Exxon Valdez Oil Spill
State/Federal Natural Resource Damage Assessment
Annual Report

Injury to Prince William Sound Crabs

Fish/Shellfish Study Number 14
Annual Report

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Study History: This study began in April 1989. Crab sampling took place in April and May 1989. The results of the 1989 research are included in this Annual Report submitted in December 1989.

Abstract: To determine the effects of exposure to oil from the *Exxon Valdez* on reproductive condition, incidence of limb loss and shell abnormalities, and histopathological responses of Dungeness and brown king crabs, we sampled crab populations using crab pots and divers. Dungeness crabs were sampled in Orca Bay (unoiled) in eastern Prince William Sound and at 12 locations in western Prince William Sound (oiled) in April/May 1989. A total of 188 crab pot pulls and 39 dives were made in search of Dungeness crabs. Brown king crabs were sampled with pots in Knight Island Passage (oiled) and outer Port Nellie Juan (unoiled) in early September 1989. Probably because of sea otter predation western Prince William Sound harbored very few Dungeness crabs, therefore precluding an assessment of the effects of the *Exxon Valdez* oil spill on Dungeness crab populations there. Approximately one-third of the brown king crabs captured in the oiled area exhibited injury with the majority of injuries to females. No oil was observed on pots, bait jars, lines, or crabs captured. Too few brown king crabs were caught in the control area to compare oiled and unoiled areas for reproductive condition, limb loss and abnormalities in new crab shells.

Key words: Brown king crab, Dungeness crab, reproduction, histopathology, pot sampling, dive surveys.

Project Data: (will be addressed in the final report)

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

The Dungeness crab, *Cancer magister*, part of this study was conducted in April and May 1989. We sampled crabs using crab pots in Orca Bay in eastern Prince William Sound and crab pots and dive surveys at 12 locations in western Prince William Sound (PWS). A total of 30 crab pot pulls were made in Orca Bay and 158 crab pot pulls and 39 dives were made in western PWS. The range in mean catch per unit effort of the crab pot sampling conducted over three days (28-30 Apr) in the depth range Orca Bay and broken down by sex and female reproductive state was 8.9-16.9 males per pot, 2.8-5.2 nonovigerous females per pot, and 0.2-1.1 ovigerous females per pot. Our sampling in western PWS revealed a very low number of Dungeness crabs there. The reduced number of crabs in the western Sound was probably a direct result of predation by the sea otter, *Enhydra lutris*, which has markedly increased in abundance in Prince William Sound since the early 1980's. The extremely low number of crabs precluded an assessment of the effects of the *Exxon Valdez* oil spill on Dungeness crab populations in Prince William Sound.

The king crab component of the study was a pot survey conducted in Western Prince William Sound during the first week of September 1989 to assess potential impacts to brown king crab (*Lithodes aequispina*) as a result of oil spilled by the *Exxon Valdez*. The study area was divided into oiled and unoiled areas. The oiled area was then divided into two depth strata of 150 to 224 fathoms and 225 fathoms and deeper in order to determine if differences exist with depth for hydrocarbon level, injury (limb loss), fecundity, or growth rate. Hydrocarbon samples of muscle tissue, hepatopancreas, and eggs were collected. Ten samples, five hepatopancreas and five egg, are currently undergoing analysis. Necropsy samples were collected, however, under the direction of the pathology unit, they will not be analyzed unless hydrocarbon sampling indicates oil exposure.

Exposure to hydrocarbons can cause reduced fecundity, limb loss and reduced growth in crabs. Samples were collected to determine if these impacts exist. Egg clutches, which are carried externally, were collected for fecundity analysis. Processing of these will begin in February 1990. Occurrence of limb loss was noted for all individuals captured. One-third of the male crabs in each pot were tagged using spaghetti tags. Through recapture of these individuals in future surveys, growth rates can be established and perhaps compared with growth information from other brown king crab stocks in Alaska. Information collected for each specimen included carapace length, sex, shell condition, shell damage and clutch condition of females. Temperature, salinity, and dissolved oxygen data were collected at selected points over the study area using a SEA-BIRD CTD water profiler.

There was little variability over the study area in temperature, salinity or dissolved oxygen. Conditions below the 80- meter depth were nearly identically for each variable between CTD casts. Approximately one-third of the crabs captured in the oiled area exhibited some form of injury with the majority of injuries occurring on females. No visible oil was observed on pots, bait jars, lines, or any of the crab captured. Hydrocarbon analysis of brown king crab tissues has not been completed, therefore no evidence of exposure to oil is available at this time. Too few brown king crabs were captured in the control area to compare oiled and unoiled areas with

regard to fecundity, egg loss, incidence of limb loss and abnormalities in newly formed crab shells.

INTRODUCTION

In Alaska and elsewhere over the geographic range of the species Dungeness crabs occupy nearshore areas in protected bays and estuaries. These habitats are usually characterized by fine benthic sediments and reduced wave action. Oil incorporated in shallow subtidal sediments may persist and can affect crab populations for several years after an oil spill (Krebs and Burns 1977, Boehm et al. 1987). Dungeness crabs may be especially susceptible to contamination from petroleum hydrocarbons because they burrow into benthic sediments, especially while brooding their eggs. If substantial amounts of oil have settled in deep benthic areas the population of brown king crabs in western Prince William Sound may also be at risk.

Petroleum hydrocarbons have deleterious effects on crabs exposed to them. 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 and Malan 1988). Sex and reproductive state may determine responses of crabs to oil pollution. Krebs and Burns (1977) reported 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 purpose of this project was to determine whether populations of Dungeness crabs, *Cancer magister*, and brown king crabs, *Lithodes aequispina,* in western Prince William Sound suffered adverse effects on reproduction, appendage and shell condition or vital tissues and organs as a result of exposure to *Exxon Valdez* oil. Oil exposure can result in short-term financial losses to fishermen caused by contamination of harvestable crabs and long-term impacts if crab reproduction is affected.

OBJECTIVES

1. Determine the effects of exposure to petroleum hydrocarbons from the Exxon Valdez on Dungeness crabs and brown king crabs through the assessment of 1) the reproductive condition of crabs in oiled and non-oiled sites by measuring such variables as fecundity, egg loss and larval production in crabs from these sites, 2) the incidence of limb loss and abnormalities in newly formed crab shells, and 3) the pathological effects, if any, of oil contamination on vital tissues and organs of crabs from oiled and unoiled sites.

2. Determine whether these observations demonstrate any adverse changes in viability.

3. Determine the levels of hydrocarbons in tissues and eggs of Dungeness crabs and brown king crabs and relate those levels to concentrations of hydrocarbons in sediments at oiled and unoiled sites in the Sound.

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

METHODS

Dungeness Crab

The Dungeness crab component of Fish/Shellfish Study Number 14 was a cooperative project between the National Marine Fisheries Service (NMFS), Auke Bay Laboratory and the Alaska Department of Fish and Game (ADF&G). The Alaska Department of Fish and Game supervised the sampling of Orca Bay in eastern Prince William Sound. The Orca Bay portion of the project was an extension of an existing ADF&G project which began in July 1988 as part of the CFSO Shellfish Increment. The Auke Bay Laboratory's plan was to sample in pairs (impacted and non-impacted) 8 sites in western Prince William Sound that were to be selected from the following list: Sleepy, Iktua, Herring, Dryer, Paddy, Ewan, Main, and Eshamy Bays, Fox Farm and Snug Harbor (Trowbridge and O'Clair 1989). However, because of the difficulty in finding adequate numbers of Dungeness crabs to sample the study was immediately expanded to include additional sites (Table 1 and Figure 1).

Sampling took place in April 1989 in Orca Bay and in May 1989 in western Prince William. Crabs in Orca Bay were sampled with Dungeness crab pots allowed to soak for 24 hours. Three strings of 10 pots each were set along the depth contour where crabs were most abundant. Depths ranged from 55 to 82 m (Table 1). In western Prince William Sound crabs were sampled with crab pots and with systematic surveys using divers who conducted ladder searches from 0 to 30.5 meters (100 ft) at each study site. Dungeness crab pots were fished in strings of 10 to 20 pots in the depth range 9 - 62 m (Table 1). Soak time for the pots was 24 h at first, but this was later reduced to 12 h when we had difficulty catching crabs.

Diver observations were recorded on the number of crabs and miscellaneous species seen, depth, slope, and substrate by distance traveled. Information on dive buddies, time underwater, visibility and direction of the ladder search were also be recorded. Information recorded during the pot sampling included: time pot gear was set, pulled, and depth at which it was set, catch composition of each pot and sex, carapace width, fresh weight and external physical condition of all crabs.

A total of 22 live female crabs were randomly sampled from the Orca Bay crab pots. The specimen number, carapace width, fresh weight, shell age, egg color, durometer reading and physical condition of each crab was recorded. The 22 crabs yielded for hydrocarbon analysis three composite ovary samples, three composite hepatopancreas samples and five egg samples consisting of a small portion of the egg clutch from the right fifth pleopod of each of two crabs. The left fifth pleopod was removed from each of 15 crabs to estimate egg development, egg mortality, egg fouling and infestation by egg predators. In western Prince William Sound so few crabs were caught that no samples were taken for hydrocarbon analysis. No ovigerous crabs were observed.

The composite samples of ovaries were placed in 8 oz glass jars rinsed with methylene chloride or heated to 440 degrees C for 4 hours. The jar was labeled with site name, date, species, "ovary", sample number, specimen numbers of the sacrificed crabs, "DUNGENESS", and "ADF&G" or "NMFS". Composite samples of eggs will be placed in 8 oz glass jars rinsed with methylene chloride. The jar was labeled with site name, date, species, "egg", sample number, specimen numbers of the sacrificed crabs, "DUNGENESS", and "ADF&G" or "NMFS". Jars containing samples were frozen until hydrocarbon analysis is initiated. Pleopods were placed in 8 oz jars. Pleopod samples were fixed in 5% neutral-buffered formalin. Each jar was labeled with site name, date, species, "pleopod", sample number, specimen numbers, "DUNGENESS", and "ADF&G" or "NMFS".

In Orca Bay sediment samples were collected with a tom-tom corer. The tom-tom corer was deployed at a randomly selected point along each of the 3 strings of pot gear that were set in Orca Bay. Four core samples were collected at each point (Table 2). Core samples were removed from the corer and placed in 8 oz glass jars that had been previously rinsed with methylene chloride or heated at 440 degrees C for 4 hours. Each jar was labeled with site name, date, depth, "sediment", sample number, "DUNGENESS", and "ADF&G". Jars with sediment samples were frozen at the lowest possible temperature until hydrocarbon analysis could be initiated.

In western Prince William Sound three composite sediment samples each consisting of eight subsamples were collected by divers in the subtidal zone and by a sampling team member in the intertidal zone at each site (Table 2). Samples were collected from randomly selected points along 30 meter transects with a chrome plated core tube and spatula. Intertidal samples were collected at a tidal height of about 2.0 meters above mean lower low water (MLLW). Subtidal samples were collected at about 6 m below MLLW.

