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Exxon Valdez Oil Spill
State/Federal Natural Resources Damage Assessment Final Report

Injury to Crabs Outside Prince William Sound

Fish/Shellfish Study Number 22
Final Report

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Study History: This study was carried out in 1989 and 1990 according to the original study plan.

Abstract: Commercial Dungeness crab fisheries exist near Kodiak Island and the eastern Alaska Peninsula. Both areas lie within the trajectory of the 1989 *Exxon Valdez* oil spill. Thirty nine sites in the region were sampled in 1989 and 1990 to assess petroleum hydrocarbon contamination of crab tissues and benthic sediments with which crabs were associated. Female crabs were found in small numbers at 15 sites. Eight of these sites exhibited low levels of petroleum hydrocarbons in the sediments. Only two of the eight sites showed oil contamination that could be linked convincingly to the *Exxon Valdez* oil spill. None of the crab tissue samples showed evidence of contamination by petroleum hydrocarbons.

Key Words: *Exxon Valdez*, oil, petroleum, hydrocarbons, sediments, tissues, Dungeness crabs, contamination

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TABLE OF CONTENTS

LIST OF TABLES	2
LIST OF FIGURES	3
EXECUTIVE SUMMARY	4
INTRODUCTION	5
OBJECTIVES	5
METHODS	6
RESULTS	12
DISCUSSION	15
CONCLUSIONS	17
LITERATURE CITED	18

LIST OF TABLES

Table 1.--Locations of sites sampled in 1989 and 1990.	8
Table 2.--Number of crab pots fished, mean depths of pot strings, sex ratio of crabs captured, and catch per unit effort (CPUE) at sites sampled in 1989.	9
Table 3.--Location and number of samples of sediments and female crab hepatopancreas and ovarian tissues, and eggs collected for hydrocarbon analysis in 1989 and 1990.	11
Table 4.--Indices of contamination by petroleum hydrocarbons for sediments from sites sampled at Kodiak Island and the eastern Alaska Peninsula during 1989 and 1990.	13
Table 5.--Total PAH concentrations in ovarian and hepatopancreas tissues sampled from crabs collected at Kodiak Island and the eastern Alaska Peninsula in 1989 and 1990.	14
Table 6.--Sex ratio and catch per unit effort (CPUE) of Dungeness crabs caught at 24 sites at Kodiak Island and the upper Alaska Peninsula in 1990. Numbers in parentheses refer to the number of ovigerous crabs caught.	16

LIST OF FIGURES

Figure 1. Map of Kodiak Island and part of the Alaska, Peninsula showing locations of study sites. Circled numbers denote sites contaminated by *Exxon Valdez* oil. The remainder of the site numbers indicate reference locations. 1. Cape Chiniak; 2. Northern Hallo Bay; 3. Southern Hallo Bay; 4. Devils Cove/Kukak Point; 5. Northern Kukak Bay; 6. Southern Kukak Bay; 7. Kuliak Bay; 8. Missak Bay; 9. Hidden Harbor/Kinak Bay; 10. Eastern Puale Bay; 11. Western Puale Bay; 12. Malina Bay; 13. Malka Bay; 14. Muskomee Bay; 15. Raspberry Strait; 16. Kupreanof Strait; 17. Dry Spruce Bay; 18. Southwest Uganik Island; 19. Eastern Uganik Passage; 20. Terror Bay; 21. Little River; 22. Broken Point; 23. Bird Rock; 24. East Arm, Uganik Bay; 25. South Arm, Uganik Bay; 26. Selief Bay; 27. Thomas Rock; 28. Sharatin Bay; 29. Barabara Cove; 30. Kizhuyak Bay; 31. Saltery Cove; 32. Hidden Basin Bay; 33. Southwest Arm, Uganik Bay 1, 34. Southwest Arm, Uganik Bay 2, 35. Santa Flavia Bay; 36. Shearwater Bay; 37. North Arm Kiliuda Bay; 38. West Arm Kiliuda Bay. 7

EXECUTIVE SUMMARY

Results from the hydrocarbon analyses of sediment samples from 45 sites around Kodiak Island and the eastern Alaska Peninsula in 1989 and 1990 indicated that subtidal sediments were contaminated by petroleum hydrocarbons at only eight sites. Of these eight sites, only two sites were identified as having been contaminated by oil from the *Exxon Valdez* spill. The concentrations of total hydrocarbons in subtidal sediments were low at contaminated sites, reaching a maximum of 37 $\mu\text{g/g}$ wet weight at Kuliak Bay in 1989. None of the Dungeness crab tissue samples from these sites showed evidence of hydrocarbon contamination. No evidence was found of injury to Dungeness crabs at or near Kodiak Island that could be linked to the *Exxon Valdez* oil spill.

