Seward for analysis. Samples will be collected from oiled and control sites on the same day and flown immediately to the laboratory.

One randomly selected individual per station (3 per site) will be sampled for hydrocarbons. Six individuals per station (18 per site) will be dissected, their body weight determined, and their gonads weighed. The ovaries from 3 females per station (9 per site) will then be fixed, stained, and sectioned for histological analysis. We will determine the developmental stage and the diameter of 100 oocytes per individual.

The remaining 13 individuals from each station will be spawned into individual containers. The eggs from 3 randomly selected females per station (9 per site) will be fertilized with the pooled sperm of 3 randomly selected males per station. Fertilization will take place in containers with filtered seawater placed in a controlled temperature room held at 10 °C. For starfish, 100 eggs will be sampled after 1 hour and the proportion of fertilized eggs noted, as evidenced by the presence of a fertilization membrane. For both starfish and bivalves, 100 individuals per container will be sampled after 48 hours and the proportion of normal larvae noted. A sample of 10 individuals per container will be preserved for later cytogenetic analysis. The cytogenetic analysis will consist of scoring 10 embryos per individual for chromosomal aberrations or the formation of micronuclei.

- *Laminaria/Agarum* experiments

Ten individuals of approximately equal size will be collected from a depth of 10 m at each station (30 individuals per site). The plants will be returned to the laboratory in Seward where the area of the blade and the area of the sorus will be measured. The plants will then be placed into 1 liter jars with filtered seawater and after 1 hour, the number of spores released per plant will be determined. Spores from 3 randomly selected plants per station (9 per site) will be used to make inoculation solutions of known spore density. A separate solution will be made for each plant. The solution will be added to petri dishes (one dish per plant) containing a glass slide. The dishes will be placed in an incubator and held at 10 °C and 451E/m^2/sec of light (continuous exposure). After 48 hours, the slides will be removed and 100 spores examined for germination success.

- Eelgrass experiments

Fifty eelgrass seeds will be sieved from the sediment at each of 3 stations per site. Quantitative airlift samples will be used for seed collection, if possible, in order to obtain an estimate of the density of seeds in the sediments. The seeds will be returned to the laboratory (in Seward) and placed into Petri dishes with filtered seawater (10 ppt) and held in a temperature controlled room at 10 °C. After 1 week, and at daily intervals for the next two weeks, we will determine the number of seeds germinating. All germinated seedlings will be preserved for possible examination of cytogenetic effects.

- Sampling frequency

All organisms used in these studies will be sampled once in 1990. The exact timing of experiments will depend on the reproductive condition of animals and plants. Animals will be checked at the beginning of the study period until sexually mature individuals are present. Based on existing literature, we anticipate that the invertebrates will be at a reproductive peak in late April or early May, that eelgrass will have its peak seed set in late July, and that *Laminaria/Agarum* will be at its peak in August.

10.0 Experiments Evaluating Germination Success of Eelgrass Seeds in Oiled and Unoiled Sediments

10.1. Site Selection

All experiments will be conducted using sediments collected from 1 oiled and 1 control site within the eelgrass habitat. The oiled site will be selected at random from the 3 oiled sites used in the stratified sampling program. The control site will be the location matched with that site.

10.2. Design

Twenty-one sediment cores (7 per station) will be collected from each site. These will be immediately transported (on ice) to the laboratory in Seward. Twelve of the sediments cores will be placed undisturbed into petri dishes (one dish per core) and placed into a flowing seawater bath. Nine cores will be sieved and placed into Petri dishes.

Four hundred fifty eelgrass seeds will be collected from a control site. The seeds will be taken to the laboratory and placed into petri dishes containing sediments. Twenty-five seeds will be placed in each of 18 dishes per site. The remaining three petri dishes (containing unsieved sediments) per site will be used as germination controls to evaluate the presence of naturally occurring seeds. The presence of germinating seeds will be noted daily for a period of 21 days. Any germinating seeds will be removed three days after germination and preserved for possible cytogenetic analysis. There have been no previous attempts to evaluate cytogenetic effects in eelgrass seedlings, so an initial screening of samples will be performed prior to full analysis. At the end of three weeks, a sediment sample will be taken from each dish and preserved for possible hydrocarbon analysis. All sediments in the previously unsieved sediments will be sieved and the number of ungerminated seeds determined.

11.0 Settling Experiments

11.1. Site Selection

All experiments will be conducted at 3 oiled and 3 control sites. These will be in *Laminaria/Agarum* habitat within island bays. The sites will be the same as those used for the stratified sampling program.

11.2. Design

Nine settling surfaces (tiles) will be placed at a depth of 7 m within each site. The tiles will be attached to rebar driven into the bottom and held in a vertical position, with faces parallel to shore, at a depth approximately 10 cm above the bottom. The rebar are to be laid along a line running parallel to shore with rebar spaced at 2 m intervals or greater. The site will be located in the approximate center of the sampling site. The location of the tiles is marked with a small surface float and with 3 subsurface floats spaced at 10 m intervals. The position of the buoy is triangulated using shoreline features and markings (if necessary) and these features are photographed to facilitate relocation of the site if the surface buoy is lost.

After 3 months, the tiles will be photographed and the number of algal sporelings and large benthic invertebrates will be counted. The tiles will be collected and preserved for latter quantification of the number species, and number of individuals (or percent cover) of each species.

12.0. *Agarum* Growth Experiment

12.1. Site Selection

All experiments will be conducted at 3 oiled, 3 control sites. These will be in the *Laminaria/Agarum* habitat within island bays. The sites will be the same as those selected in the stratified sampling program.

12.2. Design

At each island bay site, divers #3 and 4 will enter the water on the temporary buoy used to mark site for settling substrates. Diver #3 will tag 30 *Agarum* plants at each station. The plants will be the first 30 plants observed past the 3 m mark along the transect tape that are between 70 and 90 cm in length. The tape is laid from the buoy to the right (facing shore) and runs parallel to shore. If there are other *Agarum* or *Laminaria* of 70 cm or larger within 25 cm of the selected individual, the surrounding plant(s) will be removed (in order to eliminate potential confounding effects of competition) and additional plants will be selected. Plants will be double tagged by tying numbered surveyors flashing around the stipe of each individual and by placing a numbered tag on a steel spike next to each plant.

Diver #4 will follow Diver # 3 and measure the total length of each tagged plant and will place a small piece of flashing in a hole in the blade of each plant at a distance of 10 cm from the base of the blade.

After the plants are tagged and measured, an additional 30 plants will be collected, measured and weighed to obtain a regression of length vs. weight. After 2 months, the tagged plants will be collected, weighed, and measured. The distance from the base of the blade to the whole will also be measured. Differences in initial weight (estimated by a length weight regression) and final weight will be used to estimate net production (total growth - tissue lost to sloughing/grazing). The differences in distance of the hole from the base of the blade during initial and final measurements will be used to estimate relative gross production.

13.0 Data Analysis

All data will be entered and stored in an "INGRESS" database at the University of Alaska, Fairbanks. Data analyses will be supervised by Dr. Lyman McDonald.

The generic form of analysis for all data gathered will be a comparison of oiled vs control sites using t-tests or nested analyses of variance. In studies where more than one site is sampled, sites will be the primary sampling unit, with various degrees of subsampling within a site. For some experimental studies, there will be no replication of sites, and the primary sampling unit will be stations within sites.

14.0 Schedule

The 1990 field schedule for the subtidal studies is given below.

Sampling schedule for 1990 subtidal studies in Prince William Sound.

1 Apr 1 May 1 Jun 1 Jul 1 Aug 1 Sep 1 Oct 1

Recon.
1----1

Stratified Sampling
I.B. Ner Eel I.P.
1-----1-----1----1----1

Silled Fjords
1---1

Invert. Experiments.
1-----------1

Eelgrass Experiments
1------1

Laminaria Experiments
1--1

I.B. = Island Bays
Eel = Eelgrass
Ner = *Nereocystis*
I.P. = Island Points

APPENDIX B.

Paired shallow subtidal study sites in western Prince William Sound, 1990-91. Study sites within silled fjords are from 1989-91; they are not paired.

APPENDIX B. Paired shallow subtidal study sites in western Prince William Sound, 1990-91. Study sites within silled fjords are from 1989-91; they are not paired.

SITE NAME	SITE NUMBER	OILING STATUS	LATITUDE	LONGITUDE
***LAMINARIA/AGARUM* - ISLAND BAYS**				
Cabin Bay	1	Control	60° 39.5	147° 27.0
Northwest Bay	2	Oiled	60° 33.4	147° 34.6
Lower Herring Bay	4	Control	60° 23.8	147° 48.7
Herring Bay	3	Oiled	60° 26.8	147° 47.1
Mummy Bay	5	Control	60° 13.8	147° 49.0
Bay of Isles	6	Oiled	60° 23.0	147° 42.6
NEREOCYSTIS				
Procession Rocks	8	Control	60° 00.8	148° 16.0
Latouche Point	7	Oiled	59° 57.0	148° 03.3
Zaikof Point	9	Control	60° 18.3	147° 55.0
Montague Point	10	Oiled	60° 22.5	147° 04.8
Naked Island	11	Control	60° 37.5	147° 22.2
Little Smith Island	12	Oiled	60° 31.3	147° 26.0
***ZOSTERA* (EELGRASS)**				
Drier Bay	14	Control	60° 19.2	147° 44.2
Bay of Isles	13	Oiled	60° 23.2	147° 44.5
Lower Herring Bay	15	Control	60° 24.2	147° 48.0
Herring Bay	16	Oiled	60° 26.7	147° 47.2
Moose Lips Bay	18	Control	60° 12.7	147° 18.5
Sleepy Bay	17	Oiled	60° 04.0	147° 50.1
Puffin Bay	26	Control	60° 44.0	147° 25.0
Clammy Bay	25	Oiled	60° 39.1	147° 22.5
Mallard Bay	34	Control	60° 17.2	147° 48.5
Short Arm-Bay of Isles	35	Oiled	60° 22.6	147° 40.0
***LAMINARIA/AGARUM* - ISLAND POINTS**				
Lucky Point	20	Control	60° 13.2	147° 52.7
Discovery Point	19	Oiled	60° 14.9	147° 41.9
Lower Herring Bay	21	Control	60° 24.0	147° 51.0
Herring Bay	22	Oiled	60° 26.6	147° 49.4
Peak Point	24	Control	60° 42.9	147° 21.8
Ingot Point	23	Oiled	60° 28.9	147° 36.5

APPENDIX B. Continued.

SITE NAME	SITE NUMBER	OILING STATUS	LATITUDE	LONGITUDE
SILLED FJORDS				
Herring Bay	28-601	Oiled	60° 28.1	147° 42.4
Inner Lucky Bay	29	Control	60° 13.9	147° 51.5
Inner Bay of Isles	30	Oiled	60° 23.0	147° 45.3
Disk Lagoon	32	Oiled	60° 29.6	147° 39.7
Humpback Cove	33	Control	60° 12.5	148° 17.5

APPENDIX C.

Stable carbon isotope ratios ($\delta^{13}C$) of Prince William Sound subtidal sediments, subsequent to the EXXON VALDEZ oil spill.

APPENDIX C. Stable carbon isotope ratios ($\delta^{13}C$) of Prince William Sound subtidal sediments, subsequent to the EXXON VALDEZ oil spill.

Introduction

Numerous investigations have demonstrated the usefulness of stable carbon isotope ratios ($\delta^{13}C$) of organics in sediments and waters in identifying marine regions contaminated with petroleum (e.g., Calder and Parker, 1968; Spies and DesMarais, 1983; Anderson *et al.*, 1983; Eganhouse and Kaplan, 1988). The premise in these investigations was that carbon derived from various organic pools has a characteristic $\delta^{13}C$ value, e.g., the $\delta^{13}C$ of terrigenous C3 plants = -25 ‰ (Hong, 1986; Naidu *et al.*, 1992), marine phytodetritus = -21 ‰ (Fry and Sherr, 1984), seagrasses = -10 ‰ (McConnaughey and McRoy, 1979), and Prudhoe Bay crude oil = -30 ‰ (Magoon and Claypool, 1981). In principle, therefore, the $\delta^{13}C$ of marine sediments could, based on an isotope mixing equation (Calder and Parker, 1968; Eganhouse and Kaplan, 1988), help to estimate the proportion in the sediment of organic matter derived from various natural or anthropogenic pools. Based on the above premise, we have attempted to examine the possibility of subtidal sediment contamination by EXXON VALDEZ crude oil in Prince William Sound.

Methods

Organic carbon and nitrogen in bottom sediments were estimated on dry carbonate-free sample powders using the CHN

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analyzer. All OC/N rations is this report are computed on a weight to weight basis of OC and N. The $\delta^{13}C$ analysis was made by Coastal Science Laboratories, Inc. (Austin, Texas) on carbonate-free sediments, using a VG 602E mass spectrometer. The results are expressed relative to the PDB Standard, with a precison of 0.2 ‰. The mean $\delta^{13}C$ values of the oiled and unoiled samples were statistically compared using the nonparametric Mann-Whitney U Test. Differences between means at $p>0.05$ were considered insignificant.

Results

Analysis of the OC/N ratios indicated that the ratios were significantly greater ($p < 0.05$, t-test) at the oiled sites in two out of four pairs. Both Herring Bay (Site 16) and Sleepy Bay (Site 17) had higher values than their respective controls.

Stable carbon isotope values ($\delta^{13}C$) from 1990 sediments within the eelgrass bed (Appendix D) revealed a difference in only one of the four site-depth transect pairs. The values at oiled Herring Bay (16-3) were significantly more negative ($p = 0.01$; Mann-Whitney U Test) than at unoiled Lower Herring Bay (15-3). An insufficient number of samples precluded making the same comparisons for 1991.

Using pooled treatment data, no significant differences ($p > 0.05$) were detected between d13C values from oiled and control eelgrass sites in 1990. However, in 1991, the $\delta^{13}C$ values of oiled sediments (-22.2 ‰) were significantly lower ($p = 0.03$) than that of the unoiled sediments (-20.4 ‰).

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Discussion

The finding of similar $\delta^{13}C$ values in 1990 sites, was contrary to our expectations. Initially, we postulated that the $\delta^{13}C$ of unoiled sediments in the Sound would be relatively higher (less negative values) than the values for the oiled sediments. We assumed that any marked contamination of sediments from the Sound with Prudhoe Bay crude oil would shift the $\delta^{13}C$ of the oiled sediments to more negative values. The discrepancy between our postulation and the analyzed $\delta^{13}C$ values for unoiled and oiled sediments suggests that oiled sediments were not markedly contaminated with oil. Alternatively, it is possible that petroleum intercalated into the sediments was overwhelmingly diluted by natural organic material (e.g., eelgrass debris). As noted previously, lower $\delta^{13}C$ values were determined for the 1991 oiled sediments, in comparison with unoiled sediments. It is possible that the source of the lower $\delta^{13}C$ values in the 1991 sediments is petroleum from the adjacent heavily-oiled beaches. Perhaps sufficient oil had accumulated in the subtidal region by 1991 so that an isotopic signature of oil could finally be detected there. Thus, it appears that at least some oil reworked from the beaches, either by storm waves or tides, is carried offshore and may accumulate in the subtidal region.

In conclusion, we believe that in Prince William Sound sediments, unless heavily contaminated with petroleum, $\delta^{13}C$ values are of limited use to assess the extent of sediment contamination by crude oil. It is suggested that additional $\delta^{13}C$ analysis, using GC-IRMS, on the methanol and benzene soluble material (e.g., saturated and aromatic hydrocarbons) of oiled and unoiled sediments (Anderson *et al.*, 1983), could provide a more useful index of detecting petroleum contamination of the Prince William Sound sediments than $\delta^{13}C$ analysis on gross organics of sediments.

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APPENDIX D.

Standard operating procedure for laboratory treatment of benthic invertebrate samples from shallow subtidal habitats in Prince William Sound, Alaska, 1990.

APPENDIX D. Standard operating procedure for laboratory treatment of benthic invertebrate samples from shallow subtidal habitats in Prince William Sound, Alaska, 1990-91.

1. Chain-of-custody forms containing information on all samples received from the field operations are to be stored in a locked file cabinet in Room 118 O'Neill Building, UAF.

2. Preservative for all 0.1 m^2 airlift samples are immediately changed from formalin to 50 % isopropyl alcohol upon arrival in Fairbanks. Samples are then placed in a secure storage area at UAF. Samples are stored in white, air-tight, liquid-tight 5-gallon buckets appropriately labeled for contents. The samples, chain-of-custody forms and field notes containing additional sample-specific information must be retrieved from the locked file cabinet. These notes should be referred to when working up samples.

3. While working under the fume hood, rinse each sample with running water for a few minutes to remove alcohol. Samples should be washed onto a 1 mm-mesh screen and then placed on a sorting tray with sufficient water to cover the sample.

4. All rare, large (>1 cm) organisms are removed from the sample for processing later. The Laboratory Supervisor examines the remaining biota and associated material to determine if subsampling is warranted. If the amount of material to sort is more than one liter or if several thousand organisms are estimated to be present, necessitating numerous hours of processing, then a decision to subsample will be made.

5. Subsampling: Remove all large pieces of debris. Agitate the sample to insure that all animals are randomly dispersed in the pan. Evenly distribute (by spooning) debris among 16 jars (each jar is 6.25% of the whole). Between each spoonful, gently mix the debris to insure random distribution of organisms. To determine the appropriate number of subsamples, randomly select subsamples, count all organisms in each one and calculate the coefficient of variations for two subsamples, three subsamples, etc., through all sixteen subsamples if necessary. The least number of quadrats necessary to give a coefficient of variation 12.5% or less is an appropriate number of subsamples. The coefficient of variation expresses sample variability relative to the mean of the sample. This procedure will be carried out on all samples requiring subsampling. Subsample size (%) will be included on the Benthic Analysis Form for each taxon. For those rare, large organisms removed prior to subsampling the percent subsampled would be 100%.

6. For each sample or subsample, sort all animals to the family level of identification (except for organisms whose identity is known and those that dominate in density or biomass). Place each type into a petri dish of 50% isopropyl alcohol. Counts (see item 7) and blotted-dry wet weights (see item 9) are determined for each taxon and recorded on the laboratory Benthic Analysis Form. This form is filled out in the UAF laboratory during the processing of the 0.1 m^2 airlift samples. A new form is necessary for each

sample and new pages added as needed. Instructions for each field on the sheet follows:

Page:	Begin each sample with page 1.
Date:	The date the sample is analyzed.
Recorder:	The initials of the person filling out the form.
Reviewer:	The initials of the person reviewing the form and the date reviewed.
Site No.:	The number designated to each study site. Copy from sample label. Left justify.
Date:	Date sample was taken (year, month, day).
Station:	One of three randomly-selected lines perpendicular to the site baseline extending from the 0 tide depth out to a depth of 20 m.
Transect:	One of two randomly-selected lines following the depth contour to the right of a station transect.
Depth:	The randomly-selected depths in the two or three depth ranges (<3, 3-6 and 6-20 m) where samples were taken.
Quadrat:	One of two randomly-selected 0.1 m^2 plots along a transect (only quad 1 for 1989 data).
Taxon:	Lowest practical taxonomic level for each organism.
Taxon Code:	A numeric code for each taxon; established by the National Oceanographic Data Center. Left justify.
% Sampled:	The percentage of the sample that was examined for taxonomy, counts and weights. Right justify.
Count:	Total count of taxon group in the sample.
Wet Weight:	Total blotted-dry wet weight in grams (with three places to the right of the decimal) of the taxon.
Individual Length:	Currently not needed, leave blank.

7. Counting of Sample Organisms:
   - A. Counts whole organisms where possible; fragmented organisms follow the procedures below.
   - B. Amphipods may be in two parts (head plus pereon, abdomen plus telson). The sum of the numbers of whole amphipods and anterior parts will constitute the total number.
   - C. The total number of isopods will equal the number of whole organisms plus the number of separate heads.
   - D. The total number of polychaetes will equal the number of whole organisms plus the number of anterior parts will constitute the total number.
   - E. The number of whole bivalves plus the number of partial shells (greater than one-half of whole shell) will constitute the total number of bivalves.
   - F. Since bryozoans and hydroids are colonial forms and are typically fragmented their presence in a sample only receives a count of one.

8. Calibration: The Mettler PM200 electronic balance will be calibrated by a Mettler serviceman within 60 days prior to the initiation of weighing samples. Calibration checks will be made monthly by the Laboratory Supervisor using standard NBS traceable weights.

9. The wet weight of each taxonomic group and/or species is determined using a Mettler PM200 (0.001-200 g) balance. Working with one taxonomic group and/or species at a time, organisms are first transferred onto absorbent, bibulous paper and blotted until the paper fails to absorb more moisture (approximately 1-2 minutes), and then weighed. The weights are entered onto the data sheets. Taxon weighing <0.001 g will be recorded as 0.0005 g.

10. A collection of voucher specimens is made as a reference for all identifications to the genus and/or species. These specimens will be maintained by UAF.

11. In order to assure accuracy and consistency in processing the samples, systematic quality control checks are performed by the project's Laboratory Supervisor. Quality control checks will not be performed by the same individual who originally processed the sample. Approximately five percent of the samples will be rechecked. Discrepancies in the categories of identification, weight, and count shall not exceed three percent in each category. If they do, another one percent will be checked. If these are also out of compliance, then all samples to date will be reanalyzed.

12. After lab analyses are completed, each group and/or species is put into a vial with an appropriate label. All vials are put together by sites with the field tag. These samples are securely stored at UAF.

APPENDIX E.

Mean values for different eelgrass attributes at oiled and control sites, and probabilities that the means from the oiled and control sites were similar as determined by randomization tests.

Appendix E. Mean values for different eelgrass attributes at oiled and control sites, and probabilities that the means from the oiled and control sites were similar as determined by randomization tests.

Eelgrass Bed - 1990 Depth = Bed

Pair	Site#	Oil Code	Plant Density (#/m^2)	Blade Density (#/m^2)	Biomass (gm/m^2)	Flower Density (#/m^2)	Seed Pods/ Flower	Seed Pod Density (#/m^2)	Seed Density (#/m^{2}sed)
1	13	O	110.00	618.00	821.33	6.33	9.66	53.33	472.00
1	14	C	172.67	921.67	1136.00	9.00	6.09	70.67	136.00
2	16	O	197.67	910.67	1450.67	0.00	.	0.00	50.67
2	15	C	279.00	1461.00	1096.00	13.00	9.93	113.33	261.33
3	17	O	140.33	748.00	1321.33	2.67	7.33	25.67	2.67
3	18	C	119.33	658.33	1084.67	4.33	6.94	38.33	9.33
4	25	O	160.00	690.67	1031.00	2.33	10.56	27.00	10.67
4	26	C	230.33	904.67	1613.00	2.67	16.42	40.67	1.33
	mean	O	152.00	741.83	1156.08	2.83	9.18	26.50	134.00
	mean	C	200.33	986.42	1232.42	7.25	9.84	65.75	102.00
	P		0.08	0.051	0.63	0.055	0.99	0.09	0.74

Eelgrass Bed - 1991 Depth = Bed

Pair	Site#	Oilcode	Plant Density (#/m^2)	Flower Density (#/m^2)
1	13	O	137.33	1.50
1	14	C	141.33	1.12
2	16	O	183.67	1.11
2	15	C	229.00	4.40
3	17	O	112.67	2.97
3	18	C	173.33	1.68
4	25	O	189.33	1.63
4	26	C	141.67	1.77
5	35	O	126.33	1.37
5	34	C	107.67	0.93
	mean	O	149.87	1.72
	mean	C	158.60	1.98
	P		0.52	0.60

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APPENDIX F.

Macroalgal species collected in shallow subtidal habitats in Prince William Sound, 1990.

APPENDIX F. Macroalgal species collected in shallow subtidal habitats in Prince William Sound, 1990

Species	Collection Site	ID Status
CHLOROPHYTA		
Acrosiphonia sp.	Little Smith Island	Confident
Cladophora seriacea	Lower Herring Bay	Tentative
Cladophora sp.	Ingot Pt.	Tentative
Derbesia marina	Bay of Isles	Positive
Enteromorpha sp.	Bay of Isles	Tentative
Monostroma sp.	Bay of Isles	Tentative
Ulva fenestrata	Peak Pt.	Tentative
Ulva sp.	Lower Herring Bay	Confident
Ulvaria obscura	Little Smith Island	Tentative
PHAEOPHYTA		
Agarum cribosum	Peak Pt.	Positive
Alaria marginata	Peak Pt.	Positive
Alaria sp.	Little Smith Island	Positive
Chordaria flagelliformis	Sleepy Bay	Positive
Costaria costata	Peak Pt.	Positive
Cymathere triplicata	Northwest Bay	Positive
Cystoseira geminata	Peak Pt.	Positive
Desmarestia aculeata	Little Smith Island	Positive
Desmarestia ligulata	Peak Pt.	Positive
Desmarestia viridis	Peak Pt.	Positive
Dictysiphon foeniculaceus	Sleepy Bay	Positive
Eudesme virescens	Sleepy Bay	Positive
Laminaria dentigera	Zaikof Pt.	Tentative
Laminaria groenlandica	Zaikof Pt.	Positive
Laminaria saccharina	Bay of Isles	Positive
Laminaria yezoensis	Peak Pt.	Positive
Macrocystis sp.	Northwest Bay	Positive
Nereocystis luetkeana	Zaikof Pt.	Positive
Omphallophyllum ulvaceum	Peak Pt.	Positive
Omphallophyllum ulvcideum	Herring Bay	Positive
Pilayella littoralis	Herring Bay	Positive
Pleurophycus gardneri	Little Smith Island	Positive
Punctaria lobata	Sleepy Bay	Positive
Ralfsia fungiformis	Cabin Bay	Positive
Soranthera ulvoidea	Ingot Pt.	Confident
Sphacelaria rigidula	Peak Pt.	Positive

APPENDIX F. Continued

RHODOPHYTA

Ahnfeltia fastigiata	Peak Pt.	Positive
Callophyllis sp.	Mummy Bay	Positive
Callophyllis violacea	Herring Bay	Tentative
Chondrus sp.	Peak Pt.	Positive
Clathromorphum sp.	Peak Pt.	Positive
Constantinea simplex	Latouche Pt.	Tentative
Constantinea subulifera	Discovery Pt.	Positive
Corallina officinalis	Latouche Pt.	Positive
Cryptopleura ruprechtiana	Latouche Pt.	Positive
Euthora cristata	Peak Pt.	Positive
Halosaccion americanum	Lower Herring Bay	Positive
Membranopotera dimorpha	Latouche Pt.	Positive
Mikamiella ruprechtiana	Latouche Pt.	Positive
Neoptilota aspleniodes	Latouche Pt.	Positive
Neorhodomela aculeata	Peak Pt.	Positive
Neorhodomela oregona	Latouche Pt.	Positive
Neorhodomela sp.	Lower Herring Bay	Confident
Odonthalia floccosa	Little Smith Island	Positive
Odonthalia setacea	Little Smith Island	Positive
Odonthalia sp.	Peak Pt.	Positive
Opuntiella californica	Latouche Pt.	Positive
Phyllophora truncata	Lower Herring Bay	Confident
Platythamnion pectinatum	Lucky Bay	Positive
Polysiphonia pacifica	Peak Pt.	Positive
Porphyra nereocystis	Little Smith Island	Tentative
Pterosiphonia hamata	Peak Pt.	Tentative
Ptilota filicina	Herring Bay	Confident
Ptilota sp.	Peak Pt.	Positive
Pugetia fragilissima	Lower Herring Bay	Positive
Rhodymenia pertusa	Latouche Pt.	Positive
Scagelia pylaisaei	Peak Pt.	Positive
Stenogramma interrupta	Lower Herring Bay	Confident
Tayloriella sp.	Peak Pt.	Tentative
Thuretellopsis peggiana	Discovery Pt.	Positive
Weeksia coccinea	Herring Bay	Positive

APPENDIX G.