Sediment samples were extruded from the core tube and placed in 4 oz glass jars previously rinsed with methylene chloride or heated at 440 degrees C for 4 hours. Each jar was labeled with site name, date, depth, "sediment", sample number, "DUNGENESS", and "NMFS". Jars with sediments were frozen at the lowest possible temperature until hydrocarbon analysis could be initiated.

Meiofauna samples were collected only from the subtidal zone in Orca Bay. Samples were collected with a tom-tom corer. The corer was lowered to a position near where the sediment core samples were taken. Four meiofauna samples were collected at each of the three sites where sediment cores were taken (Table 2).

Meiofauna samples were removed from the corer as follows: (1) a core cylinder was carefully removed from the corer and any liquid remaining on the surface of the sediment was poured into the sample container (4 oz jar); (2) the top 2-3 cm of sediment was extruded from the cylinder by applying even pressure to the bottom of the sediment core; (3) the top 2-3 cm of sediment was cut off the core over the sample jar into which it fell undisturbed. Enough 10% formalin was added to the jar to cover the sample. The jar was labeled with the site name, date, depth, "meiofauna", sample number, "DUNGENESS", and "ADF&G".

In Western Prince William Sound meiofauna samples were collected along the same intertidal and subtidal transects where sediment samples were collected. Samples were collected with a hand-operated syringe corer immediately next to the point where sediment core subsamples were taken at each site. Eight meiofauna samples were collected along each 30 m transect (Table 2).

Meiofauna samples were extruded from the syringes into 4 oz jars where they were fixed with 10 % formalin. Each meiofauna sample was labeled with the site name, date, depth, "meiofauna", sample number, "DUNGENESS", and "NMFS".

Physical oceanographic data were collected at each site during each sampling period using an electronic instrument (CTD) that measured conductivity, temperature, depth and dissolved oxygen as it was lowered to the bottom. The CTD was deployed 6 times in Orca Bay. Measurements were taken at each end of each string of 10 pots. In western Prince William Sound the CTD was deployed 5 times. Unfortunately, the on/off switch was accidentally bumped on between deployments in Orca Bay and all available memory was used up with surface measurements in air before the accident was discovered.

Brown King Crab

The brown king crab component of Fish/Shellfish Study Number 14 was conducted by the Alaska Department of Fish and Game (ADF&G). A total of 101 pots were set in Knight Island Passage and outer Port Nellie Juan in Prince William Sound (Figure 1). The Knight Island Passage area was divided into two sampling strata, 150 fathoms to 224 fathoms and greater than or equal to 225 fathoms. Each stratum was then divided into sampling stations of approximately one square nautical mile. There were 16 stations in the deep stratum and 35 stations in the shallow stratum. The first 51 pots were set, one pot to a sample station. One of these pots was lost, leaving a total of 50 pots placed within a stratified design. The following 40 pots were set in locations within the oiled area selected to maximize the crab catch utilizing information from the first group of pots set and the charter vessel captain's experience in the commercial fishery. This was done to insure that enough crab were captured to meet sample sizes for hydrocarbon, necropsy and fecundity objectives. Therefore, a total 90 pots were placed in the oiled area of the Sound. The 50 pots in the stratified design, and the additional 40 pots were also divided into two different depth strata. A total of 46 pots were placed in a shallow stratum (<225 fathoms) and 44 pots were placed in a deep stratum (=>225 fathoms). Data analysis utilized the catch from all 90 pots. The remaining 10 pots were set in outer Port Nellie Juan, an area which, for the purposes of this study was considered to be unoiled. The vessel captain's experience was again used to select pot locations within this area. All pot locations are listed in Table 3. Commercial style king crab pots 6'x 6'x 30", were baited with two two-quart perforated jars filled with chopped herring. Each pot was rigged with a double bladder buoy system.

Carapace length, sex, shell condition, shell damage and clutch condition of females was recorded for all individuals captured in the pots. Sample collection priority was given, in order of importance, to hydrocarbon, necropsy and fecundity samples. Hydrocarbon specimens were taken from the pot and placed in a clean plastic tote. Twenty hydrocarbon samples of muscle tissue, hepatopancreas and eggs were taken (Table 4). Necropsy specimens were held in a separate tote into which a continuous flow of seawater was maintained. Twenty-one necropsy samples were collected and are being held under chain of custody protocol in Cordova (Table 5). Females to be used for fecundity sampling were held on deck until the catch was processed, at which time pleopods were removed. Incidental fish species were noted, counted and measured.

Spaghetti tags were affixed, through the isthmus, on one-third of the males in each pot. Tags were bound using crimped metal sleeves and tagged individuals were returned to the water as quickly as possible. Spaghetti tags were affixed to 37 males (Table 6). Both legal and sublegal crabs were tagged.

Twelve water profiles with a SEA-BIRD CTD were made over the study area from September 23-25. The instrument was deployed with 3/8" poly line using a Marco crab block to achieve a controlled rate of descent of approximately 60 meters per minute. Data was downloaded onto a personal computer after each cast and a graphics file created showing temperature, salinity and dissolved oxygen by depth.

RESULTS

Dungeness Crab

A total of 499 Dungeness crabs were caught in the 30 pots set in Orca Bay in April 1989. Of these crabs 73% were male and 4% (18 individuals) were ovigerous female crabs (Table 7). The range in mean catch per unit effort of the crab pot sampling conducted over three days (28-30 Apr) in the depth range Orca Bay and broken down by sex and female reproductive state was 8.9-16.9 males per pot, 2.8-5.2 nonovigerous females per pot, and 0.2-1.1 ovigerous females per pot. Other species caught in the pots in Orca Bay included Tanner crabs, *Chionoecetes bairdi*, Pacific cod, *Gadus macrocephalus*, Yellowfin sole, *Limanda aspera*, halibut, *Hippoglossus stenolepis*, and great sculpin, *Myoxocephalus polyacanthocephalus* (Table 8).

Crab pots set in western Prince William Sound were much less successful. Of the 158 pot sets made in the western Sound only one (Paddy Bay; depth, 37 m) produced one male Dungeness crab (Table 8). In western Prince William Sound crab pots were generally set in lesser depths than in Orca Bay either because greater depths were not available in the enclosed bays in the western sound or at more open bays such as Sleepy Bay because the bottom dropped off quite steeply below about 40 m to depths much greater than those at which crabs were caught in Orca Bay. Nevertheless, it seems unlikely that the reduced catches in the western Sound were due to the somewhat lesser depths at which the pots were fished because *Cancer magister* is a shallow water species and females, especially, are usually found in abundance above 30 m. Other species that commonly co-occur with Dungeness crab such as yellowfin sole and halibut were frequently captured in the pots (Table 8).

The dive surveys in western Prince William Sound were no more successful in finding Dungeness crab than was the pot sampling. Thirty-nine dives were made in the western Sound in May 1989. Only 2-3 Dungeness crabs were observed (in Paddy and Ewan Bays) during these dives.

Brown King Crab

Size frequencies of all brown king crabs, 93 female and 99 males, caught in the 90 pots in the oiled area are presented in Figure 2. There is little overlap between the two distributions with male crabs being substantially larger than female crabs (mean carapace lengths of 165.2 mm and 136.2 mm). Similar size frequency distributions were observed for the 43 males (163.8 mm mean carapace length) and 76 females (135.3 mm mean carapace length) captured in the 50 pots which were placed in a stratified design (Figure 3; see methods).

The male crab captured in the 46 shallow stratum pots were found to be significantly larger (n=34, mean carapace length=168.2 mm, ANOVA, p=.027) than those caught in the 44 deep stratum pots (n=65, mean=163.6 mm). Among those pots placed within the stratified design, however, there was found to be no significant difference in size between strata (Figures 4 and 5).

Catch per unit effort (CPUE), measured as the number of crab captured per pot, was standardized to a 24 hour soak time. The 90 pots placed in the oiled area caught an average of 2.3 crab per pot with 47 pots containing no crab (Figure 6). Pots in the deep stratum (=> 225 fathoms) caught a significantly greater number of crab (n=44, mean = 1.9, Kruskal-Wallis, p=.031). As was the case with carapace lengths, however, there was no significant difference in CPUE between depth strata within the 50 pots (Figure 7) which had been placed in a stratified design. The effort in the 40 additional pots was directed to areas of known crab concentration which could affect CPUE estimates. Therefore the results of the stratified design would be a more unbiased measure of CPUE. A total of ten crabs (7 males and 3 females) were caught in the 10 pots set in the unoiled area in outer Port Nellie Juan. Because of the small sample size data on these crabs is not included here.

Crab injuries were examined using a chi-square test. Of the 192 crab which were captured in the oiled area, 56 were documented with some form of appendage injury. Analysis by sex showed that female crab sustained a significantly higher frequency of injuries (n=37) than did male crab (n=19, p=.002, Tables 9 and 10). The frequency of injuries was also greater to new-shell crab (n=41) than to old-shell crab (n=15, p=.025,Tables 9 and 10). Similar results were found within the pots from the stratified design. Thirty-nine of the 119 crabs captured from these pots were documented as having injuries with a significantly greater frequency of injury occurring to females (n=29, p=.027, Tables 11 and 12) and to new-shell crab (n=30, p=.041, Tables 11 and

12).

The majority of the injuries to crab were either old injuries involving missing limbs (33 instances in the entire oiled area and 19 instances in the stratified pots), or limbs which had regenerated (27 in the entire area and 19 in the stratified pots, Figures 8-12).

Egg condition was noted for all females as eyed eggs, uneyed eggs, or no eggs. For the 50 pots from the stratified station sample group, the catch of 38 females with eyed eggs by stratum was 27 shallow and 11 deep. Females with uneyed eggs totaled 6 with catch by stratum at 5 shallow and 1 deep. The majority of non-egg bearing females were captured in this group of pots; these totaled 32 with each stratum contributing equally (Table 13). Fifty-four of 93 females captured in the oiled area were bearing eggs. Forty three females carried eyed eggs with 27 coming from the shallow stratum and 16 from the deep stratum. Eleven females from the oiled area carried uneyed eggs, five from the shallow stratum and 6 from the deep stratum. Thirty-nine females had no eggs (Table 14).

Ten of the20 samples of muscle and hepatopancreas tissue and eggs collected for hydrocarbon analysis are currently being analysed (Table 6). The remainder of the samples are archived at the Auke Bay Laboratory.

The 21 necropsy samples that were collected and are being held under chain of custody protocol in Cordova (Table 7). These will be analyzed in coordination with the Pathology Unit of ADF&G.

Spaghetti tags were affixed to 37 males (Table 8). Both legal and sublegal crabs were tagged. Recovery of these will give information on growth and movement of brown king crab in the Sound.