INTRODUCTION

Dungeness crabs may be especially susceptible to contamination by petroleum hydrocarbons because they burrow into benthic sediments while brooding their eggs. Dungeness crabs in Alaska occupy nearshore areas in protected bays and estuaries. These habitats are usually characterized by fine benthic sediments and minimal wave action. Oil incorporated in shallow subtidal sediments may persist and could affect crab populations for several years after an oil spill (Krebs and Burns 1977; Boehm et al. 1987).

Several studies have documented deleterious effects on crabs exposed to petroleum hydrocarbons. Sublethal concentrations can result in early post-molt autotomy of limbs, behavioral disorders and reduced reproductive capacity (Karinen and Rice 1974; Krebs and Burns 1977; Karinen et al. 1985; Malan 1988). Sex and reproductive state may determine responses of crabs to oil pollution. Krebs and Burns (1977) noted a greatly reduced proportion of females in populations of the fiddler crab, *Uca pugnax*, at oil contaminated sites in Buzzards Bay, Massachusetts. Reproductively active ghost crabs, *Ocypode quadrata*, are more sensitive to the water-soluble fraction of crude oil than are crabs not in reproductive condition (Jackson et al. 1981).

The goal of this project was to provide quantitative data on adverse impacts on populations of Dungeness crabs, *Cancer magister*, in the vicinity of Kodiak Island and the eastern Alaska Peninsula as a result of the EVOS. These data would permit assessment of short-term losses caused by contamination of harvestable crabs and long-term impacts owing to adverse effects on crab reproduction.

OBJECTIVES

1. Determine the presence or absence of petrogenic hydrocarbons in sediments from sites harboring populations of Dungeness crabs along the eastern Alaska Peninsula and at Kodiak Island.
2. Determine the levels of hydrocarbons, if present, in Dungeness crabs from oiled and control sites along the eastern Alaska Peninsula and at Kodiak Island.
3. Assess reproductive condition of Dungeness crabs from oiled and control sites by measuring the percentage of ovigerous crabs and fecundity.
4. Determine differences in intensity of settlement of Dungeness crab megalopae in oiled sites and control sites.

METHODS

1989

In 1989, Dungeness crabs were collected at 11 sites at Kodiak Island, Alaska and the eastern Alaska Peninsula (Fig. 1; Table 1) with baited commercial crab pots. From one to three strings of pots (eight pots per string) were set along depth contours where crabs were expected to be most abundant. Pots were allowed to soak for periods ranging from 12 to 44 h. The depth, time, and coordinates at which each pot was set were recorded.

After each pot was pulled, the number of crabs, sex, carapace width, presence or absence of an egg clutch, and external physical condition were recorded. We had originally planned to sample a total of 24 female crabs from each site. Three samples of eight crabs each were to be taken. A single sample was to consist of one randomly selected female crab taken from each of the eight pots in a string. Carapace width, fresh weight, clutch description and physical description of all crabs in these samples were to be recorded. We failed to catch adequate numbers of crabs at most sites for this sampling scheme to be employed (Table 2). In these cases we used all female crabs captured regardless of which pot contained them.

We sampled tissue from the ovaries and hepatopancreas of female crabs. Where sample size allowed, three crabs were randomly selected from the eight crabs selected from each string of pots and sacrificed for ovaries, eggs and hepatopancreas. Three ovaries equaled one composite hydrocarbon sample, and three hepatopancreases equaled one composite hydrocarbon sample. Only one ovigerous crab was captured during 1989; hence, egg samples were not taken. At sites where fewer than three female crabs were captured in a string of pots, samples were composed of ovaries and hepatopancreas of only one or two crabs. At eight sites, we took hepatopancreas tissue from male crabs in addition to the tissue from female crabs. Composite samples of crab tissue were placed in hydrocarbon-clean 118.28-cc (4 oz) glass jars. Samples were immediately frozen. Chain of custody procedures were followed.

Sediment samples were collected for hydrocarbon analysis. A van Veen grab was used to collect sediment samples from near the center of each string of crab pots. A metal spatula and core tube were used to remove 2-cm-d sediment cores from four randomly chosen points in each grab. The four subsamples were combined in a sample jar to form a single composite sample from each grab. The sampling implements were washed, dried, and rinsed with methylene chloride between grabs. Sample jars were baked at 440°C for 4 h or otherwise cleaned to EPA specifications before use. Hydrocarbon-clean, Teflon-lined caps were used to seal the jars. Sediment samples were frozen immediately after collection. Air blanks were collected at each site. Chain of custody procedures were followed.