Means values for percent cover, density, biomass of dominant macroalgal species at oiled and control sites in *Laminaria/Agarum* bay, *Laminaria/Agarum* point, and *Nereocystis* habitats in 1990 and 1991. Also given are probabilities that the means from the oiled and control sites were similar as determined by randomization tests.

Appendix G. Mean values for percent cover, density, and biomass of dominant macroalgal species at oiled and control sites in *Laminaria/Agarum* bay, *Laminaria/Agarum* point, and *Nereocystis* habitats in 1990. Also given are probabilities that the means from the oiled and control sites were similar as determined by randomization tests.

Island Bay - 1990 Depth = Deep

Pair	Site#	Oilcode	*Agarum* DENSITY (#/m^2)	*Agarum* % COVER	*Agarum* BIOMASS (gm/m^2)	*L. sac.* DENSITY (#/m^2)	*L. sac.* % COVER	*L. sac.* BIOMASS (gm/m^2)
1	2	O	3.33	24.58	217.33	1.33	8.33	64.67
1	1	C	2.67	17.50	519.67	0.00	1.67	0.00
2	3	O	5.67	21.08	228.00	0.67	6.42	210.00
2	4	C	5.67	27.33	410.00	0.00	0.00	1.33
3	6	O	4.67	20.50	435.00	1.00	13.75	4.67
3	5	C	3.33	51.25	657.33	0.00	0.00	0.00
	mean	O	4.56	22.06	293.44	1.00	9.50	93.11
	mean	C	3.89	32.03	529.00	0.00	0.56	0.44
	P		0.69	0.31	0.26	0.00	0.04	0.00

Island Bay - 1990 Depth = Shallow

Pair	Site#	Oilcode	*Agarum* DENSITY (#/m^2)	*Agarum* % COVER	*Agarum* BIOMASS (gm/m^2)	*L. sac.* DENSITY (#/m^2)	*L. sac.* % COVER	*L. sac.* BIOMASS (gm/m^2)
1	2	O	2.00	10.00	148.00	5.33	49.58	533.00
1	1	C	11.33	66.08	1877.33	0.00	2.08	0.00
2	3	O	10.33	64.75	1437.67	1.33	8.33	437.67
2	4	C	9.67	37.92	1071.33	1.33	7.50	728.33
3	6	O	8.33	17.92	523.00	4.33	45.50	317.00
3	5	C	5.67	51.25	1389.00	1.33	17.50	230.67
	mean	O	6.89	30.89	702.89	3.67	34.47	429.22
	mean	C	8.89	51.75	1445.89	0.89	9.03	319.67
	P		0.48	0.25	0.16	0.03	0.04	0.71

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Island Point - 1990 Depth = Deep

Pair	Site#	Oilcode	*Agarum* DENSITY (#/m^2)	*Agarum* % COVER	*L. sac.* DENSITY (#/m^2)	*L. sac.* % COVER	*L. groen.* DENSITY (#/m^2)	*L. groen.* % COVER	*L. yez.* >=10cm DENSITY (#/m^2)
1	19	O	10.00	31.25	2.67	8.42	0.00	0.00	0.00
1	20	C	5.67	43.00	0.33	18.00	0.00	0.00	0.00
2	22	O	18.33	30.58	2.33	22.58	0.67	0.00	0.00
2	21	C	2.67	44.67	2.00	5.25	0.00	0.00	0.00
3	23	O	15.67	31.00	0.67	1.92	0.33	0.42	0.00
3	24	C	4.33	16.42	12.00	7.50	0.00	0.00	0.33
	mean	O	14.67	30.94	1.89	10.97	0.33	0.14	0.00
	mean	C	4.22	34.69	4.78	10.25	0.00	0.00	0.11
	P		0.02	0.72	0.26	0.90	.	.	.

Island Point - 1990 Depth = Deep (continued)

Pair	Site#	Oilcode	*Agarum* BIOMASS (gm/m^2)	*L. sac.* BIOMASS (gm/m^2)	*L. groen.* BIOMASS (gm/m^2)	*L. yez.* BIOMASS (gm/m^2)
1	19	O	295.33	17.33	0.00	0.00
1	20	C	792.33	599.00	0.00	0.00
2	22	O	849.33	293.33	31.33	0.00
2	21	C	366.67	4.67	0.00	0.00
3	23	O	797.33	3.33	144.33	0.00
3	24	C	176.33	79.00	0.00	11.00
	mean	O	647.33	104.67	58.56	0.00
	mean	C	445.11	227.56	0.00	3.67
	P		0.45	0.80	0.00	.

Island Point - 1990 Depth = Shallow

Pair	Site#	Oilcode	*Agarum* DENSITY (#/m^2)	*Agarum* % COVER	*L. sac.* DENSITY (#/m^2)	*L. sac.* % COVER	*L. groen.* DENSITY (#/m^2)	*L. groen.* % COVER	*L. yez.* >=10cm DENSITY (#/m^2)
1	19	O	28.00	46.33	42.00	21.00	1.67	4.42	0.33
1	20	C	6.33	67.08	0.67	10.42	0.00	0.00	0.00
2	22	O	23.33	35.83	3.33	55.33	0.00	0.00	0.00
2	21	C	12.33	38.83	9.33	34.58	1.67	3.33	0.33
3	23	O	26.00	47.08	1.67	7.92	8.33	15.42	1.33
3	24	C	16.33	17.25	145.67	8.67	21.00	31.42	5.00
	mean	O	25.78	43.08	15.67	28.08	3.33	6.61	0.56
	mean	C	11.67	41.06	51.89	17.89	7.56	11.58	1.78
	P		0.06	0.85	0.49	0.22	0.24	0.59	0.07

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Island Point - 1990 Depth = Shallow (continued)

Pair	Site#	Oilcode	*Agarum* BIOMASS (gm/m^2)	*L. sac.* BIOMASS (gm/m^2)	*L. groen.* BIOMASS (gm/m^2)	*L. yez.* BIOMASS (gm/m^2)
1	19	O	866.33	465.33	245.33	0.67
1	20	C	1694.67	52.33	0.00	0.00
2	22	O	1098.00	928.33	0.00	0.00
2	21	C	1097.33	1413.33	186.33	7.67
3	23	O	985.00	330.67	707.33	64.67
3	24	C	467.33	9.33	2557.67	257.67
	mean	O	983.11	574.78	317.56	21.78
	mean	C	1086.44	491.67	914.67	88.44
	P		0.80	0.75	0.28	0.13

Nereocystis Bed - 1990 Algae Density ($\#/m^2$) Depth = Shallow

Pair	Site#	Oilcode	*Agarum*	*L. gro.*	*L. sac.*	*L. yez.*	*Pleuro*
1	7	O	0.33	39.00	0.00	0.33	3.33
1	8	C	0.00	131.00	0.00	0.67	12.00
2	12	O	8.80	252.40	0.00	8.80	0.80
2	11	C	5.83	46.83	0.83	13.50	1.33
	mean	O	4.57	145.70	0.00	4.57	2.07
	mean	C	2.92	88.92	0.42	7.08	6.67
	P		0.19	0.14	0.17	0.74	0.44

Nereocystis Bed - 1990 Algae Percent Cover Depth = Shallow

Pair	Site#	Oilcode	*Agarum*	*L. gro.*	*L. sac.*	*L. yez.*	*Pleuro*
1	7	O	0.00	81.67	0.00	0.17	1.75
1	8	C	0.00	33.17	0.00	0.00	22.17
2	12	O	19.80	31.45	0.00	7.95	1.30
2	11	C	0.00	66.21	0.21	13.33	0.00
	mean	O	9.90	56.56	0.00	4.06	1.52
	mean	C	0.00	49.69	0.10	6.67	11.08
	P		.	0.78	0.39	0.69	0.26

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Nereocystis Bed - 1990   Algae Biomass (gm/m^2)   Depth = Shallow

Pair	Site#	Oilcode	Agarum	L. gro.	L. sac.	L. yez.	Pleuro
1	7	O	14.67	3191.33	0.00	0.00	279.44
1	8	C	0.00	1825.67	0.00	55.33	1225.67
2	12	O	554.40	2279.20	0.00	406.20	20.60
2	11	C	63.67	4483.17	23.83	1496.83	21.67
	mean	O	284.53	2735.27	0.00	203.10	150.02
	mean	C	31.83	3154.42	11.92	776.08	623.67
	P		0.00	0.39	0.17	0.40	0.15

Nereocystis Stipe Density & Diameter
Nereocystis Bed - 1990   Depth = Shallow

Pair	Site#	Oilcode	DENSITY ($\#/100m^2$)	STIPE DIAMETER (mm)
1	7	O	53.06	7.25
1	8	C	12.78	11.52
2	12	O	89.33	7.24
2	11	C	7.36	9.12
	mean	O	71.19	7.24
	mean	C	10.07	10.32
	P		0.007	0.096

ACE 30286973

APPENDIX H.

Granulometric composition, organic carbon(OC), nitrogen (N), OC/N ratios and stable carbon isotope ratios ($\delta^{13}C$) of surficial sediments from *Zostera* (eelgrass) habitats in western Prince William Sound, Alaska, Summer 1990.

APPENDIX II. Granulometric composition, organic carbon (OC), nitrogen (N), OC/N ratios and stable carbon isotope ratios ($\delta^{13}C$) of surficial sediments from *Zostera* (eelgrass) habitats in western Prince William Sound, Alaska, Summer 1990.

Site (#)	Site Oiling Status	Sta.	Depth[1] Trans.	Sample #	Gravel %	Sand %	Silt %	Clay %	Mud[2] %	Mz Mean	δ Sort	OC mg/g	N mg/g	OC/N	$\delta^{13}C$
Bay of Isles Site (13)	Oiled	1	1	gs16	0.00	13.62	44.79	41.59	86.38	7.52	2.82	51.63	7.92	6.50	
		2	1	gs17	0.00	2.05	48.51	49.44	97.95	8.25	2.33	58.08	9.05	6.40	-22.10
		3	1	gs18	0.00	3.44	41.68	54.89	96.57	9.07	2.39	59.93	9.46	6.30	
		1	2	gs19	0.00	4.96	43.28	51.77	95.05	8.33	2.46	57.16	7.73	7.40	
		2	2	gs20	0.00	3.46	38.13	58.41	96.54	8.80	2.44	63.08	7.46	8.50	
		3	2	gs21	0.00	7.02	45.28	47.70	92.98	8.03	2.57	50.26	6.90	7.30	
		1	3	gs22	0.00	2.51	19.15	78.34	97.49	9.42	2.37	63.45	10.61	6.00	-18.20
		2	3	gs23	0.00	2.52	24.00	73.49	97.49	9.37	2.66	86.07	5.73	15.00	-24.10
		3	3	gs24	0.00	0.31	47.08	52.62	99.70	7.50	2.43	48.60	7.50	6.50	-22.30
				Mean	0.00	4.43	39.10	56.47	95.57			59.81	8.04	7.80	-21.70
				S.D.		3.93	10.45	12.04	3.93			11.22	1.46	2.80	
Drier Bay Site (14)	Control	1	1	gs25	0.00	67.49	27.00	5.51	32.51	3.87	1.44	34.29	3.26	10.50	
		2	1	gs26	38.86	33.87	19.44	7.83	27.27	1.83	3.56	22.72	2.96	7.70	-21.90
		3	1	gs27	0.00	68.18	22.32	9.50	31.82	3.63	3.19	13.43	2.13	6.30	
		1	2	gs28	0.00	38.84	43.51	17.65	61.16	5.83	3.25	17.02	2.50	6.80	
		2	2	gs29	79.54	17.54	1.53	1.67	3.20	-3.80	3.49	1.94	0.28	6.90	
		3	2	gs30	40.17	41.92	8.33	9.58	17.91	0.13	4.35	8.31	0.98	8.50	
		1	3	gs31	0.00	18.18	36.53	45.30	81.82	7.45	3.13	40.43	4.65	8.70	-20.40
		2	3	gs32	3.27	16.25	55.67	25.82	80.49	6.50	3.39	35.08	5.67	6.20	-20.40
		3	3	gs33	0.00	3.93	39.80	56.27	96.08	8.93	2.82	51.93	8.31	6.20	-17.90
				Mean	17.98	34.02	28.24	19.90	48.03			25.02	3.42	7.50	-20.10
				S.D.	28.62	22.68	17.36	19.06	32.65			16.45	2.48	1.50	

[1] Depth Transects 1 = 6-20 m, 2 = 3-6 m, 3 = < 3 m (center of eelgrass bed)
[2] Silt and clay

APPENDIX II .Continued.

Site (#)	Site Oiling Status	Sta.	Depth[1] Trans.	Sample #	Gravel %	Sand %	Silt %	Clay %	Mud[2] %	Mz Mean	δ Sort	OC mg/g	N mg/g	OC/N	$\delta^{13}C$
Herring Bay Site (16)	Oiled	1	1	gs61	22.53	46.65	20.37	10.45	30.82	2.43	3.59	7.69	0.81	9.50	-23.00
		2	1	gs63[3]								6.22	0.56	11.10	
		3	1	gs65	11.39	76.24	7.38	5.00	12.38	0.18	2.59	10.01	0.83	12.10	
		1	2	gs62	0.00	86.42	5.53	8.06	13.59	2.72	2.07	7.43	0.69	10.70	
		2	2	gs64	58.64	33.38	1.38	6.60	7.98	-1.92	4.91	5.45	0.48	11.40	
		3	2	gs66	74.62	15.13	4.36	5.90	10.26	-3.53	4.63	0.91	0.15	6.00	
		1	3	gs67	23.62	60.09	7.70	8.59	16.28	1.10	4.94	9.12	0.77	11.80	-20.70
		2	3	gs68	3.35	86.60	2.34	7.72	10.06	2.03	2.06	4.35	0.45	9.70	-21.40
		3	3	gs69	0.00	69.28	13.38	17.34	30.72	5.20	3.35	19.92	1.93	10.30	-21.00
				Mean	24.27	59.22	7.81	8.71	16.51			7.90	0.74	10.29	-21.50
				S.D.	28.03	25.78	6.29	3.87	9.15			5.26	0.50	1.84	1.00
Lower Herring Bay Site (15)	Control	1	1	gs52	57.45	34.86	3.34	4.34	7.68	-1.87	4.26	13.06	1.31	10.00	
		2	1	gs53	0.00	41.39	27.46	31.15	58.61	6.08	3.34	52.38	5.21	10.10	-23.00
		3	1	gs54	52.06	26.34	7.03	14.58	21.61	0.98	3.91	9.50	1.02	9.30	
		3	2	gs55	94.11	0.71	5.18	0.00	5.18	-1.88	1.29	0.52	0.11	4.70	
		2	2	gs56	69.22	16.84	3.08	10.87	13.95	-0.23	3.37	5.54	0.56	9.90	
		1	2	gs57	93.65	0.52	1.66	4.16	5.82	-1.88	1.62	12.11	1.97	6.11	
		1	3	gs58	4.87	6.23	30.73	58.17	88.90	8.67	3.42	77.49	11.73	6.60	-16.20
		2	3	gs59	9.76	10.79	46.70	32.74	79.44	5.97	4.62	62.81	7.39	8.50	-18.90
		3	3	gs60	0.00	5.00	14.10	80.40	94.50	9.63	2.38	108.92	11.51	9.50	-17.50
				Mean	42.35	15.85	15.48	26.27	41.74			38.04	4.53	8.30	-18.90
				S.D.	39.38	15.10	15.90	27.49	38.21			38.69	4.67	2.00	

[1] Depth Transects 1 = 6-20 m, 2 = 3-6 m, 3 = < 3 m (center of eelgrass bed)
[2] Silt and clay
[3] Insufficient quantity for complete analyses.

APPENDIX II.Continued.

Site (#)	Site Oiling Status	Sta.	Depth[1] Trans.	Sample #	Gravel %	Sand %	Silt %	Clay %	Mud[2] %	Mz Mean	δ Sort	OC mg/g	N mg/g	OC/N	$\delta^{13}C$
Sleepy Bay Site (17)	Oiled	1	1	gs34	0.00	83.03	12.66	4.31	16.97	3.17	1.29	7.65	1.18	6.50	
		2	1	gs35	0.00	90.97	3.24	5.80	9.04	2.52	1.89	8.76	1.15	7.60	-23.60
		3	1	gs36	0.00	92.19	3.51	4.29	7.81	2.47	1.39	5.90	0.76	7.80	
		1	2	gs37	0.14	90.39	5.30	4.18	9.48	2.85	1.08	7.60	0.79	9.60	
		2	2	gs38	0.00	99.21	0.74	0.00	0.74	2.32	0.62	4.55	0.60	7.60	
		3	2	gs39	0.00	97.69	2.31	0.00	2.31	2.65	0.81	4.40	0.64	6.90	
		1	3	gs40	0.44	86.23	9.68	3.64	13.33	2.78	1.08	5.03	0.94	5.40	-21.10
		2	3	gs41	0.18	94.12	2.19	3.50	5.69	2.32	0.88	3.94	0.67	5.80	-22.80
		3	3	gs42	0.28	98.80	0.93	0.00	0.93	1.88	0.72	5.11	0.60	8.50	-23.00
				Mean	0.12	92.51	4.51	2.86	7.37			5.88	0.81	7.30	-22.60
				S.D.	0.16	5.59	4.09	2.24	5.58			1.71	0.23	1.30	
Moose Lips Bay Site (18)	Control	1	1	gs43	0.00	62.86	33.03	4.10	37.14	4.07	1.05	5.81	0.85	6.80	
		2	1	gs44	0.00	40.99	40.88	18.13	59.01	5.85	3.30	5.30	1.00	5.30	-22.10
		3	1	gs45	0.00	60.14	34.47	5.39	39.86	4.03	1.42	3.76	0.55	6.80	
		1	2	gs46	0.00	85.00	15.00	0.00	15.00	3.42	0.68	3.36	0.49	6.90	
		2	2	gs47	0.00	85.34	11.11	3.55	14.66	3.10	0.93	3.55	0.58	6.10	
		3	2	gs48	14.12	78.45	4.86	2.57	7.43	1.80	2.65	2.56	0.44	5.80	
		1	3	gs49	0.00	90.01	5.93	4.07	10.00	3.20	0.69	2.59	0.41	6.30	-23.00
		2	3	gs50	0.00	83.35	8.24	8.41	16.65	3.18	2.20	3.19	0.52	6.10	-21.80
		3	3	gs51	29.36	59.89	4.96	5.79	10.75	0.23	5.01	3.33	0.50	6.70	-22.30
				Mean	4.83	71.78	17.61	5.78	23.39			3.72	0.59	6.30	-22.30
				S.D.	10.32	16.48	14.40	5.17	17.73			1.12	0.20	0.50	

[1] Depth Transects 1 = 6-20 m, 2 = 3-6 m, 3 = < 3 m (center of eelgrass bed)
[2] Silt and clay.

APPENDIX II.Continued.

Site (#)	Site Oiling Status	Sta.	Depth[1] Trans.	Sample #	Gravel %	Sand %	Silt %	Clay %	Mud[2] %	Mz Mean	δ Sort	OC mg/g	N mg/g	OC/N	$\delta^{13}C$
Clammy Bay Site (25)	Oiled	1	1	gs70	0.00	77.16	14.37	8.47	22.84	3.58	2.19	7.89	0.82	9.60	
		2	1	gs72	0.00	90.89	1.98	7.13	9.11	2.77	2.29	4.89	0.70	7.00	-22.40
		3	1	gs74	0.00	84.45	7.33	8.22	15.55	3.32	1.90	6.52	0.82	8.00	
		1	2	gs71	0.00	93.27	2.39	4.34	6.73	2.60	0.98	3.89	0.68	5.70	
		2	2	gs73	0.00	98.53	1.42	0.00	1.42	2.40	0.62	4.52	0.77	5.90	
		3	2	gs75	0.00	99.83	0.17	0.00	0.17	2.07	0.93	4.16	0.62	6.70	
		1	3	gs76	0.00	96.66	3.34	0.00	3.34	2.58	0.55	4.75	0.72	6.60	-22.40
		2	3	gs77	0.00	98.63	1.37	0.00	1.37	2.28	0.69	4.69	0.65	7.20	-21.90
		3	3	gs78	0.00	90.51	4.33	5.16	9.49	2.30	1.60	6.16	0.81	7.60	-21.60
				Mean		92.21	4.08	3.70	7.78			5.27	0.73	7.10	-22.10
				S.D.		7.51	4.39	3.74	7.52			1.31	0.08	1.20	
Puffin Bay Site (26)	Control	1	1	gs79	0.00	31.73	40.87	27.39	68.27	6.33	3.57	15.51	2.27	6.80	
		2	1	gs81	21.43	66.95	5.00	6.62	11.62	1.13	4.73	6.38	0.95	6.70	-22.30
		3	1	gs83	0.00	84.54	7.37	8.09	15.46	3.20	1.69	5.95	0.80	7.40	
		1	2	gs80	0.00	89.27	6.75	3.98	10.73	1.63	2.43	4.01	0.68	5.90	
		2	2	gs82	73.45	17.32	2.91	6.33	9.23	-1.95	3.06	6.91	0.84	8.20	
		3	2	gs84	1.33	95.90	2.77	0.00	2.77	2.02	0.97	4.20	0.68	6.20	
		1	3	gs85	0.24	80.41	19.35	0.00	19.35	2.43	1.30	4.11	0.65	6.30	-22.70
		2	3	gs86	0.00	96.22	3.78	0.00	3.78	2.63	0.60	4.80	0.76	6.30	-22.30
		3	3	gs87	0.00	98.59	1.40	0.00	1.40	2.18	0.65	3.96	0.64	6.20	-22.70
				Mean	10.72	73.44	10.02	5.82	15.84			6.20	0.92	6.70	-22.50
				S.D.	24.55	29.60	12.74	8.73	20.53			3.66	0.52	0.70	

[1] Depth Transects 1 = 6-20 m, 2 = 3-6 m, 3 = < 3 m (center of eelgrass bed)
[2] Silt and clay

APPENDIX I.

Granulometric composition, organic carbon (OC), nitrogen (N), OC/N ratios and stable carbon isotope ratios ($\delta^{13}C$) of surficial sediments from *Zostera* (eelgrass) habitats in western Prince William Sound, Alaska, Summer 1991.

APPENDIX I. Granulometric composition, organic carbon (OC), nitrogen (N), OC/N ratios and stable carbon isotope ratios ($\delta^{13}C$) of surficial sediments from *Zostera* (eelgrass) habitats in western Prince William Sound, Alaska, Summer 1991.

Site (#)	Site Oiling Status	Sta.	Depth[1] Trans.	Sample #	Gravel %	Sand %	Silt %	Clay %	Mud[2] %	Mz[3] Mean	δ[3] Sort	OC mg/g	N mg/g	OC/N	$\delta^{13}C$
Bay of Isles Site (13)	Oiled	1	1	25	0.00	30.98	45.09	23.94	69.03	6.39	3.09	112.40	11.40	9.90	
		2	1	26	0.10	7.04	86.16	6.97	93.13	4.33	1.44	110.70	11.20	9.90	-21.10
		3	1	27	0.00	18.79	45.63	35.58	81.21	10.00	5.20	111.00	10.90	10.20	
		1	3	28	0.00	33.82	34.78	31.40	66.18	9.03	7.22	144.40	11.60	12.40	
		2	3	29	0.00	30.69	40.46	28.84	69.31	6.80	3.46	63.40	4.00	15.90	-24.10
		3	3	30	0.00	29.32	60.41	10.27	70.68	3.98	1.58	155.20	12.90	12.00	
				Mean	0.02	25.11	52.09	22.83	74.92			116.18	10.33	11.72	-22.60
				S.D.	0.04	10.25	18.74	11.68	10.31			32.17	3.18	2.32	
Drier Bay Site (14)	Control	1	1	13	1.45	61.54	30.73	6.28	37.01	3.62	1.52	46.10	3.50	13.20	
		2	1	14	1.00	61.80	18.06	19.14	37.20	3.50	1.57	42.30	2.90	14.60	-22.60
		3	1	15	44.83	36.07	9.28	9.82	19.10	0.54	3.28	28.00	2.90	9.60	
		1	3	16	4.25	49.72	30.98	15.05	46.03	3.90	1.45	62.90	6.10	10.30	
		2	3	17	0.69	75.95	18.35	5.01	23.36	2.09	1.32	60.60	4.70	12.90	-21.50
		3	3	18	0.22	43.16	31.34	25.28	56.62	3.95	1.81	69.20	6.90	10.00	
				Mean	8.74	54.71	23.12	13.43	36.55			51.52	4.50	11.77	-22.05
				S.D.	17.74	14.52	9.24	7.88	13.94			15.44	1.70	2.07	

[1] Depth Transects 1 = 6-20 m, 3 = < 3 m (center of eelgrass bed)
[2] Silt and clay.
[3] Some mean and sorting values were not calculated because all relevant percentiles could not be obtained from the cumulative curve.

APPENDIX I. Continued

Site (#)	Site Oiling Status	Sta.	Depth[1] Trans.	Sample #	Gravel %	Sand %	Silt %	Clay %	Mud[2] %	Mz[3] Mean	δ[3] Sort	OC mg/g	N mg/g	OC/N	$\delta^{13}C$
Herring Bay Site (16)	Oiled	1	1	34	37.08	46.77	12.93	3.22	16.15	12.47	4.30	17.50	1.50	11.70	
		2	1	35	27.54	61.38	8.29	2.79	11.07	0.59	3.29	3.80	0.50	7.60	-22.10
		3	1	36	48.65	42.90	7.57	0.88	8.44	-1.65	4.08	9.50	0.90	10.50	
		1	3	37	12.24	68.73	14.21	4.83	19.03	1.42	2.84	15.20	1.30	11.70	
		2	3	38	64.54	30.82	3.45	1.20	4.64	-1.25	1.90	3.10	0.30	10.30	-21.60
		3	3	39	13.11	73.78	5.76	7.36	13.12	1.92	3.16	24.10	1.50	16.10	
				Mean	33.86	54.06	8.70	3.38	12.08			12.20	1.00	11.32	-21.85
				S.D.	20.53	16.59	4.14	2.42	5.21			8.24	0.52	2.78	
Lower Herring Bay Site (15)	Control	1	1	40	90.89	7.25	1.86	1.00	1.87	-3.18	1.32	25.10	2.70	9.30	
		2	1	41	91.19	2.23	3.81	2.76	6.58	-4.07	2.16	50.10	5.50	9.10	-21.70
		3	1	42	15.51	47.85	24.73	11.90	36.64	3.12	5.05	84.50	4.60	18.40	
		1	3	43	0.00	25.93	18.87	55.21	74.08	6.57	3.82	66.60	4.30	15.50	
		2	3	44	20.49	45.57	11.13	22.81	33.94	3.80	6.54	40.00	3.80	10.50	-15.50
		3	3	45	73.32	21.59	2.38	2.71	5.09	-2.20	2.85	7.10	0.60	11.80	
				Mean	48.57	25.07	10.46	16.07	26.37			45.57	3.58	12.43	-18.60
				S.D.	41.14	18.93	9.57	20.87	27.87			27.96	1.73	3.74	

[1] Depth Transects 1 = 6-20 m, 3 = < 3 m (center of eelgrass bed)
[2] Silt and clay.
[3] Some mean and sorting values were not calculated because all relevant percentiles could not be obtained from the cumulative curve.