DISCUSSION

Dungeness Crabs

The low number of Dungeness crabs captured by us in western Prince William Sound was probably not an artifact of our sampling methods. Other scientists sampling crabs in Prince William Sound in conjunction with the Exxon Valdez oil spill and using different methods (trawls and dredges) than ours have had similar difficulty obtaining adequate numbers of Dungeness crabs (D. Armstrong, University of Washington, personal communication). There is not now a commercial fishery for Dungeness crabs in the western Sound. Therefore, the low number of Dungeness crabs in the western Sound is probably real.

We attribute the depressed population numbers of Dungeness crabs in the western Sound to sea otter, *Enhydra lutris*, predation. Sea otters were common at most of the sites that we sampled in the Sound. Moreover, sea otters can exert a marked impact on Dungeness crab populations. Garshelis et al. (1986) reported a substantial decline in the abundance of Dungeness crabs in

1980-81 when otters moved into Orca Inlet in large numbers. They calculated that in Nelson Bay alone sea otters consumed 370,000 Dungeness crabs annually during 1980-81.

The sediment samples collected during the Dungeness crab study will be used to augment samples collected under Air/Water Study Number 2, "Petroleum Hydrocarbon-Induced Injury to Subtidal Marine Sediment Resources". These samples will be of great value to Air/Water Study Number 2 because they were collected relatively soon after the Exxon Valdez oil spill and were collected with identical sampling methods to those used in Air/Water Study Number 2. The meiofauna samples will also be processed to determine the health of the communities of smaller organisms associated with sediments possibly contaminated by the oil spill.

Brown King Crabs

The results of brown king crab hydrocarbon sample analysis have not been received. A determination that oiling has occurred will support the continuation of this project. Additionally, documentation of oil contamination will indicate that analysis of the histopathology samples should be completed.

Exposure to hydrocarbons has been shown to cause reduced fecundity, limb loss and reduced growth in crabs (Karinen and Rice 1974; Krebs and Burns 1977; Malan 1988; Gharrett et al 1985). Fecundity estimates and growth information will provide a baseline against which any future changes may be compared. A decrease in either of these, supported by the presence of hydrocarbons in tissues or eggs, will suggest negative impacts possibly caused by oil.

Given the documentation of injuries on brown king crab by the current project coupled with studies showing the increased rate of limb loss which can occur in crabs as a result of exposure to oil, continued sampling and examination of the brown king crab resource in Prince William Sound should reveal an increased rate of limb loss if there is an effect present. This study has indicated a relatively low frequency of injury in male and old-shell crab. A significant increase of injuries in either male or old-shell crab could be detectable with continued study and may indicate an effect caused by oil.

Other information pertinent to this study may come from Fish/Shellfish Study Number 19 titled “Larval Fish Injury”. This study may reveal whether larval stages of brown king crab were in the water column at a sufficiently shallow depth during the period after the spill to have been exposed to oil. Little is known about the distribution of the larval stages of brown king crab, but information on other aspects of the life history of this species indicates that larvae may occur near-bottom in deep water. Significant changes in larval abundance between years may indicate an effect of oil, but so little is known of the dynamics of larval transport and the temporal and spatial variability in brown king crab larvae that an effect of oil will be very difficult to detect.

In summary, the continued study of brown king crab in Prince William Sound may detect effects caused by oil if: 1) injuries in either male or old-shell crab increase; 2) fecundity differs significantly between years; 3) larval abundance differs significantly between years; or 4) tissue hydrocarbon content is shown to be high.

CONCLUSIONS

The Dungeness crab study was completed in May 1989. Because the abundance of the crabs was too low to be adequate for study, possible injury to the resource that may have been caused by the Exxon Valdez oil spill could not be assessed. Hydrocarbon analysis of brown king crab tissues has not been completed, therefore no evidence of exposure to oil is available as of this writing. Too few brown king crabs were captured in the control area to compare oiled and unoiled areas with regard to fecundity, egg loss, incidence of limb loss and abnormalities in newly formed crab shells.

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Table 1. Location of sites in Prince William Sound in 1989 where crab pots were set and the number of pots lifted at those sites.

Location	North Latitude ° ' "	West Longitude ° ' "	Date	Pots Lifted	Depth Range (m)
Crab Bay	60 04 39	148 02 37	4 May	10	9 - 58
Eshamy Bay	60 27 32	147 59 42	12 May	14	15 - 38
Ewan Bay	60 22 51	148 08 19	11 May	20	26 - 46
Fox Farm	59 58 07	148 10 10	6 May	10	29 - 48
Hogg Bay	60 04 30	148 12 00	7 May	20	22 - 46
Iktua Bay	60 06 43	148 00 30	5 May	13	24 - 57
Main Bay	60 31 50	148 03 27	9 May	11	31 - 35
Mallard Bay	60 17 30	147 48 44	8 May	10	38 - 62
Northeast Cove	60 19 35	147 44 53	8 May	10	15 - 40
Orca Bay	60 35 47	145 49 15	28 Apr	10	-
	60 36 13	145 50 00	29 Apr	10	77 - 82
	60 35 45	145 49 00	30 Apr	10	55 - 79
Paddy Bay	60 24 18	148 04 59	10 May	11	16 - 51
	60 24 28	148 05 37	10 May	9	33 - 37
Shelter Bay	60 08 02	147 55 57	5 May	10	33 - 51
Sleepy Bay	60 04 59	147 52 41	4 May	10	9 - 38
Total				188	

Table 2. Location of sites in Prince William Sound where intertidal and subtidal sediment and meiofauna samples were collected in 1989 and number of meiofauna and sediment samples collected. Samples were collected in the intertidal region and at depths of 3 and 6 m (33-45 m in Orca Bay).

Location	North Latitude ° ' "	West Longitude ° ' "	Date	Number of Meiofauna Samples	Number of Sediment Samples
Eshamy Bay	60 26 54	147 58 30	12 May	16	6[a]
Ewan Bay	60 22 00	148 08 00	12 May	16	6
Fox Farm	59 58 26	148 10 30	7 May	16	6
Herring Bay	60 25 51	147 47 06	9 May	16	6
Iktua Bay	60 06 00	147 59 42	6 May	16	6
Orca Bay	60 35 20	145 49 44	28 Apr	4	4
	60 36 14	145 49 35	29 Apr	4	4
	60 35 48	145 48 51	30 Apr	4	4
Paddy Bay	60 25 00	148 06 00	11 May	16	6
Sleepy Bay	60 04 01	147 50 11	5 May	16	6
Total				124	54

a. Each sediment sample collected in western Prince William Sound was a composite of eight subsamples taken along a 30 m transect.

Table 3.Locations, length of soak and depth of pots set during the 1989 brown king crab oil spill assessment project. A soak time of zero indicates a lost pot.

Pot ID Number	Date Set	Soak Time (h)	Depth (fm)	Latitude	Longitude
001-89	09/01/89	20	162	60°07.44'	147°49.40'
002-89	09/0l/89	20	150	60°07.53'	147°52.24'
003-89	09/01/89	20	152	60°08.76'	147°49.71'
004-89	09/01/89	20	163	60°08.54'	147°51.31'
005-89	09/01/89	21	152	60°08.63'	147°53.08'
006-89	09/01/89	22	175	60°09.44'	147°49.87'
007-89	09/01/89	22	160	60°09.26'	147°50.93'
008-89	09/01/89	0	182	60°09.55'	147°52.96'
009-89	09/01/89	21	163	60°09.60'	147°55.03'
010-89	09/01/89	21	210	60°10.61'	147°50.99'
011-89	09/01/89	21	199	60°10.22'	147°53.15'
012-89	09/01/89	21	192	60°10.49'	147°55.66'
013-89	09/01/89	25	192	60°10.39'	147°57.54'
014-89	09/01/89	25	216	60°11.53'	147°53.51'
015-89	09/01/89	25	216	60°12.53'	147°54.34'
016-89	09/01/89	25	241	60°12.11'	147°55.17'
017-89	09/01/89	25	230	60°11.90'	147°57.16'
018-89	09/01/89	25	268	60°12.70'	147°59.42'
019-89	09/01/89	25	175	60°12.40'	147°59.55'
020-89	09/01/89	26	231	60°11.26'	147°55.58'
021-89	09/02/89	20	182	60°12.23'	148°00.70'
022-89	09/02/89	20	222	60°12.66'	148°02.66'
023-89	09/02/89	20	256	60°13.12'	148°04.12'
024-89	09/02/89	21	265	60°14.26'	148°04.88'
025-89	09/02/89	21	258	60°14.36'	148°06.82'
026-89	09/02/89	21	175	60°14.89'	148°07.68'
027-89	09/02/89	21	178	60°15.60'	148°09.34'
028-89	09/02/89	21	177	60°16.28'	148°08.74'
029-89	09/02/89	21	156	60°18.06'	148°10.67'
030-89	09/02/89	21	197	60°15.18'	148°05.78'
031-89	09/02/89	21	248	60°14.67'	148°03.31'
032-89	09/02/89	21	186	60°14.23'	148°03.44'
033-89	09/02/89	22	190	60°13.48'	147°57.72'
034-89	09/02/89	22	289	60°13.64'	147°59.46'
035-89	09/02/89	22	302	60°15.53'	147°58.79'
036-89	09/02/89	20	290	60°16.28'	148°0l.0l'
037-89	09/02/89	23	298	60°16.87'	147°59.65'
038-89	09/02/89	23	295	60°17.55'	147°59.90'
039-89	09/02/89	23	295	60°18.50'	147°58.91'

Table 3. - (Cont.)

Pot ID Number	Date Set	Soak Time (h)	Depth (fm)	Latitude	Longitude
040-89	09/02/89	24	240	60°18.59'	147°57.12'
041-89	09/03/89	21	202	60°18.52'	148°00.00'
042-89	09/03/89	22	262	60°19.84'	147°58.23'
043-89	09/03/89	22	225	60°19.69'	147°57.42'
044-89	09/03/89	22	192	60°20.71'	147°58.25'
045-89	09/03/89	23	203	60°21.36'	147°58.06'
046-89	09/03/89	24	208	60°22.36'	147°57.64'
047-89	09/03/89	25	205	60°23.43'	147°56.43'
048-89	09/03/89	25	201	60°24.15'	147°56.32'
049-89	09/03/89	26	181	60°25.30'	147°55.24'
050-89	09/03/89	26	202	60°25.55'	147°53.40'
051-89	09/03/89	26	190	60°21.63'	147°54.76'
052-89	09/04/89	23	230	60°15.27'	148°04.53'
053-89	09/04/89	23	225	60°15.79'	148°03.47'
054-89	09/04/89	23	235	60°16.00'	148°02.42'
055-89	09/04/89	23	192	60°16.18'	148°01.35'
056-89	09/04/89	23	242	60°16.68'	148°00.97'
057-89	09/04/89	23	260	60°17.14'	148°00.82'
058-89	09/04/89	23	250	60°17.57'	148°00.57'
059-89	09/04/89	23	240	60°18.08'	148°00.21'
060-89	09/04/89	23	228	60°19.08'	148°00.70'
061-89	09/04/89	20	290	60°15.55'	148°00.35'
062-89	09/04/89	20	280	60°14.60'	147°59.96'
063-89	09/04/89	21	255	60°14.06'	147°59.76'
064-89	09/04/89	20	260	60°13.24'	147°59.65'
065-89	09/04/89	21	220	60°12.36'	147°59.26'
066-89	09/04/89	21	225	60°11.65'	147°58.92'
067-89	09/04/89	21	195	60°12.85'	148°01.14'
068-89	09/04/89	21	231	60°13.06'	148°02.26'
069-89	09/04/89	21	219	60°13.48'	148°02.46'
070-89	09/04/89	21	212	60°14.50'	148°03.08'
071-89	09/04/89	21	235	60°14.56'	148°03.75'
072-89	09/05/89	22	235	60°15.47'	148°00.85'
073-89	09/05/89	22	209	60°15.43'	148°02.12'
074-89	09/05/89	22	198	60°14.90'	148°02.47'
075-89	09/05/89	22	200	60°12.65'	148°02.60'
076-89	09/05/89	22	225	60°12.86'	148°03.59'
077-89	09/05/89	23	225	60°13.30'	148°04.99'
078-89	09/05/89	23	206	60°14.50'	148°07.08'
079-89	09/05/89	23	280	60°15.51'	148°07.81'
080-89	09/05/89	23	175	60°15.55'	148°06.73'

Table 3. - (Cont.)