1990

A total of 34 sites near Kodiak Island and the eastern Alaska Peninsula were surveyed for Dungeness crabs in 1990 (Table 1; Fig. 1). Because we were unable to capture ovigerous female

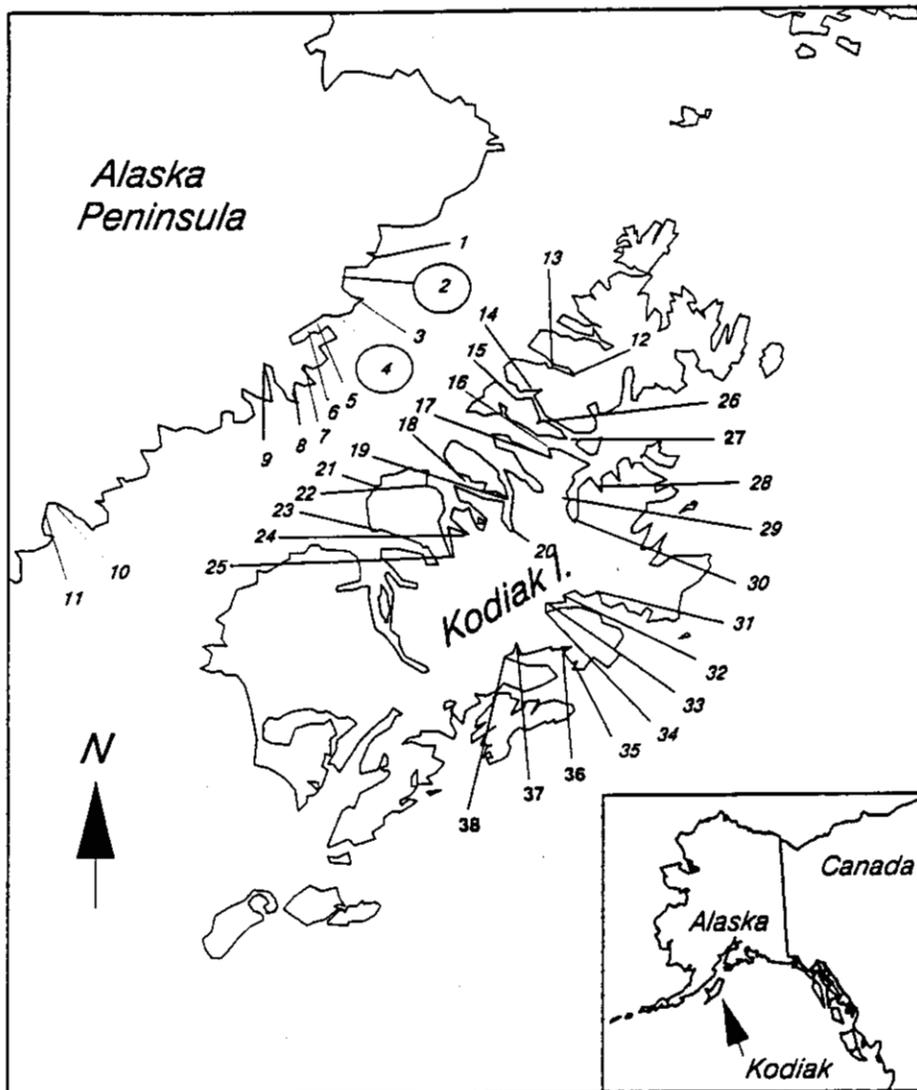


Figure 1. Map of Kodiak Island and part of the Alaska, Peninsula showing locations of study sites. Circled numbers denote sites contaminated by *Exxon Valdez* oil. The remainder of the site numbers indicate reference locations. 1. Cape Chiniak; 2. Northern Hallo Bay; 3. Southern Hallo Bay; 4. Devils Cove/Kukak Point; 5. Northern Kukak Bay; 6. Southern Kukak Bay; 7. Kuliak Bay; 8. Missak Bay; 9. Hidden Harbor/Kinak Bay; 10. Eastern Puale Bay; 11. Western Puale Bay; 12. Malina Bay; 13. Malka Bay; 14. Muskomee Bay; 15. Raspberry Strait; 16. Kupreanof Strait; 17. Dry Spruce Bay; 18. Southwest Uganik Island; 19. Eastern Uganik Passage; 20. Terror Bay; 21. Little River; 22. Broken Point; 23. Bird Rock; 24. East Arm, Uganik Bay; 25. South Arm, Uganik Bay; 26. Selief Bay; 27. Thomas Rock; 28. Sharatin Bay; 29. Barabara Cove; 30. Kizhuyak Bay; 31. Saltery Cove; 32. Hidden Basin Bay; 33. Southwest Arm, Uganik Bay 1; 34. Southwest Arm, Uganik Bay 2; 35. Santa Flavia Bay; 36. Shearwater Bay; 37. North Arm Kiliuda Bay; 38. West Arm Kiliuda Bay.