APPENDIX I. Continued

Site (#)	Site Oiling Status	Sta.	Depth[1] Trans.	Sample #	Gravel %	Sand %	Silt %	Clay %	Mud[2] %	Mz[3] Mean	δ[3] Sort	OC mg/g	N mg/g	OC/N	$\delta^{13}C$
Sleepy Bay Site (17)	Oiled	1	1	46	1.12	91.41	3.74	3.74	7.47	3.17	1.00	10.00	0.90	11.10	
		2	1	47	0.21	95.18	4.62	0.00	4.62	1.72	1.28	6.80	0.70	9.70	-22.90
		3	1	48	0.34	91.82	4.75	3.08	7.83	3.12	0.80	5.10	0.50	10.20	
		1	3	49	0.58	88.52	9.15	1.00	10.15	2.95	0.74	8.20	0.80	10.30	
		2	3	50	0.00	97.09	2.91	0.00	2.91	2.36	0.58	5.20	0.50	10.40	-22.50
		3	3	51	0.00	96.51	3.49	0.00	3.47	1.35	0.78	6.30	0.60	10.50	
				Mean	0.38	93.42	4.78	1.30	6.08			6.93	0.67	10.37	-22.70
				S.D.	0.43	3.37	2.25	1.69	2.85			1.89	0.16	0.45	
Moose Lips Bay Site (18)	Control	1	1	52	84.77	15.24	0.00	0.00	0.00	-5.18	3.27	3.60	0.60	6.00	
		2	1	53	0.00	67.66	32.34	0.00	32.34	3.68	0.49	24.40	2.00	12.20	-22.10
		3	1	54	0.00	72.18	27.82	0.00	27.82	3.63	0.57	5.20	0.60	8.70	
		1	3	55	0.00	92.84	7.16	0.00	7.16	3.43	0.43	3.40	0.40	8.50	
		2	3	56[4]								4.90	0.70	7.00	-19.70
		3	3	57[4]								4.40	0.60	7.30	
				Mean	21.19	61.98	16.83	0.00	16.83			7.65	0.82	8.28	-20.90
				S.D.	42.39	33.03	15.69	0.00	15.69			8.24	0.59	2.16	

1 Depth Transects 1 = 6-20 m, 3 = < 3 m (center of eelgrass bed)
2 Silt and clay.
3 Some mean and sorting values were not calculated because all relevant percentiles could not be obtained from the cumulative curve.
4 Insufficient quantity for complete analysis.

APPENDIX I .Continued

Site (#)	Site Oiling Status	Sta.	Depth[1] Trans.	Sample #	Gravel %	Sand %	Silt %	Clay %	Mud[2] %	Mz[3] Mean	δ[3] Sort	OC mg/g	N mg/g	OC/N	$\delta^{13}C$
Clammy Bay Site (25)	Oiled	1	1	7	0.24	77.97	11.24	10.55	21.79	3.44	1.78	8.80	1.10	8.00	
		2	1	8	0.38	92.83	4.80	1.99	6.79	3.12	0.52	7.50	1.00	7.50	-22.70
		3	1	9	0.12	92.77	2.12	4.99	7.11	2.29	1.36	6.20	0.90	6.90	
		1	3	10	0.07	92.04	6.05	1.84	7.89	2.36	0.86	6.20	0.70	8.90	
		2	3	11	0.11	96.49	2.04	1.29	3.33	1.90	0.63	6.90	0.80	8.60	-22.10
		3	3	12	0.10	95.95	2.29	1.75	4.04	2.29	0.74	5.30	0.70	7.50	
				Mean	0.17	91.34	4.76	3.74	8.49			6.82	0.87	7.90	-22.40
				S.D.	0.12	6.80	3.58	3.59	6.76			1.22	0.16	0.75	
Puffin Bay Site (26)	Control	1	1	1	1.68	73.82	20.26	4.24	24.50	2.11	1.82	14.10	1.40	10.10	
		1	3	2	0.45	87.24	0.60	11.71	12.31	2.52	1.76	5.40	0.90	6.00	
		2	1	3	42.32	52.88	3.66	1.14	4.80	0.02	3.13	5.20	0.80	6.50	-20.00
		2	3	4	0.47	92.71	4.37	0.85	5.22	2.77	0.59	7.10	1.00	7.10	-22.10
		3	1	5	0.15	94.94	3.11	2.00	5.11	2.19	0.97	5.80	0.90	6.40	
		3	3	6	0.07	87.69	2.55	8.29	10.84	2.57	1.95	8.30	1.00	8.30	
				Mean	7.52	81.55	5.76	4.71	10.46			7.65	1.00	7.40	-21.05
				S.D.	17.06	15.85	7.22	4.41	7.60			3.37	0.21	1.55	

[1] Depth Transects 1 = 6-20 m, 3 = < 3 m (center of eelgrass bed)
[2] Silt and clay.
[3] Some mean and sorting values were not calculated because all relevant percentiles could not be obtained from the cumulative curve.

APPENDIX I. Continued

Site (#)	Site Oiling Status	Sta.	Depth[1] Trans.	Sample #	Gravel %	Sand %	Silt %	Clay %	Mud[2] %	Mz[3] Mean	δ[3] Sort	OC mg/g	N mg/g	OC/N	$\delta^{13}C$
Short Arm (Bay of Isles) Site(35)	Oiled	1	3	31	0.00	2.49	22.85	74.66	97.51	12.47	5.52	44.80	5.20	8.60	
		2	3	32	0.00	26.55	34.13	39.31	73.44			80.30	5.60	14.30	-20.30
		3	3	33	0.00	21.77	20.60	57.63	78.23			132.10	10.90	12.10	
				Mean	0.00	16.94	25.86	57.20	83.06			85.73	7.23	11.67	-20.30
				S.D.	0.00	12.74	7.25	17.68	12.74			43.90	3.18	2.87	
Mallard Bay Site (34)	Control	1	1	19	0.00	82.30	11.36	6.34	17.70	4.09	1.26	85.50	9.20	9.30	
		2	1	20	51.98	26.44	14.55	7.03	21.58	-1.46	5.57	43.80	5.30	8.30	-19.80
		3	1	21	0.00	45.64	35.29	19.07	56.36	4.26	1.29	53.70	6.20	8.70	
		1	3	22	0.00	62.40	20.25	17.35	37.60	6.54	1.43	102.00	10.60	9.60	
		2	3	23	0.00	57.94	24.38	17.68	42.06	3.64	1.52	68.40	6.60	10.30	-18.70
		3	3	24	4.34	43.73	30.81	21.12	51.93	3.93	1.88	68.40	6.60	10.40	
				Mean	9.39	53.08	22.77	14.77	37.87			70.30	7.42	9.43	-19.25
				S.D.	20.94	19.06	9.25	6.40	15.68			21.08	2.03	0.84	

[1] Depth Transects 1 = 6-20 m, 3 = < 3 m (center of eelgrass bed)
[2] Silt and clay.
[3] Some mean and sorting values were not calculated because all relevant percentiles could not be obtained from the cumulative curve.

APPENDIX J.

Granulometric composition, organic carbon(OC), nitrogen (N), OC/N ratios and stable carbon isotope ratios ($\delta^{13}C$) of surficial sediments from silled fjord habitat in western Prince William Sound, Alaska, Summer 1990 and 1991.

APPENDIX J. Granulometric composition, organic carbon (OC), nitrogen (N), OC/N ratios and stable carbon isotope ratios ($\delta^{13}C$) of surficial sediments from silled fjord habitats in western Prince William Sound, Alaska, Summer 1990 and 1991.

1990

Site (#)	Site Oiling Status	Sta.	Depth[1] Trans.	Sample #	Gravel %	Sand %	Silt %	Clay %	Mud[2] %	Mz Mean	δ Sort	OC mg/g	N mg/g	OC/N	$\delta^{13}C$
Herring Bay	Oiled	1	1	gs1	0.00	1.75	48.22	50.03	98.25	7.60	2.57	41.96	7.97	5.30	-21.00
Site		2	1	gs2	0.00	0.69	36.11	63.20	99.31	8.80	2.16	48.48	7.67	6.30	
(28-601)		3	1	gs3	0.00	1.00	67.13	31.91	99.04	6.93	2.56	64.40	10.50	6.10	-21.10
				Mean	0.00	1.15	50.49	48.38	98.87	7.78	2.43	51.61	8.71	5.90	-21.05
				S.D.		0.55	15.63	15.71	0.55	0.95	0.23	11.54	1.55	0.53	
Inner Lucky Bay Site (29)	Control	5	1	gs8	0.00	6.80	44.12	49.03	93.15	8.07	2.70	34.29	6.14	5.60	-20.70
Inner Bay	Oiled	5	1	gs13	92.71	2.20	1.59	3.50	5.09	-1.92	1.34	42.01	5.32	7.90	
of Isles		6	1	gs14	42.73	24.60	8.82	23.85	32.67	2.97	5.06	31.98	5.53	5.80	
Site (30)															
				Mean	67.72	13.40	5.21	13.68	18.88	0.53	3.20	37.00	5.43	6.85	
				S.D.	35.34	15.84	5.11	14.39	19.50	3.46	2.63	7.09	0.15	1.48	

[1] Depth transect 1 ≈ 20 m
[2] Silt and clay

APPENDIX J. Continued

1991

Site (#)	Site Oiling Status	Sta.	Depth[1] Trans.	Sample #	Gravel %	Sand %	Silt %	Clay %	Mud[2] %	Mz Mean	δ Sort	OC mg/g	N mg/g	OC/N	$\delta^{13}C$
Herring Bay	Oiled	1	1	100	32.12	57.54	8.36	1.98	10.34	3.12	1.75	99.90	10.50	9.50	-20.40
Site		2	1	101	0.00	34.95	51.20	13.85	65.05	4.61	1.50	41.40	4.90	8.50	-20.40
(28-601)		3	1	102	0.00	47.62	38.76	13.62	52.38	4.22	1.60	62.80	7.80	8.10	-20.30
				Mean	10.71	46.70	32.77	9.82	42.59	3.98	1.62	68.03	7.73	8.70	-20.37
				S.D.	18.54	11.32	22.04	6.79	28.64	0.77	0.13	29.60	2.80	0.72	0.06
Inner Lucky Bay Site (29)	Control	5	1	98	26.67	48.68	14.58	10.07	24.65	3.02	2.83	87.20	8.80	9.90	-20.50

[1] Depth transect 1 ≈ 20 m
[2] Silt and clay

APPENDIX K.

Benthic invertebrates from shallow subtidal habitats in western Prince William Sound, 1989-91. All habitats were sampled by suction dredge, except *Zostera* DN, which was also sampled by dropnet.

APPENDIX K. Benthic invertebrates from shallow subtidal habitats in western Prince William Sound, 1989-91. All habitats were sampled by suction dredge, except *Zostera* DN, which was sampled by dropnet.

					HABITAT						
					ZOSTERA[3]				LAMINARIA[4]		SILLED
TAXON CODE	TAXON	COMMON NAME	EPIFAUNA/ INFAUNA[1]	FEEDING TYPE[2]	T1	T2[5]	T3	DN[6]	T1	T2	FJORD
37	Cnidaria		E/I	SF,P	X		X[7]			X[7]	X[7]
3701	Hydrozoa		E	SF,P	X	X	X	X	X	X	X[8]
373101	Eleutherocarpidae		E	P			X[7]	X			
3740	Anthozoa		E/I	SF,P	X	X	X			X[9]	
3743	Ceriantharia	Tube Anemones	I	P		X			X[9]		X[7]
3758	Actiniaria	Sea Anemones	E/I	P		X					
43	Rhynchocoela	Ribbon Worms	E/I	P	X	X	X	X	X	X	X
430302	Lineidae	Ribbon Worms	I	P	X[9]	X	X[9]				
50	Annelida		E/I								
5001	Polychaeta	Polychaetes	E/I	SDF,SF,P,O	X	X	X	X	X	X	X[8]
500101	Aphroditidae	"	E/I	P					X[9]		
500102	Polynoidae	"	E/I	P,O	X	X	X	X	X	X	X
500104	Polyodontidae	"	E/I	SDF,SSDF,P,O	X	X			X	X	X[8]
500106	Sigalionidae	"	I	P,O	X	X	X		X	X	X[8]
500108	Chrysopetalidae	"	E/I	P		X	X[7]		X[7]	X	
500111	Euphrosinidae	"	E/I	P						X[7]	
500113	Phyllodocidae	"	E/I	P,O	X	X	X	X	X	X	X[8]
500121	Hesionidae	"	E/I	P	X	X	X	X	X	X	X[8]
500123	Syllidae	"	E/I	SDF,P,O	X	X	X	X	X	X	X
500124	Nereidae	"	E/I	SDF,SF,P	X	X	X	X	X	X	X[7]
500125	Nephtyidae	"	I	SSDF,P	X	X	X		X	X	X[8]
500126	Sphaerodoridae	"	E/I	SDF	X		X[7]		X	X	X[9]
500127	Glyceridae	"	I	P	X	X	X		X	X	X[9]
500128	Goniadidae	"	I	P,O	X	X	X		X	X	X[8]
500129	Onuphidae	"	I	SDF,P,O	X		X		X		X[7]
500131	Lumbrineridae	"	I	SDF,SSDF,P,O	X	X	X		X	X	X
500136	Dorvilleidae	"	E/I	P,O	X	X	X	X	X	X	X

APPENDIX K .continued

TAXON CODE	TAXON	COMMON NAME	EPIFAUNA/ INFAUNA[1]	FEEDING TYPE[2]	HABITAT ZOSTERA[3] T1	T2[5]	T3	DN[6]	LAMINARIA[4] T1	T2	SILLED FJORD
500140	Orbiniidae	Polychaetes	I	SSDF	X	X	X		X	X	X
500141	Paraonidae	"	I	SSDF,SDF	X	X	X		X	X	X[9]
500142	Apistobranchidae	"	I	SDF	X						
500143	Spionidae	"	I	SDF,SF	X	X	X	X	X	X	X[8]
500144	Magelonidae	"	I	SDF	X	X	X[7]		X	X[9]	
500149	Chaetopteridae	"	I	SF	X	X	X		X		X[10]
500150	Cirratulidae	"	I	SDF	X	X	X		X	X	X
500151	Acrocirridae	"	I	SDF	X				X	X[7]	X[7]
500154	Flabelligeridae	"	I	SDF	X	X			X	X	X[9]
500157	Scalibregmidae	"	I	SDF,SSDF	X		X		X	X	X
500158	Opheliidae	"	I	SSDF	X	X	X	X	X	X	X
500160	Capitellidae	"	I	SSDF	X	X	X	X	X	X	X
500162	Arenicolidae	"	I	SDF			X				
500163	Maldanidae	"	I	SSDF	X	X	X		X	X	X[8]
500164	Oweniidae	"	I	SDF,SSDF,SF	X	X	X		X	X	X[8]
500165	Sabellariidae	"	I	SF	X[7]				X		
500166	Amphictenidae	"	I	SSDF	X	X	X	X	X	X	X
500167	Ampharetidae	"	I	SDF	X	X	X	X	X	X	X[8]
500168	Terebellidae	"	I	SDF	X	X	X		X	X	X
500169	Trichobranchidae	"	I	SDF	X				X	X[7]	X
500170	Sabellidae	"	I	SF	X	X	X		X	X	X
500173	Serpulidae	"	E	SF	X	X	X		X	X	
500178	Spirorbidae	"	E	SDF,SSDF,SF,P,O	X	X	X	X	X	X	X
500205	Polygordiidae	"	E/I	SDF	X[7]	X			X	X	
5012	Hirudinea	Leeches	E/I	P,O	X[9]						
	Mollusca		E/I						X[9]		
51	Gastropoda		E/I	SDF,SF,P,O	X	X	X	X	X	X	X[8]
5102	Archaeogastropoda	Limpets	E	O	X	X	X		X	X	X[9]

APPENDIX K. continued

TAXON CODE	TAXON	COMMON NAME	EPIFAUNA/ INFAUNA[1]	FEEDING TYPE[2]	HABITAT: ZOSTERA[3] T1	ZOSTERA[3] T2[5]	ZOSTERA[3] T3	ZOSTERA[3] DN[6]	LAMINARIA[4] T1	LAMINARIA[4] T2	SILLED FJORD
510204	Fissurellidae	Snails	E	O	X				X	X	
510205	Lottidae (Acmaeidae)	"	E	O	X	X	X[7]		X	X	
510207	Lepetidae	"	E	O	X	X	X[7]		X	X	X[9]
510210	Trochidae	"	E/I	O	X	X	X	X	X	X	X[9]
510309	Lacunidae	"	E/I	O	X	X	X	X	X[7]	X[7]	
510310	Littorinidae	Periwinkle	E/I	O	X[7]						
510320	Rissoidae	Snails	E/I	O	X	X	X	X	X	X	X[8]
510324	Skeneopsidae	"	E	O		X					
510333	Turritellidae	"	E/I	SDF						X[7]	
510336	Caecidae	Caecum	I	O	X	X	X		X	X	X[8]
510346	Cerithiidae	Snails	E/I	O		X			X[7]	X	
510353	Eulimidae	"	?	Ectoparasites	X[9]						
510362	Trichotropidae	"	E/I	SF	X				X	X[7]	
510364	Calyptraeidae	"	E	SF	X	X	X		X	X	X[9]
510376	Naticidae	"	E/I	P	X[7]	X	X[9]			X	
510386	Barleeiidae	"	I	O						X[7]	
510501	Muricidae	"	E/I	P	X[9]	X			X	X[7]	
510503	Pyrenidae	"	E/I	P	X	X				X[7]	X[10]
510508	Nassariidae	"	E/I	P,O	X	X	X		X	X	X[9]
510510	Olividae	"	E/I	P,O	X	X	X	X	X[7]	X[7]	
510515	Marginellidae	"	E/I	O	X[7]					X	
510602	Turridae	"	E/I	P	X	X	X		X	X	X[8]
510801	Pyramidellidae	"	?	Ectoparasites	X	X	X		X	X	X
5110	Cephalaspidea	Bubble Shells	E/I	P,O	X	X	X[7]		X	X	X
511004	Cylichnidae	"	E/I	P,O	X	X	X		X	X	X
511005	Philinidae	Paperbubble	E/I	P	X[9]	X					X[9]
511007	Gastropteridae	Batwing Seaslug	E/I	P,O	X	X	X	X	X[7]	X	X
511009	Diaphanidae	Paperbubble	E/I	P,O	X[9]		X[7]		X	X	

TAXON CODE	TAXON	COMMON NAME	EPIFAUNA/ INFAUNA[1]	FEEDING TYPE[2]	HABITAT ZOSTERA[3] T1	T2[5]	T3	DN[6]	LAMINARIA[4] T1	T2	SILLED FJORD
511012	Haminoidae	Glassy-bubble	E/I	P,O	X			X			X[9]
5123	Sacoglossa	Nudibranchia	E	O	X	X	X		X[7]	X	X[7]
512306	Stiligeridae	"	E	O		X	X[7]		X[7]		
5127	Nudibranchia	"	E	P,O	X	X	X	X	X	X	X
5128	Doridacea	"	E	P	X[7]	X	X[7]	X		X[7]	
513003	Dorididae	"	E	P			X[9]				
513105	Onchidorididae	"	E	P	X[7]	X	X	X	X[7]	X	X[7]
513107	Corambidae	"	E	P		X	X	X			X[9]
513406	Dendronotidae	"	E	P		X				X[7]	
513408	Tethydidae	"	E	P				X		X[7]	
5181	Opisthobranchia	"	E/I	P,O			X				
53	Polyplacophora	Chitons	E	O	X	X	X		X	X	X[9]
530201	Lepidopleuridae	"	E	O	X	X			X	X	X
530302	Ischnochitonidae	"	E	O	X	X	X[7]		X	X	
530307	Mopaliidae	"	E	P,O	X[9]	X	X[7]		X	X	
55	Bivalvia	Bivalves	E/I	SDF,SSDF,SF	X	X	X	X	X	X	X[8]
550202	Nuculidae	Nutclam	I	SSDF	X	X			X		X[9]
550204	Nuculanidae	"	I	SSDF	X	X	X[9]		X		X[9]
550606	Glycymeridae	Clams	E/I	SF	X	X					
550701	Mytilidae	Mussels	E	SF	X	X	X	X	X	X	X
550905	Pectinidae	Scallops	E	SF	X				X	X[7]	X
550909	Anomiidae	Jingles	E	SF	X[7]	X	X[7]		X[7]	X	X[7]
551501	Lucinidae	Clams	I	SDF,SF	X	X	X	X	X	X	X[8]
551502	Thyasiridae	"	I	SDF,SF	X	X	X		X	X	X[8]
551505	Ungulinidae	"	I	SF	X	X	X[7]		X[7]	X[7]	
551508	Kelliidae	"	E/I	SF,SDF		X					
551510	Montacutidae	"	I	SF,SDF	X	X	X	X	X	X	X[8]
551514	Turtoniidae	"	E/I	SF	X[7]		X[7]	X	X[9]	X[9]	

APPENDIX K. continued

TAXON CODE	TAXON	COMMON NAME	EPIFAUNA/ INFAUNA[1]	FEEDING TYPE[2]	HABITAT ZOSTERA[3] T1	T2[5]	T3	DN[6]	LAMINARIA[4] T1	T2	SILLED FJORD
551517	Carditidae	Clams	E/I	SF	X				X	X	X[7]
551519	Astartidae	"	E/I	SF	X	X			X		X
551522	Cardiidae	Cockles	E/I	SDF,SF	X	X	X		X	X	X
551525	Mactridae	Clams	I	SF	X[7]						
551531	Tellinidae	"	I	SDF,SF,SSDF	X	X	X		X	X	X
551547	Veneridae	"	I	SF	X	X	X		X	X	X[9]
551701	Myidae	"	I	SDF	X	X	X		X	X	X[7,10]
551706	Hiatellidae	"	E/I	SF	X	X	X	X	X	X	X[10]
552002	Pandoridae	"	E/I	SF	X[9]						
552005	Lyonsiidae	"	E/I	SF	X	X	X		X	X	X[9]
552008	Thraciidae	"	I	SF	X				X		
552010	Cuspidariidae	"	I	P	X				X		
56	Scaphapoda	Tuskshells	I	SSDF,P					X[7]		
560001	Dentaliidae	Tuskshells	I	SSDF,P	X[9]						
61	Arthropoda	Crustaceans	E/I		X	X	X	X	X	X	X[7]
6134	Balanomorpha	Barnacles	E	SF	X	X	X[9]	X	X	X	X
613401	Chthamalidae	"	E	SF	X[9]						
613402	Balanidae	"	E	SF	X[7]	X	X		X	X	X[9,10]
6154	Cumacea	Cumaceans	I	SDF,P	X	X	X		X	X	X
615401	Lampropidae	"	I	SDF	X	X	X		X	X	X[9]
615404	Leuconidae	"	I	SDF	X	X	X[7]		X	X	X[8]
615405	Diastylidae	"	I	SDF	X	X	X		X	X[7]	X
615407	Campylaspidae	"	I	SDF,P	X[7]						
615408	Nannastacidae	"	I	SDF	X	X	X[7]		X[7]	X	X[9]
615409	Bodotriidae	"	I	SDF	X				X	X	X
6155	Tanaidacea	Tanaids	E/I	SF,P			X[7]			X[7]	
615701	Tanaidae	"	E/I	U			X[9]				
615702	Paratanaidae	"	E/I	U	X[9]	X	X	X	X	X[9]	

APPENDIX K . continued

TAXON CODE	TAXON	COMMON NAME	EPIFAUNA/ INFAUNA[1]	FEEDING TYPE[2]	HABITAT: ZOSTERA[3] T1	ZOSTERA T2[5]	ZOSTERA T3	ZOSTERA DN[6]	LAMINARIA[4] T1	LAMINARIA T2	SILLED FJORD
6158	Isopoda	Isopods	E/I	SDF							X[7]
615901	Gnathiidae	"	E/I	SDF	X[9]				X[9]	X[9]	
616105	Limnoridae	"	WB	O	X[7]	X	X[7]			X[7]	
616202	Idoteidae	"	E	O		X		X			
6163	Asellota	"	E/I	SDF						X[7]	
616306	Janiridae	Isopods	E/I	U					X[7]		
616311	Jaeropsidae	"	U	U	X[9]						
616312	Munnidae	"	E/I	U	X	X	X	X	X	X	X
6169	Amphipoda	Amphipods	E/I		X	X	X	X	X	X	X[8]
616901	Acanthonotozomatidae	"	E/I	U	X[7]						
616902	Ampeliscidae	"	I	SDF,SF	X	X	X[7]		X	X	
616904	Ampithoidae	"	E/I	U	X	X	X	X	X[9]	X	X[9,10]
616906	Aoridae	"	E/I	U	X	X	X	X	X[9]	X	
616912	Calliopiidae	"	E/I	O	X[7]			X	X[9]	X[9]	
616915	Corophiidae	"	I	SDF,SF	X	X	X	X	X	X	X[7]
616917	Dexaminidae	"	E/I	SF	X	X	X		X	X	X
616920	Eusiridae	"	E/I	P	X	X	X	X	X	X	
616921	Gammaridae	"	E/I	SDF,SF	X	X	X		X	X	X
616923	Hyalellidae	"	U	U					X[9]	X[7]	
616926	Isaeidae	"	E/I	SDF	X	X	X	X	X	X	X
616927	Ischyroceridae	"	E/I	SDF,O	X	X	X	X	X	X	X
616934	Lysianassidae	"	E/I	O	X	X	X		X	X	X
616937	Oedicerotidae	"	E/I	SDF,O	X	X	X		X	X	X
616942	Phoxocephalidae	"	E/I	SDF,P,O	X	X	X		X	X	X
616943	Pleustidae	"	E/I	SDF,O	X	X	X	X	X	X	X[9]
616944	Podoceridae	"	E	U	X[7]				X[7]	X[7]	
616948	Stenothoidae	"	E/I	P	X[7]	X	X[7]	X	X[9]	X	
616950	Synopiidae	"	E	SF	X				X	X[7]	X[9]

APPENDIX K.continued

TAXON CODE	TAXON	COMMON NAME	EPIFAUNA/ INFAUNA[1]	FEEDING TYPE[2]	HABITAT ZOSTERA[3] T1	T2[5]	T3	DN[6]	LAMINARIA[4] T1	T2.	SILLED FJORD
6171	Caprellidea	Caprellids	E/I	SDF,P,O	X	X	X	X	X	X	X
6175	Decapoda		E	P,O	X	X	X	X	X	X	X[9]
6178	Pleocyemata	Shrimps	E	P,O	X[7]		X	X	X[9]	X	
617916	Hippolytidae	"	E	P,O	X	X	X	X	X	X	X[9]
617918	Pandalidae	"	E	P,O	X[9]		X	X		X[9]	X[9]
617922	Crangonidae	"	E	P,O	X		X[9]	X	X	X	X[9]
618306	Paguridae	Hermit Crabs	E	P,O	X		X[9]	X	X	X	X[9]
618308	Lithodidae	Crabs	E	P,O						X[7]	
6184	Brachyura	"	E	P,O						X[7]	
618701	Majidae	"	E	P,O	X[7]		X			X[7]	
618802	Atelecyclidae	"	E	P,O	X[7]	X	X	X	X[9]	X	
618803	Cancridae	"	E	O	X[7]					X	
6189	Brachyrhyncha	"	E	O						X[9]	
72	Sipuncula	Peanut Worms	I	SDF,SF	X		X[7]		X	X	
720002	Golfingiidae	"	I	SDF	X	X			X[9]	X	X[9]
73	Echiura	Spoon Worms	I	SDF,SF			X[9]				
74	Priapulida		I	SSDF,P						X[9]	
740001	Priapulidae		I	P		X					
77	Phoronida		E/I	SF	X	X	X		X	X	
78	Bryozoa		E	SF,P	X	X	X	X	X	X	X
80	Brachiopoda	Lamp Shells	E	SF					X		
800507	Cancellothyridae	"	E	SF	X[9]						
800511	Dallinidae	"	E	SF					X[7]		
81	Echinodermata		E/I						X[9]	X[9]	
8104	Asteroidea	Sea Stars	E	P,O	X	X	X	X	X[9]	X[7]	
811703	Asteriidae	"	E	P,O	X		X[7]	X			
8120	Ophiuroidea	Brittle Stars	E	SDF,SF,P,O	X	X	X	X	X	X	X
812902	Ophiactidae	"	E	SDF,SF						X[7]	

APPENDIX K .continued

TAXON CODE	TAXON	COMMON NAME	EPIFAUNA/ INFAUNA[1]	FEEDING TYPE[2]	HABITAT: ZOSTERA[3] T1	T2[5]	T3	DN[6]	LAMINARIA[4] T1	T2	SILLED FJORD
812903	Amphiuridae	Brittle Stars	E/I	SDF,SF	X^7	X	X		X	X^7	
8136	Echinoidea		E		X^7		X^7	X	X^7	X	
8149	Echinoida	Sea Urchins	E								
814903	Strongylocentrotidae	"	E	O	X	X	X	X	X^7	X^7	
815502	Echinarachniidae	Sand Dollars	I	SDF,SF	X	X	X				
8172	Holothuroidea	Sea Cucumbers	E/I	SDF,SSDF,SF							
817206	Cucumariidae	"	E	SF,P	X	X			X^7		
817801	Synaptidae	"	I	SSDF	X		X^7		X^9	X^7	
84	Urochordata	Tunicates	E	SF	X	X	X		X^9	X	
8401	Ascidiacea	"	E	SF	X	X	X		X	X^7	X
840601	Styelidae	"	E	SF		X					
840602	Pyuridae	"	E	SF					X^7		

Notes: No superscript under "HABITAT" means there was an occurrence in 1990 <u>and</u> 1991.

