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

Assessment of Injury to Sea Ducks from Hydrocarbon Uptake in Prince William Sound and the Kodiak Archipelago, Alaska, Following the *Exxon Valdez* Oil Spill

Volume I

Bird Study Number 11
Final Report

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Division of Wildlife Conservation
333 Raspberry Road
Anchorage, Alaska 99518

In cooperation with:

U.S. Fish and Wildlife Service

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Study History: Bird Study 11 was one of the initial resource projects approved after the oil spill. Because this study focused on migratory birds, namely sea ducks, coordination and funding came through the U.S. Fish and Wildlife Service (USFWS). Start-up funding was not made available until September of 1989, six months after the spill. This delayed the beginning of fieldwork and hampered the collection of specimens exposed to oil immediately after the spill. The collection of sea ducks for food habits and contaminant samples was suspended by USFWS in fall 1990. Comprehensive shoreline surveys, mist-netting on streams, and compilation of records on oiled habitats intensified in 1991. In addition, the study became more narrowly focused on harlequin duck distribution, abundance, and productivity. During 1991 and 1992, Bird Study 11 activities in western Prince William Sound (PWS) were conducted in tandem with Restoration Study 71 in eastern PWS. Together, these projects investigated comparative aspects of sea duck status in the oiled and unoiled portions of the Sound.

Production of a draft final report began in 1993, with guidance being rendered independently by the Division of Wildlife Conservation, ADF&G Oil Spill staff, and the EVOS Restoration Office. In June of 1993, after project supervision was transferred to the ADF&G Waterfowl Program, efforts were aimed at organizing, verifying, and summarizing a large amount of data, and redrafting the final report. By June 1994, all of the original staff, including the principal investigator, had left the project after submission of a revised draft of the final report. Since then, this final report was extensively edited for format and style, verification and expansion of original data presentations, and additional statistical analyses by the ADF&G Waterfowl Coordinator. Moreover, important points of discussion and initial conclusions have been critically reviewed and edited for prudent interpretation of findings.

Abstract: This study investigated impacts of the *Exxon Valdez* oil spill on six sea duck species, and the status and productivity of harlequin ducks in Prince William Sound, Alaska, during 1989-1992. A survey of sea duck foods was consistent with the literature, showing diverse prey in harlequins and the importance of mussels to goldeneyes and scoters. Five of 151 tested ducks contained foods contaminated with crude oil. Bile samples had elevated concentrations of hydrocarbons in 74% of harlequins and 88% of goldeneyes. Initial spill mortality of harlequin ducks may have been 423 in Prince William Sound and >1,000 for the entire spill area. May-June boat surveys showed 3.4 times as many harlequins in unoiled parts of the Sound as in oiled areas. Mist-netting for 554 hours caught 65 harlequins on 24 streams in unoiled areas and 2 harlequins on 46 streams in the oil zone. July-August surveys during 1991-1992 indicated higher densities of molting harlequins and at least 21 broods in the unoiled area, and 8 broods in oiled areas. We

suggest harlequins suffered population-level effects through 1992, but spill effects and regional ecologies can not be separated to explain differences in abundance and productivity between oiled and unoiled areas.

Key Words: Alaska, contaminants, *Exxon Valdez* oil spill, foods, harlequin duck, *Histrionicus histrionicus*, Kodiak, petroleum, Prince William Sound, reproduction.

Project Data: Project data are recorded on paper (notebooks and forms), maps, and electronic compilations. Principal data sets include: (1) necropsy and collection forms with organ and food notations, (2) laboratory reports with toxicology and histopathology results, (3) boat survey data by date and location, (4) stream mist-netting logs and banding schedules, (5) original and compiled records of oiling conditions and bird observations by numbered beach segment/stream and date, (6) compiled records of chemical oil remediation treatments by numbered beach segment/stream and date, and (7) a library of literature related to oil impacts on water birds. All data and materials are supervised and located with the Waterfowl Coordinator, Alaska Department of Fish and Game, 333 Raspberry Road, Anchorage, Alaska 99518. Contact the Coordinator by mail, telephone (907) 267-2206, or facsimile (907) 267-2433. All records not protected for litigation purposes are in the public domain and available under standard access procedures. Copies of many records also are found in the Alaska State Archives, Juneau and the Alaska Resources Library and Information Services, Anchorage.

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EXECUTIVE SUMMARY

The goal of this project was to determine whether the *Exxon Valdez* Oil Spill of March 24, 1989, had measurable sublethal effects on six species of sea ducks breeding and wintering in Prince William Sound (PWS) and the Kodiak Archipelago, Alaska. Barrow's goldeneyes, common goldeneyes, surf scoters, black scoters, and white-winged scoters occur in PWS and the Kodiak Archipelago from late fall to early spring. Harlequin ducks occur year around, with populations of summer breeders, spring and fall migrants, and winter aggregations. The coastal zones in western PWS and the Kodiak Archipelago were directly impacted by substantial amounts of *Exxon Valdez* oil during the spill.

All six sea duck species suffered direct mortality following the spill. To investigate and quantify sublethal effects to sea ducks in the spill area, the study was composed of several components: (1) investigate sea duck food habits; (2) document exposure of sea ducks to oil; (3) determine the sublethal effects of oil exposure; and (4) monitor reproduction of harlequin ducks.

We collected 231 sea ducks of six species in 1989-1990. Sea duck diets were similar to those described in previous studies, showing diverse prey in harlequins and the importance of mussels to goldeneyes and scoters. Of 151 ducks tested, proventricular contents of three harlequin ducks, one Barrow's and one common goldeneyes collected from western PWS in 1989 and 1990, were contaminated by *Exxon Valdez* crude oil.

Bile samples from harlequin ducks and goldeneyes in eastern and western PWS had concentrations of naphthalene-eq and phenanthrene-eq significantly higher than Juneau samples, indicating that some of these ducks had assimilated petroleum hydrocarbons. Bile analyses indicate that ducks taken in eastern PWS "control" areas had patterns and mean concentrations of hydrocarbons similar to western PWS samples. Samples from Kodiak had significantly higher phenanthrene-eq concentrations than Juneau samples. Mean concentrations of phenanthrene-eq decreased with distance from the spill site at Bligh Reef.

Extensive stream and coastline surveys were conducted to monitor harlequin duck abundance and breeding effort in PWS during 1990-1992. May-June boat surveys showed 3.4 times as many harlequins in unoiled parts of the Sound as in oiled areas; little courtship or nesting behavior was observed in the spill area. Mist-netting for 554 hours caught 65 harlequins on 24 streams in unoiled areas and 2 harlequins on 46 streams in the oil zone. July-August surveys during 1991-1992 indicated higher densities of molting harlequins and at least 21 broods in the unoiled area, and 8 broods in oiled areas. Of 11 broods seen in the oil spill area during 1989-1992, only 3 were in heavily oiled areas.

The initial spill mortality of harlequin ducks may have been 423 in Prince William Sound and >1,000 for the entire spill area. We suggest harlequins in western PWS suffered population-level effects from this loss and low production through 1992, but spill effects and regional ecologies can not be separated to explain differences in abundance and productivity between oiled and unoiled areas.

INTRODUCTION

The *T/V Exxon Valdez* spilled over 11 million gallons of North Slope Crude Oil into Prince William Sound on March 24, 1989. Murres, alcids, and sea ducks were among the seabirds suffering the highest immediate mortality. Significant direct mortality of sea ducks was documented in Bird Study No. 1 (ECI 1991). Estimates of total mortality were made after the fact, from counts of birds in the morgues (Piatt et al. 1990). Population changes were estimated by comparing pre-spill (1970's) and post-spill data from U.S. Fish and Wildlife Service boat and aerial surveys (Bird Study 2: Klosiewski and Laing 1994). Because the only comparable data were gathered 15 years prior to the oil spill, there is no baseline information to determine whether bird population changes occurred before or coincident with the spill.

Natural Resources Damage Assessment (NRDA) studies were planned and conducted under conditions of urgency and broad geographic scope. They also were circumscribed by a unique set of evolving legal, technical, fiscal, and administrative constraints that affected scientific designs and levels of effort. Bird Study No. 11 (B11), authorized to begin five months after the spill, commenced in September 1989.

Bird Study No. 11 focused on indirect impacts to sea ducks through investigations of the pathway of oil exposure, petroleum hydrocarbon accumulation, and resultant sublethal effects on harlequin ducks (*Histrionicus histrionicus*), Barrow's goldeneyes (*Bucephala islandica*), common goldeneyes (*Bucephala clangula*), surf scoters (*Melanitta perspicillata*), black scoters (*Melanitta nigra*), and white-winged scoters (*Melanitta deglandi*) in Prince William Sound and the Kodiak Archipelago.

Most information obtained during B11 resulted from focused investigation of oil spill injury to wintering and breeding harlequin ducks in western Prince William Sound. Harlequin ducks were selected as the focus of this study because of their year-round occurrence in PWS and their intertidal foraging habits. Information gathered during the companion Restoration Study No. 71, on harlequin duck reproduction and nesting habitat characterization in unoiled eastern Prince William Sound, has been presented by Crowley and Patten (1996). The harlequin restoration study (R71) produced complementary survey results that are included in this report for direct comparison to the damage assessment work in oiled western PWS.

Prince William Sound (PWS) and the nearshore waters of Kodiak and neighboring islands are important wintering areas for sea ducks, supporting perhaps up to several hundred thousand birds (Isleib and Kessel 1973). Prince William Sound is also an important stopover area on the migration route of sea ducks in the spring and fall. Most wintering and migrant harlequin ducks on the south coast of Alaska breed elsewhere in the state. They arrive in the south coastal area and PWS in October and depart in May. Harlequin duck populations return to the same breeding and wintering areas year after year (Kuchel 1977; Dzinbal 1982; Wallen 1987; Cassirer and Groves 1991), demonstrating a site fidelity important in the context of exposure to oiled habitats and recovery potential.

During the summer, several species of sea ducks are present in Prince William Sound, such as molting flocks of scoters, but the primary breeding species is the harlequin duck. Harlequins breeding in PWS were estimated at around 6,000 by Isleib and Kessel (1973). Harlequins breed along the mid- to upper reaches of short, forested coastal streams in Prince William Sound (Isleib and Kessel 1973; Dzinbal 1982; Crowley and Patten 1996). Broods have been reported in shoreline habitats of PWS in late summer (Isleib and Kessel 1973; Oakley and Kuletz 1979; Dzinbal 1982; Isleib, pers. comm.; Holbrook pers. comm.). Broods are found with hens on saltwater in late summer. Harlequins molt in secluded bays and lagoons, and roost on offshore rocks.

The six sea duck species studied depend on intertidal and subtidal marine invertebrates as food resources. Knowledge of the foraging habits of each sea duck species, as related to distance from the intertidal zone, is important to an understanding of the potential for petroleum exposure through the food chain. These sea duck species are segregated by preferred feeding zones, from harlequin ducks tied to shoreline intertidal zones to white-winged scoters feeding in progressively deeper water (Dzinbal and Jarvis 1982; Koehl et al. 1982; Sanger and Jones 1982; Vermeer and Bourne 1982). Harlequins feed at or near the water surface in the intertidal and consume a wide variety of small clams, snails, chitons, limpets, hermit crabs, and blue mussels (Goudie and Ankney 1986; 1988). Both species of goldeneyes and the scoters dive to feed on larger blue mussels and snails from the lower intertidal and subtidal areas (Koehl et al. 1982). The white-winged scoter feeds farthest offshore in deeper water, diving to 30 m for benthic organisms such as scallops and clams (Vermeer and Bourne 1982).

Sea ducks foraging in oil spill areas are exposed to contamination through direct intake and consumption of contaminated foods. Bivalves, particularly blue mussels, are well known for their ability to concentrate pollutants to high levels (Goldberg 1975). Crude oil contaminated some marine invertebrates, such as mussels, that support sea ducks throughout the year (USCG 1989; Karinen and Babcock 1991; Babcock et al. 1993).

The physiological effects of sublethal oil exposure to seabirds and waterfowl are poorly documented. A literature review on the effects of petroleum exposure to seabirds and waterfowl was conducted and summarized because of relevance to this study (Appendix 1). The review cites few previous studies of effects of petroleum on waterfowl and none on harlequin ducks. References specifically on effects of oil on avian reproduction were limited in number, and mostly relate to physical oiling of eggs and experimental dosage of captive mallards. Petroleum exposure has led to behavioral changes, such as the failure of Antarctic skuas to defend nestlings. This caused complete reproductive loss even when eggs and young were viable (Eppley and Rubega 1990).

No documentation was found concerning physiological and behavioral effects of oil on reproduction of waterfowl in the wild. Few experimental studies have exposed wild birds to doses of weathered crude oil (Miller et al. 1978; Peakall et al. 1980; Ainley et al. 1981; Boersma 1986; Butler et al. 1988). Exposing petrels, shearwaters and auklets to weathered crude oil prior to egg laying caused cessation of reproduction, nest abandonment, and a decreased number of birds returning to the colony in the year after exposure (Fry et al. 1986; Fry and Addiego 1988; Butler et al. 1988).

Because of their intertidal foraging habits, local breeding status, and sensitivity to disturbance, harlequin ducks have been considered especially at risk from the wide variety of impacts of the spill and its intensive clean-up, including long-term, chronic exposure to *Exxon Valdez* oil.

OBJECTIVES

A. To test the hypothesis that the incidence of petroleum hydrocarbons from the *Exxon Valdez* spill in food items from collected sea ducks was higher in the oil spill areas than those from the control areas investigated in 1989-90.

B. To determine food habits of six species of sea ducks in Prince William Sound.

C. To test the hypothesis that the incidence of petroleum hydrocarbons from the *Exxon Valdez* spill in tissues of collected sea ducks was significantly higher in the 1989-90 period in the oil spill areas than in the control areas.

D. To test the hypothesis that the physiological condition of sea ducks, as measured by body and fat indices, differs between oil spill and control areas.

E. To test the hypothesis that the breeding effort and reproductive productivity of harlequin ducks in the spill area of western Prince William Sound differs from that of control areas in eastern Prince William Sound.

METHODS

STUDY AREA

The study area for B11 consisted of two broad regions: that area of Prince William Sound and the Kodiak Archipelago included within the *Exxon Valdez* Oil Spill area, and the unoiled area of eastern Prince William Sound (Figure 1). General descriptions of the region and sea duck habitats are found in Isleib and Kessel (1973). The 1989 - 1992 oiled study area included offshore rocks, bays, lagoons and stream mouths on the mainland of western Prince William Sound from Applegate Island in Port Nellie Juan south to Bainbridge Island. It also included Chenega, Knight, Evans, Elrington, and Latouche Islands. The study area extended east to Hanning and MacLeod Harbors on Montague Island, to Green Island and north to Perry Island and the Naked Island group (see ADNR 1990). Table 1 lists the islands, bays and mainland areas in the oil spill study area of western Prince William Sound, with Exxon beach clean-up segment identifiers (ADEC 1989a) added for ease of reference. Part of sea duck collections for contaminant sampling was done in Chief Cove, a heavily oiled site on southwestern Kodiak Island.

For comparison, study activities were conducted in unoiled control areas in eastern Prince William Sound (Figure 1). The 1990 - 1992 harlequin duck survey and trapping activities in eastern Prince William Sound extended south from Valdez Arm to Hinchinbrook Entrance and east to Cordova. In 1990, sea ducks were collected for food and tissue samples at Douglas Island and Amalga Harbor near Juneau, 675 km southeast of Prince William Sound.

LOCATION OF FIELD CAMPS

Crews of 3-6 workers staffed three field camps in Prince William Sound during the 1990 - 1992 field seasons. The spill area camp was located at Herring Bay on Knight Island during 1990 - 1992). The unoiled area camp was located at Olsen Bay, Port Gravina, in eastern Prince William Sound, 1991-1992. In 1992, a third field camp was placed at Chenega Village in Sawmill Bay on east central Evans Island, in the southwestern Prince William Sound oil spill area.

SEA DUCK COLLECTIONS

Because authorization to spend funds and commence this study was not received from U.S. Fish and Wildlife Service until August 1989, no sea ducks (other than those killed directly by the spill) were collected between the date of the *Exxon Valdez* spill and September 1989. Collection procedures involved locating groups of birds; observing group composition and behavior, especially foraging activity; and either stalking or pursuing birds into suitable collection range. The ducks were taken by 12-gauge shotgun. All birds were immediately retrieved, labeled with time, date, original location, circumstances of collection, species, and sex-age class being recorded. Data were recorded in field notebooks and maps. Carcasses were kept on ice or cooled until processing at base camp or laboratory. Field handling of all birds followed a departmental protocol developed for oil spill collections (Appendix 2). All birds and subsequent samples were preserved and submitted through established oil spill chain-of-custody procedures.

Sea ducks were collected by project personnel under authorization of Alaska Department of Fish and Game and U.S. Fish and Wildlife Service scientific collecting permits. All sea duck collecting for this study, as well as bird collections for all other oil spill studies, was terminated in fall 1990 and suspended through the end of the project at the direction of the USFWS Regional Director. This precluded larger sample sizes of sea ducks and seasonal/annual comparisons in 1991 and 1992.

NECROPSIES

Gross necropsies were conducted within hours on every sea duck taken, according to the standard protocol for necropsy and tissue sampling (Appendix 2). A standard form was completed on each duck examined, including information on external signs of oiling, general condition of the individual, molt stage, amount and deposition of adipose tissue, and gross abnormalities noted on internal organs. Care was taken to collect samples of tissue and bile for contaminant analysis before other necropsy procedures were done. Table 2 lists tissues taken for histopathology and toxicology analysis.

FOOD HABITS SAMPLING

During necropsy all food items in the proventriculus were transferred to chemically clean jars (Appendix 2), examined and described in a preliminary manner, and frozen. The primary purpose of these samples was to test for petroleum exposure, precluding the use of fixatives to preserve organisms. Food habits analysis was of secondary importance. To develop a data base of prey organisms, food items were later identified to genus level in the laboratory. The food items were counted and measured to length without removal from clean storage jars in order to avoid potential petroleum contamination. Gizzard material was not used to evaluate diets because of biases associated with differential digestion and detectability (Swanson and Bartonek 1970; Collier 1991).

Data from food items were compiled to determine both how commonly prey species were found among ducks of each species (occurrence) and the importance of prey taxa as food (a function of number consumed and size of prey animals. Frequencies of occurrence for prey items were calculated from lists of food items for each duck species. Avoidance of preservatives may have allowed post-mortem digestion to dissolve soft-bodied foods.

An index to relative importance was derived for each major taxon, using an adaptation of the procedures developed by Hynes (1950) modified by Griffiths et al. (1975) and used by Johnson (1982). Twenty points were assigned to the fullest gullet of each species examined. The fullness of each other gullet was subsequently gauged against the fullest gullet, and a proportionate number of points were assigned. The points assigned to each stomach were then partitioned among the major prey taxa according to indices of relative importance.

In the cited previous studies, relative importance of taxa in stomachs were determined with volumetric measurements, visual estimates of relative volumes, and weights. Johnson (1982) found, with the Hynes/Griffiths "point" system, that the best correlations with energy (kcal) values for bivalves and most other prey taxa of Oldsquaws were obtained with ash-free dry weights and volumes. Wet weights and abundance provided the poorest reflection of energy content.

In our study, food items from all birds were to be chemically analyzed for hydrocarbons and could not be handled, dried, or immersed in fluid (displacement method) without risk of contamination. Consequently, we used indirect measures (lengths for individual prey items) and generated a sum of lengths as a relative length-importance index. Our method is less precise than use of relative volume indices because length:volume relationships that vary among prey species were not obtained. Our primary purpose was to test foods for petroleum contamination. Use of prey length allowed a practical means to approximate relative importance among food taxa.

Petroleum Contamination Sampling

The following procedures were followed to assess whether sea ducks consumed and metabolized contaminated food in the oiled area. Samples of liver, bile, and food items from the proventriculus were collected for analysis of petroleum contamination. Samples were taken with chemically cleaned instruments in clean environments, and frozen in chemically cleaned jars (Appendix 2).

By policy of the Natural Resource Damage Assessment program, all sea duck liver, bile, and food samples to be analyzed for petroleum contamination were submitted under Technical Services Project No. 1 to the U.S. Fish and Wildlife Service, Regional Contaminants Coordinator (Mr. E.F. Robinson-Wilson) in Anchorage. All samples were assigned a NRDA reference number and catalogued. Frozen samples were submitted for analysis to the Geochemical and Environmental Research Group (GERG), Texas A&M University.

Sea duck liver and food samples were processed by the NOAA Status and Trends Method (MacLeod et al. 1985) with minor revisions (Brooks et al. 1989; Wade et al. 1988). They were homogenized, and a 1-10 gm sample was extracted by adding surrogate standards, Na_2SO_4, and methylene chloride in a centrifuge tube. Tissue abstracts were purified by silica/alumina column chromatography to isolate the aliphatic and PAH (polycyclic aromatic hydrocarbon), pesticide, and PCB (polychlorinated bi-phenyl) fractions, which were further purified by HPLC. Quantitative analyses were performed by capillary gas chromatography with a flame ionization detector for aliphatic hydrocarbons and a mass spectrophotometer detector for aromatic hydrocarbons (Wade et al. 1988).

Bile samples were analyzed using HPLC methods (Krahn et al. 1987) and reported as aggregate values for the naphthalene and phenanthrene equivalents of aggregate related compounds and metabolites (hereafter annotated as naphthalene-eq, phenanthrene-eq). The methylated parent compounds of naphthalene-eq and phenanthrene-eq are two of the lighter and more volatile components of crude oil. Naphthalene-eq and phenanthrene-eq are also found in a variety of sources of environmental pollution (Eisler 1987). We found no previously reported baseline information on concentrations of these PAHs in bird bile with which to compare our data. Analysis of variance (ANOVA; Statgraphics 7.0) was applied to provide comparisons of naphthalene-eq (NAPH) and phenanthrene-eq (PHEN) concentrations in bile samples between duck species, and between oiled (PWS, Kodiak) and unoiled (eastern PWS, Juneau) collection areas.

Laboratory analyses followed these method detection limits and surrogate standard recoveries:

Method Detection Limits. Concentrations of alkane and polynuclear aromatic hydrocarbons that were lower than sample-specific method detection limits (MDL's) were considered as zero in this report. Method detection limits were experimentally determined for each calibrated alkane and PAH according to the methods described by Glaser et al. (1981) at the analytical laboratory. These MDLs were based on variance estimates derived from repetitive analysis of 10-g wet weight aliquots of mussel tissue spiked with hydrocarbons at concentrations near the MDL. Sample-specific MDL's were calculated as the ratio of the mussel tissue MDL's expressed as absolute mass and the sample wet weight. MDL's of uncalibrated hydrocarbons were assumed as the MDL of the most similar calibrated hydrocarbon. For example, the MDL used for C-3 phenanthrene is the MDL for 1-methyl phenanthrene.

Surrogate Standard Recovery Acceptance Criteria. During laboratory testing, surrogate samples were introduced to evaluate the accuracy of compound detection in field samples. Hydrocarbon results associated with either excessively high or very low surrogate standard recovery results were not accepted for further consideration in this report. In particular, test data were rejected if results indicated that > 150% or < 30% of the associated surrogate standard was recovered.

Hydrocarbon data from the petrochemical analyses of sea duck samples were initially interpreted by Mr. Robinson-Wilson. Based on hydrocarbon analyses, he classified each sea duck food sample as contaminated by crude oil or uncontaminated according to criteria listed in Table 3. Decisions were made such that values of all or nearly all parameters had to meet or exceed threshold levels for a positive finding of crude oil contamination (Robinson-Wilson, pers. comm.).

If some, but not all, aliphatic components of crude oil were present in the samples, the classification was negative.

Subsequent to initial determinations, National Marine Fisheries Service, Auke Bay Laboratory reinterpreted all hydrocarbon data for sea duck food and tissue samples and provided final conclusions, using the Texas A&M data base. NMFS also compared PAH profiles in sea duck food samples to reference samples of *Exxon Valdez* crude oil and to typical combustion products (e.g. diesel exhaust, fuels). Thus, the conclusions on oil-contaminated sea duck foods and tissues from both initial and final analyses are based on very conservative criteria.

Surveys of Contaminated Habitats and Mussel Beds

To assess the broader impacts of oil on harlequin ducks, particularly long-term contamination of feeding sites, records of the Federal On-Scene Coordinator (FOSC) and Oil Spill Public Information Center (OSPIC) were abstracted into lists of oiled habitats and sites treated with chemical remediation. During 1991 and 1992 surveys were conducted of oiled areas to document the condition of intertidal sites, particularly mussel beds. The term mussel "beds" is not precisely defined in our usage, but applies to aggregations similar to those described by Babcock et al. (1994), generally 15-100% cover of the substrate and often in multiple layers. Locations, physical site descriptions, harlequin duck sightings, and amount and condition of oil were recorded by beach segments with known histories. Fieldwork was a cooperative effort with National Marine Fisheries Service personnel, working on Coastal Habitat Study 1B and Restoration Study 103, who subsequently analyzed mussels from many of these sites for oil contamination (Babcock et al. 1993). Results on contamination of mussels from these other studies were reviewed and summarized for consideration with sea duck data.

Histopathology Tissue Sampling

Tissue samples were obtained from internal organs at necropsy and preserved for histopathological and toxicological examination according to established protocols (Table 2). Tissue samples and food items were collected using chemically cleaned dissection instruments. Tissue samples for histological analysis were preserved in 10% neutral buffered formalin. The tissue samples were forwarded to and analyzed by Dr. Terry R. Spraker, veterinary pathologist at Colorado State University, College of Veterinary Medicine, Fort Collins, under Technical Services Project No. 2.

Fat Index to Body Condition

Collected sea ducks were classified during necropsy as in good or poor condition in oiled or unoiled areas. Fat condition was judged for harlequin ducks from two oiled (PWS, Kodiak) and two unoiled (Juneau and Cordova) study areas. Five adipose tracts on each duck were scored (throat, subcutaneous, flank, mesenteric, and heart)(Sparling et al. 1992). Fat condition was classified on a subjective scale of 1-5, with larger numbers associated with less fat deposition. Ratings were made by different observers in each study area. Observers discussed means of scoring in advance, but observer differences in scoring were not tested or standardized.

A multivariate analysis of variance (Johnson and Wichern 1988) was used to test the hypothesis:

Ho: pws - controls = 0
Ha: pws - controls$\neq$ 0

where the controls were composed of ducks collected near Juneau and Cordova. The following multivariate contrast was used:

c1: pws - 0.5x (Juneau + Cordova).

To examine the differences in fat condition between harlequins collected at site of maximum oil impact on Kodiak Island (Chief Cove, near Larsen Bay), and harlequins collected at control sites near Juneau and Cordova, the following hypothesis was tested:

Ho: Kodiak - controls = 0
Ha: Kodiak - controls$\neq$ 0.

This hypothesis was tested with the following contrast:

c2: Kodiak - 0.5x (Juneau + Cordova).

Multivariate analysis of variance was also applied to compare differences in mean fat indices between the two control areas to determine if area differences existed independent of oil treatments. The hypotheses were expressed as:

Ho: E PWS - Juneau = 0
Ha: E PWS - Juneau$\neq$ 0.

PRELIMINARY HARLEQUIN DUCK SURVEYS - 1990

During the 1990 field season, this study became focused on harlequin ducks. In order to assess feasibility of harlequin duck restoration, Alaska Department of Fish and Game (ADF&G) Commercial Fisheries technicians were asked to make opportunistic records of harlequin ducks and broods along anadromous fish streams in oiled and unoiled areas of Prince William Sound during the summer of 1990, while conducting fisheries surveys (M. Hausler, ADF&G, pers. comm.). Technicians were briefed on identification of harlequins and the types of observations of value, but no specific duck survey design was imposed on normal fisheries work. Stream corridors were traversed three times from mid-June to the first week of September. Fisheries crews walked each stream from the intertidal zone to the upper limit of salmon distribution, searching for harlequin ducks. They also conducted extensive shoreline searches for harlequin broods in the oil spill area in summer 1990 (M. Hausler, ADF&G, pers. comm.).

Surveys were initiated on Hawkins and Hinchinbrook Islands, and continued northward on the mainland of eastern PWS from the Eyak River near Cordova to Valdez. The surveys included the

Coghill River in College Fjord in northwestern PWS, and continued southward on the mainland of western PWS from Port Nellie Juan to Jackpot Bay and Bainbridge Passage. The surveys also included streams on Chenega, Knight, Bainbridge, Evans, Latouche, Green and Montague Islands.

Additional information on harlequin summer distribution in Prince William Sound was provided by USFWS teams during the course of their oil spill studies (Irons and Laing pers. comm.). K. Kuletz shared the results of systematic shoreline surveys of all bird species conducted around Naked, Storey, Peak, and Eleanor Islands in 1989 and 1990.

HARLEQUIN DUCK SURVEYS - 1991 AND 1992

Boat surveys were conducted from mid-May through June (breeding season) and during July and August (post-breeding season) in both years throughout the western PWS oil spill area to determine numbers, distribution, and habitat associations of harlequin ducks. The surveys included islands, bays and the mainland from Port Nellie Juan south to Port Bainbridge and east to Montague Island (Table 1). USFWS studies contributed systematic survey data on adult harlequins and broods in 1991 around the Naked Island group and Eleanor Island, and accumulated observations from daily boat work during the summer of 1992 (Kuletz pers. comm.). As part of Restoration Study No. 71, all suitable harlequin breeding streams and suitable shoreline habitat in unoiled eastern PWS was surveyed from Valdez to Cordova in 1991 and 1992. This included Hinchinbrook Island (Crowley and Patten 1996).

During 1991, operations were from a single base camp at Herring Bay, which prevented total coverage of the western Sound spill area. Efforts were focused in the most heavily affected northern region, from Eleanor Island to Knight Island, Chenega Island, and the adjacent mainland coast. However, in 1992, two survey teams, one based in Herring Bay and the other operating out of Sawmill Bay, covered nearly the entire oil spill area (Figure 1). The exceptions were the less accessible and peripheral sites at Rocky and Ziakoff Bays on Montague Island, Seal Island, Smith and Little Smith Island, Blue Fjord in Port Nellie Juan, and the Dutch Island group north of Perry Island. In addition, unoiled areas such as Hogg Bay, Port Bainbridge, SW side of Bainbridge Island, SW coast of Bainbridge Passage on the mainland coast, and Long Bay and Culross Passage were surveyed for harlequins in 1992. This significantly expanded survey coverage to include a substantial extent of unoiled coastline within the spill zone.

These surveys were conducted from skiffs operating 2-50 m from shore, around all islands and exposed rocks, into all bays and embayments, with two observers aboard. Harlequin data were recorded along continuous shoreline tracks, mapped, and, in western PWS, referenced to Exxon beach clean-up segment identifiers (Table 1; ADEC 1989a). The segment identifier links observations with the oiling history of the site from ADEC records (see Figure 2). The oiled zone of Prince William Sound contains segments that were oiled, but oiling was not continuous throughout all the segments (ADNR 1990). Adjacent areas may have been unoiled. The oiled zone encompasses 2800 km of shoreline, of which approximately 730 km was oiled.