Table 1.--Locations of sites sampled in 1989 and 1990.

Location	N. Latitude	W. Longitude	Date
Missak Bay	58° 08' 11"	154° 19' 44"	09/27/89
Kuliak Bay	58° 12' 08"	154° 16' 29"	09/28/89
Cape Chiniak	58° 30' 52"	153° 54' 33"	09/28/89
Kukak Bay	58° 20' 30"	154° 11' 40"	09/29/89
Hallo Bay	58° 26' 56"	154° 02' 53"	09/29/89
Muskomee Bay	58° 04' 16"	153° 06' 48"	10/02/89
Sharatin Bay	57° 47' 47"	152° 46' 58"	10/02/89
Kizhuyak Bay	57° 43' 49"	152° 56' 13"	10/03/89
Uganik Bay			
E. Arm	57° 41' 19"	153° 28' 34"	10/01/89
S. Arm	57° 37' 30"	153° 30' 32"	10/01/89
Terror Bay	57° 43' 35"	153° 12' 59"	10/01/89
Puale Bay	57° 47' 09"	155° 33' 45"	05/14/90
Puale Bay	57° 46' 41"	155° 34' 49"	05/14/90
Devil's Cove	58° 21' 06"	154° 11' 36"	05/15/90
Kukak Point	58° 21' 07"	154° 05' 00"	05/15/90
Hallo Bay	58° 28' 37"	154° 02' 13"	05/16/90
Hallo Bay	58° 26' 05"	154° 02' 55"	05/16/90
Malka Bay	58° 10' 34"	152° 59' 48"	05/16/90
Malina Bay	58° 10' 37"	152° 56' 03"	05/16/90
Malina Bay	58° 10' 35"	152° 55' 30"	05/16/90
Muskomee Bay	58° 06' 18"	153° 03' 33"	05/17/90
Raspberry Str.	58° 05' 38"	153° 10' 00"	05/17/90
Dry Spruce Bay	57° 55' 00"	152° 59' 48"	05/17/90
Dry Spruce Bay	57° 56' 12"	153° 00' 06"	05/18/90
Thomas Rock	57° 58' 46"	152° 55' 55"	05/18/90
Broken Point	57° 51' 37"	153° 37' 15"	05/20/90
SW Uganik Is.	57° 51' 51"	153° 24' 34"	05/20/90
Little River	57° 50' 14"	153° 51' 31"	05/22/90
Bird Rock	57° 41' 43"	153° 54' 59"	05/22/90
Barabara Cove	57° 49' 16"	152° 54' 06"	05/23/90
Kizhuyak Bay	57° 45' 19"	152° 52' 12"	05/23/90
Hidden Basin	57° 31' 02"	152° 56' 09"	05/24/90
Kinak Bay	58° 11' 08"	154° 28' 29"	05/14/90
Selief Bay	58° 02' 05"	153° 02' 00"	05/17/90
Onion Bay	58° 05' 00"	153° 16' 06"	05/19/90
E. Uganik Psg.	57° 47' 58"	153° 11' 37"	05/19/90
Terror Bay	57° 44' 12"	153° 12' 24"	05/19/90
Uganik Bay			
S. Arm	57° 38' 09"	153° 29' 49"	05/22/90
Ugak Bay			
SW Arm	56° 26' 34"	153° 02' 00"	05/24/90
NW Arm	56° 28' 27"	153° 00' 38"	05/26/90
Kiliuda Bay			
W. Arm	57° 18' 36"	153° 12' 06"	05/24/90
N. Arm	57° 21' 18"	153° 09' 18"	05/25/90
Saltery Cove	57° 30' 00"	152° 46' 30"	08/26/90
Shearwater Bay	57° 21' 30"	152° 54' 12"	08/25/90
Santa Flavia	57° 18' 12"	152° 51' 00"	08/25/90

Table 2.--Number of crab pots fished, mean depths of pot strings, sex ratio of crabs captured, and catch per unit effort (CPUE) at sites sampled in 1989.