Pot ID Number	Date Set	Soak Time (h)	Depth (fm)	Latitude	Longitude
081-89	09/05/89	20	230	60°11.59'	147°58.94'
082-89	09/05/89	20	200	60°10.86'	147°58.44'
083-89	09/05/89	20	215	60°12.61'	147°55.34'
084-89	09/05/89	20	210	60°12.69'	147°56.26'
085-89	09/05/89	21	239	60°12.92'	147°57.57'
086-89	09/05/89	20	235	60°13.95'	147°58.52'
087-89	09/05/89	21	225	60°14.63'	147°58.75'
088-89	09/05/89	21	240	60°15.40'	147°58.52'
089-89	09/05/89	21	250	60°16.69'	147°52.72'
090-89	09/05/89	21	270	60°18.01'	147°57.33'
091-89	09/05/89	21	260	60°18.98'	147°56.61'
092-89	09/06/89	20	275	60°32.26'	147°55.86'
093-89	09/06/89	20	150	60°32.55'	147°57.14'
094-89	09/06/89	20	294	60°33.23'	147°57.75'
095-89	09/06/89	20	265	60°33.68'	147°58.91'
096-89	09/06/89	20	275	60°33.99'	148°00.49'
097-89	09/06/89	20	235	60°37.11'	148°05.85'
098-89	09/06/89	21	214	60°37.00'	148°06.20'
099-89	09/06/89	21	197	60°36.73'	148°06.72'
100-89	09/06/89	21	209	60°35.99'	148°07.79'
101-89	09/06/89	21	217	60°35.71'	148°08.28'

Table 4. Samples of brown king crab muscle and hepatopancreas tissue and eggs collected for hydrocarbon analysis during the 1989 PWS brown king crab oil spill assessment survey.

Sample Number[a]	Date Collected	Pot ID Number	Specimen Number	Stratum
HBKOOlM	09/03/89	034-89	5,6	Deep
HBK001H,FB	09/03/89	035-89	4	Deep
HBK002E	09/03/89	040-89	7	Deep
HBK003M,H,E	09/04/89	042-89	28,29	Deep
HBK004M,H,E,FB	09/04/89	046-89	15,16,17	Shallow
HBK005M,H,E	09/05/89	063-89	4,5,6	Deep
HBK006M,H	09/06/89	075-89	3,4,5	Shallow
HBK007M,H,E,FB	09/06/89	085-89	1,2,3	Deep
HBK008M,H,E	09/07/89	098-89	1,2,3	Shallow

[a] HBK=Hydrocarbon Brown King, M=muscle, H=hepatopancreas, E=eggs, FB=field blank.

Table 5. Samples from brown king crabs collected for necropsy during the 1989 PWS brown king crab oil spill assessment project. Samples include tissues in 10% formalin and blood smears.

Date Collected	Sample Number	Sex	Pot ID Number	Stratum
09/02/89	018-89-1	female	018-89	Deep
09/02/89	018-89-2	female	018-89	Deep
09/02/89	018-89-3	female	018-89	Deep
09/03/89	026-89-1	male	026-89	Shallow
09/03/89	027-89-1	male	027-89	Shallow
09/03/89	039-89-33	male	039-89	Deep
09/04/89	042-89-28	female	042-89	Deep
09/04/89	042-89-29	female	042-89	Deep
09/04/89	046-89-15	female	046-89	Shallow
09/04/89	046-89-16	female	046-89	Shallow
09/04/89	046-89-17	female	046-89	Shallow
09/05/89	063-89-4	female	063-89	Deep
09/05/89	063-89-5	female	063-89	Deep
09/05/89	063-89-6	female	063-89	Deep
09/06/89	073-89-2	male	073-89	Shallow
09/06/89	085-89-1	female	085-89	Deep
09/06/89	085-89-2	female	085-89	Deep
09/06/89	085-89-3	female	085-89	Deep
09/07/89	098-89-1	female	098-89	Shallow
09/07/89	098-89-2	female	098-89	Shallow
09/07/89	098-89-3	male	098-89	Shallow

Table 6. Carapace length, commercial status, shell condition and location of injuries of male brown king crab tagged with spaghetti tags during the 1989 brown king crab oil spill assessment project.

Tag Number	Carapace Length(mm)	Legal	Shell Condition[1]	Injuries[2]	Pot ID Number	Specimen Number
3001	160	Y	Old	L3R	014-89	1
3002	155	Y	New	0	034-89	1
3003	156	N	New	0	035-89	1
3004	167	Y	New	RCMO	036-89	1
3005	180	Y	Old	0	036-89	2
3006	153	N	New	0	040-89	8
3007	159	N	Old	0	042-89	1
3008	175	Y	Old	0	042-89	2
3009	138	N	Old	0	042-89	8
3010	161	Y	New	0	043-89	1
3011	164	Y	Old	0	043-89	2
3012	165	Y	Old	0	045-89	1
3013	171	Y	Old	0	046-89	11
3014	167	Y	Old	0	048-89	1
3015	160	Y	Old	0	050-89	8
3016	166	Y	New	0	056-89	1
3017	170	Y	Old	0	060-89	1
3018	164	Y	Old	0	060-89	2
3019	158	N	Old	0	061-89	1
3020	166	Y	Old	0	061-89	2
3021	167	Y	New	0	062-89	1
3022	179	Y	Old	0	062-89	2
3023	152	N	Old	0	063-89	1
3024	162	Y	Old	0	065-89	1
3025	182	Y	New	0	067-89	1
3026	185	Y	New	0	067-89	2
3027	161	N	New	0	073-89	1
3028	170	Y	Old	0	075-89	1
3029	165	Y	V.Old	0	075-89	2
3030	168	Y	Old	0	078-89	1
3031	170	Y	New	0[3]	084-89	1
3032	147	Y	V.Old	0	088-89	1
3033	166	Y	New	0	088-89	2
3034	177	Y	Old	0	090-89	1
3035	161	Y	New	0	095-89	1
3036	180	Y	Old	0	098-89	4
3037	185	Y	New	0	100-89	1

1. Shell condition: New= sharp dactyls, very few or no scratches on ventral surface and chelae; Old = moderate numbers of newand old scratches ventrally, chelae pitted; Very Old = large

numbers of old scratches ventrally; chelae extremely scratched, pitted, and worn.

2. Injury codes are: 1st letter = side (L,R); 2nd letter or number = location, chela (C), walking leg (1-4); 3rd letter = type, cracked (C), regenerating (R), missing (M); 4th letter = age of injury, old (O), new (N)

3. Rhizocephalian barnacle.

Table 7. Mean number of Dungeness crabs caught in crab pots in Orca Bay in April 1989. SE = standard error of the mean.

	Number of Crabs					
			Female			
	Male		Ovigerous		Nonovigerous	
Date	Mean	SE	Mean	SE	Mean	SE
28 Apr 89	8.9	±1.9	0.2	±0.1	3.7	±1.4
29 Apr 89	10.6	±2.2	0.5	±0.2	2.8	±0.7
30 Apr 89	16.9	±3.6	1.1	±0.6	5.2	±1.8

Table 8. Percent frequency of occurrence of species captured in crab pots at 13 localities in Prince William Sound in April-May 1989.

Species	Location[1]												
	OB	CB	ESB	EWB	FF	HB	IB	MB	MLB	NC	PB	SB	SLB
Fusitriton oregonensis	-	-	-	-	-	-	15	-	-	-	-	-	-
Hyas lyratus	-	-	-	5	-	-	-	-	-	10	10	-	-
Chionoecetes bairdi	28	-	-	-	-	-	-	-	-	-	-	11	-
Cancer magister	93	-	-	-	-	-	-	-	-	-	5	-	-
Asteroidea, unidentified species	7	-	-	-	-	-	-	-	-	-	-	-	-
Orthasterias koehleri	-	11	-	5	-	-	-	-	-	-	-	-	10
Pycnopodia helianthoides	-	89	57	90	90	75	46	64	10	60	35	33	80
Gadus macrocephalus	24	11	-	-	-	15	8	9	-	-	5	-	-
Cottidae, unidentified species	7	33	50	40	100	20	38	9	10	20	50	44	70
Hemilepidotus hemilepidotus	-	-	-	-	-	-	-	-	-	10	-	-	-
Myoxocephalus polyacanthocephalus	10	11	-	20	10	5	-	-	10	-	-	11	-
Anarrhichthys ocellatus	-	11	-	-	-	5	8	-	-	10	-	-	10
Pleuronectidae, unidentified species	-	11	-	-	30	-	-	-	-	-	-	-	10
Lepidopsetta bilineata	-	11	7	10	10	25	-	-	10	-	-	-	40
Limanda aspera	7	33	21	80	30	80	62	64	40	80	55	-	40
Platichthys stellatus	-	-	-	-	-	5	-	-	-	-	-	-	-
Hippoglossus stenolepis	3	11	-	-	50	5	-	-	-	-	-	67	60
Sebastes sp.	-	-	-	-	-	-	-	-	-	-	-	11	-

1. Location abbreviations are: OB, Orca Bay; CB, Crab Bay; ESB, Eshamy Bay; EWB, Ewan Bay; FF, Fox Farm; HB, Hogg Bay; IB, Iktua Bay; MB, Main Bay; MLB, Mallard Bay; NC, Northeast Cove; PB, Paddy Bay; SB, Shelter Bay; SLB, Sleepy Bay.

Table 9. Frequency of injury to brown king crabs by sex from all pots in oiled locations.