Observations of harlequin ducks were recorded in four general habitat types. Coastal habitats are typically intermingled as patches of diverse landforms and water. Therefore, we did not use a system of detailed exclusive habitat classes. In this report, harlequin ducks were tallied in Mussel Bed and Offshore Rock habitat classes, if they were on such specific sites. If not, they were counted in general Stream Mouth and Bay & Lagoon types. Harlequin ducks were tallied on Oiled Mussel Beds when they were seen actually on oiled beds documented by Restoration Study 103 or this study, not when they were merely within a segment containing oiled beds.

On all surveys, harlequins were counted and, whenever possible, classified by sex and age. Sex ratios are difficult to determine from mid-summer to September because subadult harlequin males have plumages that, to varying degrees, resemble females. In addition, adult males lose their breeding plumage during molt in July. Although males may be aged carefully from fall through early summer, there are no obvious plumage features of female age classes. Identifying juvenile harlequin young of the year may be done by presence of down during brood rearing. However, once all contour feathers are in after mid-August, it is very difficult to distinguish juveniles from females and subadult males without close inspection. The presence of a flighted bird with a group of flightless others is not a reliable sign, given the mixture of birds at different molt stages in late summer. Our brood surveys were conducted after all families would have been on coastal waters, yet early enough to detect downy broods; due caution was used to thoroughly examine all suspected brood groups.

During 1991 and 1992 in western PWS and in eastern PWS, May and June surveys were conducted to locate breeding pairs. Breeding pairs were discerned from close association that is usually apparent between a male and female, social-sexual displays, and antagonistic behavior toward other birds, indicative of bonded pairs (Myres 1959, Johnsgard 1965). Presence of harlequins or harlequin pairs on or near streams indicated probable use of these streams for breeding.

Shoreline coverage reported in km for each survey during this project represents one complete survey, with no duplication coverage included. Shoreline lengths of duck surveys in western PWS were computed from the official state/federal shoreline database developed by USFS as the standard for quantifying EVOS shoreline data. This system has a base scale of 1:63,360, as good as any maps available for the spill region. Survey lengths for eastern PWS were determined from electronic planimeter measurements on maps of the same scale.

Average shoreline densities for spring, molt and brood censuses were derived from complete counts of harlequins divided by the total length of the survey. The survey included all habitat types. Shoreline densities for specific habitat types and oiling conditions were derived by dividing the number of harlequins by the sum of the length of the segments in which the ducks were observed.

MONITORING STREAMS FOR BREEDING ACTIVITY - 1991 AND 1992

Breeding harlequin ducks fly along stream corridors between coastal feeding areas and upstream nest sites in Prince William Sound, primarily during twilight hours (Dzinbal 1982). During 1991 and 1992, mist-netting was employed to both sample breeding bird activity on potential nesting streams in oiled and unoiled areas, and to capture adults for subsequent studies of nesting. We used mist nets (4-inch mesh, Avinet, Inc.) suspended over streams, usually within 100 m of the coast (Dzinbal 1982; see also Eldridge 1986). We monitored streams from late May through early July.

Nets were deployed and monitored for an average of nine hours, usually between 1900 - 0800 hours.

The selection of streams for monitoring differed somewhat between the eastern and western study areas. In eastern PWS, we selected streams based primarily on observations of harlequins near the stream mouth during spring surveys. We also selected streams with characteristics similar to known harlequin streams (Table 4), but where we observed no harlequins during surveys. These streams were given a lower priority for trapping. Finally, we selected streams that were within the same vicinity (e.g., bay) of a known harlequin stream, regardless of habitat characteristics, to collect a sample of streams not used by breeding harlequin ducks (Crowley 1994).

Unlike eastern PWS, there were few harlequins observed near stream mouths during spring surveys of western PWS. Therefore, most streams monitored in western PWS were selected based on their similarity to known breeding streams throughout Prince William Sound (Table 4). In general, the largest streams in western PWS received highest priority for monitoring.

Radio transmitters with 3-month lithium battery packs weighing 4.5 g in total were built by Advanced Telemetry Systems (ATS, #357). The radios were epoxy-glued to the base of the tail retrices of all captured females. Radios were covered by upper tail coverts with the whip antennae exposed. Transmitters were shed by females during the molt in late summer after brood rearing was completed. We concluded that this attachment technique was the least intrusive method of radio-tagging these diving ducks (see Raim 1978; Perry 1981a,b; Widen 1982; Korschgen et al. 1984). Nesting females were radio-tracked to nest sites, where nesting habitat was characterized (Crowley and Patten 1996).

RESULTS

SEA DUCK COLLECTIONS

From fall 1989 to fall 1990, a total of 231 sea ducks of six species were collected from oiled areas throughout western PWS (PWS) and at Chief Cove on the west side of Kodiak Island (KOD), and unoiled areas of eastern PWS (CDV) and north Douglas Island near Juneau (JUN). Table 5 indicates the distribution and periods of sea duck collections, by species. Harlequin ducks made up the majority of collected birds because they are the only year round resident species, and because they became the primary focus of contaminant work. Goldeneyes and scoters are abundant in PWS only during winter, and scoters are much more difficult to collect. Also, results from Bird Study 2 (Klosiewski and Laing 1994) indicate that scoters experienced a proportionately high direct mortality among sea ducks during the oil spill and were not as abundant in the study area in 1990.

SEA DUCK FOOD HABITS

Eighty-nine (75%) of the 118 harlequin duck proventriculi examined contained food material. Harlequin ducks fed intertidally on small invertebrate prey obtained at or near the surface of the water through grazing, dabbling, and diving. The most frequently encountered prey species of harlequin ducks were snails (*Littorina* and *Lacuna*), limpets (*Lottia*), and chitons (*Tonicella*). Blue mussels (*Mytilus*)[1], 0.5-1.5 cm in length, occurred in 8% of the birds (Table 6). Harlequin diets included, on the basis of relative importance, 20% snails (*Littorina*), 18% snails (*Lacuna*), 12% blue mussels (*Mytilus*), 10% limpets (*Lottia*), and 40% in small amounts of 24 other taxa. Compared to the other species, harlequin ducks fed on a wide variety of other intertidal organisms (Tables 6). Of 80 whole blue mussels found in proventriculi of seven harlequin ducks, nearly all were less than 5 mm in length; larger mussels were found in three ducks, two with 10-mm mussels, and one with a 15-mm mussel.

Harlequin duck diets were compared between winter (January - March) and summer - fall periods (Table 7). Snails and limpets were more commonly found in harlequins during winter than during the summer-fall period. The consumption of blue mussels remained similar during the two periods. The seasonal occurrence of salmon (*Oncorhynchus*) eggs (summer and fall) and herring (*Clupea*) eggs (late winter and spring) is related to spawning schedules and availability.

Food contents were found in 33 (75%) of 44 Barrow's goldeneyes examined for foods, but all 12 common goldeneyes were empty. Barrow's and common goldeneyes fed in both intertidal and subtidal zones. The primary item in the diet of Barrow's goldeneyes was blue mussels, found in 84% of the birds and averaging 81% relative importance (Table 8). Compared to harlequins, goldeneyes foraged more by diving in deeper water and feeding on larger blue mussels. Whole mussels in five birds ranged from 10-30 mm in length, with the largest being 50 mm. Herring eggs were next in importance at 7.6%, followed by 3.8% (*Littorina*) snails, 3.4% (*Lacuna*) snails, 3.8% small whelk (*Searlesia*), and less than 1% limpet (*Lottia*). Of six common goldeneyes with proventricular foods, all contained only blue mussels.

Scoters foraged largely by diving in the subtidal zone. Surf scoters had some propensity for middle and upper intertidal zones, feeding on larger bivalves, such as blue mussels up to 40 mm in length, and less variety of other subtidal organisms. Based on foods found in all eight surf scoters that were collected, their diet consisted of blue mussels, with 43% frequency of occurrence, and 14.3% each of the clams (*Tellina*) and (*Astarte*), and the cockle (*Mactra*)(Table 9). Seven of 18 (39%) white-winged scoters contained food material. White-winged scoters fed on benthic organisms by diving in deeper water to approximately 30m. Bivalves were the most important prey group of white-winged scoters, particularly the clams (*Nuculana*)(38%) and (*Macoma*)(32%). Common but less important were the scallop (*Chlamys*)(15%) and the cockle (*Clinocardium*)(7%). Three species of snails were found less frequently and at lower importance values (1-4%) (Table 9).

Field observations suggested black scoters fed on the bottom at moderate depths beyond the intertidal. The only two black scoters collected in this study fed on the snail (*Acanthina*) and the clam (*Clinocardium*) (Table 9).

[1] *Mytilus trossulus* Gould, 1850 (formerly *M. edulis* Linnaeus, 1758). All subsequent references to blue mussels in this report are to this species. See also McDonald and Koehn (1988) and Seed (1992).

Petroleum Hydrocarbons in Sea Duck Foods

Of the 231 sea ducks collected, proventriculus contents of 151 were tested for petroleum contamination. The findings reported here are all from the definitive analyses by National Marine Fisheries Service, and not the preliminary determinations by U.S. Fish and Wildlife Service. Hydrocarbon contamination of foods was positive in three of 75 (4%) harlequin ducks, one of 33 (3%) Barrow's goldeneyes, and one of eight (12.5%) common goldeneyes (Table 10). All five ducks with contaminated food items in their gullets were collected from the western Prince William Sound spill zone in 1989-1990. No sea ducks collected in eastern PWS, Kodiak, or near Juneau contained food items with detectable oil.

Relative concentrations of PAHs in samples of proventricular contents of four ducks collected in the fall of 1989 are consistent with PAH concentration patterns that are characteristic of weathered *Exxon Valdez* crude oil (EVO) (J. Short, pers. comm.). The most abundant PAHs found in these samples included alkyl-dibenzothiophenes, alkyl-phenanthrenes, and alkyl-chrysenes, and abundance generally increased with alkylation within each homologous PAH series (Table 11). These characteristics are consistent with those of weathered EVO (Table 11), where weathering causes preferential losses of lower molecular weight PAHs and of less alkyl-substituted PAHs. The relatively abundant alkyl-chrysenes in these samples indicate a crude or less-refined petrogenic sources for these hydrocarbons, and the relatively abundant alkyl-dibenzothiophenes are consistent with the high sulfur content of EVO. In addition, phytane was consistently detected at concentrations comparable with alkyl-PAH concentrations in all four of these samples, which corroborates the petrogenic source of these hydrocarbons. Collectively, these results all indicate weathered EVO as the proximate source of the PAHs found in the proventricular contents of these four ducks.

Weathered EVO is also the proximate source of PAHs detected in the proventricular contents of one other harlequin collected in summer 1990 (Table 11). The patterns of relative PAH abundance in this sample are broadly similar to those evident in the four proventricular samples collected in 1989, except that phytane was not detected, alkyl-dibenzothiophenes were relatively less abundant, and alkyl-chrysenes were relatively more abundant (Table 11). These differences all indicate further weathering, which is consistent with the later July 1990 collection date of this duck (J. Short, pers. comm.).

Ancillary Surveys of Contaminated Foraging Sites

To facilitate future investigations of long-term food chain contamination, a large number of oiled harlequin duck habitat sites, including many blue mussel beds, are compiled in a catalogue of oiled habitats and chemical shoreline treatments (Supplements 1-3, Volume II of this report). We located and described over 50 oiled mussel beds in PWS for further monitoring of residual contamination for part of Restoration Study 103 (Appendix 3; see also USCG 1989; Babcock et al. 1993). An extensive list of oiled streams also was catalogued for future work (Supplement 2). A brief description of Inipol, a fertilizer used in bioremediation, and a summary of its applications by Exxon Corporation in Prince William Sound is included to support potential investigations into toxic effects to sea ducks (Supplement 3).

PETROLEUM HYDROCARBONS IN SEA DUCK LIVERS AND BILE

Liver tissues of 50 sea ducks collected in 1989 - 1990 were analyzed for hydrocarbons. The results did not provide evidence of exposure to *Exxon Valdez* oil in any of the samples. Although a number of hydrocarbons compounds were identified in liver tissues, the analytical process used by Texas A & M was not sufficiently refined to quantify key compounds. In addition, nearly all reported values were found to be below method detection limits, after the limits were recalculated by NMFS Auke Bay Laboratory (J. Short, pers. comm.). Consequently, no conclusions could be drawn from the liver data. The lack of measurable hydrocarbons in liver tissue does not mean these ducks were not exposed to oil; hydrocarbons are mobile in the digestive system, and they are metabolized and depurated through the liver.

Table 12 contains results from analysis of 89 bile samples from all six sea duck species collected in oiled western Prince William Sound (PWS) and Kodiak (KOD), and from unoiled eastern PWS (CDV) and Juneau area (JUN) during winter 1989-1990. Naphthalene-eq and phenanthrene-eq concentrations reported for bile in Table 12 include all compounds in these series and metabolites in aggregate. Parent compounds and methylated compounds of naphthalene and phenanthrene are found in crude oil, but little is known about the forms and quantities of metabolic products. Concentrations of naphthalene-eq (NAPH) and phenanthrene-eq (PHEN) were compared using analysis of variance (ANOVA; Statgraphics 7.0). Data were transformed to the natural log scale to meet assumptions of equal variances and distributions.

Initial analyses indicated no significant differences in concentrations of either PAH between duck species (Figures 2 and 3). The small-bodied harlequins and goldeneyes (common and Barrow's) did not differ significantly in PAH concentrations, both when modeled with (NAPH ANOVA F-ratio = 3.479, P = 0.0112, 88 d.f.; PHEN F-ratio=2.75, P=0.034) and without the Juneau samples (NAPH F-ratio=3.06, P=0.022; PHEN F-ratio=2.83, P=0.031, 78 d.f.). Scoter species (surf, white-winged, and black) likewise did not differ significantly from each other under the same model. Scoters had lower concentrations of NAPH and PHEN than did the small-bodied species (only significant for naphthalene-eq in the surf and black scoter group; Figure 2). Consequently, the 18 scoter samples were not used for testing of differences between areas. Their removal resulted in less variance and skewness in the model for testing area differences in the small-bodied ducks. The remaining degrees of freedom (70) were adequate for further testing. The absence of harlequin duck samples from eastern PWS and lack of adequate sample sizes precluded separate testing of differences between each duck species across all four areas.

The combined data from small-bodied ducks were modeled by location for NAPH and PHEN. Concentrations of NAPH were significantly greater in both eastern PWS and western PWS than in Juneau (F-ratio = 4.105, P = 0.0098, 70 d.f.) (Figure 4). NAPH concentrations in ducks from western PWS also were significantly higher than those from Kodiak. Concentrations of NAPH from Kodiak were higher (but not significantly) than those from Juneau. PHEN concentrations from in eastern PWS, western PWS, and Kodiak were significantly higher than those from Juneau (F-ratio = 6.228, P = 0.0009, 70 d.f.) (Figure 5). Figure 6 illustrates that concentrations of PHEN in bile from harlequin ducks and goldeneyes, combined, were negatively related to distance from the original spill site at Bligh Reef.

Surprisingly, the combined samples of harlequins and goldeneyes collected from unoiled eastern PWS areas had concentrations of both NAPH and PHEN well above those from the Juneau controls (Figures 4 and 5). Of 15 Barrow's and common goldeneyes collected in the eastern Sound, average concentrations of both PAHs were equivalent to western Sound birds. Small sample numbers of common goldeneye (3) and white-winged scoters (7) from eastern PWS averaged higher concentrations than western PWS birds (Table 12). Three of seven scoters from eastern PWS had high concentrations of both NAPH and PHEN, with average concentrations about twice as high as western PWS scoters.

HISTOPATHOLOGY OF SEA DUCK TISSUES

An array of tissue samples from 202 sea ducks was examined for histological phenomena related to oil exposure. The subject birds were from PWS (104), Kodiak (36), Cordova area (33), and sites near Juneau (29). Numerous lesions were found in tissue samples, but all were considered types common in free-ranging waterfowl. The majority of the lesions were associated with parasites or mild bacterial infections. No specific histological evidence that could be associated with oil toxicity was found (Appendix 4).

FAT INDEX TO BODY CONDITION

Sixty-six harlequin ducks and 40 Barrow's goldeneyes, collected during winter 1989-1990, were scored for relative fat deposition on five fat tracts as an index to body condition. Mean fat scores by fat tract are reported for harlequin ducks and Barrow's goldeneyes collected in nominal exposed and control regions (Table 13).

Several critical aspects of field data collection methods severely constrained interpretation of fat data and conclusions. Foremost, different individuals recorded fat scores for some of the collections; one did all the Kodiak birds and one did all the Juneau birds. After the fact, there was no feasible means to adjust for observer differences. Second, there are undoubtedly area effects influencing fat scores among widely separated oil spill and control collection areas. The results above suggest regional differences in the two control samples. As a consequence of non-standard scoring, differences in observers and inherent area effects are confounded with any oil spill treatment effects. Thus, the statistical differences reported here could be explained by any combination of the three factors.

Fat Indices: PWS Harlequins and Goldeneyes. A multivariate analysis of variance indicated a significant difference in fat scores between harlequin ducks from oiled western PWS and birds from unoiled control areas: eastern PWS and Juneau ($F_{5,58} = 3.2785$, $p = 0.0113$, where the F statistic was calculated from a Wilk's lambda statistic). However, tract-by-tract comparisons of scores indicate that spill area PWS harlequins were in better condition in some tracts than the controls and in poorer condition in others (Table 13). Based on an examination of calculated contrast differences and Bonferonni confidence intervals around the differences, there was a mixed area/tract effect among fat indices between oiled and unoiled areas of PWS, and between fat tracts (Table 14). Western PWS birds showed a positive contrast (poorer scores) for throat and flank tracts, but better scores than controls on the other three tracts.

Based on an examination of calculated tract score means, Barrow's goldeneyes collected from the PWS oil spill area had significantly poorer fat indices on all tracts, than ducks collected in both control areas (Table 13). Statistical analysis was significant ($F_{5,33} = 4.6610$, $p=0.0025$, where the F statistic was calculated from Wilk's lambda).

Fat Indices: Kodiak Harlequins. In order to test fat differences without the area/tract mixed effect found in western PWS harlequin ducks, Chief Cove on Kodiak Island was selected for a single-area comparison of oil spill harlequins vs. control birds. Overall, Kodiak harlequins had poorer fat scores than controls ($F_{5,58} = 4.4577$, $P = 0.0017$, where the F statistic was calculated from a Wilk's lambda statistic). An examination of the calculated contrast differences and Bonferroni confidence intervals (Table 15), indicates that harlequin ducks collected in the oil spill area at Chief Cove had significantly poorer fat indices (positive contrast values) on all adipose tracts, than did control harlequins from eastern PWS and Juneau.

Fat Indices Between Control Areas. For all tracts combined in the analysis, there was a significant difference between the eastern PWS controls and Juneau controls, in both harlequin ducks ($F_{5,58} = 2.8389$, $p=0.0232$, where the F statistic was calculated from Wilk's lambda) and Barrow's goldeneye ($F_{5,33} = 4.5673$, $p=0.0028$, where the F statistic was calculated from Wilk's lambda).

INDICES TO DISTURBANCE

In part, to document potential sources of stress to ducks, and to gather information that may have affected the distribution of birds on surveys, indices of disturbance for people, boats, aircraft, and active beach cleanup segments were compiled for 1989-1992 (Table 16).

HARLEQUIN DUCK BREEDING BIRD SURVEYS - 1991 AND 1992

Table 17 summarizes coverage and results of shoreline surveys for harlequin ducks in PWS. The 1991 May - June surveys covered approximately 429 km of oiled segments in western Prince William Sound (Figure 7). An additional 14.7 km of unoiled segments were surveyed at the time, bringing the coverage of the entire 2800-km oil spill zone to 15 percent. Coverage was most complete in the archipelago from Eleanor Island through Knight Island. A few specific harlequin habitat sites on the mainland coast from Long Bay to Whale Bay, and on Chenega, Green, Latouche, Elrington, Evans, Perry and Culross Islands were surveyed. Survey coverage of the islands in southwestern Prince William Sound was incomplete because of fuel and boat limitations.

Results from the 1991 spring survey indicated a low density (0.64/km) and patchy distribution of harlequins in western Prince William Sound. A total of 274 harlequins was recorded: 93 males, 90 females, and 91 of undetermined sex. Only four harlequin pairs were recorded in the oil spill area: at a stream mouth at Log Jam Cove (KN 211) on May 26; at Port Nellie Juan (MA001) on June 1; at Johnson Bay (KN554) on June 2; and at Whale Bay (WH504) on July 10 (Table 18). Harlequin distribution among offshore rocks, mussel beds, stream mouths and bays and lagoons was respectively 48%, 29%, 12% and 11% of total observations (Table 19). By contrast, the restoration study team observed nearly twice as many harlequins on 548 km of survey in eastern PWS during May 1991 (Figure 8), with a density 1.4 times greater (0.87/km) (Table 17). At least 49 mated pairs were identified, with many other harlequins in large mixed flocks (Table 18).

During May and June of 1992, two crews in western PWS expanded the shoreline coverage in the oiled zone to 2698 km (Figure 7). This survey included 95% of the oil spill zone. An additional 100 km was surveyed outside the oil spill zone for a total length of 2798 km, a more than six-fold increase in survey length over 1991. This spring survey was a much broader, and more intensive effort was focused on stream mouths to detect any breeding activity. Over 1800 harlequin ducks were recorded (Table 17), but only 18 pairs were located in the region (Tables 17, 20).

Harlequin density in the western PWS 1992 spring survey was low (0.65/km) and correlated well with 1991 data (Table 17). Harlequins during the spring 1992 survey were distributed on mussel beds, offshore rocks, bays and lagoons and stream mouths, which comprised respectively 32%, 26%, 26% and 16% of the total harlequins observed (Table 19).

Harlequin density in eastern PWS during May 1992 was double that of 1991 on 15% more shoreline coverage (Figure 8), and was more than twice as high as the density in western PWS. At least 116 harlequin pairs were located in the eastern Sound (Table 17).

The average harlequin densities in specific habitat types in western Prince William Sound during the 1991 and 1992 spring surveys were: mussel beds (23.7/km), offshore rocks (4.4/km), stream mouths (3.1/km), and bays and lagoons (2.3/km)(Table 19). Average harlequin densities in habitats that were heavily to moderately oiled were: mussel beds (39.5/km); bays and lagoons (4.6/km); offshore rocks (4.1/km) and stream mouths (3.1/km)(Table 21). Densities in specific habitats that were lightly to not oiled were: offshore rocks (12.6/km), mussel beds (4.9/km), bays and lagoons (2.8/km) and stream mouths (1.8/km)(Table 21).

BREEDING ACTIVITY FROM CAPTURES - 1991 AND 1992

Breeding harlequin ducks proved vulnerable to mist net capture from May to August in PWS. During April and May, harlequins used offshore rocks in bays and lagoons as roosting sites, and pairs flew to stream mouths to conduct courtship activities (Dzinbal 1982; Crowley and Patten 1996). During incubation, commencing in mid-June, and hatching in July, adult females made foraging trips to intertidal feeding areas (Dzinbal 1982; Crowley and Patten 1996). In late July or August, broods of harlequin ducklings follow hens downstream to estuaries (Dzinbal 1982; Crowley and Patten 1996).

Western PWS. In 1991, twelve streams in the oil spill area were selected for mist-netting (Figure 9). Table 22 presents 1991 mist-net locations, trap effort, and results for streams on: Knight Island (5 sites), Chenega Island (2 sites), Evans Island (1 site), Culross Island (1 site), and the mainland (3 sites). Although stream flow at the head of Mallard Bay (KN 575) on Knight Island diminished to nearly zero in mid-summer, harlequins were observed there in 1990, and it had a extensive rocky intertidal area at its mouth. This stream was netted unsuccessfully on two occasions in early June 1991 for a total of 18 hours.

During 16 sessions including more than 132 total net-hours, no harlequins were captured (Table 22), nor were harlequins seen flying along streams in 1991. These streams had similar characteristics to known harlequin streams in Prince William Sound (Table 4). Although harlequins had been observed in low densities at some stream mouths during spring surveys, no harlequins were observed using the estuaries of streams while monitored in western PWS.

Camp Creek (ASC 226-30-16982) provides an example of a potential harlequin duck nesting stream in the western Prince William Sound oil spill area. Camp Creek is the largest pink salmon spawning stream on Knight Island. Camp Creek was in front of the base camp at Herring Bay and was under nearly 24-hour observation for the entire summer of 1991. Field crews from three NRDA projects (Harlequin Ducks, River Otters and Pink Salmon) operated from Herring Bay camp during twilight hours of the night and early morning. No harlequin ducks were seen using Camp Creek or its estuary during the entire summer of 1991.

In 1992, we more than doubled the number of sample streams in the oil spill area, selecting 39 streams for monitoring (Figure 9). In the northern portion (Table 23), sites included: Knight Island (6 sites), Chenega Island (3 sites), Naked Island (1 site), Eleanor Island (1 site), and on the mainland (6 sites). In the southern part of the oil spill area (Table 24), sites were located on Latouche Island (5 sites), Evans Island (6 sites), Bainbridge Island (3 sites), Green Island (1 site), Montague Island (1 site), and the mainland (6 sites).

Breeding activity was not detected around Naked Island in 1992. The stream (222-40-12960) at the head of Cabin Bay (NA024) was netted for eight hours on July 1, 1992 (Table 23). No harlequins were captured during this effort and none were observed in the vicinity.

Capture effort totaled 384.5 net-hours in the oil spill area during 1992. The only two ducks captured were netted on June 13; both were females and both were on unoiled Hanning Creek on Montague Island (Table 24; Figure 9). The two harlequin females were radio-tagged, and one was subsequently located by radio-tracking to a nest site on upper Hanning Creek. Examination of the nest confirmed that the bird was in incubation. The other female was not nesting.

Eastern Prince William Sound. Fifteen streams were monitored in eastern PWS from Valdez to Hinchinbrook Island in 1991; 23 harlequins were captured on five streams (Figure 10) during 330 net-hours, for 14 hours/duck (Table 25) (see also Crowley and Patten 1996). Eleven harlequins were captured on Beartrap River alone, during intensive netting June 2-6. In 1992, 16 streams were monitored, resulting in 42 harlequins captured on 8 streams (Figure 10) in 224 net-hours, for 5.3 hours/duck (Table 26). Highest stream activity by harlequins was seen during the first two weeks of June on Sheep River (11 captures over 5 days), Constantine Creek (12 captures in 5 days), and for the second year on Beartrap River (12 captures).

Throughout the breeding seasons of 1991 and 1992, the lack of observed breeding activity by harlequin ducks and very low capture rates during extensive netting on suitable nesting streams in the oil spill area contrasted with breeding activity and stream use in eastern Prince William Sound

(Figure 11). Over the two years, 65 harlequins were captured during 521.5 net-hours in eastern PWS, for an average of 13.4 ducks/100 net-hours and 1.9 ducks/stream session. In the western Sound, only two ducks were captured in over 516 net-hours, for an average capture rate of 0.25 ducks/100 net-hours and 0.04 ducks/stream session.

MOLTING SITE SURVEYS

Boat surveys conducted during July and August of 1991 and 1992 in eastern and western PWS included identification of harlequin molting areas. The number of flightless molting birds, predominately flocks of males and immatures, increased from mid-July to late July, and remained high into early August. During 1991 in eastern and western PWS, harlequin densities in July and August were an average of twice those found on May surveys, but in 1992, there were only slightly more harlequins recorded in July and August surveys.

During both years of investigation, average shoreline density of harlequin ducks during the post-breeding molt period was lower in the oil spill area (mean 1.11/km) of western PWS compared to eastern PWS (1.96/km). In 1991 the population of molters in the western Sound was approximately 60% of that in the eastern Sound (Table 17), but the shoreline density of molting harlequins continued to decrease in the oil spill area, from 1.29/km in 1991 to 0.92/km in 1992 (Table 17). This was a 27% reduction in shoreline density in western PWS over 2 years. Shoreline density of molting harlequins in eastern PWS decreased slightly from 1991 (2.07/km) to 1992 (1.85/km). During 1991 and 1992 the shoreline density was (respectively) 1.6 and 2.0 times greater in the eastern area than in the oil spill area.

During the 1991 late summer survey, approximately 350 individuals, or over 50% of the harlequins counted in the spill area, were concentrated near Channel Island (Table 27). Channel Island is located on the extreme southeastern periphery of the oil spill area, between Green and Montague Island. Another group of flightless molting harlequins (50) was nearby at SW Green Island, also on the periphery of the oil spill area. A third group of molting harlequins (57) was in the oil spill area at Foul Bay, on the mainland south of Port Nellie Juan. Although classifying harlequins by sex is difficult during the molt, only six of 679 birds observed from mid-July to early August 1991 could be positively identified as females. The first harlequins observed to regain flight were seen on August 7.

The distribution of molting harlequin ducks across habitat types and oiling conditions was recorded in western Prince William Sound in 1991 and 1992; combined results are shown in Table 28. Forty-three percent of molters in 1991 and 77% of molters in 1992 were located on oiled shoreline segments. The shoreline density of molting harlequins was higher in moderately to heavily oiled areas of the western Sound (17.5/km) compared to lightly oiled to unoiled areas (7.8/km) within the spill zone, 1991 - 1992. The percentage of total molting harlequins on or near mussel beds was 20.5% for 1991 and 1992 combined. However, of the mussel beds where we observed molters in western PWS, 100% were oiled in 1991 and 59% were oiled in 1992.

BROOD SURVEYS AND ANNUAL PRODUCTION

1989 and 1990 Preliminary Brood Surveys. A single brood observed in the oil spill area in 1989 was located on a rocky reef at the SW end of Crafton Island near Loomis Creek in September 1989. The ducklings were fully-fledged and practically indistinguishable from the hen. Their status as juveniles was determined after they were collected for food and tissue samples.

ADF&G Commercial Fisheries technicians observed 12 harlequin broods during surveys of 109 streams in Prince William Sound in 1990 (Figure 12). Eight broods were located on streams in eastern PWS from Hinchinbrook Island to Port Valdez. In western PWS, all observed broods were found at unoiled sites: one on Coghill River in northwestern PWS, two on MacLeod Creek, and one on Hanning Creek, both on southwestern Montague Island (Table 29, Figure 12). All 9 streams on which broods were observed were not oiled. No broods were reported in significantly oiled areas of the spill by any agency personnel, although harlequin reproduction was observed in northern, eastern and southern Prince William Sound.

Brood Surveys - Western Prince William Sound. We searched 537 km of coastline in the western Prince William Sound oil spill area in 1991 for harlequin broods (Table 17; Figure 12). This amounted to 19% of the 2800 km of the oil spill zone. We surveyed 38% (319 of 847) of total oiled segments. Four broods were observed during this survey for a density of 0.74 broods/100 km (Table 17; Figure 12). These broods were recorded in bays where oiling was minor and confined to headlands. One brood was recorded at Whale Bay in southwestern Prince William Sound, and one brood was seen at Johnson Bay on the west side of Knight Island (Figure 12). Pairs of harlequin ducks had been observed at Johnson Bay on June 1st and at Whale Bay on July 10th; the broods were seen August 18th and 19th. Two other broods were recorded at the mouth of Hanning Creek in lightly oiled Hanning Bay on Montague Island (Table 30; Figure 12). Hanning Creek itself was unoiled.