Location	No. Pots	Depths ¹	No. Crab ²	CPUE ³
Missak Bay	24	9.2, 37.0, 43.9	8/11	0.04
Kuliak Bay	24	8.2, 20.1, 56.7	1/72	0.07
Cape Chiniak	16	9.2, 14.6	0/0	0.00
Kukak Bay	8	10.1	2/39	0.19
Hallo Bay	24	15.6, 18.3, 42.1	4/72	0.17
Muskomee Bay	8	22.9	2/0	0.11
Sharatin Bay	24	11.0, 18.3, 24.7	1/1	0.00
Kizhuyak Bay	24	11.0, 11.9, 24.7	18/43	0.18
Uganik Bay				
E. Arm	16	14.6, 19.2	112/38	0.55
S. Arm	16	15.6, 25.6	29/7	0.13
Terror Bay	16	7.3, 19.2	47/45	0.20

1. Mean depths (m) of a string of crab pots.
2. Number of female/male Dungeness crabs captured.
3. Number of Dungeness crabs captured/pot/h.

crabs with commercial pot gear in 1989, Dungeness crabs were collected by divers in 1990. Divers swam three transects at each site to collect female crabs. Three randomly-selected subsamples of ten female crabs each (30 crabs) were to be taken from the diver's total catch; however, female crabs were seen at only five sites and only 46 ovigerous crabs were seen in total. Carapace width, weight, presence or absence of an egg clutch, and a description of the physical condition of each female crab were recorded. The entire left fifth pleopod was removed from each ovigerous crab and fixed in buffered 5% formalin for subsequent processing to estimate fecundity. Sampling of hepatopancreas tissue for hydrocarbon analysis followed procedures described above. When possible, a composite sample of eggs for hydrocarbon analysis was taken by clipping a small portion of the right fifth pleopod from each of the three crabs; otherwise eggs from fewer crabs composed a sample.

Sediment samples were collected at the five sites where female Dungeness crabs were found. Divers collected sediment samples along a 30 m transect laid parallel to shore in the area where divers collected the crabs. Eight subsamples collected randomly along the 30 m transect and were combined into a single composite sample. Samples were taken from the top 2 cm of the benthic substrate with a steel core tube and spatula. Preparation of sampling implements and specimen jars followed procedures described above.

Artificial substrates were deployed to assess the intensity of settlement of larval Dungeness crabs at four oiled and four control sites at Kodiak Island. Oiled sites included the West and North Arms of Kiliuda Bay, and the Southwest and Northwest Arms of Ugak Bay. Control sites included Santa Flavia Bay, Shearwater Bay, Saltery Cove and Hidden Basin. Ten artificial substrates were deployed 0.5 m above the bottom at each site, along the approximate 6 m isobath. The artificial substrates were attached to a weighted groundline and placed 2 m apart. Individual substrates were constructed of collars of furnace filter material completely covering PVC cylinders (20.3 cm d). The substrates were set out in late June and retrieved in late August. Upon retrieval, each substrate was rinsed twice for 3 minutes with a high pressure hose into a tub, and tub contents were strained through a 0.5 mm mesh sieve. Material retained in the sieve was preserved in 5% seawater-buffered formalin for later sorting and counting of crab megalopae.

Sample Analysis

A total of 25 sediment samples, 17 female crab hepatopancreas tissue samples, and 15 crab ovarian tissue samples were collected for hydrocarbon analysis in 1989. A total of five sediment samples (from three sites), three female crab hepatopancreas tissue samples, and three samples of crab eggs were collected for hydrocarbon analysis in 1990 (Table 3).

Definitive analysis of the chemical composition of petroleum hydrocarbons in the sediments, tissues, and eggs was accomplished with gas chromatography/mass spectrometry under Technical Services Study Number 1. Technical Services Study Number 1 has promulgated a set of provisional criteria for determining the presence of petrogenic hydrocarbons. The criteria comprise the following indices: 1. the pristane/phytane ratio, 2. the Carbon Preference Index

Table 3.--Location and number of samples of sediments and female crab hepatopancreas and ovarian tissues, and eggs collected for hydrocarbon analysis in 1989 and 1990.