[1]E = Epifauna; I = Infauna; E/I = Both Epifaunal and Infaunal members.

[2]Feeding Type: SDF=surface deposit feeder; SSDF=subsurface deposit feeder; SF=suspension feeder; P=predator (carnivore); O=Other (scavenger, herbivore); WB=woodborer; U=unknown.

[3]*Zostera* T1=Transect 1 (6-20m).
Zostera T2=Transect 2 (3-6m).
Zostera T3=Transect 3 (Eelgrass Bed).

[4]*Laminaria* T1=Transect 1 (11-20m).
Laminaria T2=Transect 2 (2-11m).

[5]*Zostera* T2 was only sampled in 1990.

[6]Dropnet samples were only collected in 1990.

[7]Occurred in 1991 only.

[8]Occurred in 1989,1990 and 1991.

[9]Occurred in 1990 only.

[10]Occurred in 1989 only.

APPENDIX L.

Mean values for community parameters of dominant invertebrate families that were sampled by suction dredge at oiled and control sites in the eelgrass habitat in 1990 and 1991. Also given are probabilities that the means from the oiled and control sites were similar as determined by randomization tests.

Appendix L. Mean values for community parameters of dominant invertebrate families that were sampled by suction dredge at oiled and control sites in the eelgrass habitat in 1990 and 1991. Also given are probabilities that the means from the oiled and control sites were similar as determined by randomization tests.

1990 Infauna Diversity Indices for Alaskan Eelgrass Habitats
All Families & Higher

Transect = 1

Site	Site Code	Shannon-Weiner	Simpson	Families	Total Individuals	Total Biomass	Species Richness
Bay of Isles	13 (O)	0.92	0.61	12	244	1.054	2.082
Drier Bay	14 (C)	2.23	0.17	27	592	6.836	4.123
Herring Bay	16 (O)	3.13	0.09	54	696	8.475	8.203
Lower H. Bay	15 (C)	2.96	0.08	52	482	3.265	8.384
Sleepy Bay	17 (O)	2.70	0.13	57	768	11.307	8.417
Moose Lips	18 (C)	2.29	0.16	29	1007	10.089	4.096
Clammy Bay	25 (O)	2.58	0.14	38	661	7.089	5.716
Puffin Bay	26 (C)	3.35	0.06	62	1165	19.388	8.683
	Mean (O)	2.33	0.24	40	592	6.981	6.105
	Mean (C)	2.71	0.12	43	812	9.894	6.321
	P	0.13	0.045	0.70	0.07	0.35	0.83

1990 Infauna Diversity Indices for Alaskan Eelgrass Habitats
All Families & Higher

Transect = 3

Site	Site Code	Shannon-Weiner	Simpson	Families	Total Individuals	Total Biomass	Species Richness
Bay of Isles	13 (O)	1.64	0.28	20	708	0.553	3.014
Drier Bay	14 (C)	2.29	0.14	20	200	0.905	3.645
Herring Bay	16 (O)	2.27	0.17	38	1611	5.968	4.969
Lower H. Bay	15 (C)	1.70	0.26	18	436	1.141	2.792
Sleepy Bay	17 (O)	2.43	0.14	45	2577	19.334	5.619
Moose Lips	18 (C)	2.50	0.13	38	1428	7.971	5.130
Clammy Bay	25 (O)	2.45	0.15	44	2640	39.325	5.506
Puffin Bay	26 (C)	2.67	0.13	45	1834	15.220	5.861
	Mean (O)	2.20	0.18	37	1884	16.295	4.777
	Mean (C)	2.29	0.17	30	975	6.309	4.357
	P	0.58	0.48	0.12	<0.01	<0.01	0.39

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1991 Infauna Diversity Indices for Alaskan Eelgrass Habitats
All Families & Higher

Transect = 1

Site	Site Code	Shannon-Weiner	Simpson	Families	Total Individuals	Total Biomass	Species Richness
Bay of Isles	13 (O)	1.30	0.50	17	367	2.498	2.721
Drier Bay	14 (C)	2.22	0.20	39	1213	21.800	5.311
Herring Bay	16 (O)	3.49	0.05	67	1257	8.474	9.262
Lower H. Bay	15 (C)	2.86	0.14	56	1011	3.726	8.072
Sleepy Bay	17 (O)	2.71	0.14	53	1620	12.041	7.214
Moose Lips	18 (C)	2.57	0.19	54	1713	24.346	7.137
Clammy Bay	25 (O)	2.66	0.15	43	1057	9.782	6.176
Puffin Bay	26 (C)	3.31	0.07	71	1251	8.028	9.886
	Mean (O)	2.54	0.21	45	1075	8.199	6.343
	Mean (C)	2.74	0.15	55	1297	14.475	7.602
	P	0.46	0.44	0.11	0.26	0.46	0.15

1991 Infauna Diversity Indices for Alaskan Eelgrass Habitats
All Families & Higher

Transect = 3

Site	Site Code	Shannon-Weiner	Simpson	Families	Total Individuals	Total Biomass	Species Richness
Bay of Isles	13 (O)	2.14	0.16	26	2030	2.024	3.352
Drier Bay	14 (C)	2.44	0.14	33	1115	5.313	4.512
Herring Bay	16 (O)	2.41	0.16	47	2613	8.023	5.878
Lower H. Bay	15 (C)	2.37	0.14	30	1496	2.277	3.916
Sleepy Bay	17 (O)	2.28	0.17	47	3207	12.794	5.791
Moose Lips	18 (C)	2.47	0.14	52	4072	18.910	6.175
Clammy Bay	25 (O)	2.42	0.16	50	3427	34.933	6.024
Puffin Bay	26 (C)	1.95	0.34	64	7997	36.333	7.127
Short Arm Bay	35 (O)	2.36	0.16	35	1752	3.538	4.512
Mallard Bay	34 (C)	2.39	0.14	33	1933	4.081	4.292
	Mean (O)	2.32	0.16	41	2606	12.262	5.111
	Mean (C)	2.32	0.18	42	3322	13.383	5.205
	P	0.97	0.53	0.73	0.32	0.66	0.83

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APPENDIX M.

Mean values for abundance and biomass of dominant invertebrate families that were sampled by suction dredge at oiled and control sites in the eelgrass habitat in 1990 and 1991. Also given are probabilities that the means from the oiled and control sites were similar as determined by randomization tests.

Appendix M. Mean values for abundance and biomass of dominant invertebrate families that were sampled by suction dredge at oiled and control sites in the eelgrass habitat in 1990 and 1991. Also given are probabilities that the means from the oiled and control sites were similar as determined by randomization tests. Densities are #/0.1m^2 and biomass units are grams/0.1m^2.

Abundance - 1990

Deep

Pair	Site#	Oilcode	AMPHARET	AMPHICTE	AMPHIPOD	BIVALVIA	CAECIDAE	CAPITELL	LUCINIDA	MALDANID	MYTILIDA	NEPHTYID
1	13	O	0.00	0.00	0.17	7.00	0.00	0.00	0.00	0.00	0.00	188.00
1	14	C	6.67	14.00	4.00	78.00	0.00	17.33	58.67	17.25	1.83	0.00
2	16	O	3.56	8.89	31.11	4.45	35.11	12.45	132.44	7.11	12.89	0.00
2	15	C	10.00	6.33	63.83	54.67	0.33	8.00	7.50	0.00	2.00	2.83
3	17	O	1.67	17.91	32.05	9.33	0.00	7.05	10.71	10.19	133.74	2.00
3	18	C	0.00	18.04	90.75	5.42	0.00	5.95	88.80	0.00	4.09	2.67
4	25	O	12.67	48.00	12.67	1.33	0.00	8.67	175.33	40.39	2.67	4.33
4	26	C	22.22	43.56	28.45	10.22	70.22	92.00	35.11	30.67	21.94	10.22
	mean	O	4.47	18.70	19.00	5.53	8.78	7.04	79.62	14.42	37.32	48.58
	mean	C	9.72	20.48	46.76	37.08	17.64	30.82	47.52	11.98	7.47	3.93
	P		0.70	0.76	<0.01	0.14	0.02	0.20	0.59	0.03	0.23	0.18

Deep (continued)

Pair	Site#	Oilcode	OPHELIID	OPHIUROI	ROSSOIDA	SIGALION	SPIONIDA	SPIRORBI	SYLLIDAE	TELLINID	THYASIRI
1	13	O	4.00	0.00	2.17	0.00	0.00	0.67	0.00	0.00	4.33
1	14	C	68.17	0.17	0.00	4.67	77.17	11.17	8.67	4.83	84.00
2	16	O	36.00	13.33	22.22	6.67	62.84	70.67	8.45	0.00	0.89
2	15	C	36.67	6.17	11.50	21.67	36.83	41.67	4.67	0.00	6.50
3	17	O	32.05	0.00	0.00	0.33	177.48	4.17	66.83	17.64	6.17
3	18	C	116.89	3.11	0.89	0.00	144.36	9.33	1.33	238.67	102.93
4	25	O	11.11	12.00	0.00	2.67	94.44	0.00	9.33	50.39	46.89
4	26	C	5.33	67.11	1.33	40.00	140.44	40.89	69.33	4.00	0.89
	mean	O	20.79	6.33	6.10	2.42	83.69	18.88	21.15	17.01	14.57
	mean	C	56.76	19.14	3.43	16.58	99.70	25.76	21.00	61.88	48.58
	P		0.75	0.49	0.72	0.08	0.95	0.66	0.31	0.80	0.98

Shallow

Pair	Site#	Oilcode	AMPHICTE	AMPHIPOD	BIVALVIA	CAPRELLI	GASTROPO	LACUNIDA	LUCINIDA	MONTACUT	MYTILIDA
1	13	O	6.27	1.67	26.70	0.00	10.45	0.00	10.22	62.93	4.67
1	14	C	23.78	31.61	42.94	2.06	31.78	2.89	15.22	6.89	1.05
2	16	O	40.89	40.66	53.11	45.78	203.33	35.11	35.78	15.78	194.67
2	15	C	13.67	8.33	18.67	0.83	40.67	9.17	92.00	41.17	1.50
3	17	O	28.00	14.67	10.83	5.33	50.83	166.67	89.33	178.67	152.33
3	18	C	9.11	116.45	55.11	101.78	16.67	74.55	4.67	20.33	40.45
4	25	O	19.33	20.00	5.33	4.00	4.67	1.33	6.67	33.33	0.67
4	26	C	43.11	44.89	11.56	10.22	33.33	24.44	15.56	62.22	4.00
	mean	O	23.62	19.25	23.99	13.78	67.32	50.78	35.50	72.68	88.08
	mean	C	22.42	50.32	32.07	28.72	30.61	27.76	31.86	32.65	11.75
	P		0.28	0.07	0.80	0.82	0.34	0.75	0.94	0.48	0.21

ACE 30287001

Shallow (continued)

Pair	Site#	Oilcode	OPHELIID	PHOXOCEP	ROSSOIDA	SPIONIDA	SPIRORBI	SYLLIDAE	TELLINID
1	13	O	6.45	0.00	2.67	4.53	9.60	0.53	0.00
1	14	C	72.11	0.00	16.55	48.33	9.17	9.33	2.50
2	16	O	54.44	0.67	26.67	59.33	173.56	35.78	1.55
2	15	C	29.00	0.33	73.83	98.33	2.00	12.50	0.67
3	17	O	401.33	6.67	6.67	582.17	354.67	18.67	36.00
3	18	C	53.00	67.00	1.33	68.45	0.33	0.00	88.33
4	25	O	48.67	12.67	0.00	116.00	2.00	8.67	109.33
4	26	C	122.67	24.45	26.67	364.44	229.33	39.11	28.89
	mean	O	127.72	5.00	9.00	190.51	134.96	15.91	36.72
	mean	C	69.19	22.94	29.60	144.89	60.21	15.24	30.10
	P		0.14	0.06	0.06	0.74	0.58	0.54	0.56

Eelgrass Bed

Pair	Site#	Oilcode	AMPHICTE	AMPHIPOD	BIVALVIA	CAPITELL	CAPRELLI	GASTROPO	LACUNIDA	MONTACUT	MYTILIDA	OPHELIID
1	13	O	5.05	11.79	48.87	2.93	0.38	121.58	0.00	170.86	1.14	13.58
1	14	C	1.90	9.69	7.34	2.87	26.99	20.44	0.00	21.26	0.17	21.05
2	16	O	31.33	32.83	118.67	49.83	152.00	253.33	5.50	13.17	178.17	102.00
2	15	C	0.00	2.67	11.33	32.00	9.33	96.45	0.00	13.33	0.67	2.22
3	17	O	83.33	30.45	17.11	45.56	4.45	146.22	344.22	26.67	309.28	194.22
3	18	C	40.67	232.00	92.00	24.00	246.67	58.00	130.00	22.67	38.00	112.00
4	25	O	86.67	34.00	6.67	54.00	231.33	86.67	111.33	78.00	654.67	108.00
4	26	C	78.67	54.67	13.33	36.00	89.33	9.33	97.33	96.00	149.33	177.33
	mean	O	51.60	27.27	47.83	38.08	97.04	151.95	115.26	72.17	285.81	104.45
	mean	C	30.31	74.76	31.00	23.72	93.08	46.06	56.83	38.32	47.04	78.15
	P		0.34	0.17	0.08	0.24	0.66	0.40	0.25	0.52	0.00	0.85

Eelgrass Bed (continued)

Pair	Site#	Oilcode	PHOXOCEP	POLYNOID	ROSSOIDA	SPIONIDA	SPIRORBI	SYLLIDAE	TELLINID	TROCHIDA
1	13	O	0.00	25.81	0.00	0.38	284.62	0.53	0.00	0.00
1	14	C	0.00	14.45	2.39	2.16	49.79	2.83	0.00	4.50
2	16	O	0.00	37.83	3.17	13.33	396.00	125.83	4.33	0.00
2	15	C	0.00	37.11	0.00	0.89	188.22	15.33	0.00	0.00
3	17	O	0.67	11.56	29.56	554.00	430.67	6.00	44.00	0.00
3	18	C	112.67	3.33	4.00	190.67	2.67	10.67	108.00	0.00
4	25	O	2.67	6.67	26.00	634.67	50.67	48.00	180.83	0.00
4	26	C	26.67	2.67	16.00	525.67	92.00	9.33	113.33	26.67
	mean	O	0.83	20.47	14.68	300.60	290.49	45.09	57.29	0.00
	mean	C	34.83	14.39	5.60	179.84	83.17	9.54	55.33	7.79
	P		<0.01	0.22	0.15	0.06	0.02	0.73	0.93	<0.01

Biomass - 1990

Deep

Pair	Site#	Oilcode	AMPHICTE	AMPHIPOD	BIVALVIA	CARDIIDA	CHAETOPT	CRYPTOBR	DIPLODON	GLYCERID	GLYCYMER	GONIADID	LUCINID
1	13	O	0.000	0.000	0.016	0.000	0.000	0.000	0.000	0.000	0.000	0.013	0.000
1	14	C	0.002	0.002	0.794	0.825	0.000	0.000	0.000	1.200	0.000	0.209	0.628
2	16	O	0.042	0.084	0.003	0.000	0.000	0.000	0.000	0.003	0.000	0.004	2.369
2	15	C	0.003	0.093	0.131	0.001	0.000	0.085	0.000	0.000	0.000	0.018	0.277
3	17	O	0.159	0.096	0.321	0.000	0.292	0.000	0.399	0.026	0.003	0.022	0.028
3	18	C	0.088	0.115	0.012	0.001	0.000	0.000	0.000	0.000	0.000	0.250	5.238
4	25	O	0.111	0.022	0.008	0.000	0.001	0.000	0.174	0.001	0.000	0.031	1.830
4	26	C	0.045	0.114	4.823	1.197	0.001	0.007	0.000	0.065	0.000	0.022	0.525
	mean	O	0.078	0.051	0.087	0.000	0.073	0.000	0.143	0.007	0.001	0.018	1.057
	mean	C	0.034	0.081	1.440	0.506	0.000	0.023	0.000	0.316	0.000	0.125	1.667
	P		0.40	0.23	0.05	0.12	0.53	<0.01	0.49	0.84	0.77	0.34	0.37

Deep (continued)

Pair	Site#	Oilcode	LUMBRINE	MYTILIDA	NEPHTYID	OLIVIDAE	ORBINIID	RHYNCHOC	SPIONIDA	TELLINID	THYASIRI	VENERIDA
1	13	O	0.135	0.000	0.299	0.000	0.000	0.000	0.000	0.000	0.004	0.000
1	14	C	0.489	0.001	0.003	0.000	0.104	0.268	0.042	0.657	0.404	0.000
2	16	O	0.409	0.145	0.000	0.000	0.137	1.108	0.071	0.000	0.000	1.897
2	15	C	0.348	0.005	0.006	0.000	0.001	0.013	0.051	0.000	0.089	1.338
3	17	O	0.000	1.096	0.069	5.737	0.007	0.723	0.044	0.262	0.015	0.001
3	18	C	0.248	0.012	0.003	0.011	0.379	0.063	0.108	1.906	0.572	0.172
4	25	O	0.186	0.004	0.132	0.471	0.016	0.075	0.159	0.720	0.258	0.452
4	26	C	0.257	0.236	0.054	0.593	0.020	0.401	0.103	0.015	0.018	4.380
	mean	O	0.182	0.311	0.125	1.552	0.040	0.477	0.069	0.246	0.069	0.587
	mean	C	0.336	0.064	0.016	0.151	0.126	0.186	0.076	0.645	0.271	1.472
	P		0.27	0.49	0.97	0.95	0.48	0.40	0.72	0.98	0.74	0.02

Depth = Shallow

Pair	Site#	Oilcode	AMPHIPOD	CHAETOPT	LUCINIDA	LYONSIID	MYTILIDA	NEPHTYID	OLIVIDAE	OPHELIID
1	13	O	0.003	0.000	0.608	0.000	0.011	0.112	0.000	0.005
1	14	C	0.032	0.003	0.514	0.001	0.001	0.107	0.000	0.017
2	16	O	0.117	0.000	0.962	0.000	1.799	0.000	0.000	0.037
2	15	C	0.015	0.000	1.997	0.000	0.001	0.000	0.000	0.022
3	17	O	0.038	3.677	2.112	0.015	0.861	0.896	0.531	0.772
3	18	C	0.185	0.348	0.088	0.000	0.004	0.021	0.267	0.054
4	25	O	0.089	0.707	0.021	0.693	0.001	0.000	0.639	0.609
4	26	C	0.084	0.737	0.213	0.387	0.067	0.007	1.044	0.256
	mean	O	0.062	1.096	0.926	0.177	0.668	0.252	0.292	0.356
	mean	C	0.079	0.272	0.703	0.097	0.018	0.034	0.328	0.087
	P		0.56	0.34	0.86	0.80	0.16	0.15	0.93	0.05

Shallow (continued)

Pair	Site#	Oilcode	OPHIUROI	ORBINIID	RHYNCHOC	SPIONIDA	TELLINID	VENERIDA
1	13	O	0.019	0.000	0.371	0.002	0.000	0.000
1	14	C	0.172	0.024	0.002	0.035	0.974	0.173
2	16	O	0.043	0.403	0.332	0.129	0.070	0.079
2	15	C	0.847	0.248	0.045	0.155	0.094	0.000
3	17	O	0.051	0.067	1.987	0.288	0.559	0.000
3	18	C	0.039	0.452	0.014	0.095	0.591	2.340
4	25	O	0.292	0.258	0.043	0.109	0.894	0.000
4	26	C	0.058	0.022	0.354	0.200	0.123	0.000
	mean	O	0.101	0.182	0.683	0.132	0.381	0.020
	mean	C	0.279	0.187	0.104	0.121	0.445	0.628
	P		0.54	0.95	0.44	0.92	0.01	0.10

ACE 30287003

Eelgrass Bed

Pair	Site#	Oilcode	AMPHICTE	AMPHIPOD	ATELECYC	BIVALVIA	GLYCERID	GONIADID	LACUNIDA	LUCINIDA	LUMBRINE	MONTACUT	MYIDAE
1	13	O	0.004	0.021	0.000	0.009	0.000	0.000	0.000	0.000	0.000	0.204	0.000
1	14	C	0.001	0.008	0.010	0.014	0.000	0.000	0.000	0.005	0.000	0.017	0.000
2	16	O	0.039	0.129	0.753	0.224	0.007	0.219	0.002	0.000	0.001	0.027	0.000
2	15	C	0.000	0.004	0.259	0.003	0.000	0.000	0.000	0.000	0.000	0.008	0.000
3	17	O	0.226	0.090	0.119	0.016	0.245	0.191	0.504	1.268	0.222	0.051	0.000
3	18	C	0.424	0.276	0.044	0.034	0.003	0.143	0.137	0.000	0.714	0.031	0.002
4	25	O	0.229	0.032	0.000	0.011	0.247	0.336	0.322	1.288	0.000	0.110	4.060
4	26	C	0.099	0.080	0.363	0.013	0.924	0.269	0.140	0.260	0.128	0.137	0.077
	mean	O	0.124	0.068	0.218	0.065	0.125	0.187	0.207	0.639	0.056	0.098	1.015
	mean	C	0.131	0.092	0.169	0.016	0.232	0.103	0.069	0.066	0.211	0.048	0.020
	P		0.79	0.58	0.76	0.77	0.41	0.70	0.05	0.20	0.43	0.63	0.40

Eelgrass Bed (continued)

Pair	Site#	Oilcode	MYTILIDA	NEREIDAE	OPHELIID	ORBINIID	PHYLLODO	POLYNOID	RHYNCHOC	SPIONIDA	TELLINID	VENERIDA
1	13	O	0.002	0.000	0.006	0.000	0.005	0.068	0.005	0.002	0.000	0.000
1	14	C	0.000	0.003	0.007	0.000	0.000	0.035	0.155	0.001	0.000	0.000
2	16	O	1.080	0.203	0.044	0.003	0.150	0.101	0.042	0.012	2.014	0.040
2	15	C	0.001	0.076	0.001	0.000	0.097	0.088	0.003	0.001	0.000	0.000
3	17	O	1.882	1.039	0.272	0.000	1.077	0.065	0.154	0.453	0.229	5.155
3	18	C	0.022	0.343	0.083	0.238	0.000	0.009	0.082	0.075	0.171	3.943
4	25	O	11.082	0.448	0.144	0.312	0.001	0.015	0.095	0.686	1.057	16.811
4	26	C	3.710	0.447	0.601	0.221	0.421	0.043	0.191	0.413	1.805	1.253
	mean	O	3.511	0.423	0.117	0.079	0.308	0.062	0.074	0.288	0.825	5.502
	mean	C	0.933	0.217	0.173	0.115	0.130	0.044	0.108	0.123	0.494	1.299
	P		<0.01	0.27	0.64	0.67	0.68	0.66	0.72	<0.01	0.67	0.07

Abundance - 1991

Deep

Pair	Site#	Oilcode	AMPHARET	AMPHICTE	AMPHIPOD	BIVALVIA	CAECIDAE	CAPITELL	LUCINIDA	MALDANID	MYTILIDA	NEPHTYID
1	13	O	10.16	6.22	1.65	10.76	0.00	5.16	5.71	0.00	1.33	168.29
1	14	C	40.61	21.55	10.00	49.56	0.00	6.89	407.56	3.33	0.00	2.67
2	16	O	11.33	6.00	57.33	4.67	149.33	54.67	33.33	13.33	7.33	0.00
2	15	C	86.23	7.71	36.83	62.99	1.14	6.89	12.19	11.17	0.00	2.60
3	17	O	0.89	81.33	109.77	11.56	0.00	13.33	14.22	35.78	101.28	0.83
3	18	C	9.33	32.00	114.67	10.83	0.00	96.83	90.00	4.00	0.67	4.83
4	25	O	19.73	12.53	44.80	18.67	0.00	12.27	116.00	57.07	11.20	3.00
4	26	C	12.13	41.27	43.24	8.19	51.37	49.43	61.30	35.43	33.27	0.89
	mean	O	10.53	26.52	53.39	11.41	37.33	21.36	42.32	26.54	30.29	43.03
	mean	C	37.08	25.63	51.18	32.89	13.13	40.01	142.76	13.48	8.48	2.75
	P		0.58	0.95	0.87	0.24	0.25	0.18	0.75	0.06	0.17	0.55

Deep (Continued)

Pair	Site#	Oilcode	OPHELIID	OPHIUROI	ROSSOIDA	SIGALION	SPIONIDA	SPIRORBI	SYLLIDAE	TELLINID	THYASIRI
1	13	O	47.14	0.00	4.89	0.00	2.16	0.00	0.89	1.52	12.19
1	14	C	8.89	4.00	31.33	0.89	247.94	1.67	4.00	122.39	65.78
2	16	O	8.00	30.67	97.33	56.67	78.00	72.67	30.67	5.33	0.00
2	15	C	18.35	22.86	51.94	121.38	37.73	192.75	13.65	0.00	0.89
3	17	O	84.44	7.11	0.00	1.33	542.22	5.33	206.89	8.45	1.33
3	18	C	505.50	8.67	19.33	12.67	81.17	25.00	19.17	91.33	206.67
4	25	O	69.07	2.40	0.00	1.33	341.33	0.00	49.07	44.80	29.33
4	26	C	101.81	27.30	1.27	12.57	145.75	27.55	142.13	23.59	1.78
	mean	O	52.16	10.04	25.56	14.83	240.93	19.50	71.88	15.03	10.71
	mean	C	158.64	15.71	25.97	36.88	128.15	61.74	44.74	59.33	68.78
	P		0.17	0.31	0.68	0.76	0.08	0.34	0.56	0.85	0.79