We surveyed 54% (453 of 847) of the oiled shoreline segments in western Prince William Sound for harlequin broods in 1992. This survey included 2276 km or 81% of the 2800-km oil spill zone, which included oiled and unoiled segments (Table 17; Figure 12). Three broods were observed during this survey, for a density of 0.13 broods/100km (Table 17). A single brood of very small harlequin ducklings (Class I) and hen was observed in proximity to an oiled segment at Squire Island near Drier Bay on southwestern Knight Island in July (Table 31; Figure 12). Since there are no documented salmon spawning streams on Squire Island, and few streams of any size, this may be an indication of nesting on offshore rocks, noted in British Columbia by Campbell et al. (1990). Two broods (Class II) were located in late July at the edge of the oil spill area in unoiled MacLeod Harbor and in lightly oiled Hanning Bay on Montague Island (Table 32; Figure 12). No other broods were observed in extensive shoreline searches of the oil spill area in 1992.

U.S. Fish and Wildlife Service biologists working on Naked Island confirmed that the average number of harlequin ducks near Naked, Storey, and Peak Islands during 1989 and 1990 was reduced by more than 80% from 1978-80 levels (Table 33; Figure 13). No harlequin broods were found during 1989 - 1992, after the spill (Table 33; Kuletz pers. comm.). Table 34 summarizes known locations of harlequin broods in western PWS during 1978 - 1992, with oiling conditions of the corresponding beach segments (ADEC 1989a).

Brood Surveys - Eastern Prince William Sound. During 1991, we searched 700 km of shoreline in eastern PWS for broods and we recorded 16 brood observations (Tables 17, 35; Figure 14). Calculated linear brood density was 2.29/100 km of survey (Figure 15). Some, but not all, streams in eastern PWS were used by harlequin ducks for breeding. The ADF&G Restoration Study Team located five nests from Valdez Arm to Hinchinbrook Island in 1991. The nests were located by radio-tracking incubating females trapped at stream mouths (Crowley and Patten 1996). Productivity of harlequin ducks in 1991 in eastern PWS appeared relatively good, but there are few studies of harlequin duck productivity from which to judge (Bengtson 1966, 1972; Cassirer and Groves 1991) and none in coastal habitats.

We searched for broods along 410 km of shoreline in eastern Prince William Sound in 1992 and sighted 5 broods (Tables 17, 35; Figure 14). The brood density of 1.22/100 km was much lower than in 1991 (Figure 15). A cold, late spring probably reduced harlequin productivity in eastern Prince William Sound, as it did for other species of waterfowl in Alaska.

In summary, harlequin duck production in unoiled eastern Prince William Sound, measured by brood surveys, was 2.29 broods/100 km in 1991, 1.22/100 km in 1992, and averaged 1.76/100 km for both years (Figure 15). In contrast, only one brood each year was found in heavily oiled portions of western Prince William Sound, and five of seven broods found in both years were in lightly oiled or unoiled areas. Production in western Prince William Sound was, at best, 0.74 broods/100 km of shoreline in 1991, 0.13 broods/100 km in 1992 (Figure 15), and averaged 0.44 broods/100 km of surveyed shoreline for both years. The average brood density in the eastern Sound was four times higher than in all of western PWS.

DISCUSSION

FOOD HABITS

The limited collections and analyses done for this study do not provide definitive data on the diets of sea ducks in Prince William Sound. Gut sampling was done primarily to test for oil and to characterize food habits. Overall, the collections were relatively successful for food habits studies, with only 26% of sample birds having empty proventriculi. Regardless, sample sizes for most species were too small to provide accurate estimates of diet composition, and the 1990 prohibition on collecting curtailed further work.

Effort on other project objectives precluded localized intensive feeding studies necessary to quantify foraging and explore potential rates of contamination uptake. The data in this study and literature accounts do not provide a quantitative basis for calculating daily intake rates of prey species or calculation of potential exposure to oil over time. Our gut samples were instantaneous samples that do not provide period intake rates. Much larger numbers of samples would be required to accurately document diet composition over time. Daily consumption would have to be estimated through intensive observation of intake amounts over timed feeding bouts, and sampled diurnally and seasonally. The intake of contaminants would have to be estimated by linking the detailed food habits information with foraging data on assayed sites to determine how, where, and how often they select contaminated prey beds.

The susceptibility of sea ducks to petroleum exposure by ingestion can be generally understood by an analysis of the food habits and foraging areas of the sea duck species. While there is overlap in selection of food items, feeding activity by these six sea duck species is zonal. Harlequin ducks feed in the upper intertidal and along shorelines, the zone of maximum oil impact; goldeneyes, which feed over a wide range from intertidal to subtidal, have less exposure; white-winged scoters, feeding on lower intertidal and subtidal organisms, such as scallops in deeper water, appear least vulnerable to oiled foods (Goudie and Ankney 1986; 1988; Koehl et al. 1982; Sanger and Jones 1982; Vermeer and Bourne 1982).

The variety and proportions of prey species found in ducks during this study correspond well with previous work. Harlequin ducks took the widest variety of marine invertebrates; gastropods and chitons are consistently ranked high in abundance (Cottam 1939; Dzinbal 1982; Vermeer 1983; Rothe, unpubl. data). *Mytilus edulis* was reported by Bent (1925) as a main food item for harlequins on the Atlantic coast, but most studies record mussels as a moderate to small part of their diet. Cottam (1939) found only 1.5% *Mytilus* by volume in 63 birds mostly from the Pacific coast during January-September. Vermeer (1983) found mussels in 5 of 54 harlequin stomachs collected in March, October, and November in British Columbia. Proventriculi of 5 of 15 harlequins collected in Port Valdez during winters of 1978-80 contained *Mytilus* (Rothe, pers. comm.).

Harlequins are known to shift their diets and foraging strategies significantly between winter and summer (Pool 1962; Dzinbal 1982; Vermeer 1983) and by locality. For example, in British Columbia Vermeer (1983) found frequencies of occurrence of *Mytilus* at 23.8% during March, but in October and November only 7% or absent, similar to winter occurrence (8.3%) in this study. Wintering goldeneyes also take a variety of prey, focusing strongly on mollusks and crustaceans (Cottam 1939). Blue mussels were a dominant food of Barrow's goldeneyes in this study (84.4% frequency of occurrence), in southeast Alaska during winter (89% frequency of occurrence; 67% by volume) (Koehl et al. 1982), in British Columbia (90-95% wet weight in winter)(Vermeer 1982). *Mytilus* were important in some collections of common goldeneyes in Denmark (22% frequency of occurrence)(Madsen 1954) and Sweden (Nilsson 1972). Too few scoters were collected to describe winter diets during this study, but the literature indicates a strong dependence on blue mussels, cockles, and other benthic prey (Cottam 1939; Madsen 1954; McGilvrey 1967; Nilsson 1972; Vermeer and Bourne 1982; Sanger and Jones 1982).

CONTAMINATED FOODS

Loons, grebes, alcids, and sea ducks are considered most vulnerable to petroleum ingestion (Peakall et al. 1982; Fry and Lowenstine 1985; Piatt et al. 1990). By virtue of their nearshore habitats, they are chronically exposed to oil remaining in the intertidal by direct contact to feathers and skin, and internally through preening (Hartung 1963) and ingestion of contaminated food (Hartung and Hunt 1966).

From gullet samples of 151 sea ducks, we can state with confidence that foods of five sea ducks collected in the spill area were contaminated with oil from the *Exxon Valdez* (Table 11). In two harlequins, a common goldeneye, and a Barrow's goldeneye collected in September and December 1989, the PAH patterns were very consistent with moderately weathered *Exxon Valdez* oil (Table 11). The fifth duck, a harlequin collected on July 31, 1990 at Drier Bay, also had patterns of PAH concentrations in its food similar to further weathered EVO, but it did not have detectable concentrations of phytane, an indicator of crude oil. The loss of phytane and other volatile and low molecular weight hydrocarbons progresses with weathering of oil, and it is not unexpected that phytane was not found in the harlequin sample taken 16 months after the spill. The lack of phytane and other highly toxic low molecular weight compounds does not mean that weathered oil in 1990 did not pose a hazard to ducks or other animals. Weathered oil contains toxic higher-weight hydrocarbons that are known carcinogens and perhaps mutagenic (Vandermuelen 1982; see discussion below).

Summed PAH concentrations of proventricular contents ranged from 342 ng/g to 1,019 ng/g (wet weight) in the five ducks where EVO contamination was indicated (Table 11). These PAH concentrations correspond to whole (weathered) oil concentrations of about 17 to 50 micrograms oil/g wet weight, assuming 2% PAH content of weathered EVO. These concentrations could result from ingestion of prey that was contaminated at relatively low concentrations by EVO. For example, Short and Rounds (1993) found concentrations of PAHs derived from EVO that often exceeded 1,000 ng/g in mussels collected from sites along the path of the oil spill in late summer 1989 and subsequently.

The small proportion of digestive tract samples containing oil may indicate that few individual ducks in the sample population were exposed to oil, or it reflects problems in sampling. Instantaneous sampling provides only a minimal indication of population exposure. Results are subject to variation in the number of ducks with foods in their proventriculi during collection, availability of oiled prey, prey selection or avoidance behavior by feeding ducks, and other spatial and temporal factors. Harlequin ducks in particular feed during brief intensive bouts, and often at night (Pool 1962; Dzinbal 1982), making it difficult to collect birds with freshly taken foods. The multiple objectives and limited scope of this study precluded localized intensive study of feeding ducks to determine feeding frequencies, prey consumption rates, or foraging site selection.

The degree of contamination in aggregate food samples is affected by the composition of specific prey species and their respective susceptibility to physical or food oiling. The differences in mobility and foraging methods among prey (e.g. static filter-feeding mussels, mobile grazers, scavengers) may influence the amount of oil contamination passed to feeding ducks. For example, Barrow's goldeneyes rely heavily on mussels that accumulate contaminants and whose beds readily hold oil. In contrast, among the sea ducks, harlequin ducks have a very diverse diet. They rely on a wide array of invertebrates (Tables 6, 7)(see also Bengtson and Ulfstrand 1971) that may or may not consume or concentrate petroleum compounds. Unfortunately, other NRDA studies of invertebrate contamination only sampled *Mytilus*, but not snails and limpets that are dominant in harlequin and common goldeneye diets. Hopefully, more detailed analyses from the Coastal Habitat Studies can contribute data on contamination of other specific prey organisms.

Blue mussels have been considered a primary source of oil contamination for sea ducks, given their importance in diets of goldeneyes and surf scoters (Tables 8 and 9). Blue mussels were broadly exposed to heavy oiling in the intertidal zone (Wiener and Slocumb 1991; Babcock et al. 1993). Blue mussels also have considerable ability to accumulate contaminants (Goldberg 1975; Phillips 1976; National Research Council 1980; 1985). Mollusks have little ability to metabolize and excrete PAHs and other hydrocarbon products and may accumulate high concentrations (Jackim and Lake 1978; Lawrence and Weber 1984; Varanasi et al. 1985). Sea ducks consume blue mussels by detaching them from beds connected by mats of byssal threads and swallowing the entire mussel. Ingested mussels are retained in the proventriculus, passed to the gizzard and ground up. Soft parts are then digested, and the shell fragments passed through the entire digestive tract. This exposes ducks to petroleum from the shell surface, soft parts, and byssal threads.

A summary of contaminant analyses performed on mussels from many of these sites, as part of two other studies, is found in Appendix 5. ADEC (1989b) collected mussel tissue samples in the oil spill area of western PWS, May-June 1989. Tissues were analyzed for PAH and TPH (total petroleum hydrocarbons) by Enseco-Erco Laboratory.

Data on petroleum hydrocarbon concentrations in blue mussels at sites in PWS was also obtained from NRDA Study Coastal Habitat 1B and its complementary Restoration Study 103 (the National Marine Fisheries Service Auke Bay Laboratory blue mussel study). The intensity of petroleum hydrocarbon contamination of oiled mussel beds was determined by measuring amounts of PAHs in mussel tissue, in mussel byssal thread mats, and in underlying sediments (Appendix 5). The results of these analyses indicated very high concentrations of total aromatic hydrocarbons in mussel tissues (4.5 ppm), underlying sediments (48 ppm), and in byssal thread mats (Babcock et al. 1993). Pre-spill toxicological analyses of blue mussels documented very low concentrations of petroleum exposure to this bivalve in oil spill areas (Karinen and Babcock 1991).

Contaminated mussel beds with crude oil deposits were numerous in Prince William Sound (Appendix 3; Supplement 1). Many of these mussel beds retained crude oil and high concentrations of PAHs through August 1993 (Babcock, pers. comm.). Heavily oiled mussel beds may serve as a long-term pathway for transmitting persistent oil to sea ducks. Migration of crude oil components from the intertidal and immediate subtidal areas to deeper sediments may cause damage to other marine invertebrates that also support deeper-feeding sea ducks, such as scoters (Table 9).

Seasonally, harlequins take substantial quantities of salmon eggs (Dzinbal 1982) and herring eggs (Munro and Clemens 1931; Haegele and Schweigert 1989; Norton et al. 1990; Chadwick 1992; Haegele 1993), both resources that were contaminated in PWS in 1989 and are difficult to detect in digestive tracts. No commercial fishing was allowed in the spill area in 1989. As a result, considerable spawning of unharvested pink salmon occurred in at least 213 oiled intertidal stream mouths, some remaining contaminated through spring of 1992 (Middleton et al. 1992). Pink salmon fry collected from 1989 through May 1991 demonstrated elevated cytochrome P-450, indicating contamination (Wiedmer 1992). Both salmon eggs and fry were widely available to ducks. Eggs were found in three harlequin duck proventriculus samples (Table 6), including one of the oil-contaminated food samples, from a harlequin duck collected at Crafton Island in September 1989 (Table 10).

METABOLISM OF OIL

Chemical analysis of food samples demonstrated that harlequin ducks and goldeneyes, were internally exposed to Prudhoe Bay crude oil from the *Exxon Valdez* oil spill (Tables 10 and 11). Liver data provided only a few indications of hydrocarbon consumption, but most values were below detection limits and no conclusive link to Prudhoe Bay Crude Oil was evident. The bile samples, however, showed significantly higher concentrations of PAHs in more ducks collected in and near the spill region than did food samples, which indicated only recent exposure (Lawler et al. 1978; Leighton 1983).

There are several potential processes to explain the petroleum contamination found in sea duck liver and bile: (1) recent consumption of oiled food items; (2) excretion of petroleum metabolites into the bile; or (3) long-term cumulative petroleum exposure via ingestion of moderate levels of oil. Recent high-dose consumption would result in a rapid infusion of petroleum into the entire organism, and relatively high concentrations of oil metabolites appearing in the bile within approximately two days (Holmes et al. 1978; Lawler et al. 1978; Miller et al. 1978; McEwan and Whitehead 1980; Peakall et al. 1980; Leighton, 1983; 1991; Fry and Lowenstine 1985).

Accumulation of oil in the liver is due to active uptake of hydrocarbons by the liver parenchymal cells, with subsequent metabolism and secretion into the bile (Peakall at al. 1982; 1983; Leighton 1983; Lanenburg and Dein 1983). Mixed function oxidase enzymes of the liver are induced by exposure to oil, resulting in an accelerated metabolism of hydrocarbons (and probably steroids as well) after a few days of exposure (Szaro and Albers 1978; Szaro et al 1981; Patton and Dieter 1980; Lee et al. 1985; Fry and Addiego 1988). The metabolic products, including hydroxylated hydrocarbons and demethylated PAHs, are secreted into the bile, and are emptied into the intestine (Patton and Dieter 1980; Gorsline et al. 1981, 1982).

Bile samples provided an opportunity to measure PAHs and their byproducts to shed some light on metabolism and fate of oil contaminants in sea ducks. The PAHs in sea duck bile could be elevated with respect to the liver for several reasons. PAHs secreted into the duodenum in the bile (which acts to emulsify fats in the diet) could be reabsorbed and recycled through the liver to become more concentrated in the bile (Fry, pers. comm.). Methylated derivatives (for example: methyl-, di- and trimethylnaphthalene) in the liver could all be converted to the parent compound (naphthalene); metabolism of a single acute dose of oil could result in depuration from the liver and elevation in the bile (Fry, pers. comm.).

The concentrations of naphthalene-eq and phenanthrene-eq compounds found in many of the PWS sea duck bile samples were significantly higher than Juneau concentrations (Table 12, Figures 4 and 5). Individual aromatics exceeding 500 ppm were common, indicating that total PAHs could be in the thousands of ppm. The concentration of total naphthalenes (parent and methylated derivatives) in an American Petroleum Institute (API) reference Prudhoe Bay Crude Oil is listed as 9%, so finding 500 ppm in the bile could represent about 1.6% oil in the bile, if all fractions were transferred to the bile. This is not a low concentration of oil metabolites in the bile. The API reference Prudhoe Bay Crude Oil had approximately three times as much naphthalene-eq as phenanthrene-eq, matching closely the ratios in many of the sea duck bile samples (Fry, pers. comm.).

PAH compounds are found in crude oil but are also produced by many local sources of combustion, pollutant emissions, and discharges of petroleum hydrocarbons (Jackim and Lake 1978; Eisler 1987). Unfortunately, there are insufficient baseline data on the many primary sources of PAHs in Prince William Sound, such as exhaust emissions and petroleum discharges from vessel traffic, industrial discharges (e.g. Valdez Terminal), sewage effluents, and natural contributions from oil seeps. Separating background concentrations of PAH from EVOS-caused sources, including 11 million gallons of crude oil on the water and emissions from 1,500 clean-up vessels requires specific criteria for interpretation. Such separation might be impossible at the time of the spill and for several years afterwards, but a sufficiently long time series of data would probably describe peak contamination associated with the *Exxon Valdez* oil spill.

The occurrence of naphthalene-eq and phenanthrene-eq from eastern PWS duck biles, in concentrations similar to those from western PWS and significantly higher than Juneau samples could reflect very different "background" concentrations of PAH among regions, resulting from diesel boat contamination, tanker ballast water discharges, or other non-EVO sources. Alternately, the similar means and distributions of NAPH and PHEN data between eastern and western PWS (Figures 4 and 5) also may suggest that these ducks were quite mobile, especially during initial displacement of birds during 1989. It is highly likely that some of the birds collected in eastern PWS visited or originated from the spill region. Regardless of the reasons, elevated PAH concentrations in some ducks from eastern PWS indicate that this region is not a functional "control" area for our data.

Our bile data need to be interpreted with extreme care, with regard to both the sources of hydrocarbon contamination and the meaning of observed concentrations. The paucity of previous work on oil metabolism in birds presents a significant dilemma in interpreting the bile data. Rates and efficiencies in the conversion of oil to metabolites vary widely among animal taxa (Neff 1979) and have not been studied sufficiently in birds. Although some invertebrates, such as blue mussels, have little ability to process petroleum hydrocarbons, fish have a relatively high capacity to metabolize them and retain only low concentrations in tissue (Lawrence and Weber 1984). Mammals also apparently have the ability to process PAHs (EPA 1980). Birds in general have an advanced mixed function oxidase (MFO) system (Szaro and Albers 1978; Szaro et al. 1981; Gorsline et al. 1981; 1982; Lee et al. 1985).

Presumably, sea ducks have some capacity to metabolize petroleum compounds by means of the MFO system (Gorman and Milne 1970; Holmes et al. 1979; McEwan and Whitehead 1980; Gorsline et al. 1981; 1982). If this capacity is relatively high, we would expect to see little bioaccumulation and rapid rates (low concentrations) of metabolite transfer through bile. The high concentrations of naphthalene-eq and phenanthrene-eq we observed in sea duck bile may reflect high metabolic efficiency, measurement of two particularly light PAHs that are transitory, or repeated high dose exposure.

At this time, few if any conclusions can be drawn about oil contamination from the sea duck bile data alone. Long-term, chronic exposure to low or moderate amounts of oil in the food chain, and rapid depuration of hydrocarbons appears to be the most likely pathway for contamination in ducks in Prince William Sound. The value of bile data from this study lies in application to future studies of oil metabolism in birds and to a broader scientific record on the fate of PAHs. Ultimately, these types of data need to be evaluated through controlled dosing studies of oil metabolism in birds and more field sampling of wild bird populations exposed to crude oil.

HISTOLOGICAL AND PHYSIOLOGICAL EFFECTS

Ingestion of crude oil has been demonstrated to cause a wide variety of physical and physiological effects on birds, but there are no previous studies on harlequin ducks and few that have included sea duck species. Appendix 1 is a literature review of the diverse effects of oil exposure on bird physiology, including metabolic and reproductive changes. Within the scope and resources of this study, only visual examinations of organs during gross necropsies and indices to body fat deposition were done in the field. Detailed histological examinations were conducted by Dr. T. Spraker of Colorado State University. No evidence was found of physical aberrations that could have been caused by the oil spill in detailed histological examinations of 202 sea ducks.

Overall, the data on fat indices should be regarded with a great deal of caution. The use of a scoring system based on subjective visual comparisons was not an accurate method to gauge fat deposits, and differences between observers introduced variability in the data set. The results also suggest complexities in interpreting fat scores from differences in body condition between: (1) sea duck species, (2) sex and age classes, (3) collecting periods as they relate to seasonal dynamics in fat reserves, and (4) collection areas and their unique ecological conditions (weather, prey base). The suspension of duck collections in late 1990 precluded further evaluation of the fat scoring system and insights to factors confounding the results.

For harlequin ducks, inconsistent contrast differences among fat tracts between the western PWS oiled area and control areas in the eastern Sound and near Juneau suggest that collections of harlequin ducks throughout Prince William Sound may have included birds in a wide range of body conditions. Harlequin ducks retain relatively less body fat during winter than other sea duck species (e.g. scoters and eiders. Alternately, the wide variation could suggest that birds were mobile between oiled areas and the eastern PWS "control" area, obscuring interpretation of oil effects. In addition, significant differences in combined fat scores for harlequin ducks between the two control areas, where Juneau birds apparently had less fat, could indicate substantial natural variation between widely separated regions. Juneau Barrow's goldeneyes averaged poorer fat scores than those from eastern PWS, similar to differences between harlequin duck controls. This seems to add further credence to a regional effect between PWS and southeast Alaska. Overall, definitive conclusions can not be drawn about the condition of harlequin ducks in western PWS.

For comparison of potential spill effects, harlequins from Chief Cove, Kodiak Island, may have provided a more representative sample population from an oiled area than birds from PWS, where harlequins can readily mix throughout oiled and unoiled habitats during the non-breeding season.

However, if ecological circumstances in Kodiak are different enough from the control areas, distinct patterns of fat and body condition could be expected in wintering ducks.

During fall and early winter, fat tissue deposition was expected to be most extensive, serving both as energy reserve and as insulation. Reduced adipose tissue observed in some harlequins and Barrow's goldeneyes throughout the oil spill area could have several possible explanations: (1) the sea duck prey base was damaged, reducing opportunities for fat accumulation, (2) physiological consequences of oiling interfered with metabolism and fat deposition, or (3) the effects of physical oiling (preening, hypothermia) produced an energy deficit and reduction in fat reserves. For example, physical stress could accelerate metabolism, leading to depletion of fat. There is evidence in the literature for increased metabolism following external exposure with oil causing reduced insulation because of fouling of feathers (Holmes et al. 1979; Lanenburg and Dein 1983).

POTENTIAL IMPACTS ON HARLEQUIN DUCK REPRODUCTIVE PHYSIOLOGY

Birds that survived oiling, but ingested oil could be predicted from the literature to have reduced breeding success after the oil spill (Clark 1984; Fry et al. 1986; Piatt et al. 1990). During this study, we found no direct physiological evidence from blood or tissues to demonstrate reproductive impairment in ducks. Similar, elevated concentrations of PAH were found in bile of ducks from both oiled and unoiled regions of PWS suggest that eastern PWS breeding harlequins may have been exposed to oil, yet their productivity was substantially higher than harlequins in the western Sound. The critical problem in evaluating these results is the absence of studies that relate observed contaminant levels in birds to specific physiological responses. Consequently, the discussion of potential reproductive impairment relies on the small but growing body of literature on field and experimental work with a variety of species.

Subtle and multifaceted sublethal effects to birds, such as cessation of reproduction, may occur from minute amounts of oil ingestion without accompanying histopathology (Cavanaugh 1982; Fry et al. 1986; Fry and Addiego 1988). These effects may result from disruption of the adrenal cortex by alteration of pituitary hormone levels (Gorman and Milne 1970; Harvey et al. 1982; Gorsline 1983). Previous work on other bird species points to significant potential effects on breeding behavior and function. Oil ingestion and resultant metabolic effects may have caused cessation of reproduction in quail, penguins, petrels, shearwaters, auklets, and skuas (Grau et al. 1977; Morant et al. 1981; Fry and Lowenstine 1985; Fry et al. 1986; Butler et al. 1988; Eppley and Rubega 1990). Stress or direct effects of oil on the adrenal system results in increased release of corticosterone with partial adrenal failure. Corticosterone feedback inhibition at the pituitary level suppresses gonadotropin release and inhibits reproduction (Rattner et al. 1984; Fry and Addiego 1988).

Low gonadotropin levels, resulting from adrenal cortex stimulation, would be evident by poorly or incompletely developed male nuptial plumage (Haase and Schmedemann 1991). Incomplete male plumage was observed in harlequins by Dr. R. Jarvis (pers. comm.) at Foul Bay, a heavily oiled site, in June 1991. This aberration in plumage was three weeks in advance of normal commencement of molt in male harlequin ducks. Captive sea ducks accidentally exposed to a diesel spill in their water supply exhibited approximately 50% mortality, ceased breeding, and the males exhibited aberrant plumage for two years afterwards (C. Pilling, Seattle aviculturist, pers. comm.).

REDUCTION IN BREEDING HARLEQUIN DUCKS

Regional Pre-Breeding Season Baseline. Prior to the *Exxon Valdez* spill, breeding harlequin ducks were abundant and distributed throughout the entire PWS, with broods commonly reported in shoreline habitats (Isleib and Kessel 1973; Dwyer et al. 1976; Oakley and Kuletz 1979; Hogan and Murk 1982; Dzinbal 1982; K. Holbrook USFS, pers. comm.; the late P. Isleib, pers. comm.). For instance, K. Holbrook (USFS, pers. comm.) noted that harlequin ducks were common in Herring Bay, and especially in the Bay of Isles on Knight Island, prior to the 1989 oil spill. Klosiewski and Laing (1994) provided a summary of historical baseline data on sea ducks in PWS, mainly from interpretations of boat survey data by Dwyer et al. (1976) and Irons et al. (1988). The survey of Irons et al. (1988) was protracted and covered PWS during June-August periods during 1984 and 1985. Hogan and Murk (1982) summarized unpublished 1971 aerial surveys of PWS by the late J. Larry Haddock. Unfortunately, none of these baseline sources provided survey coverage for the entire Prince William Sound during the late May - early June breeding period of harlequin ducks. The best approximations of the minimum harlequin breeding population in PWS are 2,600 - 3,300 from early May and late summer 1971 (Hogan and Murk 1982), and 5,500 from the summers of 1984-85 (Irons et al. 1988).

Estimated Direct Mortality. Piatt et al. (1990) estimated direct losses of harlequin ducks from the March 1989 spill. During March and April, at the time of the maximum impact of the oil spill, harlequin pairs would have been concentrated on offshore rocks and rocky points during the some of the highest tides of the year. Therefore, we suspect considerable direct mortality of breeding adults occurred. This initial mortality could have affected a significant proportion of the productive component of the population in western PWS, with long-lasting consequences.

A total of 213 harlequin carcasses were recovered from all receiving stations in the oil spill areas (Piatt et al., 1990). However, the number of carcasses recovered is, at best, a poor indicator of total mortality because of the vast extent of the spill, rapid disappearance rate of oiled carcasses, removal by abundant scavenging species, and relatively few observers in the spill area, especially outside Prince William Sound (ECI, 1991).

When the total number of harlequin duck carcasses logged at all stations (213) and a proportionate number of the unidentified sea ducks (14) is extrapolated by regional recovery rate estimates (ECI 1991), minimum mortality estimates would amount to 423 harlequins in Prince William Sound alone and 1,044 for the entire spill area. Because of higher carcass disappearance rates and lower detection rates downstream in the spill (Gulf of Alaska and Kodiak), small errors in estimated recovery rates from those areas can result in large differences (>50%) in the estimated kill (Piatt, pers. comm.).

Typical proportions of local breeding birds and migrants during March are unknown from pre-spill surveys, and the effects of direct spill mortality and post-spill displacement can not be segregated. Klosiewski and Laing (1994) compared boat survey data, showing pre-spill estimates of 6,100 wintering harlequins in March 1972 and 5,700 in March 1973 for portions of PWS that were later oiled. In March of 1990 and 1991, prior to the breeding season, harlequins in oiled segments totaled only about 2,800, indicating levels 46-49% lower than the early 1970's. Immediately after the spill in March and April 1989, aerial surveys by Hotchkiss (1991) documented 52% fewer harlequins on oiled transects and disproportionately higher numbers in eastern PWS, compared to March 1971 aerial surveys (Dwyer et al. 1976). During aerial surveys in March, May, and October 1990, harlequins were generally more numerous in the Sound than in 1989, but 71-78% were found in unoiled areas (Hotchkiss 1991).

In summary, mortality estimates from carcass recoveries do not provide an accurate estimate of losses for breeding harlequin ducks in western PWS, but survey data suggest a substantial, multi-year reduction in the number of harlequins in the region prior to the breeding season. Female harlequins formerly nesting on streams in western PWS certainly suffered direct fatalities as a result of the 1989 oil spill. Because female harlequins exhibit a high degree of philopatry (fidelity to natal streams) (Kuchel 1977; Dzinbal 1982; Wallen 1987; Cassirer and Groves 1991), deaths of resident females in 1989 probably contributed significantly to the lack of breeding activity documented in western PWS. Strong philopatry also suggests that dispersal of new breeders will be slow and there will be a lengthy delay in recolonization of suitable streams.

LOW HARLEQUIN DUCK PAIR DENSITY, BREEDING ACTIVITY, AND STREAM USE

Breeding Season Densities. Evidence of low harlequin pair densities and breeding effort comes from a variety of sources. Aerial shoreline surveys of Bird Study 2A tallied no more than 350-740 harlequins in oiled areas during the May pre-nesting period of 1989 and 1990. Harlequins in oiled areas represented only 23% and 22% of total May PWS indices in those years (Hotchkiss 1991).

Our extensive surveys during the May-June breeding season of 1991 -1992 in the oil spill area of western Prince William Sound indicated a patchy distribution of harlequins, mostly on offshore rocks (37%), mussel beds (31%), secluded bays and lagoons (18%), and at stream mouths (14%) (Table 19). Harlequins in the western Sound consistently showed little use of stream mouths. Harlequins in the eastern Sound actively used stream mouths for pairing and foraging.

The breeding season shoreline densities of 0.64/km in 1991 and 0.65/km in 1992 for the oiled area of PWS can generally be related to the Sound-wide average summer density of 1.3 harlequins/km in PWS during 1984-85 (Irons et al. 1988). Concurrent eastern PWS breeding bird surveys during May of 1991 and 1992 produced densities of 0.87 and 1.58/km, 1.3-2.4 times higher than the oiled zone, and an average almost identical to Irons et al. (1988) pre-spill summer average. Low pair densities in western PWS, lack of use of stream mouths, and uneven distribution of breeding birds within the Sound are inconsistent with previous studies.