Location	Sediments	Hepatopancreas	Ovary	Eggs
1989				
Missak Bay	3	3	3	
Kuliak Bay	3	1	1	
Cape Chiniak	2	0	0	
Kukak Bay	1	1	1	
Hallo Bay	3	2	1	
Muskomee Bay	1	1	0	
Kizhuyak Bay	3	3	3	
Sharatin Bay	3	1	1	
Uganik Bay				
E. Arm	2	2	2	
S. Arm	2	1	1	
Terror Bay	2	2	2	
1990				
Hidden Basin	1	1		1
Uganik Bay				
S. Arm	3	1		1
Ugak Bay				
SW Arm	1	1		1

(Farrington and Tripp, 1977), 3. the unresolved complex mixture (UCM) and 4. the number of compounds that are present from the naphthalene, phenanthrene, and dibenzothiophene groups of aromatic hydrocarbons. A low value (1-3) for CPI indicates high concentrations of petrogenic hydrocarbons as does a large UCM and a large proportion of possible naphthalene, phenanthrene, and dibenzothiophene compounds. A high pristane/phytane ratio generally indicates the absence of petrogenic hydrocarbons.

Criteria were established for comparing hydrocarbon concentrations in sediments with those in EVO. The pattern of polynuclear aromatic hydrocarbon (PAH) concentrations in the sediment samples was judged similar to EVO if it met three criteria: (1) the ratio of alkyl dibenzothiophenes to alkyl phenanthrenes exceeded 0.30; (2) the ratio of alkyl chrysenes to alkyl phenanthrenes exceeded 0.10; and (3) the concentration of alkyl phenanthrenes exceeded 5.0 ng/g (Short et al., In press).

RESULTS

Subtidal sediments from five of eleven locations sampled in 1989 showed contamination by petroleum hydrocarbons according to criteria promulgated by Technical Services Study Number 1. The five contaminated sites included Missak, Kuliak, Hallo, and Kukak Bays, as well as Cape Chiniak. However, petrogenic hydrocarbon contamination at all these sites was very low (Table 4). According to the criteria listed above (Short et al., In press) only Hallo Bay (15 m depth) and Kukak Bay (13 m depth) showed traces of oil contamination that could be linked convincingly to the EVOS. The concentrations of total hydrocarbons (defined as the sum of the total aromatic hydrocarbons, total alkanes and UCM) in subtidal sediments were relatively low at contaminated sites declining from a maximum of 37 $\mu\text{g/g}$ wet weight at 11 m in Kuliak Bay (Table 4). The concentrations of total hydrocarbons in sediments from sites deemed not to be contaminated by petrogenic hydrocarbons were comparable in magnitude to those at contaminated sites, but were accompanied by high values of CPI and generally low numbers of naphthalene, phenanthrene and dibenzothiophene compounds (Table 4).

Sediment samples collected from three sites in 1990 showed contamination by petrogenic hydrocarbons, as determined by Technical Services Study Number 1 (Table 4). The sites were Hidden Basin, South Arm of Uganik Bay, and Southwest Arm of Ugak Bay. Again, however, the concentrations of total hydrocarbons were low, ranging from 7.0 $\mu\text{g/g}$ at the Southwest Arm of Ugak Bay to 10.4 $\mu\text{g/g}$ at Hidden Basin. These samples were not subjected to principal component analysis and thus, the source of this contamination remains an open question.

Concentrations of PAHs were low in all tissue samples collected (Table 5). Moreover, the samples contained few naphthalenes, phenanthrenes and dibenzothiophenes. Technical Services Study Number 1 concluded that none of the samples contained petrogenic hydrocarbons.

Table 4.--Indices of contamination by petroleum hydrocarbons for sediments from sites sampled at Kodiak Island and the eastern Alaska Peninsula during 1989 and 1990.

Location	Depth ¹	Pr/Ph ²	CPI ³	UCM ⁴	THC ⁵
1989					
Missak Bay	5	10.1	8.5	0.0	2.8
	16	1.0	19.2	24.6	28.8
	47	8.8	11.7	18.0	21.0
Kuliak Bay	11	3.9	26.0	33.0	37.1
	18	5.2	22.0	7.0	10.8
	68	1.4	7.2	2.7	14.3
Cape Chiniak	11	1.9	5.7	10.0	10.7
	13	1.8	5.3	9.3	10.0
Hallo Bay	13	2.2	9.3	15.0	16.9
	15	1.6	5.5	8.4	19.7
	44	4.0	9.0	17.0	19.2
Kukak Bay	13	0.8	15.0	18.2	20.0
Muskomee Bay	24	16.7	50.0	11.0	13.2
Sharatin Bay	7	2.1	20.9	0.0	0.4
	18		11.5	0.0	1.4
	25	318.0	17.7	1.0	3.6
Kizhuyak Bay	11	18.0	16.3	21.5	25.8
	13		13.9	8.6	9.7
	31	43.2	11.5	7.8	10.1
Terror Bay	11	1.8	29.0	29.0	34.8
	20	3.6	21.0	18.0	23.5
Uganik Bay E. Arm	15	0.9	13.0	13.3	14.3
	20	2.6	15.0	20.0	23.1
S. Arm	16	2.9	18.0	15.0	17.0
	27	1.1	14.0	15.9	17.0
1990					
Hidden Basin	8	3.1	21.7	52.2	10.4
Uganik Bay S. Arm					
Mean ⁶	10	3.1	17.6	57.5	8.6
SE ⁷	0	0.1	0.6	5.8	0.6
Ugak Bay SW Arm	5	3.2	15.8	41.1	7.0