Injury Status	Female	Male	Total
No Injury			
Frequency	56	80	136
Percent	29.17	41.67	70.83
Row %	41.18	58.82	
Column %	60.22	80.81	
Injury			
Frequency	37	19	56
Percent	19.27	9.90	29.17
Row %	66.07	33.93	
Column %	39.78	19.19	
Total			
Frequency	93	99	192
Percent	48.44	51.56	100

Table 10. Frequency of injury to brown king crabs by shell age from all pots in oiled locations.

Injury Status	New Shell	Old Shell	Total
No Injury			
Frequency	76	60	136
Percent	39.58	31.25	70.83
Row %	55.88	44.12	
Column %	64.96	80.00	
Injury			
Frequency	41	15	56
Percent	21.35	7.81	29.17
Row %	73.21	26.79	
Column %	35.04	20.00	
Total			
Frequency	117	75	192
Percent	60.94	39.06	100

Table 11. Frequency of injury to brown king crabs by sex from pots at stratified stations in oiled locations.

Injury Status	New Shell	Old Shell	Total
No Injury			
Frequency	47	35	82
Percent	39.50	29.41	68.91
Row %	57.32	42.68	
Column %	61.84	81.40	
Injury			
Frequency	29	8	37
Percent	24.37	6.72	31.09
Row %	78.38	21.62	
Column %	38.16	18.60	
Total			
Frequency	76	43	119
Percent	63.87	36.13	100

Table 12. Frequency of injury to brown king crabs by shell age from pots at stratified stations in oiled locations.

Injury Status	New Shell	Old Shell	Total
No Injury			
Frequency	51	31	82
Percent	42.86	26.05	68.91
Row %	62.20	37.80	
Column %	62.96	81.58	
Injury			
Frequency	30	7	37
Percent	25.21	5.88	31.09
Row %	81.08	18.92	
Column %	37.04	18.42	
Total			
Frequency	81	38	119
Percent	68.07	31.93	100

Table 13. Summary of egg condition in brown king crabs within the stratified sampling stations in the oiled area.

	Eggs present			Eggs
	eyed	not eyed	total	absent
number of females	38	6	44	32
shallow	27	5	32	16
deep	11	1	12	16
avg. carapace length (mm)	136	141	136	134
carapace length range (mm)	123-154	132-148	123-154	119-148

Table 14. Summary of overall egg condition in brown king crabs from the oiled area.

	Eggs present			Eggs
	eyed	not eyed	total	absent
number of females	43	11	54	39
shallow	27	5	32	16
deep	16	6	22	23
avg. carapace length (mm)	136	141	137	135
carapace length range (mm)	123-154	132-148	123-154	119-148

FIGURE CAPTIONS

Figure 1. Map of Prince William Sound showing study sites used in the study of injury to Prince William Sound crabs. Numbered sites are Dungeness crab study sites: 1. Orca Bay, 2. Main Bay, 3. Eshamy Bay, 4. Paddy Bay, 5. Ewan Bay, 6. Northeast Cove, 7. Mallard Bay, 8. Iktua Bay, 9. Shelter Bay, 10. Sleepy Bay, 11. Crab Bay, 12. Fox Farm, 13. Hogg Bay. Area of diagonal lines and cross hatching is the brown king crab study area.

Figure 2. Carapace length-frequency distribution of male and female brown king crabs captured in the oiled area.

Figure 3. Carapace length-frequency distribution of male and female brown king crabs captured at the stratified sampling stations in the oiled area.

Figure 4. Cumulative carapace length-frequency distribution of all male and female brown king crabs captured in the oiled area.

Figure 5. Cumulative carapace length-frequency distribution of male and female brown king crabs captured at the stratified sampling stations in the oiled areas.

Figure 6. Frequency distribution of catch per unit effort (CPUE) of brown king crabs per pot at all stations in the oiled area.

Figure 7. Frequency distribution of catch per unit effort (CPUE) of brown king crabs per pot at stratified stations in the oiled area.

Figure 8. Status of appendage and type of injury to appendages of brown king crabs captured in pots at the stratified stations in the oiled area. n = 37.

Figure 9. Status of appendage and type of injury to appendages by sex of brown king crabs captured in pots at all stations in the oiled area. n = 56.

Figure 10. Status of appendage and type of injury to appendages by shell age of brown king crabs captured in pots at all stations in the oiled area. n = 56.

Figure 11. Status of appendage and type of injury to appendages by sex of brown king crabs captured in pots at stratified stations in the oiled area. n = 37.

Figure 12. Status of appendage and type of injury to appendages by shell age of brown king crabs captured in pots at stratified stations in the oiled area. n = 37.

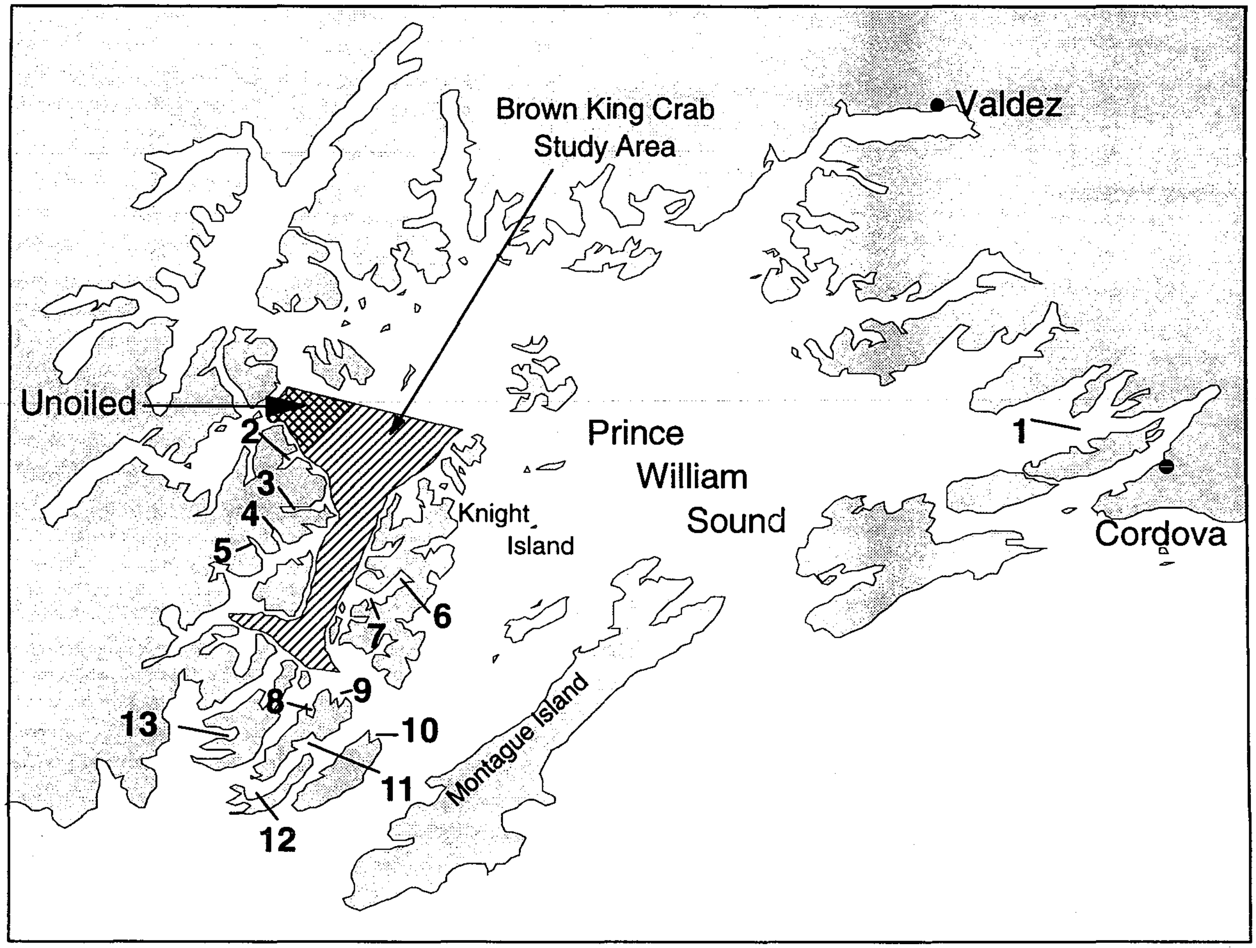
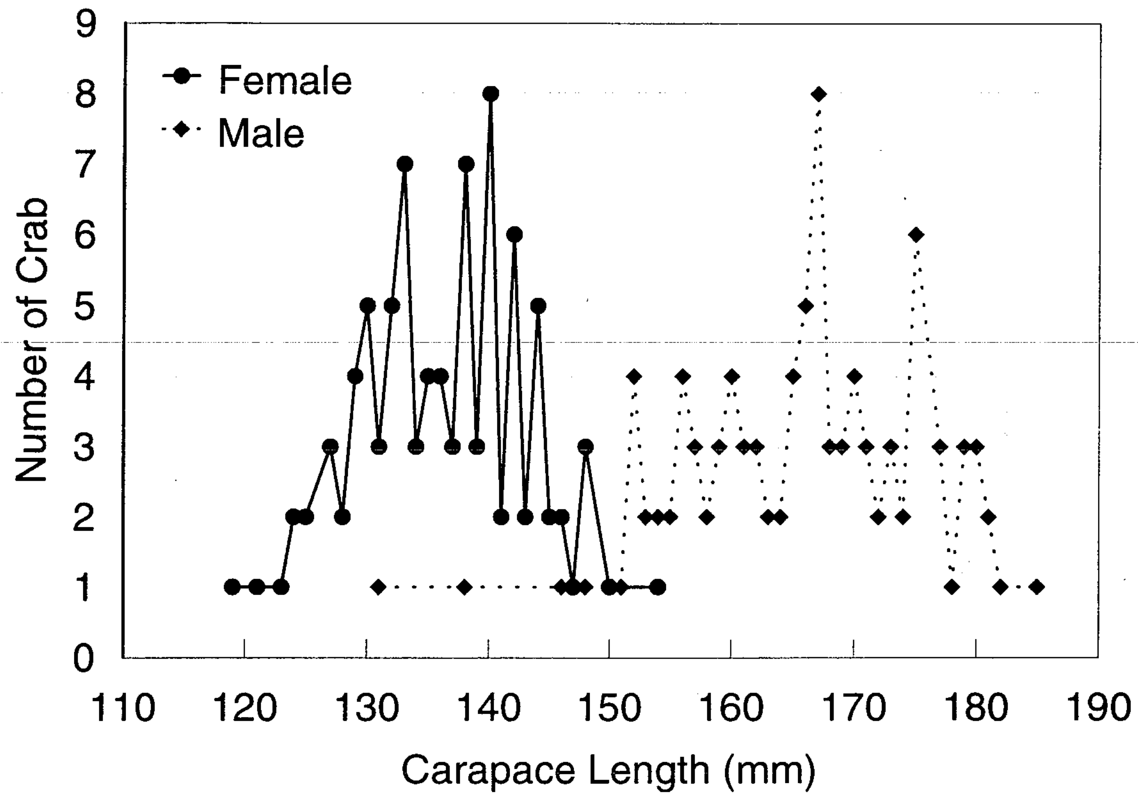
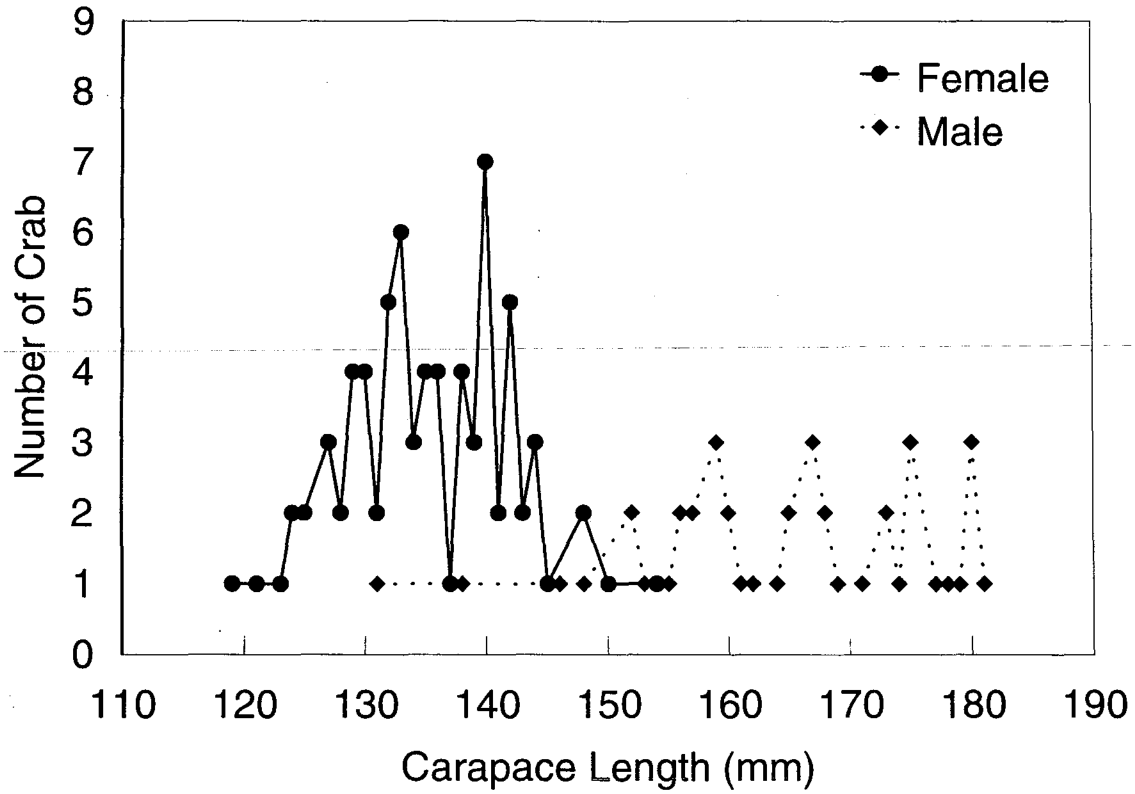