Oakley and Kuletz (1979) and Kuletz (USFWS, pers. comm.) recorded numbers of harlequin ducks observed in complete census of Naked and Storey Islands in early June, before and after the oil spill (Table 33). Before the spill (1978-1980), they observed a mean of 44.7 harlequins around Naked Island (range 18 - 75) and 15 around Storey Island in June 1979. After the spill (1989-1991), their June surveys recorded a mean of 1.3 harlequins around Naked Island (range 0 - 4) and mean of 3.7

harlequins around Storey Island (range 3 - 5)(Table 33; Figure 13). This indicates >90% fewer adult harlequins in 1989-1991 than during 1978-1980. Naked and Storey Islands were among the first areas inundated by the 1989 oil spill, and few harlequins remained near that island group where they once occurred in greater numbers (Oakley and Kuletz 1979; Kuletz pers. comm.).

Breeding Activity. Indications of low breeding effort in the PWS spill area were scarcity of observed courtship activities and only few pair associations confirmed by behavior during 1991 surveys. In 1992 we noted pre-breeding association of 18 pairs (Tables 17, 20). Although there are undoubtedly habitat differences between eastern and western PWS, identification of 10 times more breeding pairs of harlequins in the eastern Sound during both 1991 and 1992 (Table 17) further strengthens the evidence of unusually low breeding effort in the spill area. Harlequin use of stream mouths in western Prince William Sound was consistently low during the 1991 - 1992 spring surveys. By comparison, much pre-breeding activity by harlequin ducks took place at stream mouths in eastern Prince William Sound.

Stream Use. There are few documented pre-spill breeding sites for harlequin ducks in western PWS. In 1982, K. Holbrook USFS (pers. comm.) observed a harlequin brood descending the waterfalls of Otter Creek, a small (2.5-km) lake-fed stream flowing into Otter Cove near the mouth of Bay of Isles on Knight Island. Otter Creek is atypical for harlequin breeding in eastern Prince William Sound, but represents many streams in the western Sound. Otter Cove was in the heavily oiled area of Bay of Isles (ADNR 1990) and was highly disturbed by clean-up crews throughout the summers of 1989 - 1990. K. Holbrook (pers. comm.) was present in Otter Cove within three weeks after the oil spill and saw no birds of any kind. No harlequins were seen on Otter Creek during mist-netting in June 1991 and 1992 (Tables 22, 23).

Intensive mist-netting of potential nesting streams provided strong indications that breeding pair activity, nest prospecting behavior, and nesting was minimal in the western PWS oil spill area. To our knowledge, this project conducted one of the most extensive uses of mist-netting to capture riverine ducks. We believe our efforts were intensive enough (>1,000 net-hours on over 60 streams) to provide a reliable index to nesting activity in PWS (Tables 22, 23, 24, 25, 26).

During both years, mist-netting effort was nearly equal in eastern and western PWS. Only two harlequins were captured in western PWS, in a lightly oiled bay (Table 24; Figure 9), compared to 65 in the eastern Sound (Tables 25, 26; Figure 10). In eastern PWS, 39% of monitored streams (including known breeding streams and non-breeding streams that were selected for comparison) produced harlequin captures in the two years. In contrast, we observed and captured harlequins on only one of 46 monitored streams in western PWS, where emphasis was placed only on potential breeding streams (Tables 22, 23, 24). On per stream and per hour bases, harlequin capture rates in eastern PWS were at least 45 times higher than in the spill area (Figure 11).

Brood surveys, stream monitoring, and telemetry of captured harlequins enabled location of 24 breeding streams and 10 nests in eastern PWS (Crowley 1994; Crowley and Patten 1996). The observed low stream use by harlequins and low capture rates in western PWS demonstrate a lack of significant breeding activity (Tables 22, 23, 24) in 1991 and 1992. By comparison, harlequin ducks in eastern Prince William Sound paired actively, prospected for nest sites, and nested.

In the oil spill area of western Prince William Sound we are not able to identify with confidence the particulars of high quality harlequin nesting habitats. We have not focused our research efforts in western Prince William Sound on this topic, which have been driven by the need for Damage Assessment. We believe we have been studying a damaged, reduced, and in some cases absent harlequin population displaying only partial use of available habitats.

The disparity in harlequin stream use and breeding activity between eastern and western PWS could be influenced by regional differences in quantity and suitability of breeding habitats. Fieldwork was conducted to describe harlequin duck breeding habitats in eastern Prince William Sound during 1991-1992 (Crowley 1994). Crowley and Patten (1996) provide a general comparison of stream characteristics, illustrating that western stream tend to be shorter and probably have lower discharges. Stream flow data are very limited for the western Sound, and no detailed descriptions of stream and riparian nesting habitats have been developed.

We were unable to find enough nests to describe harlequin nesting habitat in western PWS, but historical data and recent brood locations indicate that harlequin ducks in western Prince William Sound may use different habitats for breeding than those of eastern Prince William Sound. Documented harlequin breeding habitats in western Prince William Sound include relatively short, steep streams with cascades, with limited anadromous fish habitat (e.g. Otter Creek in Bay of Isles on Knight Island and streams on Naked Island). Pink salmon spawn largely at stream mouths and in estuarine zones. We recorded harlequin broods in Johnson Bay, Whale Bay, and on Squire Island in western Prince William Sound (Tables 30, 31; Figure 12). Streams are absent or very small at these locations.

Although there is not sufficient information to compare potential harlequin production between eastern and western PWS, the relatively small streams in western PWS may have limited suitability for nesting, and, combined with the relatively low breeding propensity of harlequins, may not contribute annually to production, even under ideal conditions. In contrast, the larger streams in eastern Prince William Sound may produce several broods each year. In the aggregate, however, the approximately 160 anadromous fish streams in western PWS (ADF&G 1990) may have contributed to pre-spill production of harlequin ducks. Unfortunately, the lack of comprehensive baseline data precludes differentiation between oil spill effects and habitat differences as factors in low reproductive effort in western PWS.

Harlequin Duck Brood Surveys and Annual Production

There are no pre-spill baseline data for harlequin duck production in PWS, only several reports from other studies. Oakley and Kuletz (1979) reported seeing 112 juveniles in the Naked Island group in 1978 (Table 33), but there are sufficient reasons to question whether these were young of the year. There are only a few small streams on Naked Island; observations were made from late July to late August when it is difficult to distinguish young from molting birds; group sizes averaged 14 birds, larger than most broods; and adult females were not identified in these groups. The Naked Island group was heavily oiled and subject to intense clean-up; no broods were seen after the spill during 1989-1992. The only other pre-spill report we found was a brood observed at the mouth of Otter Creek in the Bay of Isles on Knight Island in 1982 (K. Holbrook, pers. comm.). We did not observe broods there in post-spill surveys.

The lack of comparable work in previous studies of coastal environments prevents assessment of "normal" production for harlequins. Age ratios in the harvest, useful indirect measures of production, are inadequately sampled by year and region for harlequin ducks in Alaska (Martin 1991). Consequently, the most useful means of evaluating production in western PWS (Tables 29-32) remains comparison with the eastern Sound (Table 35).

The very scarce observations of harlequin duck broods we recorded during extensive surveys in 1991 and 1992 (Tables 30, 31, 32) are consistent with low breeding pair densities (Tables 17, 18, 20) and minimal nesting stream activity in western PWS after the oil spill (Tables 22, 23, 24). If nesting were more common in western PWS than our data suggest, then brood surveys indicate poor nest and brood survival. There are little data on production of harlequins in western PWS during 1989. This study became operational in September 1989, and only one brood observation in the spill area was confirmed from a broad canvass of agency study teams and spill response personnel. During 1990, an extensive but non-dedicated search by fisheries crews recorded only three broods in the western Sound. All three broods observed in 1990 were in unoiled or lightly affected bays on southwest Montague Island (Table 29; Figure 12). We believe that survival would have been low for broods produced in the primary spill zone during 1989, and that survey effort was sufficient to document reproduction in 1990.

During 1989-1992, only twelve broods were found in the western PWS oil spill area (Table 34). Ten of these broods were observed in light to very lightly oiled or unoiled regions of western Prince William Sound. Of these ten broods, three were recorded in lightly oiled Whale Bay and Johnson Bay; three were observed in unoiled MacLeod Harbor on Montague Island; and four broods were sighted at the mouth of unoiled Hanning Creek on Montague Island. Only two broods were observed in heavy to moderately oiled areas (Squire Is. SQ004A and South Crafton CR004), demonstrating poor harlequin duck production in heavily oiled areas (Figure 12). Indeed, between 1989 and 1992, only five broods were observed along any oiled shoreline segments (Crafton Island CR004; Johnson Bay KN554; Whale Bay WH502; Squire Island SQ004A) (Table 34; Figure 12).

In 1991, linear brood density in eastern PWS was 3.6 times greater than in the oil spill area (Figure 15), with at least 14 broods recorded in estuaries (Tables 17, 35; Figure 14). However, in 1992, brood densities were lower throughout the Sound, most probably a result of a late spring thaw that was expected to affect duck production in much of Alaska (Conant and Groves 1992). Regardless of these less favorable conditions, brood density was 4.3 times greater in eastern PWS than in the spill zone (Figure 15). Overall, there was nearly a complete lack of production by harlequin ducks in the oil spill area through 1992, in contrast to presumably variable but normal production in the eastern Sound.

Effects of Disturbance

The effects of human disturbance from oil spill clean-up and monitoring during 1989-1991 not only confounded documentation of harlequin distribution and abundance, but could have resulted in short- and long-term effects on breeding and productivity. A brief summary of resources and people applied to the clean-up throughout the Sound is presented in Table 16, and documentation of beach treatments with Inipol in Supplement 3.

Disturbance from Activities. During the summer of 1990, clean-up activities were substantially reduced from 1989, but 54 beach segments in the western Sound were cleaned by over 1,000 workers with 78 vessels (Exxon 1989; 1990). These activities displaced birds from local habitats and altered the distribution of harlequin ducks, potentially precluding utilization of some nesting streams during nest initiation. In 1991 and 1992, clean-up activities were minimal and were not likely to have significantly affected breeding birds in the western Sound (Table 16).

The massive regional disturbance in western Prince William Sound prior to and during the 1989-1990 harlequin breeding periods involved thousands of people, hundreds of boats, barges, generators, and aircraft (Table 16). This disturbance was documented on harlequin habitats 24 hours a day during spring, summer and fall. Clean-up crews on shore and other major sources of noise, such as helicopters and other aircraft, created substantial, widespread and prolonged disturbance of much of the harlequin duck habitat in western PWS. Documentation of thousands of aircraft flights, helicopter and fixed-wing, is available in project files. Low-level helicopter overflights, spring through fall, were numerous over salmon streams where harlequins would be expected to breed. Such aircraft disturbance is especially likely to displace harlequins from stream habitats.

Human activities, and boat and helicopter disturbance on harlequin breeding grounds have been postulated as reasons for decline in other local breeding populations of harlequins in northwestern North America (Cassirer and Groves 1992; Chadwick, 1992; Clarkson 1992; Wallen 1992). Previous studies have found harlequin ducks to be particularly sensitive to disturbance during nesting and early brood-rearing periods. A study of harlequins on the Maligne River in Jasper National Park recorded the frequency of commercial raft trips during spring and summer for 6 years (Clarkson 1992; B. Hunt unpublished). Approximately 27 rafts per day traversed a section of the Maligne River. Each craft averaged six passengers. Harlequin ducks were displaced by the appearance of the rafters. The ducks were driven five to six kilometers downstream in front of the boat. Since the number of harlequins was inversely related to the number of raft trips ($p=0.001$, $r^2=0.79$, highly significant) and harlequins subsequently declined by 80-90% in the vicinity, the raft trips were curtailed during May and June (the breeding season for harlequins). After the closure, four times as many harlequin ducks were observed on the identical section of the Maligne River. The rafting activity during the breeding season displaced harlequins from preferred breeding and feeding habitats. The delay in breeding could have adversely affected survival of harlequin broods.

Another example of disturbance to harlequin nesting is provided by the long-term observations of a Parks Canada warden on Lake O'Hara, Yoho National Park. The warden observed breeding harlequins on the lake from 1975 to 1985. After a marked increase in commercial and recreational use of the alpine lake, the harlequins vanished. There has been no harlequin reproduction on the lake since 1985 (B. Hunt, Parks Canada, pers. comm.).

The effects of human disturbance on waterfowl have been frequently studied and include negative impacts on most life stage functions (Dahlgren and Korschgen 1992). Clean-up and monitoring operations very likely limited use of preferred foraging and roosting habitats by harlequins throughout the year. More importantly, disruptions from spring through fall probably had deleterious effects on harlequin duck pair formation, nest prospecting and stream selection, brood rearing, and brood survival (Cassirer and Groves 1992; Chadwick, 1992; Clarkson 1992; Wallen 1992). If 27 rafts per day for two months displaced harlequins from breeding streams in British Columbia, the effect of thousands of people and hundreds of boats, fixed-wing aircraft and helicopters on harlequins in western Prince William Sound was completely unprecedented.

Chemical Treatments of Beaches. During the 1989-1991 *Exxon Valdez* oil spill period several chemicals were applied to the shorelines of Prince William Sound. Two of the chemicals selected for extensive application were Inipol and Customblen, both bioremediation enhancers. The toxic effects of chemicals such as urea and ammonia are well documented, while the effect on wildlife of other chemicals such as laurel phosphate (23% of Inipol) were almost completely unknown. Many of the areas receiving chemicals (such as test site KN211E where three different dispersants were applied in 1989) were areas with documented harlequin use (Supplement 3, Table 1). Examples of the large quantities of Inipol and Customblen applied to harlequin habitat in PWS 1989-1991 are presented in Supplement 3.

When sprayed directly on intertidal organisms above the water level, Inipol kills most of them (Viteri, 1990). The most toxic component of Inipol is 2- butoxyethanol ethylene glycol monobutyl. This is an oil dispersant and industrial solvent. In humans, it can cause dizziness, respiratory irritation, unconsciousness, and even death. Inipol can be absorbed directly through the skin and can cause blood and kidney damage (EPA MSDS comparison, 1989). Inipol may injure birds that feed upon it before it dissolves (EPA MSDS comparison, 1989).

During 1991 and 1992, beach treatment activities subsided markedly and were more localized in the areas of salmon streams. Inipol was still being applied to harlequin habitat sites. Because production of harlequin ducks in western PWS remained poor through 1992 when disturbance was minimal, clean-up activity may have caused either long-term displacement of breeding harlequins from the region, or was a secondary factor affecting reproduction or bird survival.

POST-BREEDING/MOLTING CONCENTRATIONS AND EXPOSURE RISK

The number of harlequin males increased from our spring surveys to mid-July molt surveys (Table 17) and in surveys conducted by the USFWS in June - August 1990 (Klosiewski and Laing 1994). These data indicate a mid-summer immigration by adult and non-breeding male harlequin ducks into Prince William Sound from other breeding areas. Hens and broods presumably molt in the same areas in late August; late summer aggregations of harlequins have been noted elsewhere (Gabrielson and Lincoln 1959; Portenko 1981). Harlequins exhibit fidelity to molting areas, apparently returning year after year (Breault and Savard 1991). Molt migrations (usually northward) of males and non-breeders are common in sea ducks and other waterfowl species (Joensen 1973; Pehrsson 1975; Jepsen 1976).

Pre-spill survey reports indicated that harlequin ducks were relatively abundant and distributed throughout the Sound during the post-breeding season (Isleib and Kessel 1973; Dwyer et al. 1976; Hogan and Murk 1982). During the July post-nesting and molt periods of 1990 and 1991, Klosiewski and Laing (1994) report 77% fewer harlequins (reduction by 1,500) in oiled PWS than in 1984, using the best comparisons of boat survey data. They estimated that post-spill harlequin numbers in the oiled zone were only 17-23% of expected levels during July and only 11% of expected numbers in August.

Our July - August surveys also demonstrated that the density of molting harlequin ducks was lower in western Prince William Sound than in eastern Prince William Sound, and that the magnitude of the difference increased from 1991 to 1992 (Table 17). Differences in late summer survey dates between western and eastern PWS may have affected annual density estimates, but to an unknown degree. We generally assume that molters accumulate in the Sound from late June through August, such that later surveys are likely to record more birds. However, the chronology of influx is unknown, and our extensive survey areas were difficult to cover on a consistent schedule.

In 1991, the density of harlequins in eastern PWS was over 3 times that of the west. We believe that the 2-week earlier start and 2-week later finish of the western survey over similar survey coverage would have offsetting effects on the east-west density comparisons. If anything, the late August part of the western survey would have tallied larger accumulations of birds, yet less than 18% of the survey total were counted in August. In 1992, western PWS survey coverage was enlarged by 4 times; the survey began and ended 2 weeks earlier than in eastern PWS. Depending on the timing of harlequin arrivals and the effects of expanded habitat coverage in the west, density differences could have been overestimated for 1992. We conclude that densities of 1.6-2.0 times higher in the east represent regional differences in distribution that were not significantly affected by survey dates.

The majority of molting harlequins observed in western Prince William Sound in 1991 - 1992 were located on *oiled* habitat sites (offshore rocks, bays and lagoons, stream mouths, and mussel beds). The density of molters was also higher in moderately to heavily oiled areas than the density in light to unoiled areas, suggesting that harlequins do not avoid using oiled habitats. Use of oiled habitats by harlequin ducks indicates the potential for consumption of oiled prey items. In 1991, all mussel beds in occupied by molting harlequin ducks in western Prince William Sound were oiled. In 1992, 59% of the mussel beds where molting harlequins were observed were oiled.

During this time of rapid primary feather growth in mid-summer, large demands are made on the energy reserves of molting ducks (Bellrose 1980). An abundant food supply is required to build fat reserves and supply energy for primary feather regrowth. It is important to note that during the molt, these birds are flightless. They are obligated to feed in the immediate vicinity. Consequently, harlequins tend to occupy molting sites that contain easily accessible food resources and protective microhabitat. In western Prince William Sound these molting sites often contain oiled mussel beds. Molting harlequins are thus at substantial risk of consumption of oiled food items. Harlequins that breed elsewhere, but molt in PWS may have experienced health or reproductive effects from oil exposure. Molting flocks of harlequins on Channel and Green Islands may have gathered from nearby Montague Island, the Gulf Coast to the east, the Kenai Peninsula, or the Wrangell and Chugach Mountain drainages.

EVIDENCE OF POPULATION-LEVEL IMPACTS

Our investigation into the status of breeding harlequin ducks in Prince William Sound and apparent poor reproduction in the oil spill area (Tables 29-32) compared to eastern PWS (Table 35) focused on several hypothetical direct and indirect impacts of the oil spill: (1) reduction in survival and breeding effort resulting from physiological dysfunction; (2) direct mortality of birds breeding locally in western PWS; and (3) disruption of breeding from habitat degradation and human disturbance associated with oil spill clean-up operations. During the course of this study, it became apparent that ecological differences between eastern and western PWS also could have important effects on the interpretation of data from oiled and unoiled areas. Although it was beyond the scope of our study, inter-regional differences in climate, seasonal phenology, habitat diversity, and prey base could significantly affect harlequin duck distribution and productivity.

Bird Study 11 documented low levels of breeding activity and scarce production by harlequin ducks in the oil spill region. The lack of post-spill production in western PWS is consistent with the hypothesis that harlequin ducks, like several other species of marine birds, exhibit a high sensitivity to low-level intermittent exposure to oil, presented extensively in their intertidal feeding habitats. Specific physiological effects of oil exposure and threshold dosage rates are yet to be established for most marine birds, including harlequin ducks.

Lower harlequin duck densities and a lack of post-spill production in western PWS are also consistent with a major mortality event in 1989 that removed a portion of the local breeding population, particularly sexually mature female harlequin ducks that would have nested there. Long-term or permanent displacement of breeding birds, resulting from disturbance and habitat damage, is a correlate of this hypothesis. The strong philopatric nature of harlequin ducks suggests that vacant breeding areas may remain unoccupied for years or generations. There is no information from other coastal harlequin breeding areas on potential dispersal rates and re-establishment after a population decline. Throughout the harlequin range, there have been very little banding or genetic analyses to even describe functional population units or estimate rates of interchange and gene flow. Continued monitoring of harlequins in PWS and more in-depth studies of population composition are needed to evaluate their status and recovery potential.

An alternative hypothesis that has not been ruled out is that some of the differences in harlequin duck abundance and productivity between eastern and western PWS are attributable to regional ecological conditions. Climatic differences may affect snow melt, nest site availability, and brood-rearing conditions; we documented differences in stream characteristics between the regions; and marine habitats may differ in providing food and shelter. A variety of factors may combine to make western PWS less suitable than eastern PWS for harlequin duck breeding and production. Until harlequin duck habitat requirements are better understood and a more thorough study is conducted on both sides of PWS, ecological differences can not be rejected as an important influence on our survey results. Overall, it seems likely that some combination of oil spill mortality, physiological and behavioral effects, and regional ecological conditions have contributed to the lower densities and poor productivity of harlequin ducks in western PWS.

LONG-TERM PROSPECTS FOR HARLEQUIN DUCK RECOVERY

Oil spill effects are not an either/or case of mortality versus reproductive impairment (Stekoll et al. 1980). The intertidal foraging habits and year-round residency of harlequin ducks placed them at high risk to sublethal effects of petroleum ingestion (see also Goudie 1989; 1991). Internal petroleum contamination of their food and bile documented by this study warrant serious concerns about the potential for continuing physiological impairment of general fitness, reproductive capacity, molt cycles, and winter survival. Negative impacts on behavioral or physiological aspects of reproduction would greatly slow resumption of brood production and protract recovery of the local breeding population.

A study of the success of the rehabilitation of oiled penguins was conducted in South Africa during 1970-1979 (Morant et al. 1981; see also Fry et al. 1986). More than 2600 oiled penguins were cleaned, rehabilitated, and released after tanker accidents. Thirty percent of these 2600 penguins were subsequently observed returning to breeding colonies. Only 20% of the birds returning to the colonies were observed incubating eggs or raising chicks. Only six percent of all rehabilitated birds subsequently bred, suggesting that most of the oiled birds did not completely recover from the oiling experience. The study of penguins suggests that effects of a catastrophic oil spill could be more severe than merely disrupting reproduction when birds are exposed to oil during the breeding season. If long-term effects are a consequence of the prolonged impairments of physiological responses, exposure to oil during the non-breeding season could easily effect later breeding success.

If physiological consequences of oil ingestion are definitively documented and linked to reproductive failure in harlequin ducks during further studies, the root cause -- contaminated prey -- will remain operative for years. Our work describes numerous intertidal sites in Prince William Sound that presently have unweathered and seeping crude oil deposits (Appendix 3; Supplements 1 and 2) that pose a slowly diminishing, chronic threat to sea ducks until the oil is removed, or becomes sufficiently weathered to low toxicity (Vandermeulen 1982). At least a decade may be required for PAHs in mussel beds in the EVOS area of Prince William Sound to reach background concentrations (Rice, pers. comm.). However, these petroleum hydrocarbons may also undergo biotransformation in tissues and sediments to undetectable compounds of unknown consequence, possibly mutagenic (Vandermeulen 1982).

Eventual recolonization of nesting streams and improvement in annual production by harlequin ducks in western Prince William Sound will probably occur very slowly. Some aspects of harlequin duck breeding biology will limit recovery potential, including small breeding population, broken traditions of philopatry, deferred breeding, and delayed maturity. Given that the most effective source of future breeding birds is local offspring that will orient to their natal region when they come of age, the issue of continued oil ingestion and reproductive impairment in western PWS is a critical one. The small number of breeding harlequins that remain in the oil spill area, and the inherent low recruitment rates of sea ducks will make recovery a long process, even in the absence of residual *Exxon Valdez* oil.

SUMMARY AND CONCLUSIONS

SEA DUCK COLLECTION

From fall 1989 to fall 1990, a total of 231 sea ducks of six species were collected from oiled (PWS, Kodiak) and unoiled (Cordova, Juneau) regions. Harlequin ducks make up the majority of collected birds because they are the only year-round resident species and because they became the focus of contaminant work.

SEA DUCK FOOD HABITS

The variety and proportion of prey items in PWS sea ducks is representative of previous studies. Harlequin ducks fed intertidally on small invertebrate prey obtained at or near the surface of the water. The main prey species of harlequin ducks were snails (*Littorina*) and (*Lacuna*), limpets (*Lottia*), chitons (*Tonicella*), and blue mussels (*Mytilus*). Barrow's and common goldeneyes fed in both intertidal and subtidal zones. Compared to harlequin ducks, goldeneyes foraged more by diving in deeper water and fed on larger blue mussels. The primary item in the diet of goldeneyes in this study was blue mussels. Scoters foraged largely by extensive diving in subtidal zones; major dietary items were blue mussels for surf scoters and other bivalves for white-winged scoters.

PETROLEUM HYDROCARBONS IN SEA DUCK FOODS

Foods from 151 sea duck proventriculus samples were tested for petroleum contamination. Three harlequin ducks, one Barrow's goldeneye, and one common goldeneye indicated positive for crude oil by GERG and were confirmed as having hydrocarbon patterns consistent with *Exxon Valdez* oil by NMFS Auke Bay Laboratory.

PETROLEUM HYDROCARBONS IN SEA DUCK BILE

Bile samples of harlequin ducks and Barrow's goldeneyes from PWS (eastern and western) and Kodiak oil spill areas revealed higher concentrations of naphthalene-eq and phenanthrene-eq compounds than the Juneau baseline. Overall, 74% of harlequins and 88% of goldeneyes from oiled areas had elevated concentrations of these PAHs. Elevated PAHs in eastern PWS ducks may indicate bird movement between oiled and unoiled areas or sources of PAHs other than the spill.

FAT INDEX TO BODY CONDITION

Gross necropsies and scoring of five fat tracts on harlequin ducks and Barrow's goldeneyes indicated differences between Kodiak harlequins and controls, spill area goldeneyes and controls, and between control areas for both species. Effects of area and observers were confounded with potential oil spill effects, preventing firm conclusions on fat deposition patterns. The fat tract scoring system was expedient, but results proved to be too subjective for confidence in statistical results.

Harlequin Duck Breeding Bird Surveys - 1991 and 1992

There is very little pre-spill information on harlequin ducks in PWS and no comparable breeding population indices. There was, however, indication of considerable loss of resident breeding harlequins from direct oil spill mortality. In 1991 and 1992, breeding pairs and breeding activity were much more frequent in unoiled eastern PWS compared to the oiled region of western PWS. The total number of resident harlequin ducks observed in late May and early June surveys was 3.4 times greater in eastern Prince William Sound, compared to the oil spill area. The relative suitability of western PWS to breeding harlequins prior to the spill is largely unknown. Because there are some notable differences in stream and coastal habitats between eastern and western PWS, some of the disparity in harlequin densities and breeding activity could be attributed to regional ecological differences.

Breeding Activity from Captures - 1991 and 1992

Almost no breeding pair activity, nest prospecting and travel to nest sites was recorded on suitable nesting streams in the western PWS oil spill area. During the two years, we captured only 2 harlequins on 46 streams during 517 net hours, for a rate of 258.5 hours per duck. These two ducks were captured on an unoiled creek at the extreme periphery of the oil spill area. We captured 65 harlequins during 1991 - 1992 along 24 streams in unoiled eastern Prince William Sound. This required 554 hours of capture effort, or a rate of 8.5 hours per duck. This indicates a low level of breeding activity in the oil spill area compared to eastern PWS. We cannot, however, separate the influences of oil spill effects and ecological differences of the regions.

Molting Site Surveys

Boat surveys indicated abrupt increases in the number of molting males in July in both sections of PWS. Many of these birds probably were post-breeding males and immatures that migrated to PWS for the molt. Molting and feather regrowth by ducks demands high-energy intake. Harlequins exhibit annual fidelity to prey-rich molting areas. The linear shoreline density of molting harlequins was higher in moderately to heavily oiled areas (17.5/km) compared to lightly oiled to unoiled areas (7.8/km) within the spill zone, 1991 - 1992, indicating that harlequins use oiled habitats. Molting harlequin ducks are flightless; those inhabiting oiled areas are obligated to feed there. A significant proportion (27.5%) of molting harlequin ducks occupied oiled habitats during 1991 - 1992 (Table 28). The influx of molting harlequins in PWS during July includes migrants that breed elsewhere. Therefore, any effects of oil exposure may not be confined to harlequins that breed in PWS.

During the 2 years of investigation, average shoreline density of molting harlequin ducks was lower in the oil spill area (mean 1.11/km) of western PWS compared to the control area of eastern PWS (1.96/km). The shoreline density of molting harlequins decreased in the oil spill area, from 1.29/km in 1991 to 0.92/km in 1992 (-27%). Shoreline density of harlequins in eastern PWS also decreased by 11% from 1991 (2.07/km) to 1992 (1.85/km). During 1991 and 1992, however, the shoreline density was (respectively) 1.6 and 2.0 times greater in the eastern area than in the oil spill area.

Preliminary Harlequin Duck Brood Surveys - 1989-1990

Opportunistic efforts recorded one late brood in 1989 and no broods near 109 streams in 1990 in significantly oiled areas of PWS. A broad absence of harlequin duck production was indicated. Harlequin reproduction was observed in northern, eastern, and southern PWS.

Brood Surveys and Annual Production

Breeding harlequins and broods were formerly distributed in shoreline and estuarine habitats throughout PWS, including the oil spill area. In 1991 and 1992, extensive shoreline surveys in eastern and western PWS indicated minimal production in oil spill areas, and that average brood density in eastern PWS was nearly four times higher than in western PWS. The average linear density of harlequin broods, as an index of productivity, was 0.44/100 km in the oil spill area and 1.76/100 km in eastern PWS for the two-year period.

The magnitude of the difference in brood density between control and oil spill areas increased during the two years. In 1991 and 1992, brood density was (respectively) 3.1 and 9.4 times greater in the control area than in the oil spill area. This suggests that productivity was consistently lower in the oil spill area.

From 1989 - 1992 in the oil spill area, 2 of 11 broods we observed (18%) were in moderately to heavily oiled habitats, and 9 of 11 broods (82%) were in lightly oiled or unoiled habitats.

There were reportedly 112 harlequin juveniles (69/100 km) near the Naked Island group in 1978. Each year from 1989 through 1992 no juveniles were observed near Naked Island. If the pre-spill observations were accurate, this represents a large decline in productivity for this area.

Population-level Impacts

We believe it is likely that harlequin ducks experienced oil spill injuries sufficient to affect the breeding population in Prince William Sound, although this study does not provide the specific evidence necessary to prove it. Our opinion is based on: (1) direct mortality of sufficient numbers of harlequins to affect the size of the breeding population; (2) exposure of harlequin ducks to oil, from the limited evidence of our constrained sampling effort, extent of oiling and frequency of harlequins using oiled habitats; (3) potential effects of oil ingestion on birds reported in the literature; and (4) the absence of brood observations on the most suitable streams in the spill region.

Harlequin ducks may serve as an indicator of the health of the recovering ecosystem, but their recovery will be slow and will remain impeded if contaminated intertidal food chains disrupt use of vital habitats or suppress productivity. Recovery from initial and continuing mortality also will be hindered by the species' low fecundity and slow reoccupation of vacant habitats. Monitoring of harlequin ducks and the quality of their habitats should be continued until recovery and restoration are successful.