1. Refers to depth (m) at which sample was taken.
2. Pristane/Phytane ratio.
3. Carbon Preference Index.
4. Unresolved Complex Mixture.
5. Total Hydrocarbon Concentration ($\mu\text{g/g}$ wet weight).
6. Mean of three measurements.
7. SE, standard error of the mean.

Table 5.--Total PAH concentrations in ovarian and hepatopancreas tissues sampled from crabs collected at Kodiak Island and the eastern Alaska Peninsula in 1989 and 1990.

Location	Depth ¹	Tissue ²	Total PAH ³	
1989				
Missak Bay	9.2	H♀	41.1	
	37.0	H♀	30.2	
	43.9	H♀	37.7	
	9.2	O	27.4	
	37.0	O	28.1	
Kuliak Bay	43.9	O	25.8	
	8.2	H♂	38.0	
	20.1	H♂	39.0	
	56.7	H♀	36.7	
Kukak Bay	56.7	O	23.0	
	10.1	H♀	38.7	
	10.1	O	42.3	
Hallo Bay	10.1	H♂	36.9	
	15.6	H♂	29.7	
	15.6	H♀	30.3	
	42.1	H♂	35.1	
	42.1	H♀	37.1	
Muskomee Bay	42.1	O	26.4	
	22.9	H♀	32.3	
Kizhuyak Bay	11.0	H♂	41.1	
	11.0	H♀	37.3	
	11.0	O	35.0	
	11.9	H♂	33.6	
	11.9	H♀	39.1	
	11.9	O	22.5	
	24.7	H♂	36.3	
	24.7	H♀	34.8	
Sharatin Bay	24.7	O	35.2	
	18.3	H♂	33.1	
	18.3	H♀	39.0	
Uganik Bay	18.3	O	29.6	
	E. Arm	14.6	O	24.3
		14.6	H♀	35.0
		14.6	H♂	33.0
		18.3	O	27.6
		18.3	H♀	33.0
	S. Arm	18.3	H♂	40.3
		15.6	H♂	33.4
		15.6	H♀	26.4
		15.6	O	26.9
25.6		H♂	57.1	
Terror Bay	7.3	H♂	34.9	
	7.3	H♀	36.0	
	7.3	O	29.7	
	19.2	H♂	36.2	
	19.2	H♀	34.1	
	19.2	O	31.2	
1990				
Hidden Basin	5.0	H	26.8	
	5.0	E	56.8	
Uganik Bay	10.0	H	12.1	
		E	52.0	
Ugak Bay	8.5	H	16.9	
		E	45.1	

1. Mean depth of string of crab pots, or maximum depth (m) of dive.

2. H = hepatopancreas, E = egg.

3. Total Polynuclear Hydrocarbons (ng/g).

Only small numbers of crabs were caught at most sites in 1989 and 1990. Female crabs were caught at 10 of 11 sites in 1989, but catch per unit effort was low, ranging from 0 to 0.55 crabs/pot/hr (Table 2). Only one ovigerous crab was caught. In 1990, divers observed and collected female crabs at only five sites; only four sites had ovigerous crabs (Table 6). Catch per unit effort ranged from 1.2 to 87 crabs/diver/hr at those sites where crabs were observed. None of the crabs showed obvious somatic or reproductive injury (e.g. marked reduction in clutch size) attributable to oil exposure. The number of eggs present on the left fifth pleopods of female crabs from three sites where eggs were collected ranged from 17,919 at the Southwest Arm of Ugak Bay to 85,765 at Hidden Harbor. These numbers are primarily dependent on female size, and are comparable to those found by O'Clair and Freese (1988) on crabs collected at undisturbed sites in southeast Alaska.