Eelgrass Bed

Pair	Site#	Oilcode	AMPHICTE	AMPHIPOD	BIVALVIA	CAPITELL	CAPRELLI	GASTROPO	LACUNIDA	MONTACUT	MYTILIDA	OPHELIID
1	13	O	18.22	6.67	275.11	7.33	0.00	369.11	0.00	287.33	37.56	145.33
1	14	C	18.67	6.40	26.67	200.70	47.47	95.20	0.00	53.07	5.87	24.00
2	16	O	22.89	65.33	135.11	29.33	257.33	273.56	36.00	142.00	514.45	413.72
2	15	C	2.67	67.11	28.89	5.33	93.33	148.89	1.33	61.78	5.78	172.45
3	17	O	52.30	72.71	11.11	26.02	65.09	91.35	228.05	35.73	789.32	616.12
3	18	C	78.28	606.00	56.64	34.70	557.65	189.81	253.87	38.00	189.59	1159.21
4	25	O	23.55	101.33	33.33	160.89	904.00	23.55	55.56	132.89	700.00	276.44
4	26	C	57.33	89.77	134.67	131.56	557.33	109.78	242.67	82.67	4656.44	391.72
5	35	O	6.67	162.67	22.67	6.67	116.00	61.33	0.00	538.67	24.00	144.00
5	34	C	4.55	39.55	7.78	80.56	215.33	151.67	14.67	49.22	10.33	86.22
	mean	O	24.73	81.74	95.47	46.05	268.48	163.78	63.92	227.32	413.06	319.12
	mean	C	32.30	161.77	50.93	90.57	294.22	139.07	102.51	56.95	973.60	366.72
	P		0.92	0.23	0.71	0.87	0.78	0.98	0.19	0.61	0.39	0.96

ACE 30287005

Eelgrass Bed (Continued)

Pair	Site#	Oilcode	PHOXOCEP	POLYNOID	ROSSOIDA	SPIONIDA	SPIRORBI	SYLLIDAE	TELLINID	TROCHIDA
1	13	O	0.00	17.78	233.33	6.22	196.89	2.22	8.89	20.00
1	14	C	0.00	227.20	24.80	27.20	95.73	56.80	5.50	100.53
2	16	O	0.00	31.33	59.33	31.55	291.78	57.56	7.55	34.67
2	15	C	0.00	93.78	5.33	20.00	376.44	237.78	0.00	13.78
3	17	O	7.43	1.38	2.00	426.40	382.38	4.05	50.79	2.38
3	18	C	129.78	17.43	180.45	217.97	0.00	19.36	123.81	0.00
4	25	O	13.33	8.00	1.33	429.11	42.67	49.78	163.11	0.00
4	26	C	4.45	9.33	118.22	432.44	272.89	42.22	143.11	91.11
5	35	O	0.00	41.33	4.00	8.00	178.67	36.00	0.00	38.67
5	34	C	0.00	128.22	36.28	29.22	385.17	411.33	0.89	98.00
	mean	O	4.15	19.96	60.00	180.26	218.48	29.92	46.07	19.14
	mean	C	26.84	95.19	73.02	145.37	226.05	153.50	54.66	60.68
	P		0.16	0.85	0.47	0.47	0.92	0.57	0.79	<0.01

Biomass - 1991

Deep

Pair	Site#	Oilcode	AMPHICTE	AMPHIPOD	BIVALVIA	CARDIIDA	CHAETOPT	LEPETIDA	UNGULINI	GLYCERID	GLYCYMER	GONIADID	LUCINID
1	13	O	0.196	0.001	0.076	0.001	0.000	0.000	0.000	0.000	0.000	0.066	0.170
1	14	C	0.034	0.006	0.231	0.009	0.007	0.000	0.000	0.000	0.000	0.063	9.966
2	16	O	0.019	0.214	0.007	1.116	0.000	0.032	0.000	0.239	0.000	0.024	0.573
2	15	C	0.093	0.040	0.302	0.000	0.000	0.003	0.000	0.003	0.000	0.001	0.521
3	17	O	0.177	0.204	2.890	0.000	0.684	0.000	0.057	0.043	0.189	0.029	0.099
3	18	C	0.529	0.176	0.010	0.604	0.000	1.135	0.000	0.000	0.000	0.209	2.303
4	25	O	0.406	0.110	0.009	0.000	0.483	0.000	0.565	0.061	1.018	0.036	1.358
4	26	C	0.062	0.054	0.031	0.000	0.205	0.085	1.001	0.070	0.029	0.081	0.482
	mean	O	0.200	0.132	0.746	0.279	0.292	0.008	0.155	0.086	0.302	0.039	0.550
	mean	C	0.179	0.069	0.143	0.153	0.053	0.306	0.250	0.018	0.007	0.088	3.318
	P		0.56	0.13	0.80	0.98	0.41	0.33	0.46	0.57	0.30	0.39	0.76

Deep (Continued)

Pair	Site#	Oilcode	LUMBRINE	MYTILIDA	NEPHTYID	OLIVIDAE	ORBINIID	RHYNCHOC	SPIONIDA	TELLINID	THYASIRI	VENERIDA
1	13	O	0.000	0.001	0.429	0.000	0.000	0.187	0.011	0.387	0.098	0.000
1	14	C	0.029	0.000	0.385	0.000	0.004	0.093	0.233	8.739	0.392	0.040
2	16	O	0.419	0.051	0.000	0.000	0.062	0.961	0.120	0.009	0.000	0.019
2	15	C	0.132	0.000	0.004	0.000	0.049	0.087	0.042	0.000	0.012	0.000
3	17	O	0.000	2.667	0.718	1.492	0.004	0.289	0.285	0.132	0.017	0.005
3	18	C	0.063	0.001	1.545	0.284	0.584	0.062	0.062	5.756	0.967	0.204
4	25	O	0.196	0.017	0.444	1.021	0.006	0.168	0.186	0.657	0.195	0.079
4	26	C	0.095	0.184	0.008	0.823	0.064	0.085	0.078	0.768	0.021	0.004
	mean	O	0.154	0.684	0.398	0.628	0.018	0.401	0.151	0.296	0.077	0.026
	mean	C	0.080	0.046	0.486	0.277	0.175	0.082	0.104	3.816	0.348	0.062
	P		0.55	0.18	0.47	0.47	0.09	0.19	0.08	0.77	0.80	0.46

ACE 30287006

Eelgrass Bed

Pair	Site#	Oilcode	AMPHICTE	AMPHIPOD	ATELECYC	BIVALVIA	GLYCERID	GONIADID	LACUNIDA	LUCINIDA	LUMBRINE	MONTACUT	MYIDAE
1	13	O	0.021	0.003	0.000	0.125	0.000	0.011	0.000	0.000	0.000	0.284	0.000
1	14	C	0.153	0.008	0.000	0.300	0.000	0.119	0.000	0.143	0.000	0.066	0.000
2	16	O	0.061	0.063	1.083	0.101	0.330	0.060	0.025	0.000	0.000	0.108	0.000
2	15	C	0.001	0.053	0.000	0.008	0.000	0.136	0.001	0.000	0.000	0.028	0.000
3	17	O	0.378	0.150	0.000	0.003	0.139	0.123	0.194	0.874	0.107	0.047	0.000
3	18	C	0.439	0.516	0.000	0.035	0.000	0.266	0.275	0.000	1.163	0.019	0.053
4	25	O	0.077	0.060	0.209	0.055	0.080	0.285	0.016	1.160	0.000	0.138	2.844
4	26	C	0.024	0.061	1.560	1.078	0.064	0.057	0.202	0.598	0.582	0.037	0.860
5	35	O	0.001	0.105	0.000	0.036	0.000	0.005	0.000	0.103	0.001	0.739	0.000
5	34	C	0.001	0.080	1.644	0.029	0.000	0.034	0.008	0.000	0.000	0.058	0.000
	mean	O	0.108	0.076	0.258	0.064	0.110	0.097	0.047	0.427	0.022	0.263	0.569
	mean	C	0.124	0.143	0.641	0.290	0.013	0.122	0.097	0.148	0.349	0.042	0.183
	P		0.44	0.18	0.79	0.60	0.52	0.83	0.03	0.51	0.01	0.65	0.78

Eelgrass Bed (Continued)

Pair	Site#	Oilcode	MYTILIDA	NEREIDAE	OPHELIID	ORBINIID	PHYLLODO	POLYNOID	RHYNCHOC	SPIONIDA	TELLINID	VENERIDA
1	13	O	0.049	0.032	0.055	0.000	0.024	0.101	0.012	0.006	0.346	0.000
1	14	C	0.010	0.072	0.013	0.000	0.001	0.490	0.380	0.025	1.183	0.000
2	16	O	1.920	0.397	0.409	0.381	0.020	0.318	0.050	0.042	0.542	0.011
2	15	C	0.001	0.055	0.030	0.000	0.159	0.342	0.376	0.025	0.000	0.000
3	17	O	4.668	0.123	0.567	0.114	0.029	0.026	0.037	1.311	0.188	0.195
3	18	C	0.132	0.324	0.612	0.402	0.006	0.136	0.760	0.443	0.288	8.137
4	25	O	5.675	0.516	0.828	0.587	0.046	0.075	0.029	0.673	0.823	17.119
4	26	C	19.069	0.078	0.202	0.910	0.118	0.069	0.655	0.266	1.900	5.765
5	35	O	0.160	0.127	0.050	0.049	0.001	0.229	0.693	0.009	0.000	0.000
5	34	C	0.019	0.352	0.058	0.000	0.000	0.581	0.002	0.025	0.050	0.000
	mean	O	2.495	0.239	0.382	0.226	0.024	0.150	0.165	0.408	0.380	3.465
	mean	C	3.846	0.176	0.183	0.262	0.057	0.324	0.435	0.157	0.684	2.780
	P		0.47	0.03	0.24	0.92	0.10	0.85	0.045	0.16	0.22	0.03

ACE 30287007

APPENDIX N.

Mean values for community parameters of dominant epifaunal invertebrate families that were sampled by dropnet at oiled and control sites in the eelgrass habitat in 1990. Also given are probabilities that the means from the oiled and control sites were similar as determined by randomization tests.

Appendix N. Mean values for community parameters of dominant epifaunal invertebrate families that were sampled by dropnet at oiled and control sites in the eelgrass habitat in 1990. Also given are probabilities that the means from the oiled anc control sites were similar as determined by randomization tests.

Abundance ($\#/m^2$)

Pair	Site#	Oilcode	AMPHIPOD	BIVALVIA	CAPRELLI	COROPHII	GASTROPO	HIPPOLYT	ISCHYROC	LACUNIDA	MONTACUT
1	13	O	0.52	146.76	1.32	5.68	34.35	0.00	0.52	24.98	160.00
1	14	C	8.33	15.61	65.31	0.00	0.00	2.08	2.08	4.16	5.20
2	16	O	0.00	0.00	111.89	2.60	2.60	11.97	8.33	355.97	0.00
2	15	C	0.00	6.25	12.49	14.05	69.32	1.41	3.12	197.66	9.37
3	17	O	0.00	0.00	0.00	0.00	12.49	0.00	0.00	1192.82	3.12
3	18	C	0.00	1.04	77.57	3.12	9.63	6.32	87.07	516.45	0.00
4	25	O	0.00	0.00	48.71	0.00	4.16	21.86	17.90	183.40	0.00
4	26	C	0.00	3.12	63.49	0.00	0.00	10.41	11.45	562.06	0.00
	mean	O	0.13	36.69	40.48	2.07	13.40	8.46	6.69	439.29	40.78
	mean	C	2.08	6.51	54.72	4.29	19.74	5.05	25.93	320.08	3.64
	P										

Abundance (continued)

Pair	Site#	Oilcode	MYTILIDA	NEREIDAE	ONCHIDOR	POLYNOID	RISSOIDA	SPIRORBI	SYLLIDAE	TROCHIDA	TOTAL
1	13	O	54.15	1.85	0.00	82.92	37.44	169.23	0.00	70.29	1299.48
1	14	C	9.37	18.74	0.00	33.31	3.12	258.13	5.20	189.44	662.89
2	16	O	623.99	2.08	22.38	5.72	0.00	466.30	0.00	98.88	1743.95
2	15	C	6.87	3.12	2.50	57.46	7.18	768.15	16.86	121.47	1435.75
3	17	O	145.10	0.00	32.47	0.00	5.62	274.16	0.00	0.00	1684.73
3	18	C	43.46	0.00	7.83	0.00	4.68	0.00	0.00	0.00	804.74
4	25	O	1169.29	1.25	5.20	0.00	1.25	345.36	0.00	3.12	1813.58
4	26	C	1057.51	3.12	0.00	0.00	0.00	256.05	6.25	70.78	2082.88
	mean	O	498.13	1.30	15.01	22.16	11.08	313.76	0.00	43.07	1635.43
	mean	C	279.30	6.25	2.58	22.69	3.75	320.58	7.08	95.42	1246.56
	P										

ACE 30287009

Biomass (gm/μm^2)

Pair	Site#	Oilcode	AMPHIPOD	CAPRELLI	COROPHII	GASTROPO	HIPPOLYT	ISCHYROC	LACUNIDA	MONTACUT	MYTILIDA
1	13	O	0.001	0.001	0.008	0.010	0.000	0.001	0.112	0.589	0.204
1	14	C	0.006	0.020	0.000	0.009	0.241	0.001	0.007	0.008	0.020
2	16	O	0.002	0.028	0.003	0.004	0.450	0.004	0.384	0.000	5.251
2	15	C	0.000	0.006	0.009	0.041	0.399	0.003	0.480	0.025	0.014
3	17	O	0.000	0.000	0.000	0.009	0.000	0.000	2.318	0.002	1.065
3	18	C	0.000	0.048	0.006	0.017	0.112	0.064	0.868	0.000	0.271
4	25	O	0.002	0.025	0.000	0.002	0.323	0.006	0.704	0.000	24.124
4	26	C	0.002	0.036	0.000	0.005	0.582	0.005	1.258	0.000	27.380
	mean	O	0.001	0.013	0.003	0.006	0.193	0.003	0.879	0.148	7.661
	mean	C	0.002	0.027	0.004	0.018	0.333	0.018	0.653	0.008	6.921
	P										

Biomass (continued)

Pair	Site#	Oilcode	NEREIDAE	ONCHIDOR	PLEUSTID	POLYNOID	RISSOIDA	SPIRORBI	TROCHIDA	TOTAL
1	13	O	0.017	0.000	0.002	0.183	0.072	0.017	0.186	3.493
1	14	C	0.180	0.000	1.194	0.044	0.005	0.023	0.465	2.352
2	16	O	0.002	0.049	0.000	0.006	0.000	0.026	0.097	7.709
2	15	C	0.002	0.012	0.000	0.174	0.011	0.042	0.382	4.269
3	17	O	0.000	0.057	0.041	0.000	0.010	0.038	0.000	4.148
3	18	C	0.000	0.009	0.023	0.000	0.005	0.000	0.000	2.263
4	25	O	0.003	0.005	0.000	0.000	0.003	0.006	0.184	25.437
4	26	C	0.021	0.000	0.018	0.000	0.000	0.009	0.187	30.781
	mean	O	0.005	0.028	0.011	0.047	0.021	0.022	0.117	10.197
	mean	C	0.051	0.005	0.309	0.054	0.005	0.019	0.259	9.916
	P									

ACE 30287010

APPENDIX O.

Mean values for abundance and biomass of dominant epifaunal invertebrate families that were sampled by dropnet at oiled and control sites in the eelgrass habitat in 1990. Also given are probabilities that the means from the oiled and control sites were similar as determined by randomization tests.

Appendix O. Mean values for abundance and biomass of dominant epifaunal invertebrate families that were sampled by dropnet at oiled and control sites in the eelgrass habitat in 1990. Also given are probabilities that the means from the oiled and control sites were similar as determined by randomization tests.

Abundance (#/m^2) - 1990

Pair	Site#	Oilcode	AMPHIPOD	BIVALVIA	CAPRELLI	COROPHII	GASTROPO	HIPPOLYT	ISCHYROC	LACUNIDA	MONTACUT
1	13	O	0.52	146.76	1.32	5.68	34.35	0.00	0.52	24.98	160.00
1	14	C	8.33	15.61	65.31	0.00	0.00	2.08	2.08	4.16	5.20
2	16	O	0.00	0.00	111.89	2.60	2.60	11.97	8.33	355.97	0.00
2	15	C	0.00	6.25	12.49	14.05	69.32	1.41	3.12	197.66	9.37
3	17	O	0.00	0.00	0.00	0.00	12.49	0.00	0.00	1192.82	3.12
3	18	C	0.00	1.04	77.57	3.12	9.63	6.32	87.07	516.45	0.00
4	25	O	0.00	0.00	48.71	0.00	4.16	21.86	17.90	183.40	0.00
4	26	C	0.00	3.12	63.49	0.00	0.00	10.41	11.45	562.06	0.00
	mean	O	0.13	36.69	40.48	2.07	13.40	8.46	6.69	439.29	40.78
	mean	C	2.08	6.51	54.72	4.29	19.74	5.05	25.93	320.08	3.64
	P		0.12	0.97	0.55	0.46	0.93	0.39	0.19	0.46	0.30

Abundance (#/m^2) - 1990 (continued)

Pair	Site#	Oilcode	MYTILIDA	NEREIDAE	ONCHIDOR	POLYNOID	RISSOIDA	SPIRORBI	SYLLIDAE	TROCHIDA	TOTAL
1	13	O	54.15	1.85	0.00	82.92	37.44	169.23	0.00	70.29	1299.48
1	14	C	9.37	18.74	0.00	33.31	3.12	258.13	5.20	189.44	662.89
2	16	O	623.99	2.08	22.38	5.72	0.00	466.30	0.00	98.88	1743.95
2	15	C	6.87	3.12	2.50	57.46	7.18	768.15	16.86	121.47	1435.75
3	17	O	145.10	0.00	32.47	0.00	5.62	274.16	0.00	0.00	1684.73
3	18	C	43.46	0.00	7.83	0.00	4.68	0.00	0.00	0.00	804.74
4	25	O	1169.29	1.25	5.20	0.00	1.25	345.36	0.00	3.12	1813.58
4	26	C	1057.51	3.12	0.00	0.00	0.00	256.05	6.25	70.78	2082.88
	mean	O	498.13	1.30	15.01	22.16	11.08	313.76	0.00	43.07	1635.43
	mean	C	279.30	6.25	2.58	22.69	3.75	320.58	7.08	95.42	1246.56
	P		0.34	0.08	<0.01	0.88	0.37	0.97	<0.01	0.15	0.33

ACE 30287012

Biomass (gm/m^2) - 1990

Pair	Site#	Oilcode	AMPHIPOD	CAPRELLI	COROPHII	GASTROPO	HIPPOLYT	ISCHYROC	LACUNIDA	MONTACUT	MYTILIDA
1	13	O	0.001	0.001	0.008	0.010	0.000	0.001	0.112	0.589	0.204
1	14	C	0.006	0.020	0.000	0.009	0.241	0.001	0.007	0.008	0.020
2	16	O	0.002	0.028	0.003	0.004	0.450	0.004	0.384	0.000	5.251
2	15	C	0.000	0.006	0.009	0.041	0.399	0.003	0.480	0.025	0.014
3	17	O	0.000	0.000	0.000	0.009	0.000	0.000	2.318	0.002	1.065
3	18	C	0.000	0.048	0.006	0.017	0.112	0.064	0.868	0.000	0.271
4	25	O	0.002	0.025	0.000	0.002	0.323	0.006	0.704	0.000	24.124
4	26	C	0.002	0.036	0.000	0.005	0.582	0.005	1.258	0.000	27.380
	mean	O	0.001	0.013	0.003	0.006	0.193	0.003	0.879	0.148	7.661
	mean	C	0.002	0.027	0.004	0.018	0.333	0.018	0.653	0.008	6.921
	P		0.03	0.19	0.75	0.30	0.42	0.17	0.44	0.18	0.89

Biomass (gm/m^2) - 1990 (continued)

Pair	Site#	Oilcode	NEREIDAE	ONCHIDOR	PLEUSTID	POLYNOID	RISSOIDA	SPIRORBI	TROCHIDA	TOTAL
1	13	O	0.017	0.000	0.002	0.183	0.072	0.017	0.186	3.493
1	14	C	0.180	0.000	1.194	0.044	0.005	0.023	0.465	2.352
2	16	O	0.002	0.049	0.000	0.006	0.000	0.026	0.097	7.709
2	15	C	0.002	0.012	0.000	0.174	0.011	0.042	0.382	4.269
3	17	O	0.000	0.057	0.041	0.000	0.010	0.038	0.000	4.148
3	18	C	0.000	0.009	0.023	0.000	0.005	0.000	0.000	2.263
4	25	O	0.003	0.005	0.000	0.000	0.003	0.006	0.184	25.437
4	26	C	0.021	0.000	0.018	0.000	0.000	0.009	0.187	30.781
	mean	O	0.005	0.028	0.011	0.047	0.021	0.022	0.117	10.197
	mean	C	0.051	0.005	0.309	0.054	0.005	0.019	0.259	9.916
	P		0.04	0.05	0.47	0.72	0.39	0.74	0.11	0.97

ACE 30287013

APPENDIX P.

Mean values and results of 2 way randomization ANOVAs comparing community parameters for invertebrates that were sampled by suction dredge at oiled and control sites in the eelgrass habitat in 1990 and 1991.

Appendix P. Mean values and results of 2-way randomization ANOVAs comparing community parameters for invertebrates that were sampled by suction dredge at oiled and control sites in the eelgrass habitat in 1990 and 1991. All taxa were used at the family level or higher. Only sites sampled both years were used for analyses.

Deep

Year		Oil Code	Shannon-Weiner	Simpson	Families	Total Individuals	Total Biomass	Species Richness
1990	Mean	(O)	2.33	0.24	40	592	6.981	6.105
1990	Mean	(C)	2.71	0.12	43	812	9.894	6.321
1991	Mean	(O)	2.54	0.21	45	1075	8.199	6.343
1991	Mean	(C)	2.74	0.15	55	1297	14.475	7.602
Oilcode		P	0.08	0.03	0.13	0.11	0.06	0.20
Year		P	0.45	0.97	0.02	<0.01	0.25	0.19
Interaction		P	0.61	0.44	0.13	1.00	0.55	0.36

Bed

Year		Site Code	Shannon-Weiner	Simpson	Families	Total Individuals	Total Biomass	Species Richness
1990	Mean	(O)	2.20	0.18	37	1884	16.295	4.777
1990	Mean	(C)	2.29	0.17	30	975	6.309	4.357
1991	Mean	(O)	2.31	0.16	43	2819	14.443	5.261
1991	Mean	(C)	2.31	0.19	45	3670	15.708	5.433
Oilcode		P	0.06	0.02	0.14	0.10	0.07	0.18
Year		P	0.45	0.98	0.04	<0.01	0.25	0.16
Interaction		P	0.58	0.42	0.38	0.99	0.54	0.35

ACE 30287015

APPENDIX Q.

Mean values and results of 2 way randomization ANOVAs comparing abundance and biomass of invertebrates that were sampled by suction dredge at oiled and control sites in the eelgrass habitat in 1990 and 1991.

Appendix Q. Mean values and results of 2-way randomization ANOVAs comparing abundance and biomass of invertebrates that were sampled by suction dredge at oiled and control sites in the eelgrass habitat in 1990 and 1991. Densities are #/0.1m^2 and biomass units are grams/0.1m^2.