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LITERATURE CITED

Ainley, D.G, C.R. Grau, and S.H. Morell. 1979. Influence of petroleum on egg formation and embryonic development in seabirds. OCSEAP Final Rep., Research Unit 423.

Alaska Dept. of Environmental Conservation (ADEC). 1989a. Prince William Sound oil spill segment file. Alphabetical indicator by island. ADEC Oil Spill Response Office, Anchorage.

________. 1989b. ADEC mussel bed study, Prince William Sound. ADEC EVOS Ctr., Anchorage.

________. 1990. An atlas to the catalog of waters important for spawning, rearing or migration of anadromous fishes. ADF&G Habitat Division, Southcentral Region, Anchorage. 131pp.

Alaska Dept. of Natural Resources. 1990. Shoreline types and oiling impacts, Prince William Sound Region: fall 1989 beach survey oiling. Map 00220. Alaska Dept. Nat. Resour., Land Records Information Section, Anchorage.

Babcock, M., G. Irvine, S. Rice, P. Rounds, J. Cusick, and C.C. Brodersen. 1993. Oiled mussel beds in Prince William Sound two and three years after the *Exxon Valdez*. Pages 184-185 *in* Oil Spill Symposium Abstracts. *Exxon Valdez* Oil Spill Trustee Council, Oil Spill Public Information Center, Anchorage.

________, P.M. Rounds, C.C. Brodersen, and S.D. Rice. 1994. 1991 and 1992 recovery monitoring and restoration of intertidal oiled mussel (*Mytilus trossulus*) beds in Prince William Sound impacted by the *Exxon Valdez* oil spill. Alaska Fisheries Sci. Ctr. Rep. 94-02. National Mar. Fisheries Serv., Juneau, Alaska.

Bellrose, F.C. 1980. Ducks, geese, and swans of North America. 3rd Ed. Wildlife Management Institute. Stackpole books, Harrisburg, PA. 540pp.

Bengtson, S-A. 1966. Field studies on the harlequin duck in Iceland. Wildfowl Trust Ann. Rep. (1964-1965) 17:79-94.

________. 1972. Breeding ecology of the harlequin duck, *Histrionicus histrionicus*, in Iceland. Ornis. Scand. 3(1): 1-19.

________, and S. Ulfstrand. 1971. Food resources and breeding frequency of the harlequin duck *Histrionicus histrionicus* in Iceland. Ornis Scand. 3:25-43.

Bent, A.C. 1925. Life histories of North American waterfowl. Part II. U.S. Nat. Mus. Bull. 130. Washington, D.C. 396pp.

Boersma, P.D. 1986. Ingestion of petroleum by seabirds can serve as a monitor of water quality. Science 231:373-376.

Breault, A.M., and J.-P. Savard. 1991. Status report on the distribution and ecology of harlequin ducks in British Columbia. Tech. Rep. Ser. 110. Can. Wildl. Serv., Pac. and Yukon Region, Delta, BC. 108pp.

Brooks, J.M., T.L. Wade, E.L. Atlas, M.C. Kennicutt II, B.J. Presley, R.R. Fay, E.N. Powell, and G.Wolff. 1989. Analysis of bivalves and sediments for organic chemicals and trace elements. Third Ann. Rep., NOAA Status and Trends Program, Contract 50-DGNC-5-00262.

Butler, R.G., A. Harfenst, F.F. Leighton, and D.B. Peakall. 1988. Impact of sublethal oil and emulsion exposure on the reproductive success of Leach's storm petrels: short and long-term effects. J. Appl. Ecol. 25:125-143.

Campbell, R.W., N.K. Dawe, I. McT.-Cowan, J.M. Cooper, G.W. Kaiser, and M.C.E. McNall. 1990. The birds of British Columbia. Vol. 1. Nonpasserines. Brit. Col. Prov. Mus. CWS. pp. 332 - 334.

Cassirer, E.F., and C.R. Groves. 1991. Harlequin duck ecology in Idaho: 1987-1990. Idaho Dept. Fish and Game, Boise. 93pp.

________, and ________. 1992. Status and breeding ecology of harlequin ducks in Idaho. Page 9 *in* Proceedings of the harlequin duck symposium, April 1992. Moscow, Idaho.

Cavanaugh, K.P. 1982. The effects of South Louisiana and Kuwait crude oils on reproduction. Aspects of avian endocrinology: practical and theoretical implications. Grad. Studies, Texas Tech. Univ. 26:371-377.

Chadwick, D. 1992. Some observations of a concentration of harlequin ducks in the Strait of Georgia, B.C. Pages 33-40 *in* Proceedings of the harlequin duck symposium, April 1992. Moscow, Idaho.

Clark, R.B. 1984. Impact of oil pollution on seabirds. Environ. Pollut. Ser. A. Ecol. Biol. 33:1-22.

Clarkson, P. 1992. A preliminary investigation into the status and distribution of harlequin ducks in Jasper National Park. Unpubl. tech. rep. Heritage Resource Conservation, Jasper National Park. 65 pp.

Collier, K.J. 1991. Invertebrate food supplies and diet of blue duck on rivers in two regions of the North Island, New Zealand. NZ Journal of Ecology 15(2):131-138.

Conant, B., and D.J. Groves. 1992. Alaska-Yukon waterfowl breeding population survey. Unpubl. rep. U.S. Fish and Wildl. Serv., Juneau. 25pp.

Cottam, C. 1939. Food habits of North American diving ducks. U.S. Dept. Agric. Tech Bull. 643. 140pp.

Crowley, D.W. 1994. Breeding habitat of harlequin ducks in Prince William Sound, Alaska. M.S. thesis. Department of Wildlife Sciences. Oregon State Univ., Corvallis. 61pp.

________, and S.M. Patten, Jr. 1996. Harlequin duck restoration and monitoring in Prince William Sound, Alaska. Final Report. *Exxon Valdez* Oil Spill Restoration Study No. 71. Alaska Dept. Fish and Game, Div. Wildl. Conserv., Anchorage. 75pp.

Dahlgren, R.B., and C.E. Korschgen. 1992. Human disturbances of waterfowl: an annotated bibliography. Resour. Publ. 188. U.S. Fish Wildl. gggServ., Washington, D.C. 229pp.

Dwyer, T.J., M.E. Isleib, and J.L. Haddock. 1976. Marine bird populations in Prince William Sound, Alaska. Unpubl. Rep. U.S. Fish and Wildl. Serv., Anchorage. 21pp.

Dzinbal, K.A. 1982. Ecology of harlequin ducks in Prince William Sound, Alaska, during summer. M.S. thesis. Department of Wildlife Sciences. Oregon State Univ., Corvallis. 89pp.

________, and R.L. Jarvis. 1982. Coastal feeding ecology of harlequin ducks in Prince William Sound, Alaska, during summer. Pages 6-10 *in* D.N. Nettleship, G.A. Sanger, and P.F. Springer (eds.). Marine Birds: their feeding ecology and commercial fisheries relationships. Can. Wildl. Serv. Spec. Publ., Ottawa.

Ecological Consulting Inc. (ECI). 1991. Assessment of direct seabird mortality in Prince William Sound and the western Gulf of Alaska resulting from the *Exxon Valdez* oil spill. Contract Rep. by Ecological Consulting Inc. for U.S. Fish and Wildl. Serv., Anchorage. 153pp. + appendices.

Eisler, R. 1987. Polycyclic aromatic hydrocarbon hazards to fish, wildlife, and invertebrates: a synoptic review. Contaminant Hazard Rev. Rep. No. 11. Biol. Rep. 85(1.11). U.S. Fish and Wildl. Serv., Patuxent Wildl. Res. Ctr., Laurel, MD. 81pp.

Eldridge, J.L. 1986. Territoriality in a river specialist: the blue duck. Wildfowl 37:123-135.

Environmental Protection Agency. 1980. Ambient water quality criteria for polynuclear aromatic hydrocarbons. U.S. Environ. Prot. Agency Rep. 440/5-80-069. 103pp.

Eppley, Z.A., and M.A. Rubega. 1990. Indirect effects of an oil spill: reproductive failure in population of South Polar skuas following the `Bahia Paradiso' oil spill in Antarctica. Mar. Ecol. Prog. Ser. 67:1-6.

Exxon Corp. 1989. Daily reports: operation status. April 8, 1989 - September 19, 1989. OSPIC Library, Anchorage.

________. 1990. 1990 Alaska spring and summer program daily reports. May 1, 1990 - September 16, 1990. OSPIC Library, Anchorage.

Fry, D.M., and L.J. Lowenstine. 1985. Pathology of common murres and Cassin's auklets exposed to oil. Arch. Environ. Contam. Toxicol. 14:725-737.

________, J. Swenson, L.A. Addiego, C.R. Grau, and A. Kang. 1986. Reduced production of wedge-tailed shearwaters exposed to weathered Santa Barbara crude oil. Arch. Environ. Contam. Toxicol. 15:453-463.

________, and L.A. Addiego. 1988. Effects of oil exposure and stress on seabird endocrine systems. Proc. 1988 Int. Assoc. Aquat. Animal Med. 19:60-67

Gabrielson, I.N., and F.C. Lincoln. 1959. Birds of Alaska. The Stackpole Co., Harrisburg, PA and Wildl. Manage. Inst., Washington, D.C. 922pp.

Glaser, J.A., D.L. Foerst, G.D. McKee, S.A. Qave, and W.L. Budde. 1981. Trace analyses for wastewaters. Environ. Sci. Technol. 15:1426-1435.

Goldberg, E.D. 1975. The mussel watch -- a first step in global marine monitoring. Mar. Pollut. Bull. 6:111.

Gollop, J.B., and W.H. Marshall. 1954. A guide for aging duck broods in the field. Miss. Flyway Council Tech. Sect. 14pp.

Gorman, M.L., and H. Milne. 1970. Seasonal changes in the adrenal steroid tissue of the common eider *Somateria mollisima* and its relation to organic metabolism in normal and oil-polluted birds. Ibis 113:218-228.

Gorsline, J. 1982. Variations with age in the adrenocortical responses of mallard ducks (*Anas platyrhynchos*) consuming petroleum contaminated food. Bull. Environ. Contam. Toxicol. 29:146-152.

________. 1983. Effects of petroleum hydrocarbons on adreno-cortical and ovarian function in laboratory-maintained mallard ducks (*Anas platyrhynchos*). *In* The effects of oil on birds: physiological research, clinical applications, and rehabilitation. 1982 Proceedings, Tri-State Bird Rescue and Research, Inc., Wilmington, Delaware. pp. 48-57.

________, W.N. Holmes, and J. Cronshaw. 1981. The effects of ingested petroleum on the naphthalene-metabolizing properties of liver tissue in seawater-adapted mallard ducks (*Anas platyrhynchos*). Environ. Res. 24:377-390.

________, ________, and ________. 1982. Adrenocortical function and hepatic naphthalene metabolism in mallard ducks (*Anas platyrhynchos*) consuming petroleum distillates. Environ. Res. 28:139-146.

Goudie, R.I. 1989. Historical status of harlequin ducks wintering in eastern North America -- a reappraisal. Wilson Bull. 101(1):112-114.

________. 1991. The status of the harlequin duck (*Histrionicus histrionicus* in eastern North America. Canadian Wildlife Service. St. John's, Newfoundland. 59 pp.+ appendices.

_______, and C.D. Ankney. 1986. Body size, activity budgets, and diets of sea ducks wintering in Newfoundland. Ecology 67(6):1475-1482.

________, and ________. 1988. Patterns of habitat use by sea ducks wintering in southeastern Newfoundland. Ornis Scand. 19(4):249-256.

Gould, A.A. 1850. Shells from the United States Exploring Expedition. Proc. Boston Soc. Nat. Hist. 3: 343-348.

Grau, C.R., T. Roudybush, J. Dobbs, and J. Wathen. 1977. Altered yolk structure and reduced hatchability of eggs from birds fed single doses of petroleum oils. Science 195:779-781.

Griffiths, W.B., P.C. Craig, and G. Mann. 1975. Fisheries investigations in a coastal region of the Beaufort Sea (Nunaluk Lagoon, Y.T.). Arct. Gas Biol. Rep. Ser. 34:1-219.

Haase, E., and R. Schmedemann. 1991. Dose-dependent effect of testosterone on the induction of eclipse coloration in castrated wild mallard drakes (*Anas platyrhynchos*). Can. J. Zool. 70:428-431.

Haegele, C.W. 1993. Seabird predation of Pacific herring, *Clupea pallasi*, spawn in British Columbia. Can. Field-Nat. 107(1):73-82.

________, and J.F. Schweigert. 1989. Egg loss from Pacific herring spawns in Barkley Sound in 1988. Can. Ms. Rep. Fish. Aquat. Sci. No. 2037.

Hartung, R. 1963. Ingestion of oil by waterfowl. Pap. Mich. Acad. Sci., Arts and Let. Vol. XLVIII:49-55.

________, and G.S. Hunt. 1966. Toxicity of some oils to waterfowl. J. Wild. Mgmt. 30(3):564.

Harvey, S., P.J. Sharp, and J.G. Phillips. 1982. Influence of ingested petroleum on the reproductive performance and pituitary-gonadal axis of domestic ducks (*Anas platyrhynchos*). Gen. and Comp. Endocrinology 45:372-80.

Hogan, M.E., and J. Murk. 1982. Seasonal distribution of marine birds in Prince William Sound, based on aerial surveys, 1971. Unpubl. Rep. U.S. Fish and Wildl. Serv., Special Studies, Anchorage. 22 pp.+ appendices.

Holmes, W.N., J. Cronshaw, and J. Gorsline. 1978. Some effects of ingested petroleum on seawater-adapted ducks (*Anas platyrhynchos*). Environ. Res. 17:177-190.

________, W. N., J. Gorsline, and J. Cronshaw. 1979. Effects of mild cold stress on the survival of seawater-adapted mallard ducks (*Anas platyrhynchos*) maintained on food contaminated with petroleum. Environ. Res. 20:425-444.

Hotchkiss, L.A. 1991. Assessment of injury to waterbirds from the *Exxon Valdez* oil spill: surveys to determine distribution and abundance of migratory birds in Prince William Sound and the northern Gulf of Alaska. Interim Report, NRDA Bird Study 2A (Aerial Survey). U.S. Fish and Wildl. Serv., Anchorage. 205 pp.

Hynes, H.B.N. 1950. The food of the freshwater sticklebacks (*Gasterosteus aculeatus* and *Pygosteus pungitius*), with a review of methods used in studies of the food of fishes. J. Anim. Ecol. 19:36-58.

Irons, D.B., D.R. Nysewander, and J.L. Trapp. 1988. Prince William Sound waterbird distribution in relation to habitat type. Unpubl. Rep. U.S. Fish and Wildl. Serv., Migratory Bird Manage., Anchorage. 28 pp. + appendices.

Isleib, M.E., and B. Kessel. 1973. Birds of the North Gulf Coast - Prince William Sound, Alaska. Biol. Pap. Univ. Alaska No. 14. 149pp.

Jackim, E., and C. Lake. 1978. Polynuclear aromatic hydrocarbons in estuarine and nearshore environments. Pages 415-428 *in* M.L. Wiley (ed.). Estuarine interactions. Academic Press, New York.

Jepsen, P.U. 1976. Feeding ecology of goldeneye (*Bucephala clangula*) during the wing-feather moult in Denmark. Dan. Rev. Game Biol. 10(4):1-23.

Joensen, A.H. 1973. Moult migration and wing-feather moult of seaducks in Denmark. Dan. Rev. Game Biol. 8(4):1-42.

Johnsgard, P.A. 1965. Handbook of waterfowl behavior. Cornell Univ. Press, Ithaca, NY. 378pp.

Johnson, R.A., and D.W. Wichern. 1988. Applied multivariate statistical analysis. 2nd Ed. Prentice Hall. Englewood Cliffs, N.J. 607pp.

Johnson, S.R. 1982. Prey selection by oldsquaws in a Beaufort Sea lagoon, Alaska. Pages 12-19 *in* Marine Birds: their feeding ecology and commercial fisheries relationships. Nettleship, D.N., G.A. Sanger, and P.F. Springer, (eds.) Can. Wildl. Serv. Spec. Publ., Ottawa.

Karinen, J.F., and M. M. Babcock. 1991. Pre-spill and post-spill concentrations of hydrocarbons in sediments and mussels at intertidal sites within Prince William Sound and the Gulf of Alaska. NRDA Draft Status Report, Coastal Habitat Study No. 1B. Nat. Mar. Fish. Serv., Auke Bay Lab., Auke Bay, Alaska.

Klosiewski, S.P., and K.K. Laing. 1994. Marine bird populations of Prince William Sound, Alaska, before and after the *Exxon Valdez* oil spill. EVOS Bird Study No. 2. U.S. Fish and Wildl. Serv., Anchorage. 89pp.

Koehl, P.S., T.C. Rothe, and D.V. Derksen. 1982. Winter food habits of Barrow's goldeneyes in southeast Alaska. Pages 1-5 *in* D.N. Nettleship, G.A. Sanger, and P.F. Springer (eds.). Marine Birds: their feeding ecology and commercial fisheries relationships. Can. Wildl. Serv. Spec. Publ., Ottawa.

Korschgen, C.E., S.J. Maxon, and V.B. Kuechle. 1984. Evaluation of implanted radio transmitters in ducks. J. Wildl. Manage. 2:138-149.

Krahn, M.M., D.G. Burrows, W.D. MacLeod, Jr., and D.C. Malins. 1987. Determination of individual metabolites of aromatic compounds in hydrolyzed bile of English sole *(Parophrys vetulus)* from polluted sites in Puget Sound, Washington. Arch. Environ. Contam. Toxicol. 16:511-522.

Kuchel, C.R. 1977. Some aspects of the behavior and ecology of harlequin ducks breeding in Glacier National Park, Montana. M.S. thesis. Univ. Montana, Missoula. 147pp.

Lanenburg, J.A., and F.J. Dein. 1983. Pathology of ruddy ducks *Oxyura jamaicensis*) contaminated with spilled No. 6 Fuel Oil. *In* The effects of oil on birds: physiological research, clinical applications and rehabilitation. A multi-disciplinary symposium. 1982 Proceedings. Tri-State Bird Rescue and Research, Inc., Wilmington, DE. pp. 139-142.

Lawler, G.C., W. Loong, and J.L. Laseter. 1978. Accumulation of aromatic hydrocarbons in tissues of petroleum-exposed mallard ducks (*Anas platyrhynchos*). Envir. Sci. Tech. 12(1):51-54.

Lawrence, J.F., and D.F. Weber. 1984. Determination of polycyclic aromatic hydrocarbons in some Canadian commercial fish, shellfish, and meat products by liquid chromatography with confirmation by capillary gas chromatography-mass spectrometry. J. Agric. Food Chem. 32:789-794.

Lee, Y.Z., F.A. Leighton, D.B. Peakall, R.J. Norstrom, P.J. O'Brien, J.F. Payne, and A.D. Rahimtula. 1985. Effects of ingestion of Hibernia and Prudhoe Bay Crude Oils on hepatic and renal mixed oxidase in nestling herring gulls (*Larus argentatus*). Environ. Res. 36: 248-255.

Leighton, F.A. 1983. The pathophysiology of petroleum oil toxicity in birds: a review. Pages 1-28 *in* The effects of oil on birds: physiological research, clinical applications, and rehabilitation. Proceedings. Tri-state Bird Rescue and Res., Inc., Wilmington, DE.

________. 1991. The toxicity of petroleum oils to seabirds: an overview. Pr. 43-57 in J. White (ed.). The effects of oil on wildlife. Sheridan Press, Hanover, PA.

Linnaeus, C. 1758. Systema naturae per regna tria naturae. Regnum animale, 10th Ed., Vol. 1. Laurentii Salvii, Stockholm.

MacLeod, W.D., D.W. Brown, A.J. Friedman, D.G. Burrow, O. Mayes, R.W. Pearce, C.A. Wigren, and R.G. Bogar. 1985. Standard analytical procedures of the NOAA National Analytical Facility 1985-1986. Extractable toxic organic compounds, 2nd ed. NOAA Tech. Memo. NMFS F/NWC-92. U.S. Dept. of Commerce.

Madsen, F.J. 1954. On the food habits of the diving ducks in Denmark. Danish Rev. Game Biol. 2:157-266.

Martin, E.M. 1991. 1981-90 average U.S. waterfowl harvest by species and county. Unpubl. data. U.S. Fish and Wildl. Serv., Laurel, MD.

McDonald, J.H., and R.K. Koehn. 1988. The mussels *Mytilus galloprovincialis* and *M. trossulus* on the Pacific Coast of North America. Mar. Biol. 99:111-118.

McEwan, E.H., and P.M. Whitehead. 1980. Uptake and clearance of petroleum hydrocarbons by the glaucous-winged gull (*Larus glaucescens*) and the mallard duck (*Anas platyrhynchos*). Can. J. Zool. 58: 723-726.

McGilvrey, F.B. 1967. Food habits of sea ducks from the northeastern United States. Wildfowl 18:142-145.

Middleton, K., M. Fink, K. Sundet, and M. Kuwada. 1992. Alaska Department of Fish and Game *Exxon Valdez* Oil Spill Response Operations Report - Habitat Division, 1989-1992. Alaska Dep. Fish and Game, Habitat Div., Anchorage.

Miller, D.S., D.B. Peakall, and W.B. Kinter. 1978. Ingestion of crude oil: sublethal effects in Herring Gull chicks. Science 199:315-317.

Morant, P.D., J. Cooper, and R.N. Randall. 1981. The rehabilitation of oiled Jackass Penguins (*Spheniscus demersus*), 1970 - 1980. In: Cooper, J. (ed.) Proc. Symp. Birds of the Sea and Shore, Capetown SA. African Seabird Gp. pp. 267-301.

Munro, J.A., and W.A. Clemens. 1931. Waterfowl in relation to the spawning of herring, British Columbia. Biol. Brd. Canada Bull. 17: 1-46.

Myres, M.T. 1959. The behavior of sea-ducks and its value in the systematics of the tribes Mergini and Somateriini, of the family Anatidae. Ph.D. Thesis. Univ. British Columbia. 504pp.

National Research Council. 1980. The international mussel watch. Workshop Rep. Envir. Studies Board, Comm. of Natur. Res. National Acad. Sci., Washington, D.C. 248pp.

________. 1985. Oil in the sea: inputs, fates and effects. National Academy Press, Washington, D.C.

Neff, J.M. 1979. Polycyclic aromatic hydrocarbons in the aquatic environment. Applied Sci. Publ., Ltd., London. 262pp.

Nilsson, L. 1972. Habitat selection, food choice and feeding habits of diving ducks in coastal waters of south Sweden during the non-breeding season. Ornis Scand. 3:55-78.

Norton, D.W., S.E. Senner, R.E. Gill, Jr., P.D. Martin, J.M. Wright, and A.K. Fukuyama. 1990. Shorebirds and herring roe in Prince William Sound, Alaska. Amer. Birds 44(3):367-508.

Oakley, K.L., and K.J. Kuletz. 1979. Summer distribution and abundance of marine birds and mammals in the vicinity of Naked Island, Prince William Sound, Alaska in 1978 and aspects of the reproductive ecology of the pigeon guillemot. Unpubl. Rep. U.S. Fish and Wildl. Serv., Special Studies, Anchorage. 95 pp.

Patton, J.F., and M.P. Dieter. 1980. Effects of petroleum hydrocarbons on hepatic function in the duck. Comp. Biochem. Physiol. 65C:33-36.

Peakall, D.B., D. Hallett, D.S. Miller, R.G. Butler, and W. B. Kinter. 1980. Effects of ingested crude oil on black guillemots: a combined field and laboratory study. Ambio 9: 28-30.

________, ________, D.J. Bend, J.L. Foureman, and D.S. Miller. 1982. Toxicity of Prudhoe Bay Crude Oil and its aromatic fractions to nestling herring gulls. Environ. Res. 27:206-215.

Pehrsson, O. 1975. Regional, seasonal, and annual fluctuations of the goldeneye, *Bucephala clangula* (L.) on the Swedish west coast. Viltrevy (Swedish Wildlife) 9(6):241-298.

Perry, M.C. 1981a. Abnormal behavior of canvasbacks equipped with radio transmitters. J. Wildl. Manage. 45 (3):786-789.

________. 1981b. Radio transmitters for mourning doves: a comparison of attachment techniques. J. Wildl. Manage. 45(2):524-527.

Phillips, D.J.H. 1976. The common mussel *Mytilus edulis* as an indicator of pollution by zinc, cadmium, lead and copper. I. Effects of environmental variables on uptake of metals. Mar. Biol. 38:59-69.

Piatt, J.F., C.J. Lensink, W. Butler, M. Kendziorek, and D.R. Nysewander. 1990. Immediate impact of the '*Exxon Valdez*' oil spill on marine birds. Auk 107:387-397.

Pool, W. 1962. Feeding habits of the harlequin duck. Wildfowl 13:126-129.

Portenko, L.A. 1981. Birds of the Chukchi Peninsula and Wrangel Island. Amerind Publishing Co., New Dehli. 445pp.

Raim, A. 1978. A radio transmitter attachment for small passerine birds. Bird-banding. 49(4):327-332.

Rattner, B.A., V.P. Eroschenko, G.A. Fox, D.M. Fry, and J. Gorsline. 1984. Avian endocrine responses to environmental pollutants. J. Exp. Zool. 232:683-689.

Sanger, G.A., and R.D. Jones, Jr. 1982. Winter feeding ecology and trophic relationships of oldsquaws and white-winged scoters in Kachemak Bay, Alaska. Pages 20-28 *in* D.N. Nettleship, G.A. Sanger, and P.F. Springer (eds.). Marine Birds: their feeding ecology and commercial fisheries relationships. Can. Wildl. Serv. Spec. Publ., Ottawa.

Seed, R. 1992. Systematics, evolution and distribution of mussels belonging to the genus *Mytilus*: an overview. Amer. Malacol. Bull. 9(2):123-137.

Short, J. W., and P. Rounds. 1993. Petroleum hydrocarbons in near-surface seawater of Prince William Sound, Alaska, following the *Exxon Valdez* oil spill: analysis of caged mussels. Draft final rep. *Exxon Valdez* Natural Resources Damage Assessment Project Air/Water #3.

Sparling, D.W., J.A. Barzen, J.R. Lovvorn, and J.R. Serie. 1992. An evaluation of regression methods to estimate nutritional condition of canvasbacks and other water birds. USDI, Fish and Wildlife Service. Tech. Rep. Ser. Biol. Rep. 3:1-11.

Stekoll, M.S., L.E. Clement, and D.G. Shaw. 1980. Sublethal effects of chronic oil exposure on the intertidal clam *Macoma balthica*. Marine Biology 57:51-60.

Swanson, G.A., and J.C. Bartonek. 1970. Bias associated with food analysis in gizzards of blue-winged teal. J. Wildl. Manage. 34:739-746.

Szaro, R.C., and P.H. Albers. 1978. Petroleum: effects on mallard egg hatchability. J. Wildl. Manage. 42:404-406.

________, G. Hensler, and G.H. Heinz. 1981. Effects of chronic ingestion of No. 2 fuel oil on mallard ducklings. J. Toxicol. Environ. Health 7:789-799.

U. S. Coast Guard. 1989. Prince William Sound Oil Spill Segment File. Alphabetical indicator by island. Federal On-Scene Coordinator (FOSC), Key Bank Bldg., Anchorage.

Vandermeulen, J.H. 1982. Some conclusions regarding long-term biological effects of some major oil spills. Phi. Trans. R. Soc. Lond. Vol. 297:335-351.

Varanasi, U., W.L. Reichert, J.E. Stein, D.W. Brown, and H.R. Sanborn. 1985. Bioavailability and biotransformation of aromatic hydrocarbons in benthic organisms exposed to sediment from an urban estuary. Environ. Sci. Technol. 19:836-841.

Vermeer, K. 1982. Food and distribution of three *Bucephala* species in British Columbia waters. Wildfowl 33:22-30.

________. 1983. Diet of the harlequin duck in the Strait of Georgia, British Columbia. Murrelet 64:54-57.

________, and N. Bourne. 1982. The white-winged scoter diet in British Columbia: resource partitioning with other scoters. Pages 30-38 *in* D.N. Nettleship, G.A. Sanger, and P.F. Springer (eds.). Marine Birds: their feeding ecology and commercial fisheries relationships. Can. Wildl. Serv. Spec. Publ., Ottawa.

Viteri, A. 1990. Memorandum: April 27, 1990. Environmental Engineer, Alaska Dept. Envir. Conserv. (ADEC). Habitat Div., ADF&G EVOS Library, Anchorage.

Wade, T.L., E.L. Atlas, J.M. Brooks, M.C. Kennicutt II, R.G. Fox, J. Sericano, B. Garcia, and D. DeFreitas. 1988. NOAA Gulf of Mexico Status and Trends Program: Trace organic contaminant distribution in sediments and oysters. Estuaries 11: 171-179.

Wallen, R.L. 1987. Habitat utilization by harlequin ducks in Grand Teton National Park. M.S. thesis. Montana State Univ., Bozeman, MT 67pp.

________. 1992. Annual variation in harlequin duck population size, productivity and fidelity in Grand Teton National Park, Wyoming. Proceedings of the harlequin duck Symposium, April 1992. Moscow, Idaho. p.8.

Widen, P. 1982. Radio monitoring the activity of goshawks. *In* C. L. Cheeseman and R.B. Mitson, (eds.) Telemetric studies of vertebrates. Symp. Zool. Soc. London 49:153-160.

Wiedmer, M. 1992. Cytochrome P-450 Induction of Pink Salmon (*Oncorhynchus gorbuscha*) eggs and larvae in Prince William Sound, Alaska: Effects of the *Exxon Valdez* Oil Spill. Technical Rep. 92-3. Alaska Dept. Fish and Game, Habitat Div., Anchorage.

Wiener, A.H., and J. Slocumb. 1991. Mussel bed study draft GIS product. Alaska Dept. Nat. Resour., Div. of Land. OS Project Office, Anchorage. 9pp.

Table 1. Islands, bays and mainland investigated in the oil spill area of western Prince William Sound, Alaska 1991-1992.

Name	EBCSI[a]	Year(s) Surveyed	
Aguliak	AG		1992
Applegate	AE	1991	1992
Bainbridge	BA	1991	1992
Block	BL		1992
Chenega	CH	1991	1992
Crafton	CR	1991	1992
Culross	CU		1992
Danger	DA		1992
Delenia	DE		1992
Disk	DI		1992
Eleanor	EL		1992
Eshamy Bay	EB	1991	1992
Elrington	ER		1992
Evans	EV		1992
Ewan Bay	EW	1991	
Falls Bay	FA		1992
Flemming	FL	1991	1992
Granite Bay	GB		1992
Green	GR	1991	1992
Ingot	IN	1991	1992
Knight	KN	1991	1992
Latouche	LA		1992
Mainland	MA	1991	1992
Montague	MN	1991	1992
Mummy	MU		1992
Naked	NA	1991	1992
New Year's	NY		1992
Paddy Bay	PA	1991	
Perry	PR		1992
Point Nowell	PN		1992
Port Nellie Juan	NJ	1991	1992
Sphinx	SP		1992
Squire	SQ		1992
Squirrel	SL		1992
Whale Bay	WH	1991	1992

[a] Exxon beach clean-up segment identifier (ADEC 1989a)

Table 2. Tissue samples of sea ducks collected during 1989-1990 for histological and toxicological analyses.