No Dungeness crab megalops were found on any of the artificial substrates that we deployed, although numerous post-larval shrimp, gammarid amphipods and helmet crabs (*Telmessus cheiragonus*) were present.

DISCUSSION

Evidence of contamination of subtidal sediments by petrogenic hydrocarbons was detected at eight of 45 sites examined in 1989 and 1990, but only two of the sites (Hallo Bay and Kukak Bay) were determined to be contaminated with crude oil from the EVOS. Levels of contamination at Hallo and Kukak Bays were low. Levels of petrogenic hydrocarbons at Hallo Bay, the only site we examined that was also examined in Air/Water Study Number 2 (O'Clair et al., In prep), showed contamination levels similar to those found in that study.

Although relatively large concentrations of male Dungeness crabs were present at many of our sample sites, we were able to capture only small numbers of female crabs at most locations. Work by O'Clair et al. (1990) showed that ovigerous female crabs are much less active than either male or non-ovigerous female crabs, and thus presumably less likely to encounter and enter commercial crab pots. We captured female Dungeness crabs at only two sites (Hallo Bay and Kukak Bay) confirmed to have been contaminated by *Exxon Valdez* crude oil. None of the tissue samples we collected showed evidence of hydrocarbon contamination, as evidenced by the low levels of PAHs that were found. The results of the analyses of the hepatopancreas samples may be somewhat misleading because metabolism of hydrocarbons taken up by that organ may have taken place during the time between exposure to oil and capture of the crabs. In general, though low levels of petroleum hydrocarbons were detected in sediments to which the crabs were presumably exposed, the exposure was apparently not great enough to result in detectable uptake into crab tissues.

Our site selection criteria for this investigation were predicated on the need to locate populations of female Dungeness crabs in areas both in and away from the trajectory of the oil spill. We relied heavily on anecdotal information supplied by local commercial crab fishermen to

Table 6.--Sex ratio and catch per unit effort (CPUE) of Dungeness crabs caught at 24 sites at Kodiak Island and the upper Alaska Peninsula in 1990. Numbers in parentheses refer to the number of ovigerous crabs caught.

Location	Depth ¹	Ratio ²	CPUE ³
Puale Bay	9.2	0/0	0.00
	10.7	0/0	0.00
Devil's Cove	15.2	0/0	0.00
Kukak Point	15.2	0/0	0.00
Hallo Bay	15.2	0/0	0.00
	12.2	0/0	0.00
Malka Bay	12.2	0/0	0.00
Malina Bay	15.2	0/0	0.00
	15.2	0/0	0.00
Muskomee Bay	12.2	0/0	0.00
Raspberry Str.	24.4	0/0	0.00
Dry Spruce Bay	11.3	0/5	2.70
	18.6	0/3	3.33
Thomas Rock	19.2	0/0	0.00
Broken Point	9.5	0/1	1.18
SW Uganik Is.	22.6	0/1	1.15
Little River	9.2	0/0	0.00
Bird Rock	19.5	0/0	0.00
Barabara Cove	12.2	0/0	0.00
Kizhuyak Bay	7.3	14/14	40.00
Hidden Basin	7.3	20(4)/47	87.01
Kinak Bay	8.5	28(28)/6	20.36
Selief Bay	9.2	0/0	0.00
Onion Bay	18.6	0/0	0.00
E. Uganik Psg.	25.0	0/0	00.00
Terror Bay	5.5	0/0	00.00
Uganik Bay			
S. Arm	9.8	6(4)/1	7.22
Ugak Bay			
SW Arm	12.2	18(10)/2	15.04

1. Refers to maximum depth (m) of dive.

2. Female/male ratio of Dungeness crabs captured.

3. Number of Dungeness crabs captured/diver/h.

determine areas that harbored substantial numbers of Dungeness crabs. Areas that were likely to contain Dungeness crabs did not, in most cases, coincide with areas that were heavily impacted by the oil spill.

CONCLUSIONS

This study fails to establish injury to adult Dungeness crabs because it does not identify any biological effects that may be linked to environmental contamination by oil. None of the tissues of Dungeness crabs collected from areas contaminated by the EVOS contained petrogenic hydrocarbons. Furthermore, no obvious somatic or reproductive abnormalities attributable to petrogenic hydrocarbons were noted. The question of impacts of the EVOS on Dungeness crab reproduction remains open because we were unable to collect adequate numbers of ovigerous female crabs at either oiled or control sites, and because no post-larval Dungeness crabs were found on the artificial substrates.

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