Abundance

Deep

Year		Oilcode	AMPHARET	AMPHICTE	AMPHIPOD	BIVALVIA	CAECIDAE	CAPITELL	LUCINIDA	MALDANID	MYTILIDA	NEPHTYID
1990	mean	O	4.47	18.70	19.00	5.53	8.78	7.04	79.62	14.42	37.32	48.58
1990	mean	C	9.72	20.48	46.76	37.08	17.64	30.82	47.52	11.98	7.47	3.93
1991	mean	O	10.53	26.52	53.39	11.41	37.33	21.36	42.32	26.54	30.29	43.03
1991	mean	C	37.08	25.63	51.18	32.89	13.13	40.01	142.76	13.48	8.48	2.75
Oilcode		P	0.73	0.90	0.78	0.21	0.04	0.03	0.16	<0.01	0.02	0.09
Year		P	0.66	0.90	0.08	0.60	0.07	0.55	0.55	0.08	0.78	0.88
Interaction		P	0.49	0.86	0.12	0.61	0.99	0.99	0.16	0.97	0.76	0.69

Deep (continued)

Year		Oilcode	OPHELIID	OPHIUROI	ROSSOIDA	SIGALION	SPIONIDA	SPIRORBI	SYLLIDAE	TELLINID	THYASIRI
1990	mean	O	20.79	6.33	6.10	2.42	83.69	18.88	21.15	17.01	14.57
1990	mean	C	56.76	19.14	3.43	16.58	99.70	25.76	21.00	61.88	48.58
1991	mean	O	52.16	10.04	25.56	14.83	240.93	19.50	71.88	15.03	10.71
1991	mean	C	158.64	15.71	25.97	36.88	128.15	61.74	44.74	59.33	68.78
Oilcode		P	0.10	0.72	0.86	0.68	0.17	0.25	0.49	0.53	0.53
Year		P	0.48	0.04	<0.01	0.10	0.22	0.56	0.06	0.46	0.69
Interaction		P	0.94	0.24	0.44	0.61	0.28	0.57	0.72	0.41	0.85

Eelgrass Bed

Year		Oilcode	AMPHICTE	AMPHIPOD	BIVALVIA	CAPITELL	CAPRELLI	GASTROPO	LACUNIDA	MONTACUT	MYTILIDA	OPHELIID
1990	mean	O	51.60	27.27	47.83	38.08	97.04	151.95	115.26	72.17	285.81	104.45
1990	mean	C	30.31	74.76	31.00	23.72	93.08	46.06	56.83	38.32	47.04	78.15
1991	mean	O	29.24	61.51	113.67	55.89	306.61	189.39	79.90	149.49	510.33	362.90
1991	mean	C	39.24	192.32	61.71	93.07	313.95	135.92	124.47	58.88	1214.42	436.84
Oilcode		P	0.56	<0.01	0.12	0.92	0.76	0.78	0.92	0.90	0.54	0.83
Year		P	0.03	0.30	0.95	0.06	0.02	0.78	0.34	0.71	0.01	<0.01
Interaction		P	0.51	0.90	0.65	0.42	0.92	0.25	0.04	0.24	0.31	0.92

Eelgrass Bed (continued)

Year		Oilcode	PHOXOCEP	POLYNOID	ROSSOIDA	SPIONIDA	SPIRORBI	SYLLIDAE	TELLINID	TROCHIDA
1990	mean	O	0.83	20.47	14.68	300.60	290.49	45.09	57.29	0.00
1990	mean	C	34.83	14.39	5.60	179.84	83.17	9.54	55.33	7.79
1991	mean	O	5.19	14.62	74.00	223.32	228.43	28.40	57.59	14.26
1991	mean	C	33.56	86.93	82.20	174.40	186.27	89.04	68.11	51.36
Oilcode		P	<0.01	0.73	0.33	0.08	0.02	0.59	0.94	0.05
Year		P	0.52	0.65	0.52	0.36	0.72	0.57	0.36	<0.01
Interaction		P	0.36	0.96	0.09	0.75	0.12	0.72	0.92	0.24

Biomass

Deep

Year		Oilcode	AMPHICTE	AMPHIPOD	BIVALVIA	CARDIIDA	CHAETOPT	CRYPTOBR	DIPLODON	GLYCERID	GLYCYMER	GONIADID	LUCINID
1990	mean	O	0.078	0.051	0.087	0.000	0.073	0.000	0.143	0.007	0.001	0.018	1.057
1990	mean	C	0.034	0.081	1.440	0.506	0.000	0.023	0.000	0.316	0.000	0.125	1.667
1991	mean	O	0.200	0.132	0.746	0.279	0.292	0.008	0.155	0.086	0.302	0.039	0.550
1991	mean	C	0.179	0.069	0.143	0.153	0.053	0.306	0.250	0.018	0.007	0.088	3.318
Oilcode		P	0.61	0.32	0.46	0.25	0.43	0.13	0.94	0.87	0.71	0.046	0.61
Year		P	0.92	0.21	0.46	0.76	0.40	0.36	0.39	0.87	0.58	0.44	0.71
Interaction		P	0.54	0.24	<0.01	0.18	0.58	0.65	0.39	0.64	0.74	0.31	0.45

Deep (continued)

Year		Oilcode	LUMBRINE	MYTILIDA	NEPHTYID	OLIVIDAE	ORBINIID	RHYNCHOC	SPIONIDA	TELLINID	THYASIRI	VENERIDA
1990	mean	O	0.182	0.311	0.125	1.552	0.040	0.477	0.069	0.246	0.069	0.587
1990	mean	C	0.336	0.064	0.016	0.151	0.126	0.186	0.076	0.645	0.271	1.472
1991	mean	O	0.154	0.684	0.398	0.628	0.018	0.401	0.151	0.296	0.077	0.026
1991	mean	C	0.080	0.046	0.486	0.277	0.175	0.082	0.104	3.816	0.348	0.062
Oilcode		P	0.39	0.03	0.89	0.64	0.03	0.12	0.21	0.57	0.44	<0.01
Year		P	0.03	0.49	0.80	0.81	0.58	0.44	0.37	0.81	0.67	<0.01
Interaction		P	0.11	0.40	0.19	0.74	0.76	0.79	0.41	0.91	0.77	<0.01

Eelgrass Bed

Year		Oilcode	AMPHICTE	AMPHIPOD	ATELECYC	BIVALVIA	GLYCERID	GONIADID	LACUNIDA	LUCINIDA	LUMBRINE	MONTACUT	MYIDAE
1990	mean	O	0.124	0.068	0.218	0.065	0.125	0.187	0.207	0.639	0.056	0.098	1.015
1990	mean	C	0.131	0.092	0.169	0.016	0.232	0.103	0.069	0.066	0.211	0.048	0.020
1991	mean	O	0.134	0.069	0.323	0.071	0.137	0.120	0.059	0.509	0.027	0.144	0.711
1991	mean	C	0.154	0.159	0.390	0.355	0.016	0.145	0.119	0.185	0.436	0.038	0.228
Oilcode		P	0.80	0.05	0.77	0.60	0.61	0.62	0.47	0.12	0.04	0.67	0.35
Year		P	0.52	0.84	0.53	0.31	0.08	0.31	0.57	0.68	0.67	0.50	0.99
Interaction		P	0.38	0.60	0.82	0.09	0.11	0.99	0.010	0.54	0.49	0.19	0.59

Eelgrass Bed (continued)

Year		Oilcode	MYTILIDA	NEREIDAE	OPHELIID	ORBINIID	PHYLLODO	POLYNOID	RHYNCHOC	SPIONIDA	TELLINID	VENERIDA
1990	mean	O	3.511	0.423	0.117	0.079	0.308	0.062	0.074	0.288	0.825	5.502
1990	mean	C	0.933	0.217	0.173	0.115	0.130	0.044	0.108	0.123	0.494	1.299
1991	mean	O	3.078	0.267	0.465	0.271	0.030	0.130	0.032	0.508	0.475	4.331
1991	mean	C	4.803	0.132	0.214	0.328	0.071	0.259	0.543	0.190	0.843	3.475
Oilcode		P	0.81	0.16	0.50	0.80	0.93	0.83	0.13	<0.01	0.95	0.01
Year		P	0.20	0.13	0.39	0.23	0.44	0.28	0.57	0.45	0.85	0.98
Interaction		P	0.10	0.85	0.11	0.99	0.51	0.68	0.24	0.66	0.91	0.51

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APPENDIX R.

Mean values for community parameters of dominant invertebrate families that were sampled by suction dredge at oiled and control sites in the *Laminaria/Agarum* bay habitat in 1990 and 1991. Also given are probabilities that the means from the oiled and control sites were similar as determined by randomization tests.

Appendix R. Mean values for community parameters of dominant invertebrate families that were sampled by suction dredge at oiled and control sites in the *Laminaria/Agarum* bay habitat in 1990 and 1991. Also given are probabilities that the means from the oiled and control sites were similar as determined by randomization tests. All infauna taxa were used at the family level and higher.

Deep - 1990

Site	Site Code	Shannon-Weiner	Simpson	Families	Total Individuals	Total Biomass	Species Richness
Northwest Bay	2 (O)	3.23	0.06	50	450	6.421	8.213
Cabin Bay	1 (C)	2.29	0.18	26	210	2.479	4.708
Herring Bay	3 (O)	3.40	0.05	51	815	4.149	7.558
L. Herring Bay	4 (C)	2.97	0.10	59	933	7.697	8.505
Bay of Isles	6 (O)	2.93	0.08	48	773	7.338	7.119
Mummy Bay	5 (C)	2.91	0.10	56	1111	6.884	7.832
Mean	(O)	3.19	0.06	50	679	5.969	7.630
Mean	(C)	2.72	0.13	47	752	5.687	7.015
	P	0.02	<0.01	0.66	0.61	0.85	0.58

Shallow - 1990

Site	Site Code	Shannon-Weiner	Simpson	Families	Total Individuals	Total Biomass	Species Richness
Northwest Bay	2 (O)	2.57	0.18	49	801	5.620	7.238
Cabin Bay	1 (C)	2.59	0.12	32	741	2.304	4.744
Herring Bay	3 (O)	2.45	0.18	43	1361	6.392	5.940
L. Herring Bay	4 (C)	2.65	0.12	37	626	3.671	5.649
Bay of Isles	6 (O)	2.85	0.11	50	1003	13.325	7.172
Mummy Bay	5 (C)	2.51	0.16	42	849	4.481	6.038
Mean	(O)	2.62	0.16	47	1055	8.446	6.783
Mean	(C)	2.59	0.13	37	739	3.485	5.477
	P	0.80	0.44	0.01	0.12	0.03	0.02

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Appendix R. (continued)

Deep - 1991

Site	Site Code	Shannon-Weiner	Simpson	Families	Total Individuals	Total Biomass	Species Richness
Northwest Bay	2 (O)	3.17	0.07	53	723	11.387	7.978
Cabin Bay	1 (C)	2.99	0.07	42	657	5.608	6.290
Herring Bay	3 (O)	3.40	0.05	62	1288	6.244	8.577
L. Herring Bay	4 (C)	3.07	0.07	46	757	11.088	6.921
Bay of Isles	6 (O)	3.10	0.08	62	1441	8.151	8.341
Mummy Bay	5 (C)	2.90	0.10	67	2124	9.013	8.611
Mean	(O)	3.22	0.07	59	1151	8.594	8.299
Mean	(C)	2.98	0.08	51	1179	8.569	7.274
	P	0.06	0.07	0.26	0.91	0.99	0.20

Shallow - 1991

Site	Site Code	Shannon-Weiner	Simpson	Families	Total Individuals	Total Biomass	Species Richness
Northwest Bay	2 (O)	2.77	0.12	54	1595	3.793	7.234
Cabin Bay	1 (C)	3.02	0.10	63	2063	16.210	8.095
Herring Bay	3 (O)	3.03	0.08	63	1912	7.205	8.171
L. Herring Bay	4 (C)	2.79	0.15	57	1427	7.190	7.701
Bay of Isles	6 (O)	2.96	0.10	75	3912	25.156	8.965
Mummy Bay	5 (C)	2.67	0.15	68	2903	14.639	8.391
Mean	(O)	2.92	0.10	64	2473	12.052	8.124
Mean	(C)	2.83	0.13	62	2131	12.680	8.062
	P	0.46	0.15	0.74	0.37	0.90	0.92

APPENDIX S.

Mean values for abundance and biomass of dominant invertebrate families that were sampled by suction dredge at oiled and control sites in the *Laminaria/Agarum* bay habitat in 1990 and 1991. Also given are probabilities that the means from the oiled and control sites were similar as determined by randomization tests.

Appendix S. Mean values for abundance and biomass of dominant invertebrate families that were sampled by suction dredge at oiled and control sites in the *Laminaria/Agarum* bay habitat in 1990 and 1991. Also given are probabilities that the means from the oiled and control sites were similar as determined by randomization tests.

Abundance (#/0.1m^2) - 1990

Deep

Pair	Site#	Oilcode	AMPHARET	AMPHICTE	AMPHIPOD	CAECIDAE	CAPITELL	CIRRATUL	DORVILLE	LEPIDOPL	LUCINIDA	LUMBRINE
1	2	O	9.47	1.33	17.44	28.00	13.06	53.98	11.81	22.12	1.87	20.42
1	1	C	0.17	1.50	1.78	2.00	15.56	4.45	2.17	2.67	51.94	8.11
2	3	O	4.00	0.00	166.67	84.00	21.33	13.33	33.33	30.67	18.67	8.00
2	4	C	0.53	1.63	61.16	135.65	19.26	3.56	30.87	15.08	79.23	10.52
3	6	O	1.33	2.67	23.33	98.00	11.11	1.78	37.56	29.33	92.22	13.06
3	5	C	6.84	2.53	39.86	273.65	10.89	11.11	56.69	63.73	66.49	18.92
	mean	O	4.93	1.33	69.15	70.00	15.17	23.03	27.57	27.37	37.59	13.83
	mean	C	2.52	1.89	34.27	137.10	15.23	6.37	29.91	27.16	65.89	12.52
	P		0.42	0.39	0.45	0.09	0.99	0.08	0.82	0.98	0.19	0.80

Deep (continued)

Pair	Site#	Oilcode	OPHELIID	OPHIUROI	PEISIDIC	PROTOMED	SERPULID	SIGALION	SPIONIDA	SPIRORBI	SYLLIDAE
1	2	O	0.00	10.53	38.87	1.33	6.11	12.72	23.48	2.33	10.33
1	1	C	0.00	0.00	9.50	0.00	5.50	0.00	5.56	16.28	1.33
2	3	O	0.00	33.33	16.00	78.67	0.00	49.33	33.33	2.67	24.00
2	4	C	0.00	93.81	13.96	15.62	30.70	42.40	160.03	35.38	4.45
3	6	O	20.67	60.00	29.50	2.67	3.22	62.00	25.78	42.39	5.89
3	5	C	0.00	97.98	53.45	2.67	39.30	49.19	81.01	10.40	52.61
	mean	O	6.89	34.62	28.12	27.56	3.11	41.35	27.53	15.80	13.41
	mean	C	0.00	63.93	25.63	6.09	25.17	30.53	82.20	20.69	19.46
	P		0.11	0.21	0.83	0.12	0.02	0.37	0.09	0.72	0.62

Shallow

Pair	Site#	Oilcode	AMPHARET	AMPHICTE	AMPHIPOD	AORIDAE_	BIVALVIA	CAECIDAE	CAPITELL	DORVILLE	GASTROPO	HIATELLI	LUCINID
1	2	O	2.31	7.07	6.93	0.00	6.45	8.62	34.57	6.09	34.80	5.50	14.92
1	1	C	1.33	4.00	45.67	4.00	42.67	0.00	35.17	10.67	56.00	0.00	4.00
2	3	O	0.00	12.89	57.78	0.00	28.00	28.89	95.11	33.78	21.78	0.45	278.67
2	4	C	0.00	3.55	55.11	13.33	6.67	5.78	32.00	5.33	5.33	0.89	36.89
3	6	O	0.00	31.20	36.53	4.27	5.87	21.33	40.53	25.60	28.53	0.53	61.07
3	5	C	1.87	8.53	22.93	0.00	4.53	135.20	54.13	16.00	8.27	0.00	74.40
	mean	O	0.77	17.05	33.75	1.42	13.44	19.61	56.74	21.82	28.37	2.16	118.22
	mean	C	1.07	5.36	41.24	5.78	17.96	46.99	40.43	10.67	23.20	0.30	38.43
	P		0.57	0.09	0.62	0.41	0.79	0.32	0.40	0.25	0.39	0.19	0.24

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Shallow (continued)

Pair	Site#	Oilcode	MONTACUT	OPHELIID	OPHIUROI	POLYNOID	ROSSOIDA	SIGALION	SPIONIDA	SPIRORBI	SYLLIDAE
1	2	O	11.56	3.91	9.96	1.78	30.35	19.11	345.68	47.04	13.89
1	1	C	70.67	56.00	16.00	0.00	40.00	12.00	165.50	47.17	17.50
2	3	O	48.89	7.55	21.78	31.55	24.00	14.67	442.22	71.56	17.33
2	4	C	26.67	11.56	35.11	21.78	76.89	33.33	143.56	37.72	11.56
3	6	O	9.87	27.47	15.60	54.93	27.20	79.47	125.60	190.97	1.87
3	5	C	5.07	5.60	24.00	6.93	14.67	9.60	290.40	46.93	6.40
	mean	O	23.44	12.98	15.78	29.42	27.19	37.75	304.50	103.19	11.03
	mean	C	34.13	24.39	25.04	9.57	43.85	18.31	199.82	43.94	11.82
	P		0.56	0.58	0.53	0.05	0.58	0.24	0.34	0.13	0.85

Biomass ($gm/0.1m^2$) - 1990

Deep

Pair	Site#	Oilcode	AMPHICTE	AMPHIPOD	CAECIDAE	CARDIIDA	CYLICHNI	HIATELLI	ISCHNOCH	LEPIDOPL	LUCINIDA	LUMBRINE	MYIDAE
1	2	O	0.001	0.044	0.215	0.000	0.001	0.001	0.250	0.032	0.001	0.495	0.014
1	1	C	0.048	0.002	0.017	0.001	0.000	0.000	0.000	0.011	1.438	0.080	0.000
2	3	O	0.000	0.279	0.751	0.041	0.087	0.000	0.333	0.063	0.030	0.036	0.025
2	4	C	0.247	0.046	0.987	0.668	0.032	0.000	0.447	0.082	1.842	0.291	0.029
3	6	O	0.030	0.033	0.705	0.042	0.098	0.000	0.154	0.158	1.627	0.157	0.000
3	5	C	0.012	0.072	1.672	0.000	0.034	0.001	0.058	0.131	0.978	0.107	0.001
	mean	O	0.010	0.119	0.557	0.028	0.062	0.000	0.246	0.084	0.553	0.229	0.013
	mean	C	0.102	0.040	0.892	0.223	0.022	0.000	0.168	0.074	1.419	0.159	0.010
	P		0.16	0.17	0.15	0.75	0.12	0.53	0.50	0.69	0.12	0.64	0.80

Deep (continued)

Pair	Site#	Oilcode	MYTILIDA	NUCULANI	ONUPHIDA	OPHIUROI	PEISIDIC	RHYNCHOC	SERPULID	SPIONIDA	TELLINID
1	2	O	0.099	0.000	0.013	0.022	0.122	0.002	0.417	0.038	0.000
1	1	C	0.053	0.000	0.000	0.000	0.038	0.014	0.185	0.003	0.000
2	3	O	0.042	0.069	0.232	0.116	0.039	0.328	0.000	0.043	0.000
2	4	C	0.000	0.050	0.008	0.216	0.023	0.051	0.114	0.114	0.012
3	6	O	0.627	0.000	0.011	0.365	0.048	0.175	0.007	0.012	0.000
3	5	C	0.003	0.049	0.244	0.161	0.074	0.135	0.140	0.071	0.008
	mean	O	0.256	0.023	0.085	0.168	0.069	0.168	0.141	0.031	0.000
	mean	C	0.018	0.033	0.084	0.126	0.045	0.067	0.146	0.062	0.007
	P		0.10	0.63	0.95	0.90	0.43	0.19	0.95	0.21	.

Shallow

Pair	Site#	Oilcode	AMPHICTE	AMPHIPOD	ANOMIIDA	CAECIDAE	CANCRIDA	CAPITELL	CARDIIDA	CYLICHNI	GLYCERID	ISCHNOCH
1	2	O	0.002	0.006	0.003	0.070	1.658	0.024	0.000	0.011	0.346	0.077
1	1	C	0.003	0.084	0.000	0.000	0.000	0.008	0.000	0.015	0.131	0.000
2	3	O	0.104	0.084	0.000	0.249	0.000	0.040	0.000	0.096	0.384	0.013
2	4	C	0.005	0.112	0.000	0.040	0.171	0.013	0.000	0.011	0.436	0.000
3	6	O	0.036	0.062	0.000	0.161	0.485	0.006	0.091	0.069	0.000	0.018
3	5	C	0.058	0.017	0.007	0.886	0.000	0.006	0.000	0.015	0.155	0.292
	mean	O	0.047	0.051	0.001	0.160	0.714	0.023	0.030	0.059	0.243	0.036
	mean	C	0.022	0.071	0.002	0.308	0.057	0.009	0.000	0.013	0.241	0.097
	P		0.56	0.48	0.80	0.45	0.22	0.04	0.51	0.05	0.91	0.99

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Shallow (continued)

Pair	Site#	Oilcode	LUCINIDA	LUMBRINE	LYONSIID	MONTACUT	NASSARII	NEREIDAE	OPHELIID	OPHIUROI	ORBINIID	RHYNCHOC
1	2	O	0.891	0.240	0.001	0.020	0.000	0.078	0.011	0.015	0.093	0.043
1	1	C	0.029	0.000	0.000	0.119	0.000	0.000	0.221	0.037	0.199	0.208
2	3	O	3.176	0.158	0.000	0.056	0.000	0.002	0.071	0.098	0.149	0.028
2	4	C	0.947	0.000	0.000	0.038	0.000	0.066	0.040	0.102	0.187	0.331
3	6	O	2.313	0.287	0.036	0.013	0.002	0.328	0.069	0.073	0.251	0.168
3	5	C	1.290	0.137	0.000	0.002	0.000	0.000	0.016	0.017	0.033	0.322
	mean	O	2.127	0.228	0.012	0.030	0.001	0.136	0.050	0.062	0.164	0.080
	mean	C	0.755	0.046	0.000	0.053	0.000	0.022	0.092	0.052	0.139	0.287
	P		0.04	0.10	0.13	0.45	.	0.04	0.59	0.73	0.79	0.20

Shallow (continued)

Pair	Site#	Oilcode	ROSSOIDA	SERPULID	SPIONIDA	VENERIDA
1	2	O	0.027	0.003	0.338	0.362
1	1	C	0.047	0.001	0.487	0.124
2	3	O	0.033	0.006	0.535	0.024
2	4	C	0.078	0.000	0.136	0.000
3	6	O	0.012	0.247	0.154	6.473
3	5	C	0.012	0.001	0.213	0.000
	mean	O	0.024	0.085	0.342	2.286
	mean	C	0.046	0.001	0.279	0.041
	P		0.35	0.02	0.63	0.15

Abundance (#/0.1m^2) - 1991

Deep

Pair	Site#	Oilcode	AMPHARET	AMPHICTE	AMPHIPOD	CAECIDAE	CAPITELL	CIRRATUL	DORVILLE	LEPIDOPL	LUCINIDA	LUMBRINE
1	2	O	9.33	5.20	55.47	19.33	7.33	13.33	16.00	20.00	17.33	8.13
1	1	C	33.56	57.11	47.78	3.11	15.33	7.78	0.00	0.67	13.78	3.33
2	3	O	30.67	26.22	103.56	140.45	36.89	33.78	42.22	50.67	46.22	28.89
2	4	C	12.89	6.67	112.78	37.78	8.89	8.00	46.67	5.78	34.11	4.00
3	6	O	126.66	17.16	28.89	105.33	19.47	13.69	42.22	41.33	80.35	15.29
3	5	C	64.00	41.33	55.11	357.56	26.44	15.11	76.67	107.11	81.33	10.44
	mean	O	55.55	16.19	62.64	88.37	21.23	20.27	33.48	37.33	47.97	17.44
	mean	C	36.81	35.04	71.89	132.81	16.89	10.30	41.11	37.85	43.07	5.93
	P		0.56	0.38	0.75	0.64	0.67	0.19	0.65	0.98	0.71	0.09

Deep (continued)

Pair	Site#	Oilcode	OPHELIID	OPHIUROI	PEISIDIC	PROTOMED	SERPULID	SIGALION	SPIONIDA	SPIRORBI	SYLLIDAE
1	2	O	88.27	24.00	12.53	0.67	1.33	38.27	76.80	2.67	48.40
1	1	C	29.78	1.78	0.00	4.00	2.67	2.22	91.78	5.78	4.44
2	3	O	18.22	56.45	22.67	18.67	1.33	120.45	150.67	21.33	37.33
2	4	C	14.67	24.00	26.67	66.67	10.72	89.11	20.00	38.78	24.89
3	6	O	80.71	91.72	40.45	1.87	7.29	80.35	197.23	122.20	16.94
3	5	C	7.05	116.45	34.00	5.11	44.00	202.45	404.67	26.00	90.67
	mean	O	62.40	57.39	25.22	7.07	3.32	79.69	141.57	48.73	34.23
	mean	C	17.17	47.41	20.22	25.26	19.13	97.93	172.15	23.52	40.00
	P		0.03	0.88	0.68	0.60	0.06	0.79	0.62	0.43	0.79

Shallow

Pair	Site#	Oilcode	AMPHARET	AMPHICTE	AMPHIPOD	AORIDAE_	BIVALVIA	CAECIDAE	CAPITELL	DORVILLE	GASTROPO	HIATELLI	LUCINID
1	2	O	47.33	35.33	38.00	0.67	37.33	6.67	29.33	6.67	44.67	90.00	10.67
1	1	C	114.67	98.67	56.00	5.33	5.33	61.33	72.00	17.33	6.67	20.00	94.67
2	3	O	52.00	104.76	95.72	25.33	3.43	89.81	83.71	64.19	33.24	15.81	88.09
2	4	C	19.55	96.00	61.33	1.33	9.33	69.78	21.78	7.55	49.33	16.00	40.00
3	6	O	104.89	122.22	125.56	48.67	22.67	6.00	13.28	16.44	112.89	90.89	81.55
3	5	C	28.53	66.04	162.04	80.27	21.69	24.00	59.56	1.78	30.13	54.31	32.00
	mean	O	68.07	87.44	86.42	24.89	21.14	34.16	42.11	29.10	63.60	65.57	60.11
	mean	C	54.25	86.90	93.12	28.98	12.12	51.70	51.11	8.89	28.71	30.10	55.56
	P		0.63	0.98	0.78	0.77	0.48	0.50	0.63	0.08	0.07	0.20	0.86

Shallow (continued)

Pair	Site#	Oilcode	MONTACUT	OPHELIID	OPHIUROI	POLYNOID	ROSSOIDA	SIGALION	SPIONIDA	SPIRORBI	SYLLIDAE
1	2	O	16.67	379.33	14.00	12.00	292.67	18.67	219.33	66.67	14.67
1	1	C	17.33	135.17	25.33	4.00	254.67	58.67	430.67	52.17	40.00
2	3	O	31.62	283.33	43.81	8.86	38.10	26.00	295.14	228.67	23.81
2	4	C	6.67	315.56	29.33	32.45	70.22	34.22	138.22	170.22	16.89
3	6	O	80.00	486.22	38.22	44.00	953.11	155.78	113.11	407.78	93.56
3	5	C	52.45	277.15	38.67	21.23	173.69	31.20	908.00	469.69	36.71
	mean	O	42.76	382.96	32.01	21.62	427.96	66.81	209.20	234.37	44.01
	mean	C	25.48	242.63	31.11	19.23	166.19	41.36	492.30	230.69	31.20
	P		0.23	0.16	0.68	0.79	0.15	0.45	0.10	0.95	0.86

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Biomass ($gm/0.1m^2$) - 1991

Deep

Pair	Site#	Oilcode	AMPHICTE	AMPHIPOD	CAECIDAE	CARDIIDA	CYLICHNI	HIATELLI	ISCHNOCH	LEPIDOPL	LUCINIDA	LUMBRINE	MYIDAE
1	2	O	0.003	0.111	0.155	0.592	0.073	0.015	0.204	0.045	0.055	0.040	0.017
1	1	C	0.175	0.153	0.026	0.416	0.023	1.534	0.000	0.003	0.111	0.013	0.366
2	3	O	0.060	0.137	1.180	0.000	0.057	0.065	0.277	0.098	0.524	0.830	1.211
2	4	C	0.001	0.053	0.351	0.000	0.107	0.000	0.124	0.034	0.811	0.035	0.259
3	6	O	0.022	0.115	0.780	0.006	0.042	0.005	0.166	0.156	0.884	0.237	0.100
3	5	C	0.051	0.126	2.418	0.003	0.105	0.000	0.279	0.278	1.227	0.331	0.041
	mean	O	0.028	0.121	0.705	0.199	0.057	0.028	0.216	0.100	0.488	0.369	0.443
	mean	C	0.076	0.111	0.932	0.139	0.078	0.511	0.134	0.105	0.716	0.126	0.222
	P		0.69	0.81	0.74	0.38	0.56	0.97	0.39	0.99	0.31	0.35	0.82

Deep (continued)

Pair	Site#	Oilcode	MYTILIDA	NUCULANI	ONUPHIDA	OPHIUROI	PEISIDIC	RHYNCHOC	SERPULID	SPIONIDA	TELLINID
1	2	O	0.004	0.085	0.019	0.166	0.017	0.005	0.001	0.099	0.000
1	1	C	0.088	0.001	0.000	0.001	0.000	0.139	0.002	0.142	0.150
2	3	O	0.003	0.196	0.026	0.143	0.023	0.082	0.001	0.080	0.007
2	4	C	0.041	0.053	0.040	0.147	0.048	0.137	0.054	0.023	0.003
3	6	O	0.058	0.000	0.000	0.529	0.086	0.169	0.003	0.240	0.022
3	5	C	0.707	0.001	0.153	0.216	0.112	0.204	0.018	0.350	0.175
	mean	O	0.022	0.094	0.015	0.279	0.042	0.085	0.002	0.140	0.010
	mean	C	0.279	0.018	0.064	0.121	0.053	0.160	0.025	0.171	0.109
	P		0.27	0.32	0.35	0.13	0.66	0.37	0.07	0.56	0.13

Shallow

Pair	Site#	Oilcode	AMPHICTE	AMPHIPOD	ANOMIIDA	CAECIDAE	CANCRIDA	CAPITELL	CARDIIDA	CYLICHNI	GLYCERID
1	2	O	0.024	0.074	0.019	0.037	0.006	0.022	0.001	0.093	0.134
1	1	C	0.639	0.071	1.561	0.369	0.189	0.027	0.803	0.152	0.147
2	3	O	0.056	0.135	0.000	0.797	1.691	0.052	0.000	0.057	0.012
2	4	C	0.004	0.097	0.000	0.624	0.000	0.007	0.000	0.048	0.008
3	6	O	0.157	0.113	0.003	0.049	0.312	1.813	0.025	0.130	0.315
3	5	C	0.015	0.165	0.012	0.180	0.280	0.029	0.009	0.053	0.000
	mean	O	0.079	0.107	0.007	0.294	0.670	0.629	0.009	0.094	0.154
	mean	C	0.220	0.111	0.524	0.391	0.156	0.021	0.271	0.084	0.051
	P		0.40	0.90	0.41	0.62	0.49	0.33	0.54	0.84	0.59

Shallow (continued)

Pair	Site#	Oilcode	ISCHNOCH	LUCINIDA	LUMBRINE	LYONSIID	MONTACUT	NASSARII	NEREIDAE	OPHELIID	OPHIUROI
1	2	O	0.001	0.574	0.164	0.035	0.064	0.191	0.000	0.294	0.019
1	1	C	0.859	1.729	0.100	0.887	0.025	0.000	0.000	0.394	0.125
2	3	O	0.076	1.069	0.008	0.041	0.046	0.017	0.000	0.479	0.235
2	4	C	0.013	1.741	0.100	0.002	0.005	0.269	0.007	0.126	0.150
3	6	O	0.082	2.306	0.048	0.015	0.108	0.355	0.095	0.423	0.217
3	5	C	0.000	0.369	0.000	0.000	0.060	0.304	0.001	0.084	0.122
	mean	O	0.053	1.316	0.073	0.030	0.073	0.188	0.032	0.399	0.157
	mean	C	0.291	1.280	0.067	0.296	0.030	0.191	0.003	0.202	0.133
	P		0.44	0.96	0.91	0.40	0.13	0.98	0.38	0.19	0.77

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Shallow (continued)

Pair	Site#	Oilcode	ORBINIID	RHYNCHOC	ROSSOIDA	SERPULID	SPIONIDA	VENERIDA
1	2	O	0.001	0.013	0.285	0.003	0.205	0.003
1	1	C	0.005	0.577	0.404	0.042	0.685	0.156
2	3	O	0.000	0.058	0.111	0.001	0.349	0.449
2	4	C	0.199	0.142	0.076	0.005	0.119	0.000
3	6	O	0.019	1.830	0.826	0.012	0.084	0.190
3	5	C	0.197	0.027	0.214	0.009	0.846	0.010
	mean	O	0.007	0.634	0.407	0.005	0.212	0.214
	mean	C	0.134	0.249	0.231	0.019	0.550	0.055
	P		0.29	0.40	0.30	0.22	0.08	0.38

ACE 30287023

APPENDIX T.