Histopathology[a]	Toxicology[b]
brain	proventriculus (food samples)
eyes	liver
neck (vertebrae w/tissue)	bile
lungs	
liver	
pancreas	
upper, middle, lower intestine	
kidney	
adrenals	
reproductive tract	

[a] Preserved in formalin.
[b] Frozen

Table 3. Initial decision criteria developed by U. S. Fish and Wildlife Service to determine exposure to crude oil in food and liver tissues from sea ducks.

Index of Exposure	Units	Threshold Decision Value[a]
Pristane/C17	(ratio)	>1.0
Phytane/C18	(ratio)	>1.0
Even/Odd Alkane	(ratio)	1
UCM[b]	(ug/g)	present
Alkanes	(ug/g)	>1000
Dibenzothiophene	(ug/g)	present
Methyl-		
naphthalene	(ug/g)	present
dibenzothiophene	(ug/g)	present
chrysene	(ug/g)	present
fluorene	(ug/g)	present
phenanthrene	(ug/g)	present
Aromatics	(ug/g)	>100

[a] Decisions were made such that values of all or nearly all parameters had to meet or exceed threshold levels for a positive finding of crude oil contamination.

[b] UCM = unresolved complex mixture

Table 4. Characteristics of 9 streams used by breeding harlequins throughout Prince William Sound in 1990, and 46 streams investigated in the oil spill zone during 1991 - 1992.

	Prince William Sound 1990	Western PWS 1991 - 1992
Offshore rocks	yes	yes
Semi-enclosed estuary	yes	usually
Intertidal alluvial delta	yes	usually
Spawning salmon	yes	usually
Width at mouth (m)	10 - 30	2 - 30
Discharge rate m^3/sec	1.5 - 7.0	0.5 - 2.5
Depth (m)	0.3 - 1.5	0.1 - 0.5
Elevation at onset (m)	400	250
Stream length (km)	5 - 14	0.5 - 8
Gradient	Moderate	Moderate
Turbidity	Clear	Clear
Substrate	(Gravel/cobble/boulder - both)	
Forest age	Old-growth	Old-growth
Dominant Community	Spruce-hemlock	Spruce-hemlock or Muskeg

Table 5. Collections of 231 sea ducks used in Bird Study 11, by locations and time periods in the *Exxon Valdez* oil spill area and unoiled control areas, 1989 -1990.

Location/Period			Harlequin Duck	Barrow's Goldeneye	Common Goldeneye	White -winged Scoter	Surf Scoter	Black Scoter
Western PWS (Oiled)		**9-11/89**	**18**	**4**	**0**	**0**	**3**	**0**
Mainland	Main Bay		3	-	-	-	-	-
	Crafton Is.		3	-	-	-	-	-
	Eshamy Bay		8	-	-	-	-	-
Perry Island			-	4	-	-	-	-
Naked Island	Outer Bay		4	-	-	-	1	-
	McPherson Bay		-	-	-	-	2	-
Western PWS (Oiled)		**12/89-1/90**	**13**	**20**	**11**	**11**	**1**	**1**
Mainland	Main Bay		2	6	8	6	1	-
	Crafton Is.		-	-	-	1	-	-
	Foul Bay		8	-	-	-	-	-
	Eshamy Bay		3	9	2	4	-	1
Knight Is.	Herring Bay		-	1	1	-	-	-
	Louis Bay		-	2	-	-	-	-
	Falls Bay		-	2	-	-	-	-

Table 5. Sea duck collections (continued).

Location/Period			Harlequin Duck	Barrow's Goldeneye	Common Goldeneye	White -winged Scoter	Surf Scoter	Black Scoter
Western PWS (Oiled)		**6/90-10/90**	**52**	**1**	**0**	**0**	**0**	**0**
Mainland	Foul Bay		10	-	-	-	-	-
Knight Is.	Herring Bay		9	-	-	-	-	-
	Drier Bay		9	1	-	-	-	-
	Bay of Isles		8	-	-	-	-	-
Disc Island			1	-	-	-	-	-
Green Island			5	-	-	-	-	-
Latouche Island			10	-	-	-	-	-
TOTAL WESTERN PWS			**83**	**25**	**11**	**11**	**4**	**1**
Kodiak Island, Chief Cove (Oiled)		**2/90**	**27**	**4**	**2**	**0**	**2**	**1**
Eastern PWS (Unoiled)		**1-2/90**	**11**	**12**	**3**	**7**	**0**	**0**
Hawkins Island			1	-	-	-	-	-
Nelson Bay			-	5	-	3	-	-
Orca Bay			-	4	2	4	-	-
Simpson Bay			10	3	1	-	-	-

Table 5. Sea duck collections (continued).

Location/Period		Harlequin Duck	Barrow's Goldeneye	Common Goldeneye	White -winged Scoter	Surf Scoter	Black Scoter
Juneau Area (Unoiled)	**3/90**	**11**	**9**	**4**	**0**	**5**	**0**
Amalga Harbor		11	2	2	-	-	-
Douglas Island		-	2	2	-	4	-
Favorite Channel		-	5	-	-	1	-
TOTAL ALL LOCATIONS	**231**	**132**	**48**	**20**	**18**	**11**	**2**

Table 6. Mean percent length-importance index (based on 407 points total), frequency of occurrence, and percent frequency of occurrence of identifiable prey in proventriculus samples from 89 harlequin ducks from Prince William Sound.

Food Item Common Name	Genus	Length-Importance Index %	Frequency of Occurrence Number	Occurrence Percent[a]
snail	*Littorina*[b]	20	18	20.2
snail	*Lacuna*	18	15	16.9
blue mussel	*Mytilus trossulus*	12	7	7.9
limpet	*Lottia*	10	11	12.4
herring eggs	*Clupea*	9	4	4.5
chiton	*Tonicella*	8	14	15.7
hermit crab	*Pagurus*[b]	7	6	6.7
limpet	*Acmaea*	2	4	4.5
salmon eggs	*Onchorhyncus*	2	3	3.4
clam	*Macoma*	1	2	2.2
small crab	*Hyas*	1	3	3.4
Annelid worm	*Nereis*	1	1	1.1
sm. starfish	*Pisaster*	1	2	2.2
clam	*Ocenebra*	1	1	1.1
shrimp	*Crangon*	1	2	2.2
sea cucumber	*Cucumaria*	1	2	2.2
sea urchin	*Strongylocentrotus*	1	1	1.1
small fish	*Ammodytes*	1	1	1.1
amphipod	*Amphipoda*	<1	2	2.2
small whelk	*Searlesia*	<1	1	1.1
clam	*Crenella*	<1	1	1.1
snail	*Thais*	<1	1	1.1
snail	*Lirularia*	<1	1	1.1
disc. Mussel	*Musculus*	<1	1	1.1
snail	*Margarites*	<1	1	1.1
limpet	*Megatebennus*	<1	1	1.1
limpet	*Tectura*	<1	1	1.1
crustacean	*Saduria*	<1	1	1.1
Total	26 taxa	100	n = 89	

[a] Percent frequency of occurrence is the percentage of all gullets containing the taxon, e.g., *Littorina* was present in 18 of 89 (20.2%) of gullets.

[b] *Pagurus* and *Littorina* data must be interpreted with caution because hermit crabs often inhabit empty *Littorina* shells.

Table 7. Percent frequency of occurrence of identifiable prey in 89 harlequin duck proventriculus samples during winter (January - March) compared to summer-fall (July - October).

Common Name	Genus	% Frequency of Occurrence Winter n=46	Summer-Fall n=43
snail	*Lacuna*	41.3	9.3
limpet	*Lottia*	26.1	7.0
snail	*Littorina*	21.7	11.6
chiton	*Tonicella*	21.7	16.3
blue mussel	*Mytilus*	8.7	7.0
herring eggs	*Clupea*	8.7	--
hermit crab	Pagurus	8.7	7.0
limpet	Acmaea	2.2	2.3
salmon eggs	Oncorhynchus	--	7.0
clam	Macoma	--	2.3
small crab	Hyas	--	4.7
Annelid worm	Nereis	--	2.3
small starfish	Pisaster	2.2	2.3
clam	Ocenebra	--	2.3
shrimp	*Crangon*	8.7	--
sea cucumber	*Cucumaria*	8.7	--
sea urchin	*Strongylocentrotus*	2.2	--
small fish	*Ammodytes*	2.2	--
amphipod	Amphipoda	--	4.7
small whelk	*Searlesia*	--	2.3
clam	*Crenella*	--	2.3
snail	*Thais*	2.2	--
snail	*Lirularia*	2.2	--
discord mussel	*Musculus*	2.2	--
snail	*Margarites*	2.2	--
limpet	*Megatebennus*	2.2	--
limpet	*Tectura*	2.2	--
small crustacean	*Saduria*	--	2.3
		19 taxa	17 taxa

Table 8. Mean percent length-importance index (237 total points), frequency of occurrence, and percent frequency occurrence of identifiable prey in 33 Barrow's goldeneye proventriculus samples.

Common Name	Genus	Length-Importance Index %	Frequency of Occurrence Number	Percent
blue mussel	*Mytilus*	81.0	27/33	84.4
herring eggs	*Clupea*	7.6	1/33	3.1
snail	*Littorina*	3.8	1/33	3.1
small whelk	*Searlesia*	3.8	1/33	3.1
snail	*Lacuna*	3.4	1/33	3.1
limpet	*Lottia*	< 1.0	1/33	3.1
Total	6 taxa	100.0	n = 33	

* Sample size shown is less than the number of ducks collected. Ducks with no proventriculus contents were omitted.

Table 9. Mean percent length-importance index, frequency of occurrence, and percent frequency of occurrence of identifiable prey in scoter proventriculus samples.

Common Name	Genus	Length Importance Index %	Frequency of Occurrence Number	Frequency of Occurrence Percent
Surf scoter				
blue mussel	*Mytilus*	50.9	3/8	42.9
clam	*Tellina*	8.0	1/8	14.3
clam	*Astarte*	5.4	1/8	14.3
clam	*Nuculana*	3.4	1/8	14.3
cockle	*Mactra*	32.3	1/8	14.3
		Total Points = 74.6	n=8	
White-winged scoter				
clam	*Nuculana*	38	2/7	28.6
clam	*Macoma*	32	1/7	14.3
scallop	*Chlamys*	15	2/7	28.6
cockle	*Clinocardium*	7	2/7	28.6
snail	*Acanthina*	4	2/7	14.3
snail	*Lirularia*	3	2/7	14.3
snail	*Lacuna*	1	2/7	14.3
		Total Points = 61	n=7	
Black scoter				
N = 2, Small Samples Not Quantified:				
snail	*Acanthina*	1 individual, 1 cm		
clam	*Clinocardium*	6 individuals, 1.0 - 3.0 cm		

Table 10. Collection data and foods of the 5 sea ducks with proventriculus contents confirmed to have *Exxon Valdez* crude oil; foods of 151 ducks were tested.*

Species	Specimen Number	Collection Location	Date	Food Items No. Size Taxa
Harlequin	PWS-HD-SP-02 NRDA 20918	Main Bay entrance	09/15/89	10 - 0.5-1.0 cm *Littorina* 2 - 1.5 cm *Hyas* 1 - 1.5 cm *Saduria*
Harlequin	PWS-HD-SP-06 NRDA 21029	Crafton Is. SW Reef	09/15/89	7 - 0.5-1.0 cm *Littorina* 1 - 1.5 cm *Hyas* 2cc salmon eggs
Harlequin	PWS-HD-RH-28 NRDA 21995	Drier Bay outer rocks Knight Island	07/31/90	1 - 3 cm unident. white substance *Protothaca* clam neck ?
Common goldeneye	PWS-CG-JF-101 NRDA 21798	Herring Bay Knight Island	12/01/89	20 - 0.5 cm *Mytilus*
Barrow's goldeneye	PWS-BG-JF-103 NRDA 25412	Louis Bay Knight Island	12/08/89	15 - 1.0 cm *Mytilus*

* USFWS Batch Number 6651; Texas A & M analysis confirmed by NMFS Auke Bay Laboratory.

Table 11. PAH and phytane concentrations and proportions (%) of total PAH in proventriculus contents of 5 ducks, compared to relative abundance of PAHs in weathered *Exxon Valdez* crude oil (EVO). Hydrocarbon concentrations are in ng/g wet weight. EVO values are proportions of total PAH in a sample of sea-surface oil collected April 4, 1989 at Snug Harbor, Alaska (Sale et al. 1994). Entries of zero indicate concentrations below method detection limits or 0.0005.

Species Date Collected Location	Harlequin Duck 15-Sep-89 Main Bay	Harlequin Duck 15-Sep-89 Crafton Is.	Harlequin Duck 31-Jul-90 Drier Bay	Common Goldeneye 01-Dec-89 Herring Bay	Barrow's Goldeneye 08-Dec-89 Louis Bay	EVO Mousse 04-Apr-89 Snug Harbor
	ng/g (%)	ng/g (%)	ng/g (%)	ng/g (%)	ng/g (%)	% total PAH
Naphthalene	0	0	0	0	0	0.8
C1naphthalene	0	0	0	0	0	7.9
C2naphthalene	0	18.0 (5.3)	0	0	0	17.2
C3naphthalene	0	0	0	0	0	16.9
C4naphthalene	0	0	43.8 (4.5)	0	0	6.7
Biphenyl	0	0	0	0	0	0.9
Acenaphthylene	0	0	0	0	0	0
Acenaphthene	0	0	0	0	0	0
Fluorene	0	0	0	0	0	0.6
C1fluorene	8.24 (0.8)	0	0	0	0	1.9
C2fluorene	37.8 (3.8)	8.98 (2.6)	45.1 (4.6)	0	0	2.7
C3fluorene	0	28.5 (8.3)	0	42.6 (8.3)	0	1.7
Dibenzothiophene	0	0	0	0	0	1.6
C1dibenzothiophe	0	0	0	5.14 (1.0)	0	2.1
C2dibenzothiophe	44.7 (4.5)	17.5 (5.1)	21.1 (2.2)	23.7 (4.6)	21.5 (5.9)	3.1
C3dibenzothiophe	136 (13.6)	44.6 (13.0)	60.7 (6.2)	53.6 (10.5)	47.4 (12.9)	3.7
Phenanthrene	0	0	0	0	0	2.3
C1phenanthrene	0	0	0	0	15.6 (4.3)	7.9
C2phenanthrene	76.0 (7.6)	24.4 (7.1)	0	48.1 (9.4)	36.1 (9.8)	8.5
C3phenanthrene	223 (22.3)	65.9 (19.3)	194 (19.9)	109 (21.3)	64.2 (17.5)	5.7
C4phenanthrene	220 (22.0)	71.7 (21.0)	294 (30.2)	123 (24.0)	70.2 (19.1)	2.9
Anthracene	0	0	0	0	0	0.1
Fluoranthene	0	0	0	0	0	0.1
Pyrene	0	0	0	0	0	0.2
C1fluoranthrene	22.6 (2.3)	14.5 (4.2)	39.3 (4.0)	26.4 (5.2)	10.0 (2.7)	0.7
Benz-a-anthracene	0	0	0	0	0	0.1
Chrysene	21.4 (2.1)	0	0	11.0 (2.1)	12.4 (3.4)	0.7
C1chrysene	70.9 (7.1)	10.9 (3.2)	54.1 (5.6)	24.5 (4.8)	32.4 (8.8)	0.8
C2chrysene	97.3 (9.7)	20.1 (5.9)	127 (13.0)	32.8 (6.4)	41.8 (11.4)	1.0
C3chrysene	45.4 (4.5)	16.5 (4.8)	94.9 (9.7)	12.1 (2.4)	15.1 (4.1)	0.5
Total PAH	1000	342	974	512	367	99.3
Phytane	826	120	0	90.5	111	16.3

Table 12. Sea duck bile analysis for petroleum metabolites of naphthalene-eq and phenanthrene-eq.

Specimen Number	Collection Site	Naphthalene-eq ug/g wet wt.	Phenanthrene-eq ug/g wet wt.
EXPOSED AREA- Harlequin			
PWS-HD-CH-O4	Foul Bay	190	21
PWS-HD-CH-05	Foul Bay	300	100
PWS-HD-CH-06	Foul Bay	210	15
PWS-HD-CH-07	Foul Bay	130	17
PWS-HD-CH-08	Foul Bay	230	16
PWS-HD-CH-09	Foul Bay	300	95
PWS-HD-CH-10	Foul Bay	120	14
PWS-HD-SP-11	Foul Bay	170	20
PWS-HD-CH-02	Eshamy Bay	140	18
PWS-HD-CH-03	Eshamy Bay	860	15
PWS-HD-SP-07	Eshamy Bay	230	32
PWS-HD-SP-09	Eshamy Bay	560	76
PWS-HD-CH-11	Eshamy Bay	190	28
PWS-HD-SP-12	Eshamy Bay	1000	180
PWS-HD-SP-13	Eshamy Bay	530	87
PWS-HD-SP-16	Eshamy Bay	850	120
mean wPWS		**376**	**54.3**
KOD-HD-RH-01	Chief Cove	150	25
KOD-HD-RH-02	Chief Cove	91	16
KOD-HD-RH-06	Chief Cove	95	16
KOD-HD-RH-08	Chief Cove	140	19
KOD-HD-RH-09	Chief Cove	410	57
KOD-HD-RH-10	Chief Cove	130	24
KOD-HD-RH-12	Chief Cove	77	12
KOD-HD-RH-13	Chief Cove	610	94
KOD-HD-RH-15	Chief Cove	100	18
KOD-HD-RH-16	Chief Cove	270	38
KOD-HD-RH-17	Chief Cove	95	13
KOD-HD-RH-19	Chief Cove	81	12
KOD-HD-RH-20	Chief Cove	720	110
KOD-HD-RH-21	Chief Cove	110	20
KOD-HD-RH-22	Chief Cove	90	12
mean KOD		**211.3**	**32.4**

Table 12. (cont.) Bile analysis.

Specimen Number	Collection Site	Naphthalene-eq ug/g wet wt.	Phenanthrene-eq ug/g wet wt.
CONTROL AREA - Harlequin			
JUN-HD-SP-03	Amalga Harbor	96	10
JUN-HD-SP-08	Amalga Harbor	150	12
JUN-HD-SP-11	Amalga Harbor	120	8
mean JUN		**122.0**	**10.0**
EXPOSED AREA - Barrow's goldeneye			
PWS-BG-CH-02	Eshamy Bay	150	27
PWS-BG-CH-04	outer Main Bay	190	22
PWS-BG-CH-06	Falls Bay	190	36
PWS-BG-CH-07	Eshamy Bay	110	23
PWS-BG-CH-08	Main Bay	310	41
PWS-BG-CH-09	Main Bay	100	16
PWS-BG-CH-12	Eshamy Bay	200	38
PWS-BG-CH-14	Eshamy Bay	480	79
PWS-BG-CH-15	Eshamy Bay	360	55
PWS-BG-JF-101	Herring Bay	210	51
PWS-BG-JF-102	Louis Bay	100	21
PWS-BG-JF-103	Louis Bay	750	170
PWS-BG-JF-04	Main Bay	170	28
mean wPWS		**246.5**	**46.7**
CONTROL AREA - Barrow's goldeneye			
CDV-BG-CH-01	Orca Inlet	92	14
CDV-BG-CH-02	Orca Inlet	100	16
CDV-BG-CH-03	Orca Inlet	430	68
CDV-BG-CH-04	Orca Inlet	190	26
CDV-BG-CH-05	Nelson Bay	270	40
CDV-BG-CH-06	Nelson Bay	420	64
CDV-BG-CH-07	Nelson Bay	120	14
CDV-BG-CH-08	Nelson Bay	76	11
CDV-BG-CH-09	Nelson Bay	470	63
CDV-BG-CH-10	Simpson Bay	150	24
CDV-BG-CH-11	Simpson Bay	400	57
CDV-BG-CH-12	Simpson Bay	240	24
mean sePWS		**246.5**	**35.1**

Table 12. (cont.) Bile analysis.

Specimen Number	Collection Site	Naphthalene-eq ug/g wet wt.	Phenanthrene-eq ug/g wet wt.
CONTROL AREA - Barrow's goldeneye			
JUN-BG-RH-01	Douglas Is.	160	9
JUN-BG-RH-06	Amalga Harbor	120	13
JUN-BG-RH-07	Amalga Harbor	85	13
JUN-BG-RH-08	Amalga Harbor	77	11
JUN-BG-RH-09	Amalga Harbor	100	15
mean JUN		**108.4**	**12.1**
EXPOSED AREA - Common goldeneye			
PWS-CG-JF-01A	Eshamy Bay	160	29
PWS-CG-JF-02A	Eshamy Bay	170	32
PWS-CG-JF-05	Main Bay	80	10
PWS-CG-JF-101	Herring Bay	350	100
mean wPWS		**190**	**42.7**
CONTROL AREA - Common goldeneye			
CDV-CG-CH-01	Orca Inlet	340	52
CDV-CG-CH-02	Orca Inlet	270	32
CDV-CG-CH-03	Simpson Bay	590	82
mean sePWS		**300**	**55.3**
EXPOSED AREA - White-winged scoter			
PWS-WWS-CH-03	Eshamy Bay	80	17
PWS-WWS-CH-04	Eshamy Bay	130	17
PWS-WWS-CH-06	Main Bay	110	15
mean wPWS		**106.7**	**16.3**
CONTROL AREA - White-winged scoter			
CDV-WWS-CH-01	Orca Inlet	160	18
CDV-WWS-CH-02	Orca Inlet	100	14
CDV-WWS-CH-03	Nelson Bay	530	74
CDV-WWS-CH-04	Nelson Bay	35	5
CDV-WWS-CH-05	Orca Inlet	120	16
CDV-WWS-CH-06	Orca Inlet	400	60
CDV-WWS-CH-07	Orca Inlet	120	15
mean sePWS		**209.3**	**28.8**

Table 12. (cont.) Bile analysis.

Specimen Number	Collection Site	Naphthalene-eq ug/g wet wt.	Phenanthrene-eq ug/g wet wt.
EXPOSED AREA - Surf scoter			
PWS-SS-JF-01	Cabin Bay	150	28
PWS-SS-CH-01	Main Bay	69	10
KOD-SS-CH-01	Chief Cove	82	12
KOD-SS-CH-02	Chief Cove	98	15
mean wPWS/ KOD		**99.8**	**16.3**
CONTROL AREA - Surf scoter			
JUN-SS-SP-01	Douglas Is.	74	17
JUN-SS-SP-05	Douglas Is.	83	6
mean JUN		**78.5**	**12.8**
EXPOSED AREA - Black scoter			
PWS-BS-CH-01	Eshamy Bay	67	12
KOD-BS-CH-01	Chief Cove	72	10
mean wPWS/ KOD		**69.5**	**11.0**

Table 13. Mean scores for fat deposits of harlequin ducks and Barrow's goldeneyes. Scores are by adipose tract from western PWS and Kodiak oil spill areas (E), compared to eastern PWS and Juneau control sites (C).

Species Area	n	Mean Score* Throat	Subcu.	Flank	Mesen.	Heart
Harlequin						
W PWS (E)	17	2.35	1.94	2.35	2.76	2.71
Kodiak (E)	27	2.44	2.41	2.44	3.26	3.26
E PWS (C)	11	2.18	2.18	2.18	2.91	2.91
Juneau (C)	11	2.27	2.50	2.09	2.82	2.82
B. Goldeneye						
W PWS (E)	19	2.68	2.89	2.74	3.05	2.95
E PWS (C)	12	1.33	1.33	1.33	2.17	2.17
Juneau (C)	9	2.33	2.67	2.28	2.78	2.78

* Tracts scored on a scale of 1 (best) to 5 (worst).

Table 14. Contrast differences in harlequin duck fat deposits. Differences are by adipose tract from western Prince William Sound spill area, compared to Cordova and Juneau control areas.

Adipose Tract	Contrast Difference	95% Bonferroni C. I.	
Throat	0.12567	-0.449429	0.74562
Subcutaneous	-0.39973	-1.09404	0.29458
Flank	0.21658	-0.37120	0.80435
Mesenteric	-0.09893	-0.59578	0.39793
Heart	-0.15776	-0.66020	0.34469

Multivariate analysis of variance (Johnson and Wichern, 1988) used to test the hypothesis:

Ho: pws - controls = 0
Ha: pws - controls$\neq$ 0

The following multivariate contrast was used:

cl: pws - 0.5x (Juneau + Cordova).

For all contrasts combined, the test statistic was significant ($F_{5,58}$ = 3.2785, p = 0.0113, where the F statistic was calculated from a Wilk's lambda statistic).

Table 15. Contrast differences in harlequin duck fat deposits. Contrast differences are by adipose tract from Chief Cove, Kodiak Island spill area, compared to Cordova and Juneau control areas.

Adipose Tract	Contrast Difference	95% Bonferroni C.I.	
Throat	0.21717	-0.33424	0.76857
Subcutaneous	0.06650	-0.55103	0.68403
Flank	0.30808	-0.21471	0.83086
Mesenteric	0.39563	-0.04629	0.83754
Heart	0.39563	-0.05126	0.84251

Multivariate analysis of variance used to test the following hypothesis:

Ho: Kodiak - controls = 0
Ha: Kodiak - controls≠ 0.

The following multivariate contrast was used:

c2: Kodiak - 0.5x (Juneau + Cordova).

For all contrasts combined, the test statistic was significant ($F_{5,58} = 4.4577$, $P = 0.0017$, where the F statistic was calculated from a Wilk's lambda statistic; Johnson and Wichern, 1988).

Table 16. Exxon oil spill clean-up activity index for Prince William Sound (Exxon 1989, 1990; Fraker, pers. comm).

Number	1989	1990	1991	1992
Vessels	1,430	78	17	2
Aircraft	84	34	10	2
People	11,300	1,030	300	30
Beach Segments Worked	654	54	6	--

Table 17. Summary of coverage and results from shoreline surveys for Harlequin ducks in the western PWS oil spill area and unoiled eastern PWS, 1991 and 1992. May/Jun columns present results from the breeding season. Jul/Aug columns present results from the post-breeding season (molting birds and brood surveys).

	Western PWS				Unoiled Eastern PWS			
	May/Jun 1991	Jul/Aug 1991	May/Jun 1992	Jul/Aug 1992	May 1991	Jul/Aug 1991	May 1992	Jul/Aug 1992
Start	5/24	7/06	5/15	7/16	5/22	7/23	5/16	7/28
End	6/22	8/23	6/10	8/06	5/30	8/09	5/22	8/20
Males	93	673[1]	493	473	53	491	318	359
Females	90	6	244	412	54	181	239	129
Sex Unk.	91	0	1083	1208	367	724	443	255
Young	-	14	-	11	-	52	-	17
Total Harlequins	274	693	1820	2104	474	1448	1000	760
Survey km	429	537	2798	2276	548	700	635	410
Ducks/km	0.64	1.29	0.65	0.92	0.87	2.07	1.58	1.85
M:F Ratio	1:1	112:1	2.0:1	1.2:1	1:1	2.7:1	1.3:1	2.8:1
As Pairs	4	-	18	-	49	-	116	-
Broods	-	4	-	3	-	16	-	5
Broods/100km	-	0.74	-	0.13	-	2.29	-	1.22

[1] Includes a concentration of molting males in a single large (350) group at Channel Island on the periphery of oil spill area.

Table 18. Locations, dates, and sex composition indicating potential breeding pairs of Harlequin ducks. Shoreline survey of 429 km in the PWS oil spill area, May-June 1991.+

Location Unknown	Segment	Date	Time	Females	Males	
Bay of Isles	KN022*	5/25	0800	5	10	
Log Jam Bay	KN211\210*	5/25	1900	**1	1	
Otter Island	KN020*	5/26	2200	7	1	
Bay of Isles	KN019	5/26	2130	2	1	
Solf Cove	KN144b*	5/29	0900	7	5	
NW Knight Is	KN554*	5/30	1140	9	5	5
Bay of Isles	KN022*	5/31	1110	11	6	3
Otter Island	KN020*	5/31	1900	10	10	15
Foul Bay	MA002	6/1	0930	15	17	30
Main Bay	MA005a	6/1	1050	12	14	
Nellie Juan	MA001	6/1	1330	**1	1	
Bay of Isles	KN021*	6/1	1530			28
Johnson Bay	KN554*	6/2	1345	**1	1	
Herring Bay	KN144b*	6/19	1745	2	3	
Bay of Isles	KN020*	6/19	1915	6	14	
Bay of Isles	KN022*	6/20	1025	3	9	
Foul Passage	IN031	6/20	1120	10	8	10
Whale Bay (w)	WH504	7/10	1400	**1	1	

\+ Table lists locations only where Harlequins were observed.
* Surveyed on more than one date.
** Pair association confirmed by behavior.

Table 19. Distribution of harlequin ducks by shoreline habitat types in shoreline habitats during spring surveys in western Prince William Sound, Alaska, 1991 - 1992.

Occurrence In Habitat	1991	1992	Mean
OFFSHORE ROCKS			
% of Total Harlequins[a]	48	26	37
Density (ducks/km)	5.7	3.0	4.4
MUSSEL BEDS			
% of Total Harlequins	29	32	31
Density (ducks/km)	37.1	10.2	23.7
STREAM MOUTHS			
% of Total Harlequins	12	16	14
Density (ducks/km)	2.4	3.8	3.1
BAYS AND LAGOONS			
% of Total Harlequins	11	26	18
Density (ducks/km)	0.5	4.0	2.3

[a] Percent of total harlequin ducks observed in all habitats.

Table 20. Locations, dates, and sex composition indicating potential breeding pairs of Harlequin ducks. Shoreline survey of 2,698 km in western PWS oil spill area May-June 1992.+

Location	Segment	Date	Time	Females	Males	Unknown
Chenega Island	CH011	5/13	1200	1	4	
Herring Bay	KN133	5/15	1445	1*	1	
Herring Bay	KN133A	5/15	1505	1*	1	
Chenega Island	CH011	5/15	0930	4	6	
Bay of Isles	KN018	5/16	0900	5	7	
Bay of Isles	KN022	5/17	0940	1	2	
Bay of Isles	KN022	5/17	1215	1*	1	
Elrington Island	EL0106	5/18	1411	2*	2	
Sphinx Island	SP044	5/19	1131	2	4	
Log Jam Bay	KN211	5/19	1145	6	7	3
Bay of Isles	KN011	5/19	1515	1	2	
Herring Bay	KN132	5/19	1845	3*	1	
Green Island	GR300	5/22	0900	3	9	
Green Island	GR301	5/22	0930	1*	1	
Channel Island	GR004	5/22	1000	3	1	
Snug Harbor	KN408	5/22	1200	1*	1	
Bay of Isles	KN205	5/22	1300	1*	1	
Latouche Island	LA015	5/23	1245	2	2	
Fault Cove	Mont Is	5/23	1330	27	16	
MacLeod Harbor	Mont Is	5/23	1400	1	7	
Danger Island	DA002	5/23	1530	10	6	
Herring Bay	KN117	5/24	0830	2	1	
Herring Bay	KN114	5/24	0925	2	1	
Knight Island	KN506	5/24	1618	1*	1	
Sleepy Bay	LA018	5/24	0900	1*	1	
Knight Island	KN574	5/24	0930	1*	1	
Perry Island	PR002	5/24	1230	2	2	
Knight Island	KN551	5/25	1232	2	1	
Aguliak Island	AG009	5/25	1440	1*	1	
Johnson Bay	KN554	5/27	1610	1	2	
Point Nowell	PN001	5/28	1955			10
Applegate Island	AE005	5/28	1030	12	33	
Foul Bay	MA002	5/28	1000	13	25	
Main Bay	MA004	5/28	1300	1*	1	
Main Bay	MA009	5/28	1315	2	2	
Crafton Island	CR004	5/28	1410	1*	1	

Table 20. (cont.) 1992 breeding pair survey.