Brown King Crab
Study Area
Valdez
Unoiled
Prince
William
Sound
Knight
Island
Cordova
Montague Island
1
2
3
4
5
6
7
8
9
10
11
12
13

Figure 1.



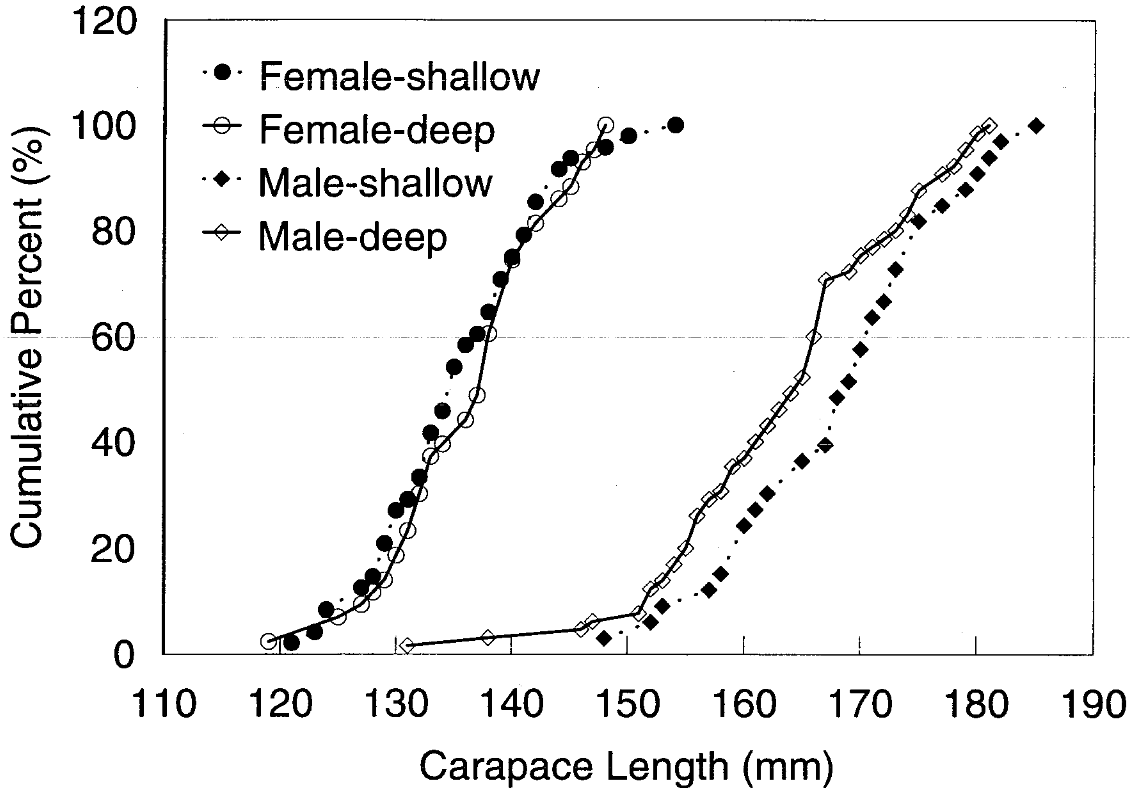
Female
Male
Number of Crab
0
1
2
3
4
5
6
7
8
9
110
120
130
140
150
160
170
180
190
Carapace Length (mm)

Figure 2.



Female
Male
Number of Crab
0
1
2
3
4
5
6
7
8
9
110
120
130
140
150
160
170
180
190
Carapace Length (mm)

Figure 3.



120
100
80
60
40
20
0
Cumulative Percent (%)
Female-shallow
Female-deep
Male-shallow
Male-deep
110
120
130
140
150
160
170
180
190
Carapace Length (mm)

Figure 4.

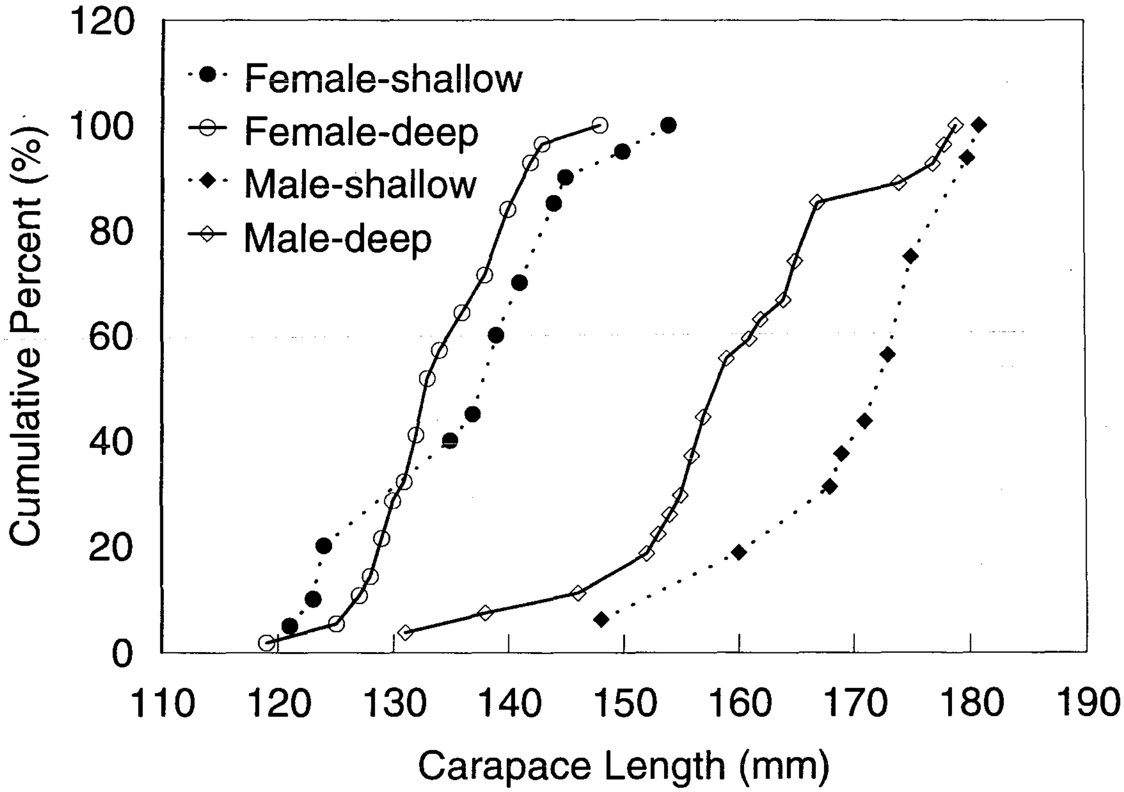

120
100
80
60
40
20
0
Cumulative Percent (%)
Female-shallow
Female-deep
Male-shallow
Male-deep
110
120
130
140
150
160
170
180
190
Carapace Length (mm)

Figure 5.