Mean values and results of 2 way randomization ANOVAs comparing community parameters for invertebrates that were sampled by suction dredge at oiled and control sites in the *Laminaria/Agarum* habitat in 1990 and 1991.

Appendix T. Mean values and results of 2-way randomization ANOVAs comparing community parameters for invertebrates that were sampled by suction dredge at oiled and control sites in the *Laminaria/Agarum* habitat in 1990 and 1991. All taxa were used at the family level and higher.

Deep

Year	Site Code	Shannon-Weiner	Simpson	Families	Total Individuals	Total Biomass	Species Richness
1990	Mean (O)	3.19	0.06	50	679	5.969	7.630
1990	Mean (C)	2.72	0.13	47	752	5.687	7.015
1991	Mean (O)	3.22	0.07	59	1151	8.594	8.299
1991	Mean (C)	2.98	0.08	51	1179	8.569	7.274
Oilcode	P	<0.01	<0.01	0.20	0.78	0.91	0.10
Year	P	0.20	0.20	0.12	<0.01	0.11	0.36
Interaction	P	0.34	0.07	0.60	0.91	0.95	0.68

Shallow

Year	Site Code	Shannon-Weiner	Simpson	Families	Total Individuals	Total Biomass	Species Richness
1990	Mean (O)	2.62	0.16	47	1055	8.446	6.783
1990	Mean (C)	2.59	0.13	37	739	3.485	5.477
1991	Mean (O)	2.92	0.10	64	2473	12.052	8.124
1991	Mean (C)	2.83	0.13	62	2131	12.680	8.062
Oilcode	P	0.55	0.81	0.25	0.38	0.46	0.18
Year	P	<0.01	0.13	<0.01	<0.01	0.01	<0.01
Interaction	P	0.78	0.09	0.41	0.97	0.34	0.27

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APPENDIX U.

Mean values and results of 2 way randomization ANOVAs comparing abundance and biomass of invertebrates that were sampled by suction dredge at oiled and control sites in the *Laminaria/Agarum* habitat in 1990 and 1991.

Appendix U. Mean values and results of 2-way randomization ANOVAs comparing abundance and biomass of invertebrates that were sampled by suction dredge at oiled and control sites in the *Laminaria/ Agarum* habitat in 1990 and 1991. Abundance units are #/0.1m^2 and Biomass units are gm/0.1m^2.

Abundance - Deep

Year		Oilcode	AMPHARET	AMPHICTE	AMPHIPOD	CAECIDAE	CAPITELL	CIRRATUL	DORVILLE	LEPIDOPL	LUCINIDA	LUMBRINE
1990	mean	O	4.93	1.33	69.15	70.00	15.17	23.03	27.57	27.37	37.59	13.83
1990	mean	C	2.52	1.89	34.27	137.10	15.23	6.37	29.91	27.16	65.89	12.52
1991	mean	O	55.55	16.19	62.64	88.37	21.23	20.27	33.48	37.33	47.97	17.44
1991	mean	C	36.81	35.04	71.89	132.81	16.89	10.30	41.11	37.85	43.07	5.93
Oilcode		P	0.59	0.40	0.55	0.10	0.67	0.03	0.61	1.00	0.37	0.11
Year		P	<0.01	<0.01	0.46	0.87	0.44	0.93	0.38	0.56	0.62	0.72
Interaction		P	0.65	0.41	0.32	0.80	0.68	0.60	0.82	0.98	0.21	0.21

Abundance - Deep (continued)

Year		Oilcode	OPHELIID	OPHIUROI	PEISIDIC	PROTOMED	SERPULID	SIGALION	SPIONIDA	SPIRORBI	SYLLIDAE
1990	mean	O	6.89	34.62	28.12	27.56	3.11	41.35	27.53	15.80	13.41
1990	mean	C	0.00	63.93	25.63	6.09	25.17	30.53	82.20	20.69	19.46
1991	mean	O	62.40	57.39	25.22	7.07	3.32	79.69	141.57	48.73	34.23
1991	mean	C	17.17	47.41	20.22	25.26	19.13	97.93	172.15	23.52	40.00
Oilcode		P	0.06	0.46	0.66	0.72	<0.01	0.91	0.36	0.55	0.68
Year		P	<0.01	0.95	0.59	0.87	0.67	0.01	0.01	0.21	0.11
Interaction		P	0.18	0.27	0.87	0.22	0.65	0.70	0.81	0.34	0.99

Abundance - Shallow

Year		Oilcode	AMPHARET	AMPHICTE	AMPHIPOD	AORIDAE_	BIVALVIA	CAECIDAE	CAPITELL	DORVILLE	GASTROPO	HIATELLI
1990	mean	O	0.77	17.05	33.75	1.42	13.44	19.61	56.74	21.82	28.37	2.16
1990	mean	C	1.07	5.36	41.24	5.78	17.96	46.99	40.43	10.67	23.20	0.30
1991	mean	O	68.07	87.44	86.42	24.89	21.14	34.16	42.11	29.10	63.60	65.57
1991	mean	C	54.25	86.90	93.12	28.98	12.12	51.70	51.11	8.89	28.71	30.10
Oilcode		P	0.74	0.77	0.74	0.66	0.74	0.26	0.73	0.02	0.08	0.24
Year		P	<0.01	<0.01	<0.01	0.01	0.89	0.61	0.84	0.70	0.07	<0.01
Interaction		P	0.76	0.80	0.99	1.00	0.42	0.79	0.26	0.52	0.34	0.31

Abundance - Shallow (continued)

Year		Oilcode	LUCINID	MONTACUT	OPHELIID	OPHIUROI	POLYNOID	ROSSOIDA	SIGALION	SPIONIDA	SPIRORBI	SYLLIDAE
1990	mean	O	118.22	23.44	12.98	15.78	29.42	27.19	37.75	304.50	103.19	11.03
1990	mean	C	38.43	34.13	24.39	25.04	9.57	43.85	18.31	199.82	43.94	11.82
1991	mean	O	60.11	42.76	382.96	32.01	21.62	427.96	66.81	209.20	234.37	44.01
1991	mean	C	55.56	25.48	242.63	31.11	19.23	166.19	41.36	492.30	230.69	31.20
Oilcode		P	0.28	0.83	0.41	0.39	0.08	0.21	0.12	0.36	0.63	0.86
Year		P	0.81	0.71	<0.01	0.21	0.89	<0.01	0.07	0.32	<0.01	0.01
Interaction		P	0.39	0.33	0.33	0.46	0.14	0.17	0.85	0.04	0.61	0.80

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Biomass - Deep

Year		Oilcode	AMPHICTE	AMPHIPOD	CAECIDAE	CARDIIDA	CYLICHNI	HIATELLI	ISCHNOCH	LEPIDOPL	LUCINIDA	LUMBRINE	MYIDAE
1990	mean	O	0.010	0.119	0.557	0.028	0.062	0.000	0.246	0.084	0.553	0.229	0.013
1990	mean	C	0.102	0.040	0.892	0.223	0.022	0.000	0.168	0.074	1.419	0.159	0.010
1991	mean	O	0.028	0.121	0.705	0.199	0.057	0.028	0.216	0.100	0.488	0.369	0.443
1991	mean	C	0.076	0.111	0.932	0.139	0.078	0.511	0.134	0.105	0.716	0.126	0.222
Oilcode		P	0.19	0.22	0.29	0.81	0.62	0.10	0.27	0.97	0.04	0.30	0.82
Year		P	0.92	0.31	0.75	0.86	0.21	0.03	0.65	0.63	0.17	0.71	<0.01
Interaction		P	0.59	0.39	0.86	0.44	0.15	0.98	0.98	0.91	0.25	0.59	0.82

Biomass - Deep (continued)

Year		Oilcode	MYTILIDA	NUCULANI	ONUPHIDA	OPHIUROI	PEISIDIC	RHYNCHOC	SERPULID	SPIONIDA	TELLINID
1990	mean	O	0.256	0.023	0.085	0.168	0.069	0.168	0.141	0.031	0.000
1990	mean	C	0.018	0.033	0.084	0.126	0.045	0.067	0.146	0.062	0.007
1991	mean	O	0.022	0.094	0.015	0.279	0.042	0.085	0.002	0.140	0.010
1991	mean	C	0.279	0.018	0.064	0.121	0.053	0.160	0.025	0.171	0.109
Oilcode		P	0.88	0.41	0.49	0.18	0.78	0.81	0.83	0.50	0.09
Year		P	0.86	0.55	0.22	0.47	0.63	0.92	0.05	<0.01	0.03
Interaction		P	0.01	0.27	0.50	0.41	0.40	0.07	0.91	1.00	0.25

Biomass - Shallow

Year		Oilcode	AMPHICTE	AMPHIPOD	ANOMIIDA	CAECIDAE	CANCRIDA	CAPITELL	CARDIIDA	CYLICHNI	GLYCERID
1990	mean	O	0.047	0.051	0.001	0.160	0.714	0.023	0.030	0.059	0.243
1990	mean	C	0.022	0.071	0.002	0.308	0.057	0.009	0.000	0.013	0.241
1991	mean	O	0.079	0.107	0.007	0.294	0.670	0.629	0.009	0.094	0.154
1991	mean	C	0.220	0.111	0.524	0.391	0.156	0.021	0.271	0.084	0.051
Oilcode		P	0.56	0.58	0.43	0.35	0.18	0.08	0.56	0.29	0.70
Year		P	0.12	0.02	0.04	0.44	0.86	0.14	0.32	0.03	0.27
Interaction		P	0.38	0.72	0.65	0.84	0.73	0.71	0.25	0.49	0.67

Biomass - Shallow (continued)

Year		Oilcode	ISCHNOCH	LUCINIDA	LUMBRINE	LYONSIID	MONTACUT	NASSARII	NEREIDAE	OPHELIID	OPHIUROI
1990	mean	O	0.036	2.127	0.228	0.012	0.030	0.001	0.136	0.050	0.062
1990	mean	C	0.097	0.755	0.046	0.000	0.053	0.000	0.022	0.092	0.052
1991	mean	O	0.053	1.316	0.073	0.030	0.073	0.188	0.032	0.399	0.157
1991	mean	C	0.291	1.280	0.067	0.296	0.030	0.191	0.003	0.202	0.133
Oilcode		P	0.27	0.12	0.12	0.50	0.64	0.99	0.14	0.36	0.74
Year		P	0.31	0.75	0.31	0.07	0.61	<0.01	0.34	<0.01	0.02
Interaction		P	0.44	0.13	0.16	0.38	0.11	0.98	0.66	0.13	0.39

Biomass - Shallow (continued)

Year		Oilcode	ORBINIID	RHYNCHOC	ROSSOIDA	SERPULID	SPIONIDA	VENERIDA
1990	mean	O	0.164	0.080	0.024	0.085	0.342	2.286
1990	mean	C	0.139	0.287	0.046	0.001	0.279	0.041
1991	mean	O	0.007	0.634	0.407	0.005	0.212	0.214
1991	mean	C	0.134	0.249	0.231	0.019	0.550	0.055
Oilcode		P	0.51	0.63	0.49	0.64	0.21	0.11
Year		P	0.27	0.18	<0.01	0.99	0.53	0.68
Interaction		P	0.27	0.13	0.35	0.04	0.05	0.64

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APPENDIX V.

List of large (>10 cm) epifaunal invertebrates enumerated from shallow subtidal habitats in Prince William Sound, 1990-91.

Appendix V. List of large (>10 cm) epifaunal invertebrates enumerated from shallow subtidal habitats in Prince William Sound, 1990-1991.

Taxonomic Name	Common Name
Metridium senile	White-plumed anemone
Tealia crassicornis	Red & green anemone
Cnidaria	Orange anemone
Cryptochiton stelleri	Gum boot chiton
Isochnochiton sp.	Chiton
Ceratostoma sp.	Whelk
Fusitriton oregonensis	Oregon hairy triton
Triopha sp.	Nudibranch
Anisodoris sp.	Nudibranch
Cadlina luteomarginata	Nudibranch
Hermissenda crassicornis	Horned nudibranch
Doridae	Nudibranch
Nudibranch	Nudibranch
Hyas lyratus	Lyre crab
Octopus sp.	Octopus
Sclerocrangon boreas	Tank shrimp
Hippolytidae	Hippolytid shrimp
Pugettia sp.	Kelp crab
Telmessus cheiragonus	Helmet crab
Majidae	Spider crab
Oregonia gracilis	Decorator crab
Cancer sp.	Cancer crab
Cancer magister	Cancer crab
Cancer oregonensis	Cancer crab
Placetron wossnessenskii	Scaled crab
Rhinolithodes wossnessenskii	Rhinocerous crab
Phyllolithodes papillosus	Flat-spined triangle crab
Parastichopus californicus	California sea cucumber
Strongylocentrotus droebachiensis	Green sea urchin
Strongylocentrotus franciscanus	Red sea urchin
Asteroidea	Orange star
Leptasterias hexactus	Six-rayed sea star
Orthasterias koehleri	Rainbow sea star
Pisaster brevispinus	Short-spined sea star
Pycnopodia helianthoides	Sunflower sea star
Dermasterias imbricata	Leather star
Evasterias troschelli	False Ochre sea star
Mediaster aequalis	Vermillion sea star
Solaster sp.	Sun star
Stylasterias forreri	Sea star
Henricia leviuscula	Blood star
Pteraster tessalatus	Cushion sea star
Tunicata	Orange colonial tunicate
Tunicata	Orange solitary tunicate

APPENDIX W.

Mean values for the abundance of large(>10 cm) epibenthic invertebrates at oiled and control sites in eelgrass, *Laminaria/Agarum* bay, *Laminaria/Agarum* point, and *Nereocystis* habitats in 1990 and 1991. Also given are probabilities that the means from the oiled and control sites were similar as determined by randomization tests.

Appendix W. Mean values for the abundance (#/100m^2) of large (>10 cm) epibenthic invertebrates at oiled and control sites in eelgrass, Laminaria/Agarum bay, Laminaria/Agarum point, and Nereocystis habitats in 1990 and 1991. Also given are probabilities that the means from the oiled and control sites were similar as determined by randomization tests.

Eelgrass Bed - 1990 Depth = Bed

Pair	Site#	Oilcode	CRABS	Dermasterias	Evasterias	Orthasterias	Telmessus	Pycnopodia ALL	Pycnopodia ADULT	Pycnopodia JUV.
1	13	O	0.00	0.56	0.00	0.00	0.00	4.44	1.67	2.78
1	14	C	0.56	1.11	0.00	0.00	0.56	10.00	4.44	5.56
2	16	O	1.11	0.56	0.56	1.11	1.11	3.33	1.67	1.67
2	15	C	6.11	5.56	1.67	0.00	5.00	1.67	1.67	0.00
3	17	O	0.56	1.67	0.00	0.00	0.56	5.00	2.78	2.22
3	18	C	4.44	0.56	0.00	0.00	3.89	6.67	6.67	0.00
4	25	O	0.00	0.00	0.00	0.00	0.00	13.57	10.32	3.25
4	26	C	3.89	0.00	0.00	0.00	3.33	12.22	9.44	2.78
	mean	O	0.42	0.69	0.14	0.28	0.42	6.59	4.11	2.48
	mean	C	3.75	1.81	0.42	0.00	3.19	7.64	5.56	2.08
	P		<0.01	0.15	.	.	<0.01	0.63	0.38	0.79

Island Bay - 1990 Depth = Deep

Pair	Site#	Oilcode	CRABS	Dermasterias	Evasterias	Henricia	Orthasterias	Telmessus	Pycnopodia ALL	Pycnopodia ADULT	Pycnopodia JUV.
1	2	O	0.00	0.00	1.11	0.00	0.00	0.00	2.78	2.78	0.00
1	1	C	0.00	0.00	0.00	0.00	0.56	0.00	3.33	3.33	0.00
2	3	O	1.11	1.11	1.11	0.00	2.22	0.56	5.56	5.00	0.56
2	4	C	3.89	1.11	2.22	0.00	1.67	2.22	1.11	0.56	0.56
3	6	O	0.00	0.56	0.00	0.00	3.33	0.00	16.11	15.56	0.56
3	5	C	3.33	2.22	2.22	1.67	8.33	1.11	9.44	9.44	0.00
	mean	O	0.37	0.56	0.74	0.00	1.85	0.19	8.15	7.78	0.37
	mean	C	2.41	1.11	1.48	0.56	3.52	1.11	4.63	4.44	0.19
	P		<0.01	0.18	0.20	.	0.18	<0.01	0.22	0.19	0.19

Island Bay - 1990 Depth = Shallow

Pair	Site#	Oilcode	CRABS	Dermasterias	Evasterias	Henricia	Orthasterias	Telmessus	Pycnopodia ALL	Pycnopodia ADULT	Pycnopodia JUV.
1	2	O	4.44	1.11	5.00	0.56	1.67	3.89	26.11	23.33	2.78
1	1	C	6.11	3.33	1.67	3.33	1.67	6.11	20.56	20.56	0.00
2	3	O	3.33	3.89	6.11	0.00	10.00	3.33	24.44	23.89	0.56
2	4	C	7.22	3.89	3.89	0.00	1.11	2.78	10.00	10.00	0.00
3	6	O	2.22	0.00	3.33	1.67	1.11	1.67	35.56	35.56	0.00
3	5	C	8.33	16.67	4.44	0.00	7.78	7.78	17.22	16.67	0.56
	mean	O	3.33	1.67	4.31	0.74	4.26	2.96	28.70	27.59	1.11
	mean	C	7.22	7.96	3.33	1.11	3.52	5.56	15.93	15.74	0.19
	P		0.07	0.046	0.36	0.43	0.81	0.29	0.03	0.05	0.26

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Island Point - 1990 Depth = Deep

Pair	Site#	Oilcode	CRABS	Dermas-terias	Evas-terias	Hen-ricia	Orthas-terias	Tel-messus	Pycnopodia ALL	Pycnopodia ADULT	Pycnopodia JUV.
1	19	O	0.56	1.67	0.56	6.11	10.00	0.00	18.89	16.11	2.78
1	20	C	3.33	1.67	2.22	0.56	12.22	1.67	35.56	28.33	7.22
2	22	O	0.56	3.33	1.67	3.33	11.67	0.00	30.00	24.44	5.56
2	21	C	1.67	8.33	7.78	4.44	18.33	0.00	13.33	10.56	2.78
3	23	O	1.11	0.56	3.89	5.00	15.56	0.00	14.44	14.44	0.00
3	24	C	1.11	0.00	0.00	13.89	9.44	0.00	8.89	6.11	2.78
	mean	O	0.74	1.85	2.04	4.81	12.41	0.00	21.11	18.33	2.78
	mean	C	2.04	3.33	3.33	6.30	13.33	0.56	19.26	15.00	4.26
	P		0.07	0.36	0.37	0.57	0.75	<0.01	0.83	0.61	0.60

Island Point - 1990 Depth = Shallow

Pair	Site#	Oilcode	CRABS	Dermas-terias	Evas-terias	Hen-ricia	Orthas-terias	Tel-messus	Pycnopodia ALL	Pycnopodia ADULT	Pycnopodia JUV.
1	19	O	0.00	3.33	1.11	8.89	19.44	0.00	42.78	26.67	16.11
1	20	C	7.78	8.89	10.00	3.33	10.56	6.11	21.11	16.11	5.00
2	22	O	6.11	3.89	5.00	1.67	6.11	2.78	38.89	30.56	8.33
2	21	C	10.56	28.33	16.11	2.22	14.44	8.33	14.44	10.56	3.89
3	23	O	1.11	6.67	3.33	10.00	15.56	0.00	38.33	36.11	2.22
3	24	C	0.56	8.89	0.56	16.11	30.56	0.00	43.33	35.00	8.33
	mean	O	2.41	4.63	3.15	6.85	13.70	0.93	40.00	31.11	8.89
	mean	C	6.30	15.37	8.89	7.22	18.52	4.81	26.30	20.56	5.74
	P		0.09	0.05	0.05	0.77	0.38	0.03	0.10	0.09	0.41

Nereocystis Bed - 1990 Depth = Shallow

Pair	Site#	Oilcode	CRABS	Dermas-terias	Evas-terias	Hen-ricia	Orthas-terias	Pycnopodia ALL	Pycnopodia ADULT	Pycnopodia JUV.
1	7	O	0.00	10.00	0.00	13.89	1.67	50.00	50.00	0.00
1	8	C	0.00	34.44	3.33	21.11	13.33	125.00	122.78	2.22
2	12	O	0.00	18.67	0.67	6.67	14.33	96.00	81.67	14.33
2	11	C	0.28	8.89	1.39	8.61	19.17	39.44	31.39	8.06
	mean	O	0.00	14.33	0.33	10.28	8.00	73.00	65.83	7.17
	mean	C	0.14	21.67	2.36	14.86	16.25	82.22	77.08	5.14
	P		0.39	0.79	0.05	0.13	0.20	0.68	0.79	0.35

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Island Bay - 1991 Depth = Shallow

Pair	Site#	Oilcode	Dermas-terias	Evas-terias	Orthas-terias	Tel-messus	Pycnopodia ALL	Pycnopodia ADULT	Pycnopodia JUV.
1	2	O	0.56	0.00	0.00	0.56	8.89	6.11	2.78
1	1	C	0.00	0.00	0.56	0.00	8.33	7.78	0.56
2	3	O	4.44	4.44	4.44	1.67	12.22	7.78	4.44
2	4	C	0.56	2.22	0.56	0.56	1.11	1.11	0.00
3	6	O	3.89	3.89	6.67	0.00	37.78	11.67	26.11
3	5	C	22.22	6.11	3.89	6.11	23.89	9.44	14.44
	mean	O	2.96	2.78	3.70	0.74	19.63	8.52	11.11
	mean	C	7.59	2.78	1.67	2.22	11.11	6.11	5.00
	P		0.36	0.92	0.22	0.27	0.08	0.38	<0.01

Eelgrass Bed - 1991 Depth = Bed

Pair	Site#	Oilcode	Dermas-terias	Evas-terias	Orthas-terias	Tel-messus	Pycnopodia ALL	Pycnopodia ADULT	Pycnopodia JUV.
1	13	O	2.78	0.00	0.00	2.78	30.00	3.33	26.67
1	14	C	8.33	0.00	0.00	2.78	44.44	8.33	36.11
2	16	O	1.11	1.11	0.00	1.11	36.67	4.44	32.22
2	15	C	10.00	0.00	0.00	3.89	29.44	3.89	25.56
3	17	O	1.67	0.00	0.00	0.56	21.67	2.22	19.44
3	18	C	0.00	0.00	0.00	0.56	58.33	6.11	52.22
4	25	O	0.00	0.00	0.00	0.00	216.11	1.67	214.44
4	26	C	0.56	0.00	0.00	0.00	10.56	3.33	7.22
5	35	O	0.00	0.00	0.00	0.56	42.22	2.22	40.00
5	34	C	3.89	0.00	0.00	0.56	6.67	3.89	2.78
	mean	O	1.11	0.22	0.00	1.00	69.33	2.78	66.56
	mean	C	4.56	0.00	0.00	1.56	29.89	5.11	24.78
	P		0.02	0.23	.	0.23	0.18	0.03	0.12

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APPENDIX X.

Mean values and results of 2 way randomization ANOVAs comparing abundance and biomass of large (>10 cm) epibenthic invertebrates at oiled and control sites in the eelgrass and *Laminaria/Agarum* bay habitats in 1990 and 1991.

Appendix X. Mean values and results of 2-way randomization ANOVAs comparing abundance (#/100m2) of large (>10 cm) epibenthic invertebrates at oiled and control sites in the eelgrass and *Laminaria/Agarum* bay habitats in 1990 and 1991. Only sites sampled both years were used for analyses.

Eelgrass Bed - Bed

Year		Oilcode	Dermas-terias	Evas-terias	Orthas-terias	Tel-messus	Pycnopodia ALL	Pycnopodia ADULT	Pycnopodia JUV.
1990	mean	O	0.69	0.14	0.28	0.42	6.59	4.11	2.48
1990	mean	C	1.81	0.42	0.00	3.19	7.64	5.56	2.08
1991	mean	O	1.39	0.28	0.00	1.11	76.11	2.92	73.19
1991	mean	C	4.72	0.00	0.00	1.81	35.69	5.42	30.28
Oilcode		P	0.01	0.70	.	<0.01	0.21	0.31	0.17
Year		P	0.09	0.21	.	0.59	<0.01	0.37	<0.01
Interaction		P	0.31	0.17	.	0.09	0.18	0.94	0.19

Island Bay - Shallow

Year		Oilcode	Dermas-terias	Evas-terias	Orthas-terias	Tel-messus	Pycnopodia ALL	Pycnopodia ADULT	Pycnopodia JUV.
1990	mean	O	1.67	4.81	4.26	2.96	28.70	27.59	1.11
1990	mean	C	7.96	3.33	3.52	5.56	15.93	15.74	0.19
1991	mean	O	2.96	2.78	3.70	0.74	19.63	8.52	11.11
1991	mean	C	7.59	2.78	1.67	2.22	11.11	6.11	5.00
Oilcode		P	0.03	0.51	0.39	0.10	<0.01	0.15	0.22
Year		P	0.85	0.20	0.47	0.03	0.11	<0.01	<0.01
Interaction		P	0.79	0.46	0.71	0.73	0.64	0.27	0.35

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APPENDIX Y.