Location	Segment	Date	Time	Females	Males	Unknown
Latouche	LA042	5/31	1000	14	21	
Wilson Bay	LA035	5/31	1445	1	9	
Windy Bay	LA039	5/31	1235	14	6	
Chenega Island	CH001	6/02	1230	50		
Iktua Bay	EV010	6/06	1400	4	17	
Port Waters	Bain. Pass.	6/07	1300	1*	1	
Culross Island	CU018	6/07	1058			40
Delenia Island	DE001	6/08	1650			35
Latouche Island	LA018A	6/09	0945	1*	1	
MacLeod Harbor	Mont Is	6/10	1145	14	3	
Knight Island	KN608B	5/24	****	1*	1	

+ Table lists locations only where harlequins were observed.

* Pair association confirmed by behavior.

Table 21. Density of harlequin ducks by habitat type and oiling conditions during spring surveys, western Prince William Sound, Alaska, 1991 - 1992.

	Oiling Condition of Habitat	
Occurrence In Habitat	Heavy to Moderate	Light to None
MUSSEL BEDS		
Density (ducks/km)	39.5	4.9
BAYS AND LAGOONS		
Density (ducks/km)	4.6	2.8
OFFSHORE ROCKS		
Density (ducks/km)	4.1	12.6
STREAM MOUTHS		
Density (ducks/km)	3.1	1.8

Table 22. 1991 mist net sites on streams in the western Prince William Sound oil spill area⁺.

Location	Segment	Date	ASC Number*	Net-Hours	Captures
Snug Harbor	KN402	6/3	226-30-16820	12.0	0
Mallard Bay	KN575	6/8	226-20-16980	9.0	0
Mallard Bay	KN575	6/9	226-20-16980	9.0	0
Otter Creek	KN018	6/6	226-20-16880	8.5	0
Otter Creek	KN018	6/7	226-20-16880	8.5	0
West Arm, BI	KN201	6/11	226-30-16870	8.5	0
Kake Cove	CH017	6/22	226-20-16270	12.0	0
Paddy Bay	PA001	6/24	226-20-26010	12.0	0
Brizgaloff Cr.	none	7/4	226-20-16230	12.0	0
Whale Bay s.	WH502	7/8	226-20-16340	12.0	0
Whale Bay w.	WH504	7/10	226-20-16300	11.0	0
Iktua Bay	EV008	7/18	226-40-16543	9.0	0
Culross Pass.	none	7/19	224-30-14800	9.0	0
Total			12 streams	132.5	0

+ Camp Creek (ASC 226-30-16982, KN132) was in front of the base camp at Herring Bay and was under nearly 24-hour observation for the entire summer. Field crews from three NRDA projects (Harlequin Ducks, River Otters, and Pink Salmon) operated from Herring Bay camp during twilight hours of the night and early morning. No harlequin ducks were seen using Camp Creek or the estuary during the entire summer.

* Anadromous Stream Catalogue (ADFG 1990).

Table 23. 1992 mist net sites on streams in the northwestern Prince William Sound oil spill area and periphery.

Location	Segment	Date	ASC Number*	Net-Hours	Captures
Camp Creek	KN132	6/10	226-10-16982	6.5	0
Camp Creek	KN132	6/11	226-10-16982	7.0	0
Otter Creek	KN018	6/12	226-20-16880	7.0	0
South Arm, BI.	KN205b	6/13	226-30-16860	8.5	0
South Arm, BI.	KN205b	6/14	226-30-16860	8.0	0
NE Chenega Is.	CH009	6/15	226-20-16182	6.0	0
Port Audrey a	KN575a	6/16	226-20-16950	8.5	0
Port Audrey b	KN575a	6/16	226-20-16949	8.5	0
Port Audrey a	KN575a	6/22	226-20-16950	9.0	0
Port Audrey b	KN575a	6/22	226-20-16949	9.0	0
Port Audrey a	KN575a	6/23	226-20-16950	6.5	0
Port Audrey b	KN575a	6/23	226-20-16949	6.5	0
Eshamy Creek	none	6/24	225-30-15110	7.5	0
NE Nellie Juan	NJ001	6/25	224-40-14990	8.0	0
Mink Creek	none	6/26	224-40-14800	9.0	0
Mink Creek	none	6/27	224-40-14800	9.0	0
Brizgaloff Ck	none	6/29	226-20-16230	8.0	0
Brizgaloff 'B'	none	6/29	unnumbered	8.0	0
Jackpot Creek	none	6/30	226-20-16080	7.5	0
Cabin Bay	NA024	7/1	222-40-12960	8.0	0
West Arm, BI	KN0201a	7/2	226-30-16870	8.5	0
NW Bay, EI	EL052b	7/3	226-10-16902	9.0	0
Loomis Creek	EB001	7/4	225-30-15060	8.5	0
Gunboat Creek	EB007	7/5	225-30-15070	7.0	0
Total			17 streams	189.0	0

* Anadromous Stream Catalogue (ADFG 1990).

Table 24. 1992 mist net sites on streams in the southwestern Prince William Sound oil spill area and periphery.

Location	Segment	Date	ASC Number*	Net-Hours	Captures
Wilson Bay	LA035	6/10	226-40-16770	9.0	0
Wilson Bay	LA035	6/10	226-40-16768	8.0	0
Windy Bay	LA039a	6/11	226-40-16730	8.0	0
Windy Bay	LA039a	6/11	226-40-16740	7.0	0
Green Island	GR103	6/12	227-20-17880	8.0	0
Hanning Creek	none	6/13	227-10-17110	8.0	2
Sleepy Bay	LA018**	6/14	226-40-16780	9.0	0
Shelter Bay	EV26a	6/15	226-40-16610	12.0	0
Crab Bay	EV500a	6/15	229-40-16665	9.0	0
Crab Bay	EV500a	6/16	229-40-16670	8.0	0
Iktua Bay	EV007a	6/17	226-40-16550	8.0	0
Iktua Bay	EV008a	6/17	226-40-16543	6.5	0
Hogg Bay	none	6/23	226-50-16530	9.0	0
Hogg Bay	none	6/23	226-50-16535	9.0	0
Bathtub Cove	BA2a	6/25	226-40-16451	9.0	0
Wales Passage	EV071	6/25	226-40-16475	8.0	0
Bainbridge Is	BA006a	6/27	226-40-16279	9.0	0
Bainbridge Bay	BA006a	6/27	226-40-16269	8.0	0
Sleepy Bay	LA018**	6/30	226-40-16780	5.0	0
Whale Bay	none	7/2	226-20-16340	8.5	0
Whale Bay	WH502	7/2	226-20-16360	8.5	0
Whale Bay	WH502	7/4	226-20-16362	11.5	0
Port Waters	none	7/5	226-50-16550	9.5	0
Total			22 streams	195.5 hrs	2

* Anadromous Stream Catalogue (ADFG 1990).

** Sleepy Bay site netted twice.

Table 25. 1991 mist net sites on streams in eastern Prince William Sound.

Location	Date	ASC Number*	Net-Hours	Captures
Beartrap River	6/2-6	221-30-10480	47.0	11
East Cove, Jack Bay	6/20-21	221-50-11230	8.0	1
East Cove, Jack Bay	6/23-24	221-50-11230	8.0	2
East Cove, Jack Bay	6/26-27	221-50-11230	2.0	1
Rain Creek	6/1	221-30-10450	9.0	0
Sheep River	6/12-14	221-20-10360	22.0	3
Stellar Creek	6/18-23	221-50-11530	53.5	4
St. Matthews Creek	6/8-10	221-30-10560	23.0	0
East Olsen Creek	5/22-24	221-30-10516	24.0	0
East Olsen Creek	6/1-2	221-30-10516	10.5	0
East Olsen Creek	6/8-10	221-30-10516	14.0	0
East Olsen Creek	6/29-30	221-30-10516	11.0	0
West Olsen Creek	5/17	221-30-10517	6.0	0
West Olsen Creek	5/23-24	221-30-10517	12.0	0
West Olsen Creek	6/1	221-30-10517	6.5	0
West Olsen Creek	6/29-30	221-30-10517	11.0	0
Control Creek	5/22-24	221-30-10520	24.0	0
West Cove, Jack Bay	6/23	221-50-11210	4.0	0
Two Moon Creek	6/10-11	221-40-10735	10.0	0
Koppen Creek	6/13	221-20-10350	5.0	0
Nuchek Creek	7/2-4	228-60-18120	11.5	1
East Nuchek Creek	7/4	228-60-18110	3.0	0
Indian River	6/25	221-50-11170	5.0	0
Totals		15 streams	330.0	23

* Anadromous Stream Catalogue (ADFG 1990)

Table 26. 1992 mist net sites on streams in eastern Prince William Sound.

Location	Date	ASC Number*	Net-Hours	Captures
Sheep River	6/3-4	221-20-10360	7.5	10
Sheep River	6/7-10	221-20-10360	25.5	1
Rain Creek	6/5	221-30-10450	18.5	0
Comfort Creek	7/1	221-30-10460	5.5	1
Beartrap River	5/24	221-30-10480	2.5	0
Beartrap River	5/26-27	221-30-10480	15.5	1
Beartrap River	5/29-6/1	221-30-10480	34.0	6
Beartrap River	6/7	221-30-10480	4.5	2
Beartrap River	6/27	221-30-10480	4.0	3
Beartrap River	6/29	221-30-10480	4.5	0
East Olsen Creek	6/5	221-30-10516	8.0	0
Fish Creek	6/12	221-40-10890	7.5	1
Duck River	6/27	221-50-11160	5.0	1
East Cove, Jack Bay	6/24-25	221-50-11230	10.5	1
Stellar Creek	6/25-26	221-50-11530	8.0	2
Stellar Creek	6/28	221-50-11530	4.0	1
Nuchek Creek	6/15	228-60-18120	1.0	0
Constantine Creek	6/12-16	228-60-18150	23.0	12
Whalen Creek	6/12-13	221-40-10800	6.5	0
Garden Cove	6/12	228-60-18100	9.5	0
Little Fish Creek	6/9	221-40-10950	10.0	0
Native Creek	7/8	221-30-10470	4.0	0
Close Sheep Creek	7/6	221-20-10370	5.0	0
Totals		16 streams	224.0	42

* Anadromous Stream Catalogue (ADFG 1990)

Table 27. List of observed molting sites and number of harlequin ducks present in western Prince William Sound, 1991.

Location	Segment	Date	Time	Total Harlequins	Number Flightless
Flemming Is.	FL003	7/19	1045	18	18
Bainbridge Is.	BA006	7/19	1130	23	23
Lucky Bay	KN600	7/19	1450	5	5
Foul Bay	MA002	7/20	1230	57	57
Applegate Is.	AG004	7/20	1130	8	7
Otter Island	KN021	7/25	1145	5	2
Foul Passage	IN031	7/25	1815	5	1
Bay of Isles	KN022	7/25	1730	25	24
Herring Bay	KN141a	7/25	1000	5	3
Channel Is.	GR004	7/26	1200	350	350
Green Island	GR300	7/26	1250	50	50
Gibbon Anch.	GR002	7/26	1130	29	29
Herring Point	KN500a	8/3	1100	5	5
NW Knight Is.	KN500a/b	8/3	1115	4	4
NW Knight Is.	KN504	8/3	1200	11	10
Junction Is.	CHO11	8/4	1215	26	25
Masked Bay	none	8/4	1050	14	14
Small Bay	KN553	8/4	1400	7	7
Eshamy Bay	EB009	8/5	1015	5	5
Eshamy Lagoon	EB012/013	8/5	1040	7	7
Crafton Island	CR004	8/5	1100	7	7
Total				666 *	653

* All ducks tallied on July/August surveys (Table 17) were not classified by molt status for this table.

Table 28. Distribution of harlequin ducks by habitat type and oiling conditions during post-breeding molt surveys, western Prince William Sound, Alaska, 1991and 1992 combined.

Habitat Oiling Conditions	Heavy	Moderate	Light	Very Light	None	Total
MUSSEL BEDS						
Number of Ducks	162	80	61	86	104	493
Percent of all ducks	6.8	3.3	2.5	3.6	4.3	20.5
BAYS AND LAGOONS						
Number of Ducks	18	27	156	206	234	641
Percent of all ducks	0.8	1.1	6.5	8.6	9.8	26.8
OFFSHORE ROCKS						
Number of Ducks	57	135	192	348	389	1121
Percent of all ducks	2.4	5.6	8.0	14.5	16.3	46.8
STREAM MOUTHS						
Number of Ducks	13	0	0	0	125	138
Percent of all ducks	0.5	0	0	0	5.2	5.7
ALL HABITATS						
Number of Ducks [•]	250	242	409	640	852	2393
Percent of all ducks	10.5	10.0	17.0	26.7	35.6	

[•] All ducks tallied on July/August surveys (Table 17) were not classified by molt status for this table.

Table 29. 1990 observations of Harlequin duck broods. Recorded by ADFG fisheries crews on surveys of 109 salmon streams in Prince William Sound, June - September. Brood sizes indicated in parentheses.

Location	ASC Number*	Date	Observations
Eastern PWS			
Stellar Creek	221-50-11530	8/07	1 brood (5)
Olsen Creek	221-30-10517	7/28	1 brood (3)
Etches Creek	228-60-18060	8/17	1 brood (1)
Nuchek Creek	228-60-18120	7/29	3 broods (4,4,5)
Constantine Cr.	228-60-18150	7/30	1 brood (1)
Eyak River	212-10-10050	8/15	1 brood (4)
Northern PWS			
Coghill River	223-30-13220	8/10	1 brood (3)
Western PWS+			
MacLeod Creek	227-10-17060	7/26	2 broods (3,4)
Hanning Creek	227-10-17110	7/26	1 brood (2)
Total	9 streams		12 broods

* Anadromous Stream Catalogue (ADFG 1990).

\+ These streams are in unoiled bays at the edge of the oil spill area.

Table 30. 1991 Harlequin duck brood survey in western Prince William Sound oil spill area and adjacent unoiled locations. (Number in parenthesis under broods indicates number of ducklings.)

Location	Segment	ASC Number*	Date	Time	Broods
Goose Bay	(none)	224-30-14860	8/13	1530	0
Goose Bay	(none)	224-30-14850	8/13	1535	0
Long Bay	(none)	224-30-14760	8/13	1600	0
Culross Pass.	(none)	224-30-14800	8/13	1615	0
Lower Pass.	KN103	226-10-16922	8/17	1630	0
Lower Pass.	INO31	226-10-16906	8/17	1710	0
Northwest Bay	EL052	226-10-16902	8/18	1200	0
Block Island	EL015	226-10-16906	8/18	1215	0
Lower Herring	KN551	226-20-16846	8/18	1320	0
Lower Herring	KN551	226-20-16862	8/18	1330	0
Lower Herring	KN551	226-20-16868	8/18	1335	0
Lower Herring	KN551	226-20-16881	8/18	1340	0
Lower Herring	KN551	226-20-16895	8/18	1345	0
Mallard Bay	KN575	226-20-16980	8/18	1410	0
Barnes Cove	KN575	226-20-16970	8/18	1415	0
Northeast Cove	KN575	226-20-16963	8/18	1420	0
Port Audrey	KN575	226-20-16950	8/18	1430	0
Johnson Bay	KN554	(none)	8/18	1500	1 (3)+
Johnson Bay	KN554	226-20-16940	8/18	1530	0
Kake Cove	CH017	226-20-16270	8/19	1130	0
Guguak Cove	EV070	226-40-16509	8/19	1230	0
Iktua Bay	EV007	226-40-16550	8/19	1235	0
Bainbridge	BA006	226-40-16269	8/19	1410	0
Bainbridge	BA006	226-40-16279	8/19	1415	0
Whale Bay	WH502	226-20-16362	8/19	1445	1 (4)+
Whale Bay	WH502	226-20-16360	8/19	1500	0
Whale Bay	WH502	226-20-16340	8/19	1508	0
Whale Bay	WH003	226-20-16321	8/19	1529	0
Whale Bay	WH504	226-20-16300	8/19	1630	0
Brizgaloff Cr.	(none)	226-20-16230	8/19	1700	0
Masked Bay	(none)	226-20-16190	8/19	1730	0
Cabin Bay	NA024	222-40-12960	8/20	1130	0
Outside Bay	NA026	222-40-12950	8/20	1200	0

Table 30. (cont.) Harlequin duck broods, western PWS, 1991.

Location	ASC Segment	Number*	Date	Time	Broods
Log Jam Bay	KN211	226-10-16875	8/20	1330	0
Log Jam Bay	KN211	226-10-16880	8/20	1355	0
Snug Harbor	KN401	226-30-16820	8/20	1520	0
Rua Cove	KN213	226-30-16853	8/20	1550	0
Otter Cove	KN018	226-30-16880	8/20	1600	0
South Arm	KN205	226-30-16860	8/20	1610	0
Bay of Isles	KN134	226-30-16865	8/20	1620	0
West Arm	KN201	226-30-16870	8/20	1630	0
Hanning Creek	(none)	227-10-17110	8/21	1200	2 (4,3)+
Jackpot Bay	(none)	226-20-16130	8/22	1130	0
Jackpot Bay	(none)	226-20-16100	8/22	1200	0
Jackpot Bay	(none)	226-20-16110	8/22	1210	0
Jackpot Bay	(none)	226-20-16120	8/22	1215	0
Jackpot Bay	(none)	226-20-16090	8/22	1218	0
Jackpot Bay	(none)	226-20-16080	8/22	1220	0
Ewan Bay	EW001	226-20-16040	8/22	1320	0
Ewan Bay	EW001	226-20-16036	8/22	1325	0
Ewan Bay	EW001b	226-20-16030	8/22	1330	0
Paddy Bay	PA001	226-20-16010	8/22	1400	0
Loomis Creek	EB002a	226-10-16560	8/23	1030	0
Eshamy Bay	EB009	226-10-15160	8/23	1040	0
Eshamy Bay	EB009	226-10-15140	8/23	1045	0
Gunboat Creek	EB007	226-10-15070	8/23	1130	0
Eshamy Lagoon	(none)	226-10-15110	8/23	1230	0

* Anadromous Stream Catalogue (ADFG 1990).

\+ Unoiled bays near adjacent oil spill area.

Table 31. 1992 Harlequin duck brood survey in northwestern Prince William Sound oil spill area (brood size in parentheses).

Location	Start Segment	End Segment	Date	Broods
Squire Island	SQ004A	SQ004B	7/16	1 (6)
Green Island	GR013	GR300	8/08	0
Herring Bay	KN132C	KN300A	8/11	0
NW Knight Island	KN500A	KN510D	8/11	0
Lower Herring Bay	KN550	KN552A	8/12	0
Aguliak Isles	AG001A	AG009B	8/12	0
Chenega Island	CH002A	CH13A	8/14	0
Granite Bay	GB002	GB001C	8/14	0
Point Nowell	EB11A	PN005	8/14	0
Crafton Island	CR001A	CR005A	8/14	0
Eshamy Bay	EB007A	EB008A	8/14	0
Eshamy Lagoon	EB12A	EG15A	8/14	0
Eshamy - Falls Bay	EB001B	EB004A	8/14	0
Falls Bay	FA001A	FA002A	8/14	0
Falls Bay - Main B.	MA10A	MA009A	8/14	0
Main Bay	MA005A	MA008	8/14	0
Main Bay - Foul B.	MA004A	--	8/14	0
Foul Bay	MA003	MA001A	8/14	0
Ingot Island	IN20A	IN334	8/16	0
Disk Island	DI59A	DI68A	8/16	0
Eleanor Island	EL11A	EL104C	8/16	0
N. Knight Island	KN0025C	KN110A	8/16	0
New Year's Island	NY001A	NY001C	8/17	0
Mummy Island	MU001C	MU003A	8/17	0
Squire Island	SQ001A	SQ005A	8/17	0
Squirrel Island	SL001	SL001D	8/17	0
Drier Bay (entire)	KN575A	KN575A	8/17	0
Drier - Johnson B.	KN574A	KN574A	8/17	0
Johnson Bay	KN574A	KN554A	8/17	0
Culross Island	CU001A	CU021A	8/18	0
Applegate Island	AE001A	AE007A	8/18	0

Table 32. 1992 Harlequin duck brood survey in southwestern Prince William Sound oil spill area and periphery (brood size in parentheses).

Location	Start Segment	End Segment	Date	Broods
Hanning Creek	none	none	7/31	1 (3)
Fault Bay	none	none	7/31	0
MacLeod Harbor	none	none	7/31	1 (2)
Danger Island	DA001	DA001	7/31	0
SW Latouche Island	LA042	LA042	7/31	0
Swanson Bay	none	none	7/31	0
Hogg Bay	none	none	7/31	0
Puffin Cove	none	none	7/31	0
Port Waters	none	none	7/31	0
N Latouche Island	LA20	LA031	7/31	0
Elrington Island	ER031	ER013	7/31	0
Copper Bay	KN577	KN577	8/06	0
Mummy Island	MU002	MU002	8/07	0
Green Island	GR103	GR300	8/08	0
Foul Bay	MA002	MA002	8/09	0
E Knight Island	KN207	KN405	8/10	0
Log Jam Cove, KI	KN211	KN211	8/10	0
Rua Cove, KI	KN213	KN213	8/10	0
Evans I.	EV064	EV500	8/12	0
SE Elrington Is.	ER020	ER024	8/12	0
Flemming Island	FL001	FL005	8/13	0
Bainbridge Island	BA001	BA007	8/13	0
Whale Bay, S. Arm	WH500	WH502	8/13	0
Whale Bay, Claw Cr.	WH003	WH503	8/13	0

Table 33. Complete census of adult Harlequin ducks around Naked and Storey Islands*. Pre-spill data from June and July 1978-1980; post-spill data from June and July 1989-1991 (Oakley and Kuletz 1979; Kuletz, USFWS, pers. comm.). Additional pre- and post-spill comparison of observed number of young, 1978 vs. 1989-1991.

Island	Year	Number of Harlequin Ducks	Observations of Young	Survey Date+
Naked	1978	41	--	6/04/78
			13 E. McPherson Bay	7/20/78
			13 Cadet, NE Naked Is	7/20/78
			11 N. Cabin Bay	7/26/78
			12 Bass Harbor	8/29/78
			5 Bass Harbor	8/29/78
			18 Outside Bay	8/29/78
	1979	18	--	6/05/79
	1980	75	--	6/05/80
	1989	4	--	6/13/89
		0	none	7/25/89
			none	8/29/89
	1990		--	6/02/90
		7	none	7/29/90
	1991		--	6/05/91
		8	none	8/09/91
Storey	1978	20	20 Little Storey Is.	7/26/78
			20 N. Storey Is.	7/26/78
	1979	15	--	6/06/79
	1989	3	--	6/17/89
		0	none	7/26/89
	1990	3	--	6/03/90
		0	none	7/30/90
	1991	5	--	6/07/91

* In 1978, groups of young (6, 30) were seen July 29 on NE Eleanor Island, and August 24 on Peak Island (8).

+ Surveys were initiated on indicated date and required two days.

Table 34. Locations, dates, segment identifiers, and oiling conditions of harlequin brood sightings in western William Sound 1978 - 1992.

Year	Segment	Location	Oiling Condition	Month	Broods	Agency/Obs.
Naked Island						
1978	All	Naked Gp	PRIOR EVOS	August	>20[a]	USFWS
1991	All	Naked Gp	MOD.-HEAVY	August	0	USFWS
Knight Island						
1982	KN018	Otter Creek	PRIOR EVOS	August	1	K. Holbrook
1991	KN018	Otter Creek	MOD.-HEAVY	August	0	ADFG
1992	KN018	Otter Creek	MOD.-HEAVY	August	0	ADFG
Knight Island						
1991	KN554	Johnson Bay	LIGHT	August	1	ADFG
1992	KN554	Johnson Bay	LIGHT	August	0	ADFG
Squire Island						
1991	SQ004	Squire Is.	HEAVY	August	0	ADFG
1992	SQ004	Squire Is.	HEAVY	July	1	ADFG
Montague Island						
1990	Unseg.	MacLeod	UNOILED	August	2	ADFG
1992	Unseg.	MacLeod	UNOILED	August	1	ADFG
1990	Unseg.	Hanning[b]	UNOILED	August	1	ADFG
1991	Unseg.	Hanning	UNOILED	August	2	ADFG
1991	Unseg.	Hanning	UNOILED	August	1	ADFG
Whale Bay (Mainland)						
1991	WH502	South Arm	V. LIGHT	August	1	ADFG
1992	WH502	South Arm	V. LIGHT	August	1	ADFG
Crafton Island						
1989	CR003	S. Crafton	MOD.-HEAVY	Sept.	1	ADFG
1990	CR003	S. Crafton	MOD.-HEAVY	August	0	ADFG
1991	CR003	S. Crafton	MOD.-HEAVY	August	0	ADFG
1992	CR003	S. Crafton	MOD.-HEAVY	August	0	ADFG

[a] Number of broods unknown; a total of 112 juveniles counted at separate locations July 26-29 (Oakley and Kuletz 1979).

[b] Broods were recorded 1990-1992 at the mouth of Hanning Creek in the unoiled inner portion of Hanning Bay on Montague Island. Only the Hanning Bay entrances were lightly oiled in 1989.

Table 35. Harlequin duck brood survey in unoiled eastern Prince William Sound, 1991 and 1992.

Location	ASC Number*	Date	Size	Class+	Habitat
1991					
Beartrap River	221-30-10480	7/7	7	Ia	Nest Bowl
Beartrap River	221-30-10480	8/14	2	IIa	Estuary
Beartrap River	221-30-10480	8/18	1	IIc	Estuary
Constantine	228-60-18150	8/7	8	Ia	Estuary
Duck River	221-50-11160	8/4	1	Ic	Estuary
Fish Bay	221-40-10950	8/19	2	IIc	Estuary
Fish Bay	221-40-10950	8/19	4	IIIa	Estuary
Jack Bay	221-50-11230	8/20	4	IIc	Estuary
Jack Bay	221-50-11230	8/20	6	IIb	Estuary
Rain Creek	221-30-10450	8/22	1	IIc	Estuary
Rain Creek	221-30-10450	8/22	2	IIIa	Estuary
Sheep River	221-20-10360	7/10	2	Ia	Stream
Sheep River	221-20-10360	8/15	3	IIc	Estuary
Sheep River	221-20-10360	8/15	4	IIIa	Estuary
Stellar Creek	221-50-11530	8/20	2	IIc	Estuary
Stellar Creek	221-50-11530	8/20	5	IIb	Estuary
1992					
Fish Bay	221-40-10950	8/13	4	IIc	Estuary
Stellar Creek	221-50-11530	8/20	5	IIb	Estuary
Constantine	228-60-18150	8/18	1	IIc	Estuary
Constantine	228-60-18150	8/18	5	IIc	Estuary
Indian River	221-50-11170	8/20	2	IIc	Estuary

* Anadromous Stream Catalogue (ADFG 1990).

+ Brood classes of Gollop and Marshall (1954)

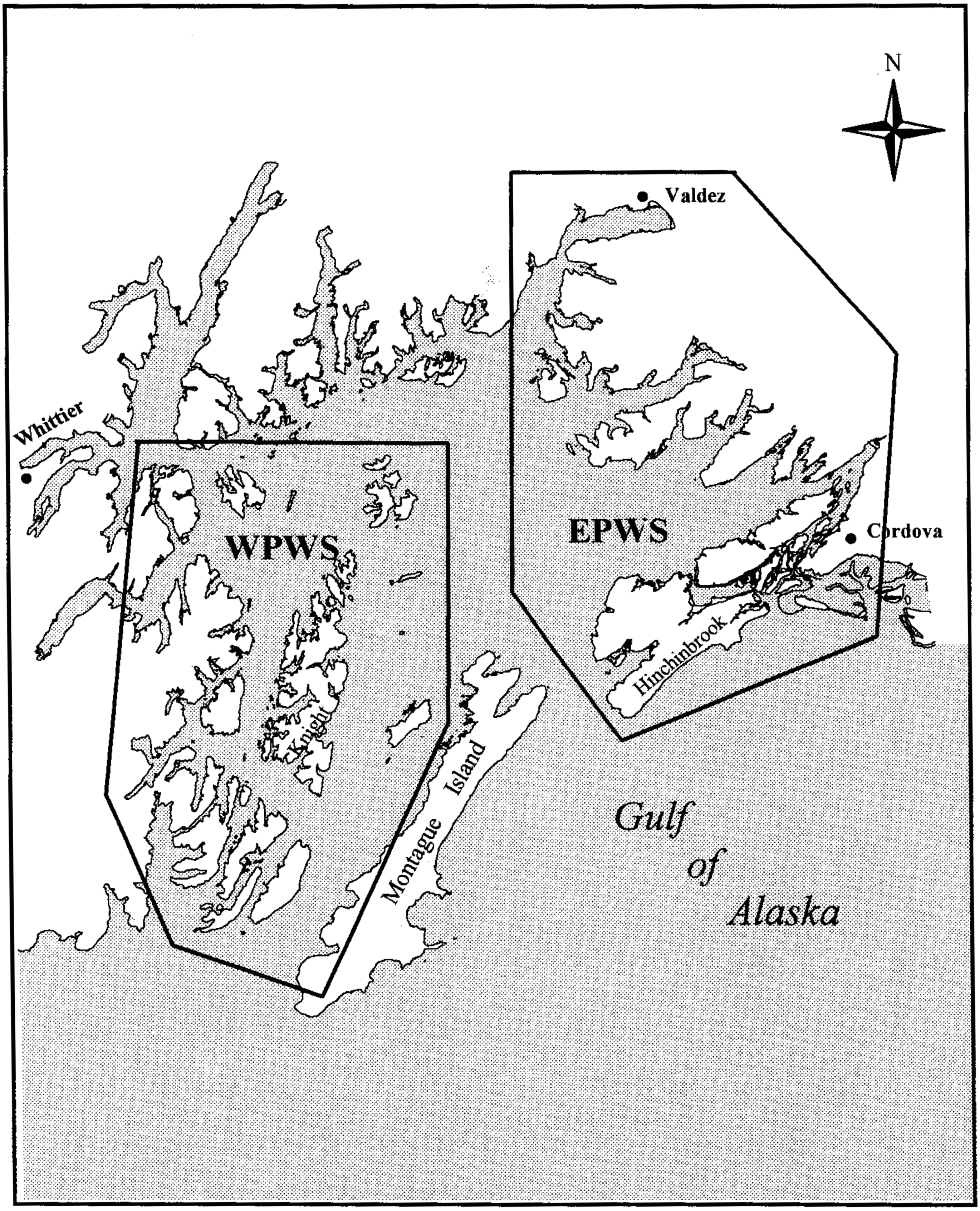

Fig. 1. Location of sea duck study areas in oiled (WPWS) and unoiled (EPWS) regions of Prince William Sound, Alaska, 1989 - 1992.