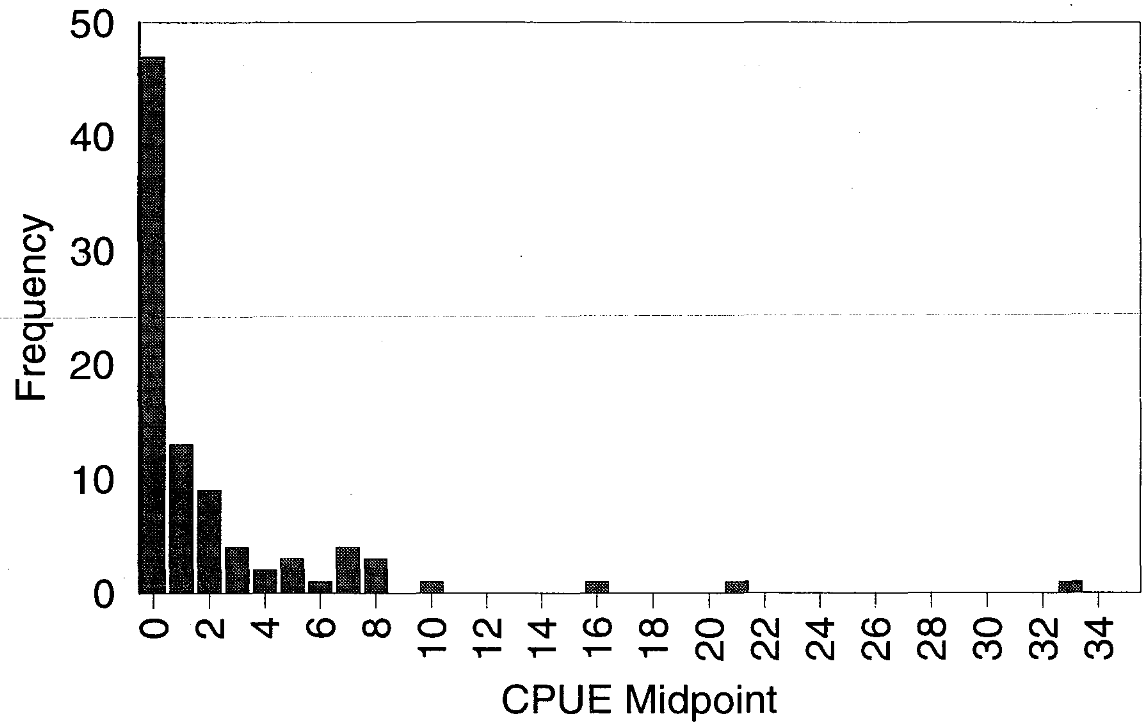
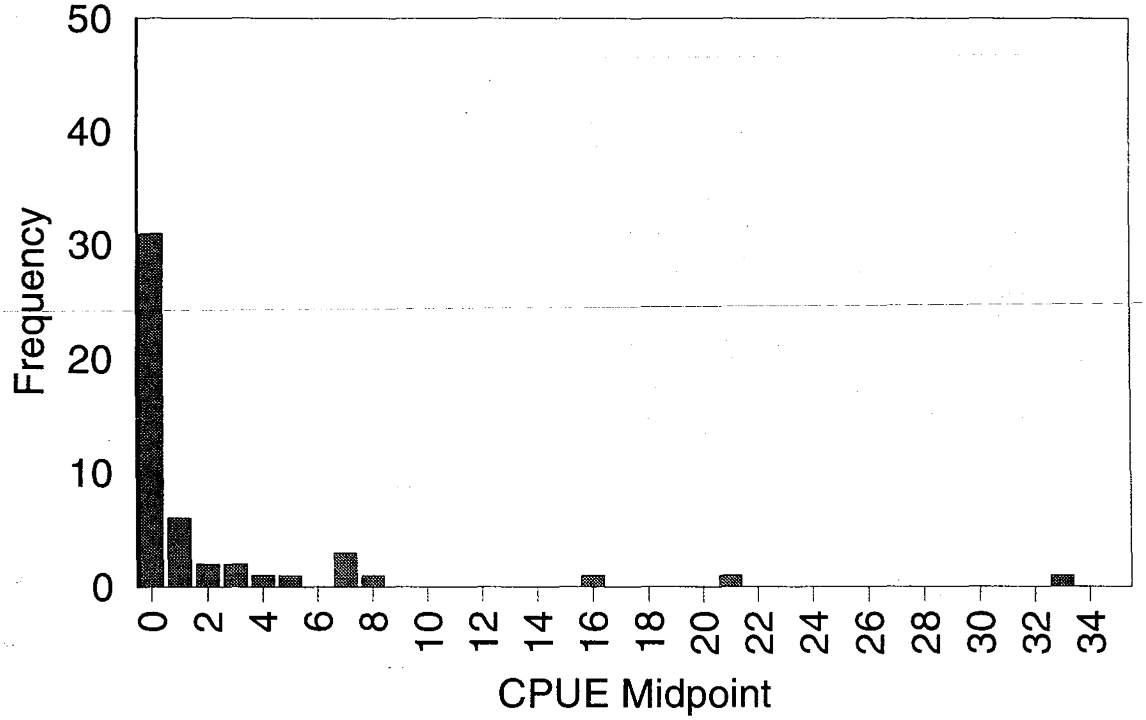

50
40
30
20
10
0
Frequency
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
CPUE Midpoint

Figure 6.



50
40
30
20
10
0
Frequency
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
CPUE Midpoint

Figure 7.

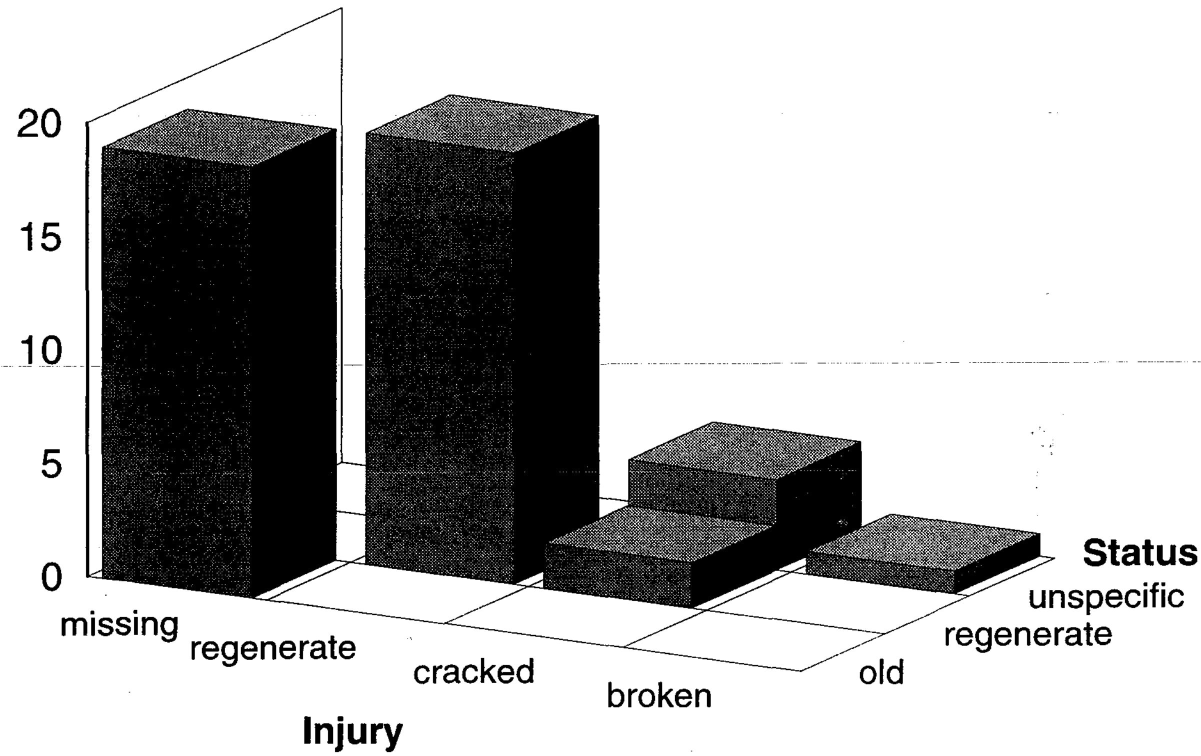

20
15
10
5
0
missing
regenerate
cracked
broken
Injury
Status
unspecific
regenerate
old

Figure 8.

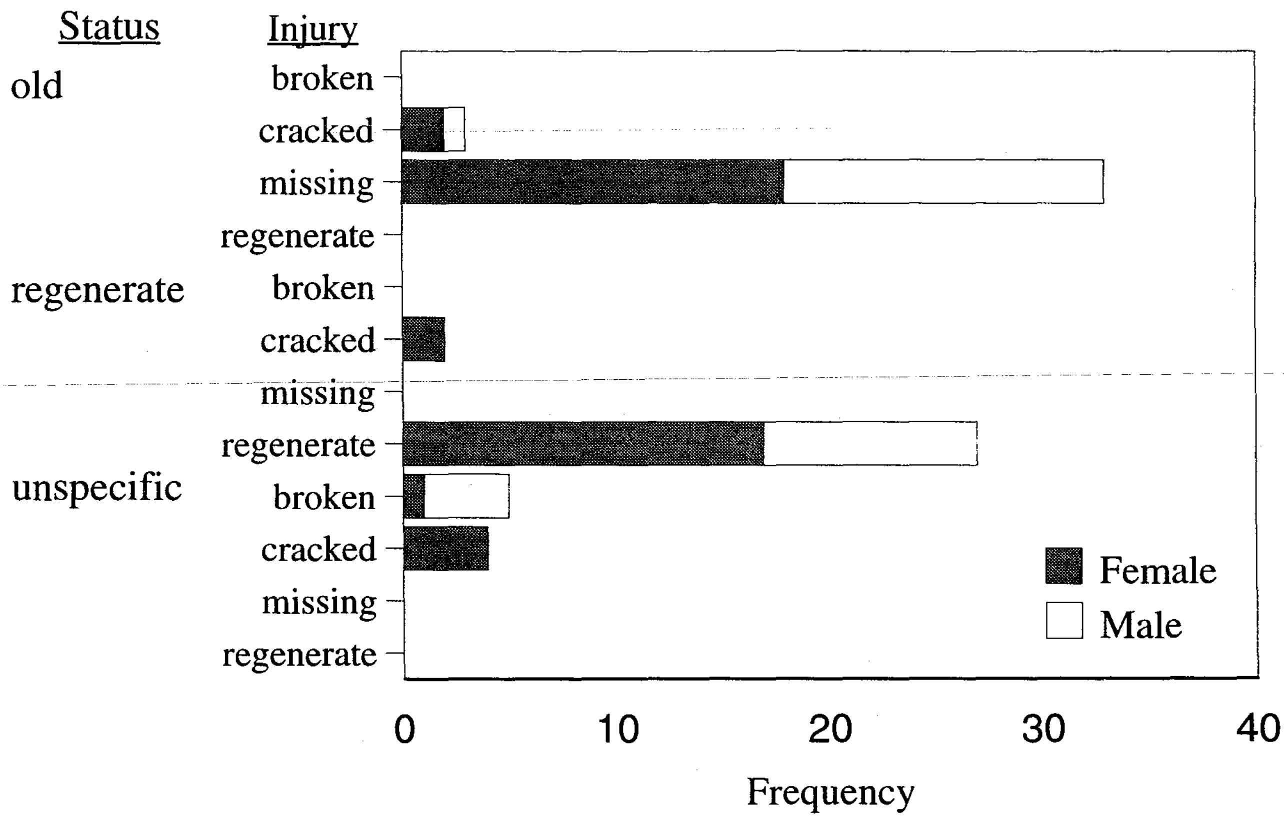

Status
Injury
old
regenerate
unspecific
broken
cracked
missing
regenerate
broken
cracked
missing
regenerate
broken
cracked
missing
regenerate
Female
Male
0
10
20
30
40
Frequency

Figure 9.