Fishes sampled during 1990 and 1991 shallow subtidal surveys in Prince William Sound.

APPENDIX Y. Fishes sampled during 1990 and 1991 shallow subtidal surveys in Prince William Sound.

1990

Family	Common Name	Taxonomic Name	Code	Group
Gadidae	Pacific Cod	Gadus macrocephalus	pac cod	Gadidae without Pollock
Gadidae	Pacific Tom Cod	Microgadus proximus	tom cod	Gadidae without Pollock
Gadidae	Walleye Pollock	Theragra chalcogramma	poll	Other
Gadidae	Unidentified cod	Gadus sp.	cod	Gadidae without Pollock
Hexagrammidae	Kelp Greenling	Hexagrammos decagrammus	kelp grn	Hexagrammos spp.
Hexagrammidae	Masked Greenling	Hexagrammos octogrammus	mask grn	Hexagrammos spp.
Hexagrammidae	Rock Geenling	Hexagrammos lagocephalus	rock grn	Hexagrammos spp.
Hexagrammidae	White Spotted Greenling	Hexagrammos stellari	white grn	Hexagrammos spp.
Hexagrammidae	Lingcod	Ophiodon elongatus	ling	Other
Cottidae	Brown Irish Lord	Hemilepidotus spinosus	brown lord	Large Cottidae
Cottidae	Red Irish Lord	Hemilepidotus hemilepidotus	red lord	Large Cottidae
Cottidae	Yellow Irish Lord	Hemilepidotus jordani	yell lord	Large Cottidae
Cottidae	Unidentified Irish lord	Hemilepidotus sp.	lord	Large Cottidae
Cottidae	Great Sculpin	Myoxocephalus polyacanthocephalus	grt sculp	Large Cottidae
Cottidae	Buffalo Sculpin	Enophrys bison	buf sculp	Large Cottidae
Cottidae	Antlered Sculpin	Enophrys diceraus	ant sculp	Small Cottidae
Cottidae	Unidentified large sculpins	--	lg sculp	Large Cottidae
Cottidae	Crested Sculpin	Blepsias bilobus	crest sculp	Small Cottidae
Cottidae	Silverspotted sculpin	Blepsias cirrhosus	silver scul	Small Cottidae
Cottidae	Unidentified Blepsias	Blepsias sp.	blepsias	Small Cottidae
Cottidae	Pit-head Sculpin	Icelinus cavifrons	ice	Small Cottidae
Cottidae	Mosshead sculpin	Clinocottus globiceps	mosshead	Small Cottidae
Cottidae	Grunt Sculpin	Rhamphocottus richardsonii	rhampho	Small Cottidae
Cottidae	Sailfin Sculpin	Nautichthys oculofasciatus	sail sculp	Small Cottidae
Cottidae	Sand Sculpin	--	and cot	Small Cottidae
Cottidae	Atredius sculpins	Artedius sp.	art	Small Cottidae
Cottidae	Unidentified small sculpins	--	cot	Small Cottidae
Pholidae	Crescent Gunnel	Pholis laeta	cres gun	Pholidae
Pholidae	Penpoint Gunnel	Apodichthys flavidus	pen gun	Pholidae
Pholidae	Saddleback Gunnel	Pholis ornata	sad gun	Pholidae
Pholidae	Unidentified gunnels	--	gun	Pholidae
Stichaeidae	Arctic Shanny	Stichaeus punctatus	arc shan	Stichaeus punctatus

APPENDIX Y. continued.

Stichaeidae	Mosshead Warbonnet	Chirolophis nugator	warbon	Other
Stichaeidae	Slender Eelblenny	Lumpenus fabricii	slen eel	Other
Stichaeidae	Black prickleback	Xiphister atropurpureus	xiphis	Other
Stichaeidae	Unidentified eelblenny	--	eelblen	Other
Stichaeidae	Unidentified prickleback	--	stich	Other
Scorpaenidae	China Rockfish	Sebastes nebulosus	china	Scorpienidae
Scorpaenidae	Dusky Rockfish	Sebastes ciliatus	dusky	Scorpienidae
Scorpaenidae	Quillback Rockfish	Sebastes maliger	quill	Scorpienidae
Scorpaenidae	Copper Rockfish	Sebastes caurinus	s caurinus	Scorpienidae
Scorpaenidae	Dusky Rockfish	Sebastes ciliatus	s ciliatus	Scorpienidae
Scorpaenidae	Yelloweye Rochfish	Sebastes ruberrimus	yell eye	Scorpienidae
Scorpaenidae	Black rockfish	Sebastes melanops	blk rock	Scorpienidae
Scorpaenidae	Unidentified rockfish	Sebastes sp.	rockfish	Scorpienidae
Bathymasteridae	Alaskan Ronquil	Bathymaster caeruleofasciatus	ak ronquil	Bathymasteridae
Bathymasteridae	Creme Ronquil	Bathymaster sp.	creme ronq	Bathymasteridae
Bathymasteridae	Searcher	Bathymaster signatus	search	Bathymasteridae
Bathymasteridae	Unidentified ronquil	Bathymaster sp.	bathy	Bathymasteridae
Bathymasteridae	Northern Ronquil	Ronquilis jordani	no. ronq	Bathymasteridae
Agonidae	Smooth Alligatorfish	Anoplagonus inermis	alligator	Other
Agonidae	Unidentified poacher	--	poach	Other
Pleuronectidae	Rock sole	Lepidopsetta bilineata	rock sole	Other
Pleuronectidae	Unidentified right-eyed flounder	--	pleuron	Other
Pleuronectidae	Unidentified flatfish/flounder	--	flatfish	Other
Salmonidae	Pink Salmon	Oncorhynchus gorbuscha	pink sal	Other
Ammodytidae	Pacific Sand Lance	Ammodytes hexapterus	san lan	Other
Aulorhynchidae	Tubesnout	Aulorhynchus flavidus	tubesnout	Other
Anarachthyidae	Wolf-eel	Anarrhichthys ocellatus	wolf-eel	Other
Clupeidae	Pacific Herring	Clupea harengus	clupeiformes	Other
Zoarcidae	Wattled Eelpout	Lycodes palearis	lycodes pal.	Other
Other	fish	--	fish	Other
Other	larval fish	--	ich larv	Other
Other	oar-like pectorals fish	--	oar-pects fish	Other
Other	snake	--	snake	Other

APPENDIX Y. continued.

1991

Family	Common Name	Taxonomic Name	Code	Group
Stichaeidae	Arctic Shanny	Stichaeus punctatus	yarc harc & aarc	Stichaeus punctatus
Gadidae	Pacific Cod	Gadus macrocephalus	ypcod hpcod & apcod	Gadidae without Pollock
Gadidae	Pacific Tom Cod	Microgadus proximus	ytcod htcod & atcod	Gadidae without Pollock
Cottidae	Unidentified small sculpins	--	cotd	Small Cottidae
Scorpaenidae	Copper Rockfish	Sebastes caurinus	curf	Scorpienidae

APPENDIX Z.

Mean values for the abundance of dominant fishes at oiled and control sites in eelgrass, *Laminaria/Agarum* bay, *Laminaria/Agarum* point, and *Nereocystis* habitats in 1990 and 1991. Also given are probabilities that the means from the oiled and control sites were similar as determined by randomization tests.

Appendix Z. Mean values for the abundance (#/100m^2) of dominant fishes at oiled and control sites in eelgrass, *Laminaria/Agarum* bay, *Laminaria/Agarum* point, and *Nereocystis* habitats in 1990 and 1991. Also given are probabilities that the means from the oiled and control sites were similar as determined by randomization tests.

Eelgrass Bed - 1990 Depth = Bed

Pair	Site#	Oilcode	All GADIDAEW	All HEXAGRAM	All PHOLIDAE	Adult GADIDAEW	Juvenile GADIDAEW
1	13	O	14.44	1.11	0.56	9.44	5.00
1	14	C	5.56	0.56	0.56	2.78	2.78
2	16	O	140.56	8.89	12.78	2.78	137.78
2	15	C	12.78	7.22	5.56	1.11	11.67
3	17	O	169.44	3.33	0.00	8.33	161.11
3	18	C	13.33	5.56	5.56	0.00	13.33
4	25	O	62.78	6.51	3.81	0.00	62.78
4	26	C	30.00	5.56	2.78	0.00	30.00
	mean	O	96.81	4.96	4.29	5.14	91.67
	mean	C	15.42	4.72	3.61	0.97	14.44
	P		<0.01	0.90	0.76	<0.01	<0.01

Eelgrass Bed - 1991 Depth = Bed

Pair	Site#	Oilcode	Adult GADIDAEW	Juvenile GADIDAEW
1	13	O	9.44	4.44
1	14	C	10.00	6.67
2	16	O	15.56	108.89
2	15	C	0.00	1.11
3	17	O	0.00	775.56
3	18	C	29.44	0.00
4	25	O	21.67	95.00
4	26	C	1.11	262.78
5	35	O	1.67	0.00
5	34	C	2.22	0.56
	mean	O	9.67	196.78
	mean	C	8.56	54.22
	P		0.88	0.19

Island Bay - 1990 Depth = Deep

Pair	Site#	Oilcode	All HEXAGRAM	All LARGECOT	All SMALLCOT	All PHOLIDAE	Adult STICHAEU	Juvenile STICHAEU
1	2	O	0.00	1.11	3.89	0.00	1.11	0.00
1	1	C	0.00	0.00	2.22	0.56	2.22	0.00
2	3	O	0.56	0.56	30.00	2.78	7.22	0.00
2	4	C	0.00	0.56	6.11	2.22	8.89	0.00
3	6	O	0.00	0.56	4.44	0.00	16.11	1.11
3	5	C	0.56	1.11	25.00	3.33	18.89	0.00
	mean	O	0.19	0.74	12.78	0.93	8.15	0.37
	mean	C	0.19	0.56	11.11	2.04	10.00	0.00
	P		0.47	0.69	0.85	0.17	0.22	0.23

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Island Bay - 1990 Depth - Shallow

Pair	Site#	Oilcode	All HEXAGRAM	All LARGECOT	All SMALLCOT	All PHOLIDAE	Adult STICHAEU	Juvenile STICHAEU
1	2	O	1.67	0.00	1.67	0.56	11.11	0.00
1	1	C	0.00	0.56	5.56	22.22	5.56	27.78
2	3	O	1.67	1.67	12.78	3.89	28.89	0.00
2	4	C	0.00	0.00	6.11	0.56	4.44	0.00
3	6	O	1.67	0.56	1.11	5.00	28.89	11.11
3	5	C	0.00	3.33	17.78	2.78	63.33	1.11
	mean	O	1.67	0.74	5.19	3.15	22.96	3.70
	mean	C	0.00	1.30	9.81	8.52	24.44	9.63
	P		0.07	0.43	0.32	0.39	0.84	0.85

Island Bay - 1991 Depth - Shallow

Pair	Site#	Oilcode	Adult GADIDAEW	Juvenile GADIDAEW	Adult SMALLCOT	Adult STICHAEU	Juvenile STICHAEU
1	2	O	6.67	0.00	0.00	5.56	2.78
1	1	C	16.67	0.00	3.33	30.56	3.33
2	3	O	2.78	0.00	0.56	15.56	0.56
2	4	C	1.11	25.00	1.67	12.22	1.11
3	6	O	8.33	16.67	1.11	0.00	11.67
3	5	C	0.00	0.56	1.11	10.56	0.56
	mean	O	5.93	5.56	0.56	7.04	5.00
	mean	C	5.93	8.52	2.04	17.78	1.67
	P		0.98	0.80	0.02	0.06	0.25

Island Point - 1990 Depth - Deep

Pair	Site#	Oilcode	All BATHYMAS	All HEXAGRAM	All LARGECOT	All PHOLIDAE	All SCORPIEN	All SMALLCOT	Adult STICHAEU	Juvenile STICHAEU	Juvenile GADIDAEW
1	19	O	25.00	4.44	1.11	0.00	33.33	24.44	2.78	13.33	0.00
1	20	C	8.89	1.11	3.33	1.67	2.22	31.11	52.78	8.89	11183.33
2	22	O	2.22	2.22	1.11	1.11	1.11	43.89	48.89	34.44	21.67
2	21	C	7.22	0.56	0.00	3.33	4.44	36.67	27.22	21.11	51.11
3	23	O	10.00	2.22	1.11	0.00	1.67	30.56	0.00	18.89	0.00
3	24	C	1.67	1.67	1.11	1.11	0.00	15.56	1.67	2.22	9.44
	mean	O	12.41	2.96	1.11	0.37	12.04	32.96	17.22	22.22	7.22
	mean	C	5.93	1.11	1.48	2.04	2.22	27.78	27.22	10.74	3747.96
	P		0.48	0.10	0.67	0.08	0.70	0.39	0.57	0.07	0.02

Island Point - 1990 Depth - Shallow

Pair	Site#	Oilcode	All BATHYMAS	All HEXAGRAM	All LARGECOT	All PHOLIDAE	All SCORPIEN	All SMALLCOT	Adult SCORPIEN	Adult STICHAEU	Juvenile STICHAEU	Juvenile GADIDAEW
1	19	O	17.22	9.44	3.33	1.67	12.78	17.22	4.44	4.44	24.44	0.00
1	20	C	6.11	5.56	2.22	1.11	1.11	8.39	0.56	56.11	52.78	5630.00
2	22	O	7.22	8.89	0.56	6.11	0.00	40.00	0.00	55.00	54.44	6.11
2	21	C	1.11	7.78	2.78	12.78	0.56	5.00	0.00	74.44	26.11	75.00
3	23	O	2.78	2.22	1.67	3.33	1.11	62.78	0.00	5.00	38.33	0.00
3	24	C	2.78	7.22	2.22	0.00	36.67	18.39	7.78	0.00	2.22	0.00
	mean	O	9.07	6.85	1.85	3.70	4.63	40.00	1.48	21.48	39.07	2.04
	mean	C	3.33	6.85	2.41	4.63	12.78	10.93	2.78	43.52	27.04	1901.67
	P		0.05	0.95	0.52	0.31	0.90	<0.01	0.31	0.12	0.34	0.02

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Nereocystis Bed - 1990 Depth = Shallow

Pair	Site#	Oilcode	All HEXAGRAM	All LARGECOT	All SMALLCOT	Juvenile GADIDAEW
1	7	O	0.00	0.00	0.00	0.00
1	8	C	4.44	1.67	1.67	0.00
2	12	O	24.00	3.33	1.33	333.33
2	11	C	7.22	1.67	0.56	69.44
	mean	O	12.00	1.67	0.67	166.67
	mean	C	5.83	1.67	1.11	34.72
	P		0.08	0.53	0.79	0.57

ACE 30287050

APPENDIX AA.

Mean values and results of 2 way randomization ANOVAs comparing abundance and biomass of dominant families of fish at oiled and control sites in the eelgrass and *Laminaria/Agarum* bay habitats in 1990 and 1991.

Appendix AA. Mean values and results of 2-way randomization ANOVAs comparing abundance (#/100m^2) of dominant families of fish at oiled and control sites in the eelgrass and *Laminaria/Agarum* bay habitats in 1990 and 1991. Only sites sampled during both years were used for analyses.

Island Bays - Shallow

YEAR	GROUP	STAGE	OILCODE	DENSITY	SE	N
1990	Stichaeus punctatus	A	O	22.96	5.93	3
1990	Stichaeus punctatus	A	C	24.44	19.45	3
1991	Stichaeus punctatus	A	O	7.04	4.55	3
1991	Stichaeus punctatus	A	C	17.78	6.41	3

Oilcode	P	0.36
Year	P	0.08
Interaction	P	0.47

Island Bays - Shallow

YEAR	GROUP	STAGE	OILCODE	DENSITY	SE	N
1990	Stichaeus punctatus	J	O	3.70	3.70	3
1990	Stichaeus punctatus	J	C	9.63	9.08	3
1991	Stichaeus punctatus	J	O	5.00	3.39	3
1991	Stichaeus punctatus	J	C	1.67	0.85	3

Oilcode	P	0.99
Year	P	0.78
Interaction	P	0.42

ACE 30287052

Eelgrass - Bed

YEAR	GROUP	STAGE	OILCODE	DENSITY	SE	N
1990	Gadidae without Pollock	A	O	5.14	2.25	4
1990	Gadidae without Pollock	A	C	0.97	0.66	4
1991	Gadidae without Pollock	A	O	11.67	4.62	4
1991	Gadidae without Pollock	A	C	10.14	6.81	4

Oilcode P 0.47
Year P 0.015
Interaction P 0.74

Eelgrass - Bed

YEAR	GROUP	STAGE	OILCODE	DENSITY	SE	N
1990	Gadidae without Pollock	J	O	91.67	35.70	4
1990	Gadidae without Pollock	J	C	14.44	5.68	4
1991	Gadidae without Pollock	J	O	245.97	178.04	4
1991	Gadidae without Pollock	J	C	67.64	65.06	4

Oilcode P 0.015
Year P 0.08
Interaction P 0.45

APPENDIX BB

Polycyclic aromatic hydrocarbons analyzed as present in EXXON VALDEZ crude oil and included in the estimation of concentrations of EXXON VALDEZ PAHs.

APPENDIX BB. Polycyclic aromatic hydrocarbons analyzed as present in EXXON VALDEZ crude oil and included in the estimation of concentrations of EXXON VALDEZ PAHs.

naphthalene
2-methylnaphthalene
1-methylnaphthalene
C-2 naphthalenes
C-3 naphthalenes
C-4 naphthalenes
biphenyl
fluorene
C-1 fluorenes
C-2 fluorenes
C-3 fluorenes
dibenzothiophene
C-1 dibenzothiophenes
C-2 dibenzothiophenes
C-3 dibenzothiophenes
phenanthrene
C-1 phenanthrenes/anthracenes
C-2 phenanthrenes/anthracenes
C-3 phenanthrenes/anthracenes
C-4 phenanthrenes/anthracenes
C-1 fluoranthenes/pyrenes
chrysene
C-1 chrysenes
C-2 chrysenes

APPENDIX CC.

Concentrations of EXXON VALDEZ PAHs (ng/g) in shallow subtidal surficial sediments in Prince William Sound, 1990-91. (Data provided by the Technical Service Task Force: Analytical Chemistry Group).

Appendix CC. Estimated concentrations of EXXON VALDEZ PAHs (ng/g) in shallow subtidal surficial sediments in Prince William Sound, 1990-91. Estimates were made by summing values for all of the analytes present in EXXON VALDEZ crude oil. Analytes are presented in Appendix BB.

Eelgrass Beds - Deep

YEAR	PAIR	OILCODE	SITNUM	SITNAME	HCSUM	SE	N	CV	STD
1990	1	O	13	Bay of Isles	1383.56	470.784	3	58.936	815.422
1990	1	C	14	Drier Bay	932.43	328.301	3	60.984	568.635
1990	2	O	16	Herring Bay	25.80	9.605	3	64.485	16.637
1990	2	C	15	L. Herring Bay	651.33	120.650	2	26.196	170.625
1990	3	O	17	Sleepy Bay	527.57	250.427	3	82.217	433.752
1990	3	C	18	Moose Lips Bay	571.88	513.900	3	155.645	890.101
1990	4	O	25	Clammy Bay	23.87	6.740	3	48.911	11.673
1990	4	C	26	Puffin Bay	29.51	9.841	3	57.754	17.045
1990		O Mean			490.200	320.497	4	130.762	640.995
1990		C Mean			546.288	188.823	4	69.129	377.645
		P-value for Oilcode = 0.919							

Eelgrass Beds - Shallow

YEAR	PAIR	OILCODE	SITNUM	SITNAME	HCSUM	SE	N	CV	STD
1990	1	O	13	Bay of Isles	1274.95	516.728	3	70.199	894.999
1990	1	C	14	Drier Bay	342.64	183.336	3	92.677	317.546
1990	2	O	16	Herring Bay	41.66	14.495	3	60.260	25.106
1990	2	C	15	L. Herring Bay	103.31	53.579	3	89.831	92.801
1990	3	O	17	Sleepy Bay	113.85	29.225	3	44.460	50.619
1990	3	C	18	Moose Lips Bay	68.03	19.627	3	49.972	33.994
1990	4	O	25	Clammy Bay	290.54	110.657	3	65.967	191.663
1990	4	C	26	Puffin Bay	562.78	270.917	3	83.379	469.242
1990		O Mean			430.252	286.376	4	133.120	572.753
1990		C Mean			269.187	115.316	4	85.677	230.632
		P-value for Oilcode = 0.532							

Eelgrass Beds - Bed

YEAR	PAIR	OILCODE	SITNUM	SITNAME	HCSUM	SE	N	CV	STD
1990	1	O	13	Bay of Isles	1148.15	548.871	3	82.800	950.672
1990	1	C	14	Drier Bay	303.33	132.477	3	75.647	229.457
1990	2	O	16	Herring Bay	116.23	37.158	3	55.372	64.359
1990	2	C	15	L. Herring Bay	60.44	11.384	3	32.623	19.719
1990	3	O	17	Sleepy Bay	157.78	95.881	3	105.257	166.072
1990	3	C	18	Moose Lips Bay	79.86	20.517	3	44.498	35.537
1990	4	O	25	Clammy Bay	568.62	200.122	3	60.958	346.621
1990	4	C	26	Puffin Bay	402.56	174.864	3	75.237	302.872
1990		O Mean			497.695	239.650	4	96.304	479.300
1990		C Mean			211.548	84.203	4	79.607	168.407
		P-value for Oilcode = 0.039							

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Eelgrass Beds - Deep

YEAR	PAIR	OILCODE	SITNUM	SITNAME	HCSUM	SE	N	CV	STD
1991	1	O	13	Bay of Isles	164.860	65.704	3	69.030	113.802
1991	1	C	14	Drier Bay	45.797	7.986	3	30.203	13.832
1991	2	O	16	Herring Bay	74.943	32.098	3	74.184	55.596
1991	2	C	15	L. Herring Bay	43.540	4.830	2	15.688	6.831
1991	3	O	17	Sleepy Bay	118.300	16.312	3	23.882	28.253
1991	3	C	18	Moose Lips Bay	72.877	7.411	3	17.613	12.836
1991	4	O	25	Clammy Bay	89.520	5.998	3	11.605	10.389
1991	4	C	26	Puffin Bay	91.197	24.627	3	46.772	42.654
1991		O Mean			111.906	19.817	4	35.417	39.633
1991		C Mean			63.352	11.426	4	36.072	22.853
		P-value for Oilcode = 0.027							

Eelgrass Beds - Bed

YEAR	PAIR	OILCODE	SITNUM	SITNAME	HCSUM	SE	N	CV	STD
1991	1	O	13	Bay of Isles	114.623	35.789	3	54.080	61.988
1991	1	C	14	Drier Bay	102.000	25.771	3	43.761	44.636
1991	2	O	16	Herring Bay	82.443	12.713	3	26.709	22.019
1991	2	C	15	L. Herring Bay	14.493	1.545	3	18.468	2.677
1991	3	O	17	Sleepy Bay	103.753	46.718	3	77.991	80.918
1991	3	C	18	Moose Lips Bay	41.510	2.586	3	10.790	4.479
1991	4	O	25	Clammy Bay	97.267	9.642	3	17.170	16.700
1991	4	C	26	Puffin Bay	104.460	30.486	3	50.549	52.803
1991	5	O	35	Short Arm Bay	133.113	27.317	3	35.544	47.314
1991	5	C	34	Mallard Bay	148.423	59.245	3	69.137	102.616
1991		O Mean			106.240	8.501	5	17.893	19.009
1991		C Mean			82.177	23.993	5	65.285	53.649
		P-value for Oilcode = 0.264							

Island Bays - Deep

YEAR	PAIR	OILCODE	SITNUM	SITNAME	HCSUM	SE	N	CV	STD
1990	1	O	2	Northwest Bay	220.563	129.465	3	101.667	224.240
1990	1	C	1	Cabin Bay	41.517	13.699	3	57.152	23.728
1990	2	O	3	Herring Bay	59.593	10.624	3	30.878	18.401
1990	2	C	4	L. Herring Bay	25.497	13.904	3	94.450	24.082
1990	3	O	6	Bay of Isles	246.617	36.609	3	25.712	63.409
1990	3	C	5	Mummy Bay	43.013	29.719	3	119.671	51.475
1990		O Mean			175.591	58.485	3	57.690	101.298
1990		C Mean			36.676	5.606	3	26.475	9.710
		P-value for Oilcode = 0.016							

Island Bays - Shallow

YEAR	PAIR	OILCODE	SITNUM	SITNAME	HCSUM	SE	N	CV	STD
1990	1	O	2	Northwest Bay	306.673	80.133	3	45.258	138.794
1990	1	C	1	Cabin Bay	131.837	14.949	3	19.640	25.892
1990	2	O	3	Herring Bay	863.557	330.185	3	66.226	571.897
1990	2	C	4	L. Herring Bay	280.640	70.710	2	35.632	99.999
1990	3	O	6	Bay of Isles	393.757	330.490	3	145.375	572.426
1990	3	C	5	Mummy Bay	182.660	36.349	3	34.467	62.958
1990		O Mean			521.329	172.951	3	57.461	299.559
1990		C Mean			198.379	43.669	3	38.127	75.637
		P-value for Oilcode = 0.076							

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Island Points - Deep

YEAR	PAIR	OILCODE	SITNUM	SITNAME	%CSUM	SE	N	CV	STD
1990	1	O	19	Discovery Pt.	24.460	10.849	3	76.824	18.791
1990	2	O	22	O. Herring Bay	58.830	.	1	.	.
1990	2	C	21	O.L. Herring Bay	65.533	22.151	3	58.545	38.366
1990	3	O	23	Ingot Point	50.673	34.059	3	116.417	58.993
1990	3	C	24	Peak Point	49.173	5.681	3	20.010	9.839
1990		O Mean			44.654	10.368	3	40.216	17.958
1990		C Mean			57.353	8.180	2	20.170	11.568
		P-value for Oilcode = 0.904							

Island Points - Shallow

YEAR	PAIR	OILCODE	SITNUM	SITNAME	%CSUM	SE	N	CV	STD
1990	1	C	20	Lucky Point	11.577	4.361	3	65.243	7.553
1990	2	O	22	O. Herring Bay	64.790	30.160	2	65.832	42.653
1990		O Mean			64.790	.	1	.	.
1990		C Mean			11.577	.	1	.	.
		Insufficient data for analysis							

Nereocystis Beds - Shallow

YEAR	PAIR	OILCODE	SITNUM	SITNAME	%CSUM	SE	N	CV	STD
1990	1	O	7	Latouche Pt.	39.76	.	1	.	.
1990		C - no samples analyzed for control sites							
1990		O Mean			39.76	.	1	.	.
1990		C Mean - no samples analyzed for control sites							

Silled Fjords

YEAR	PAIR	OILCODE	SITNUM	SITNAME	%CSUM	SE	N	CV	STD
1990	1	O	30	I. Bay of Isles	283.150	168.390	2	84.104	238.14
1990	1	O	31	O. Bay of Isles	662.044	417.319	5	140.950	933.15
1990	1	C	27	O. Lucky Bay	720.687	659.162	3	158.419	1141.70
1990	1	C	29	I. Lucky Bay	479.495	37.355	2	11.017	52.83
1990		O Mean			472.597	189.447	2	56.691	267.919
1990		C Mean			600.091	120.596	2	28.420	170.548
		P-value for Oilcode = 0.821							

ACE 30287059-12