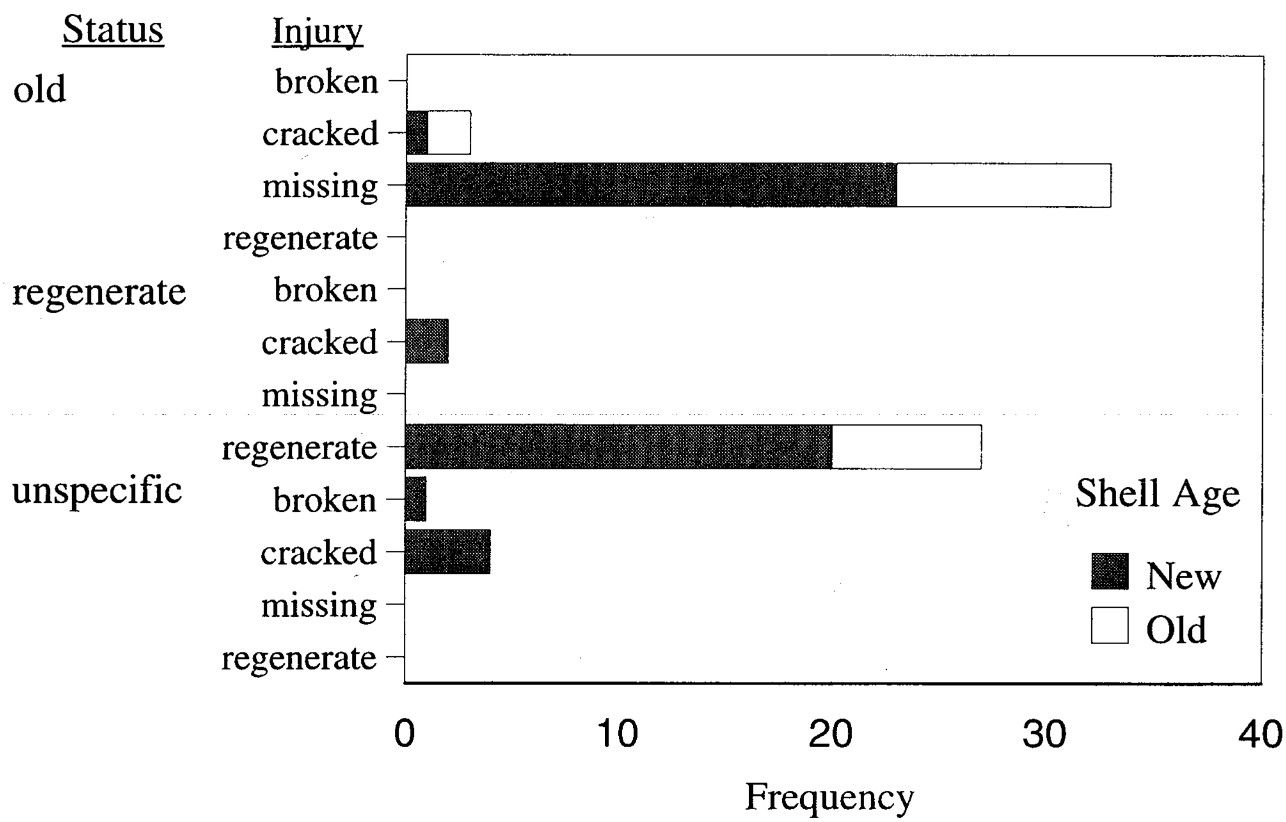

Status
Injury
old
broken
cracked
missing
regenerate
regenerate
broken
cracked
missing
regenerate
unspecific
broken
cracked
missing
regenerate
Shell Age
New
Old
0
10
20
30
40
Frequency

Figure 10.

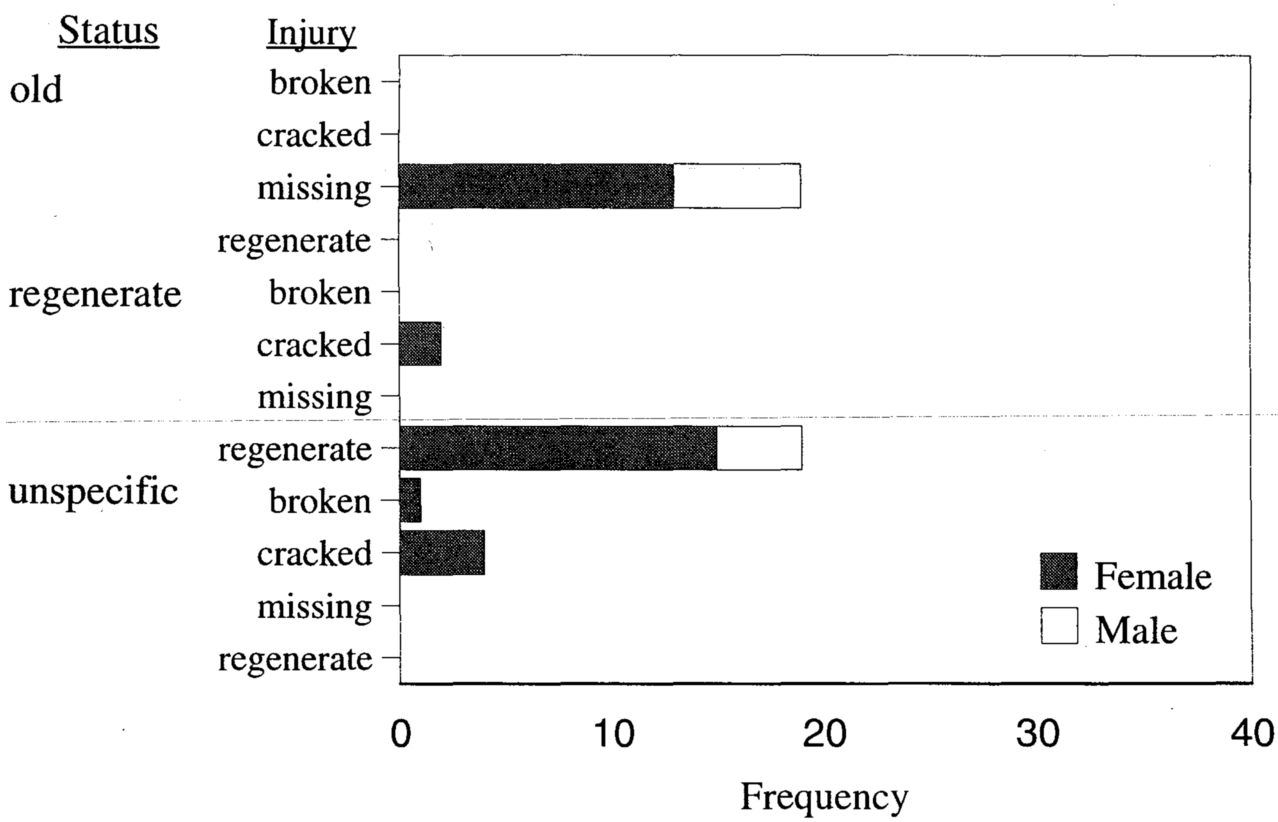

Status
Injury
old
regenerate
unspecific
broken
cracked
missing
regenerate
broken
cracked
missing
regenerate
broken
cracked
missing
regenerate
Female
Male
0
10
20
30
40
Frequency

Figure 11.

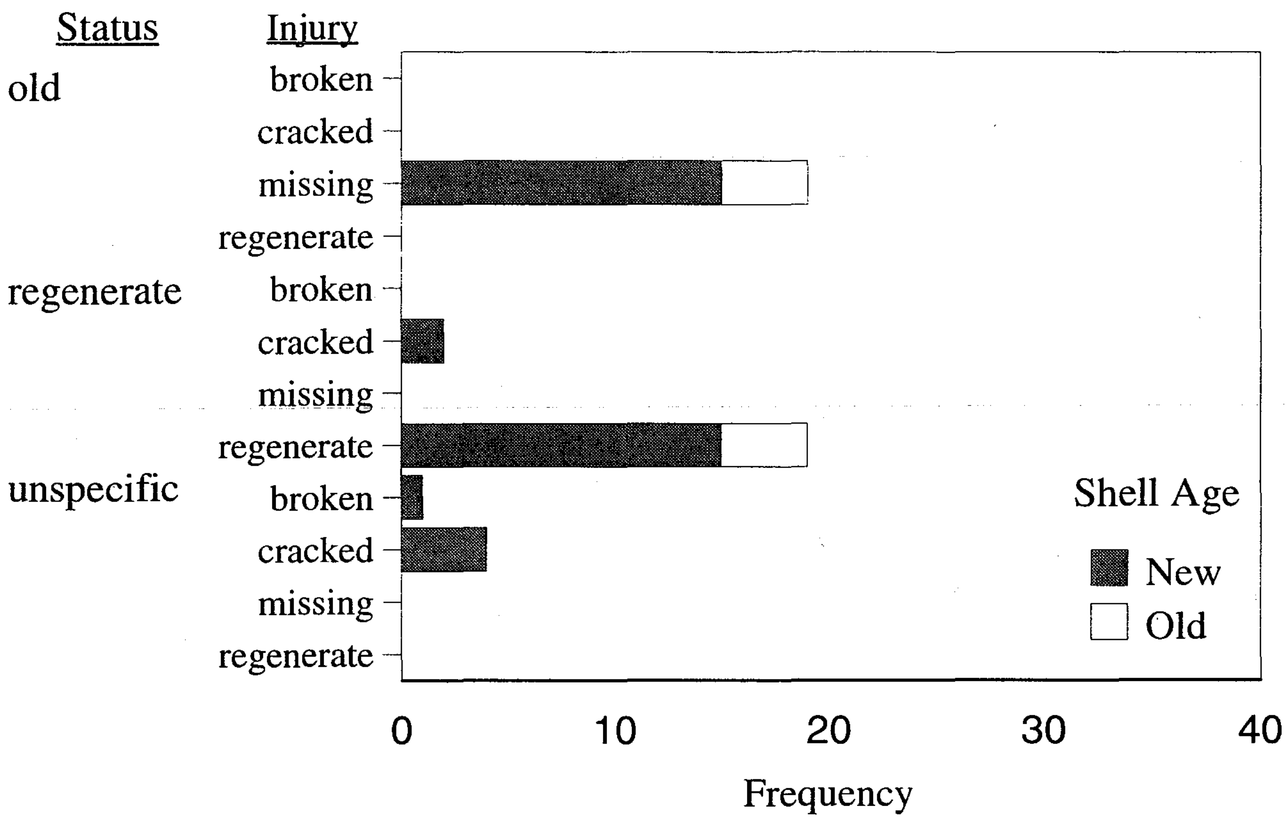

Status
Injury
old
regenerate
unspecific
broken
cracked
missing
regenerate
broken
cracked
missing
regenerate
broken
cracked
missing
regenerate
Shell Age
New
Old
0
10
20
30
40
Frequency

Figure 12.