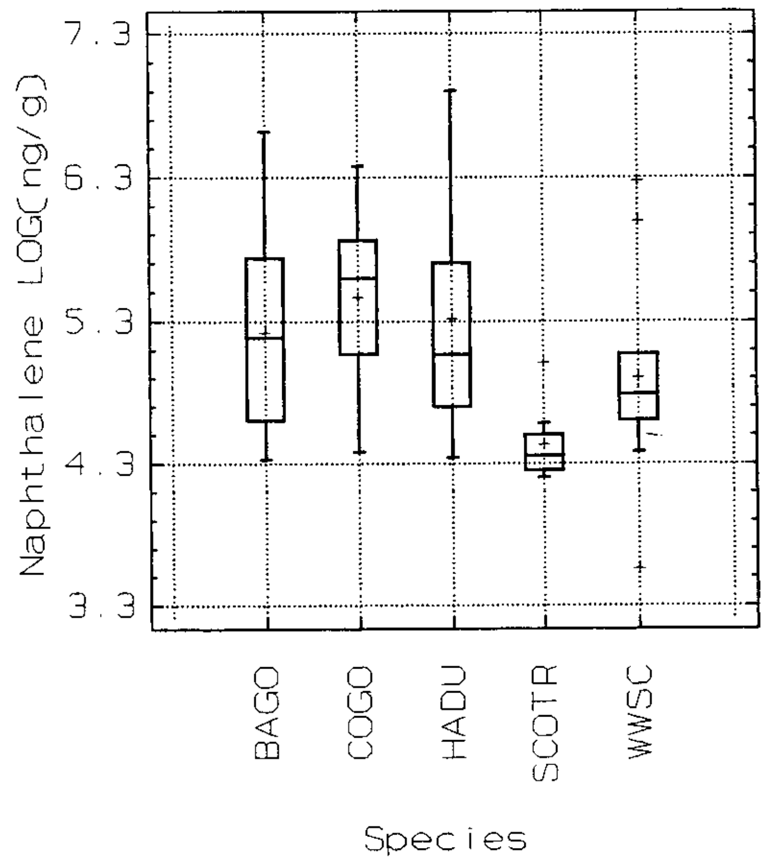

Figure 2. Mean concentrations of naphthalene-eq in bile, compared among Barrow's and common goldeneyes (BAGO, COGO), harlequin ducks (HADU), black and surf scoters combined (SCOTR) and white-winged scoters (WWSC) collected in eastern and western PWS, Kodiak, and Juneau area during winters 1989-1990. Means are shown as (+) and median values are shown as cross-bars in the box plots.

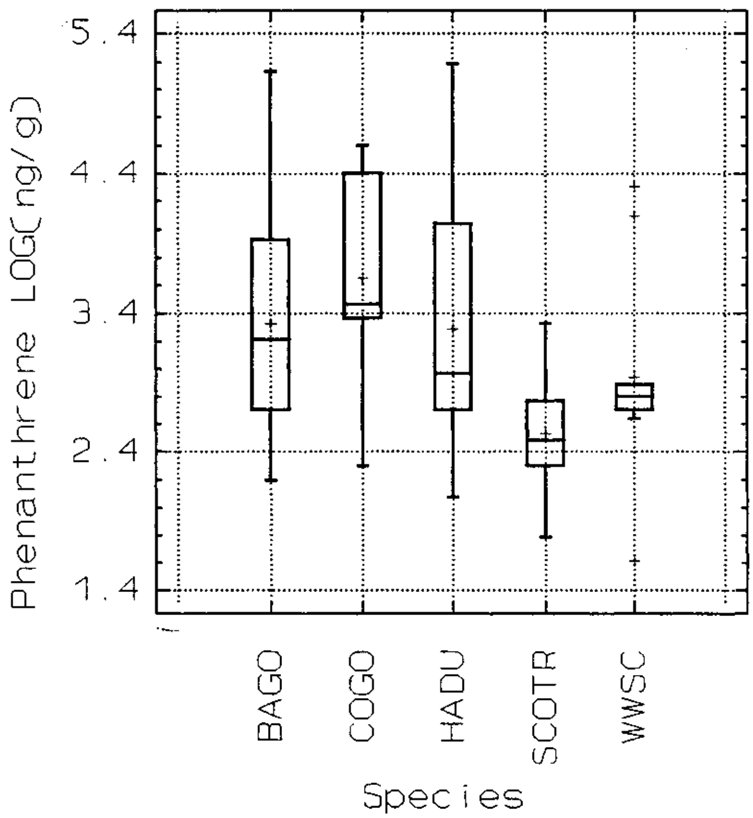

Figure 3. Mean concentrations of phenanthrene-eq in bile, compared among Barrow's and common goldeneyes (BAGO, COGO), harlequin ducks (HADU), black and surf scoters combined (SCOTR) and white-winged scoters (WWSC) collected in eastern and western PWS, Kodiak, and Juneau area during winters 1989-1990. Means are shown as (+) and median values are shown as cross-bars in the box plots.

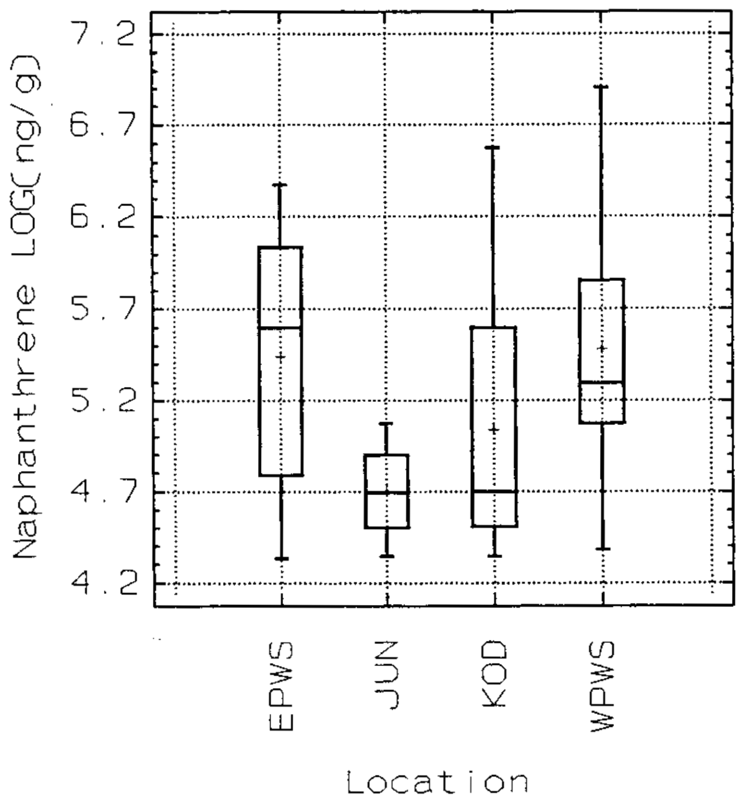

Figure 4. Mean concentrations of naphthalene-eq in bile of Barrow's and common goldeneyes, and harlequin ducks combined, compared by collection areas in unoiled eastern PWS (EPWS) and Juneau area (JUN), and Kodiak (KOD) and western PWS (WPWS) oil spill areas, winters 1989-1990. Means are shown as (+) and median values are shown as cross-bars in the box plots.

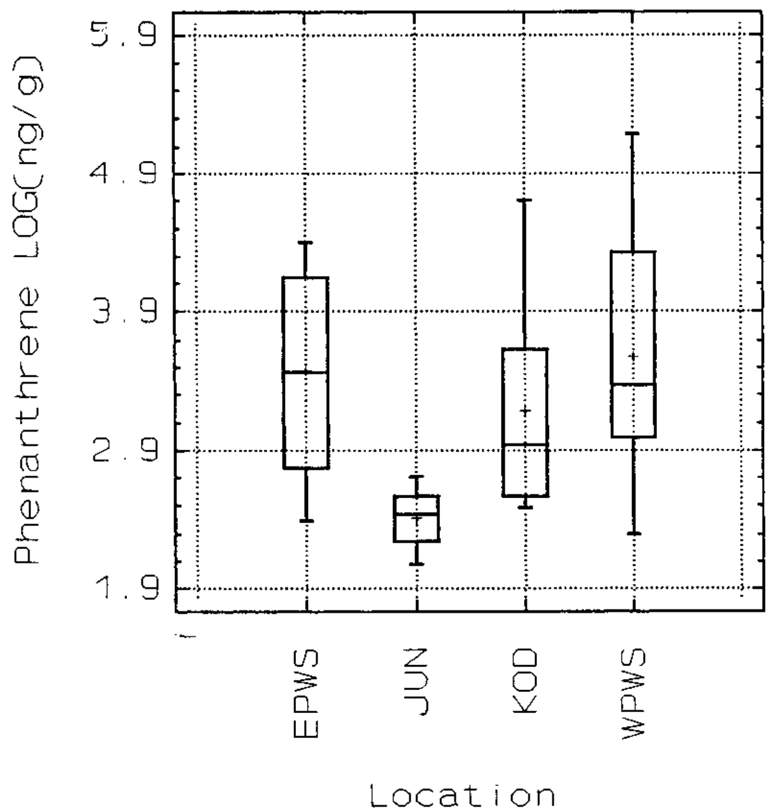

Figure 5. Mean concentrations of phenanthrene-eq in bile of Barrow's and common goldeneyes, and harlequin ducks combined, compared by collection areas in unoiled eastern PWS (EPWS) and Juneau area (JUN), and Kodiak (KOD) and western PWS (WPWS) oil spill areas, winters 1989-1990. Means are shown as (+) and median values are shown as cross-bars in the box plots.

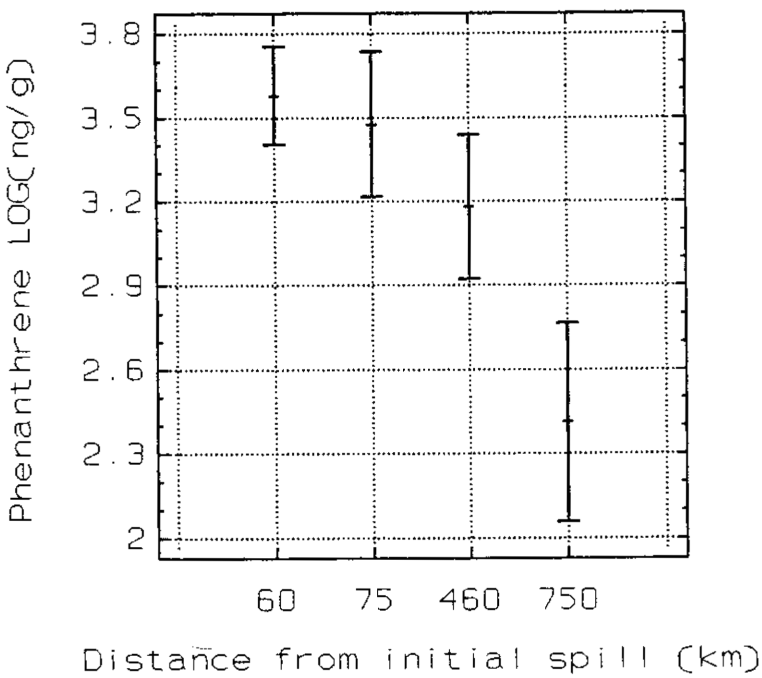

Figure 6. Mean concentrations of phenanthrene-eq in bile of Barrow's and common goldeneyes, and harlequin ducks combined, compared by distance (km) of collection sites (winters 1989-1990) from the origin of the *Exxon Valdez* spill on Bligh Reef (March 1989).

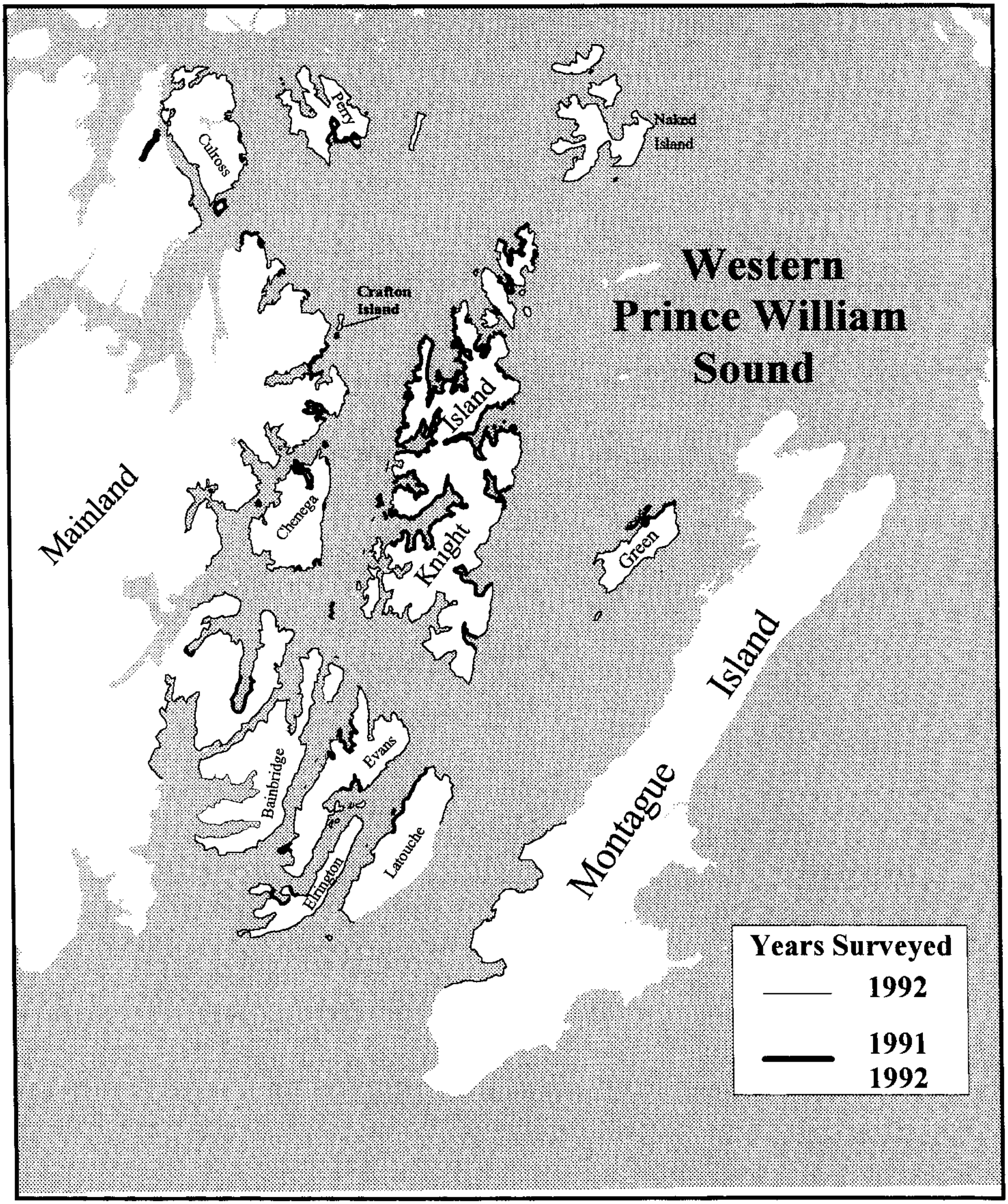

Fig. 7. Shoreline surveyed for harlequin ducks during the May-June breeding season in western Prince William Sound, Alaska in 1991 and 1992.

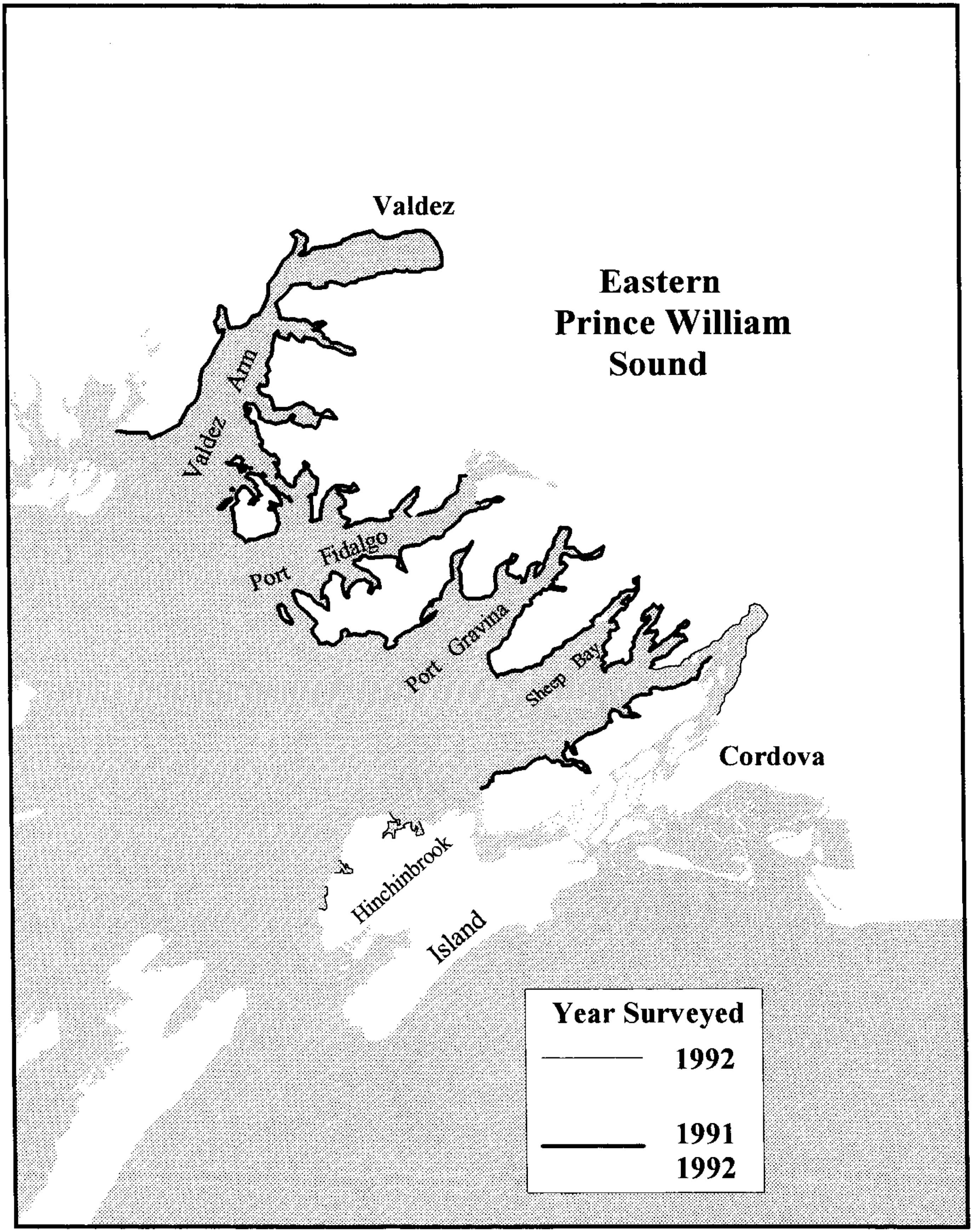

Fig. 8. Shoreline surveyed for harlequin ducks during the May - June breeding season in eastern Prince William Sound, Alaska in 1991 and 1992.

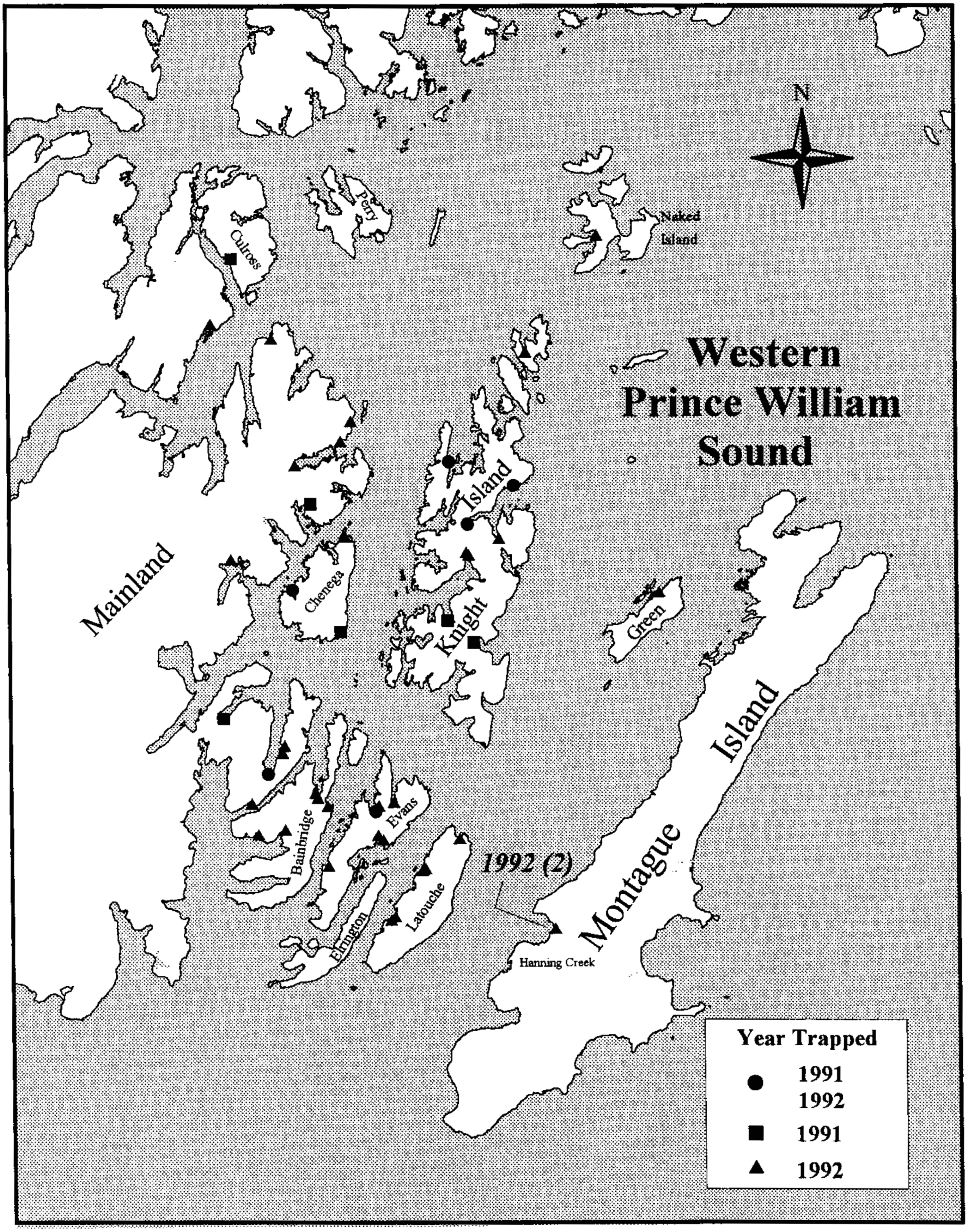

Fig. 9. Location of mist net sites on streams and the number of harlequin ducks captured in western Prince William Sound, Alaska in 1991 and 1992.

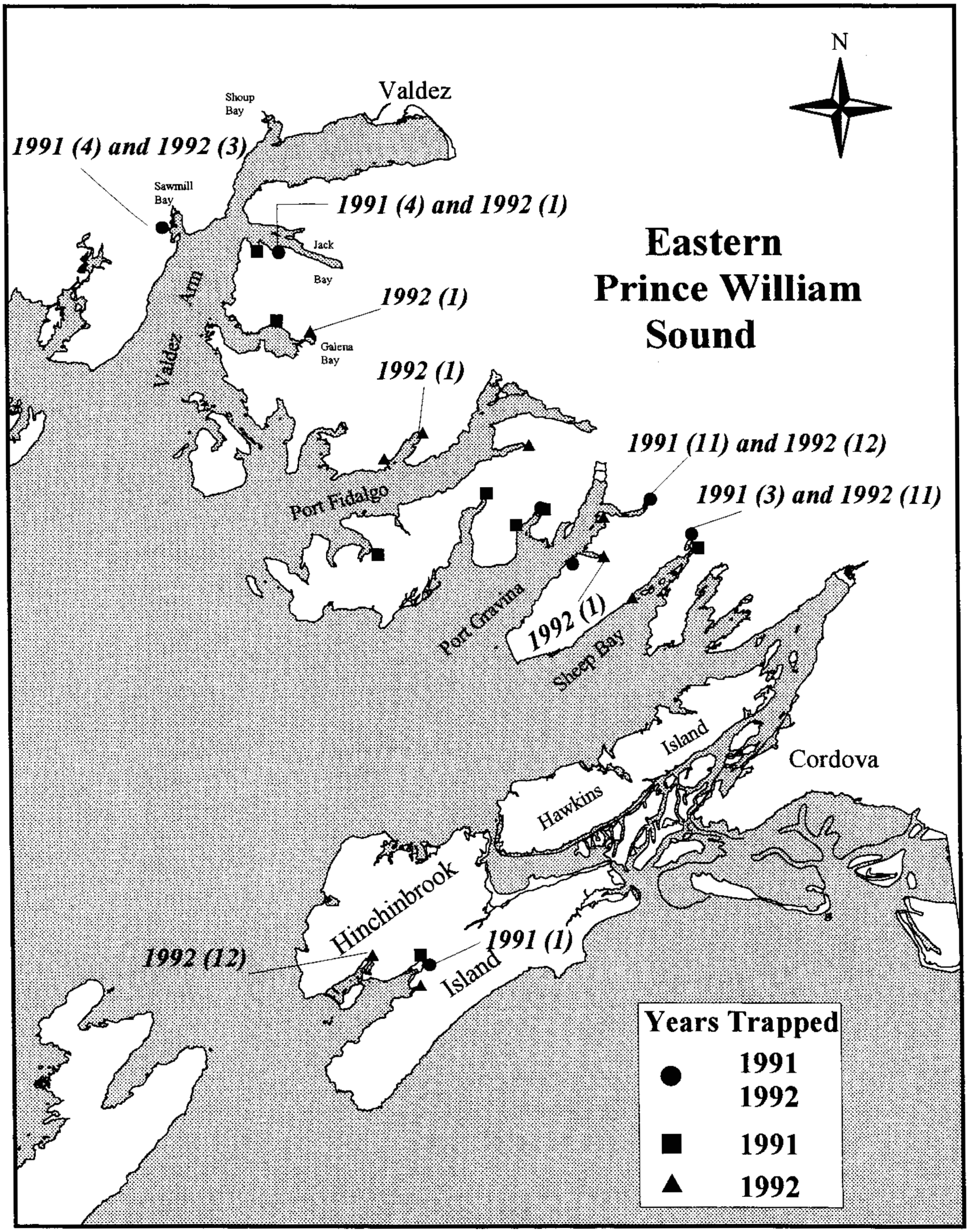

Fig. 10. Location of mist net sites on streams and the number of harlequin ducks captured in eastern Prince William Sound, Alaska in 1991 and 1992.

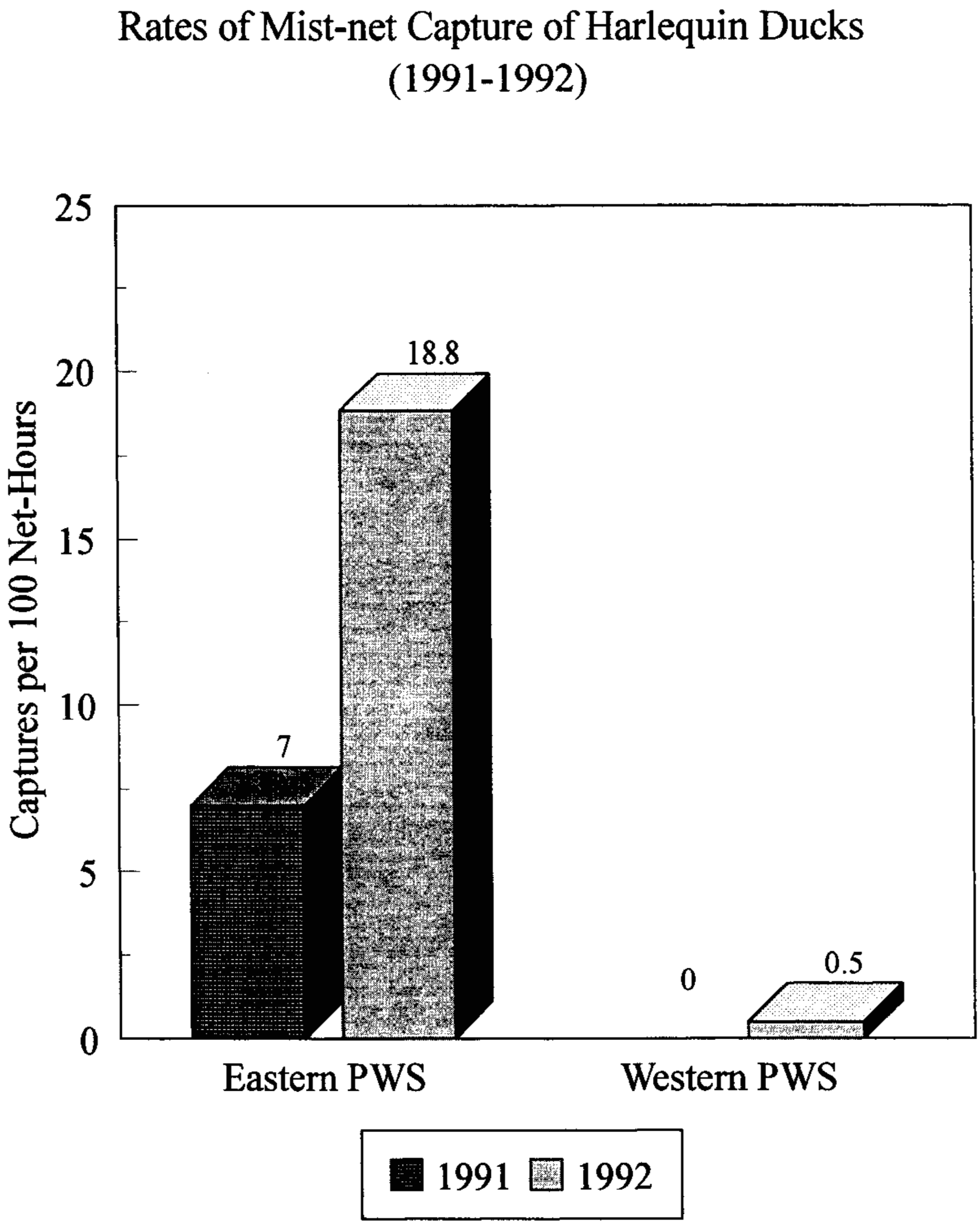

Figure 11. Rates of mist-net capture of harlequin ducks in oiled western and unoiled eastern Prince William Sound, 1991 and 1992.

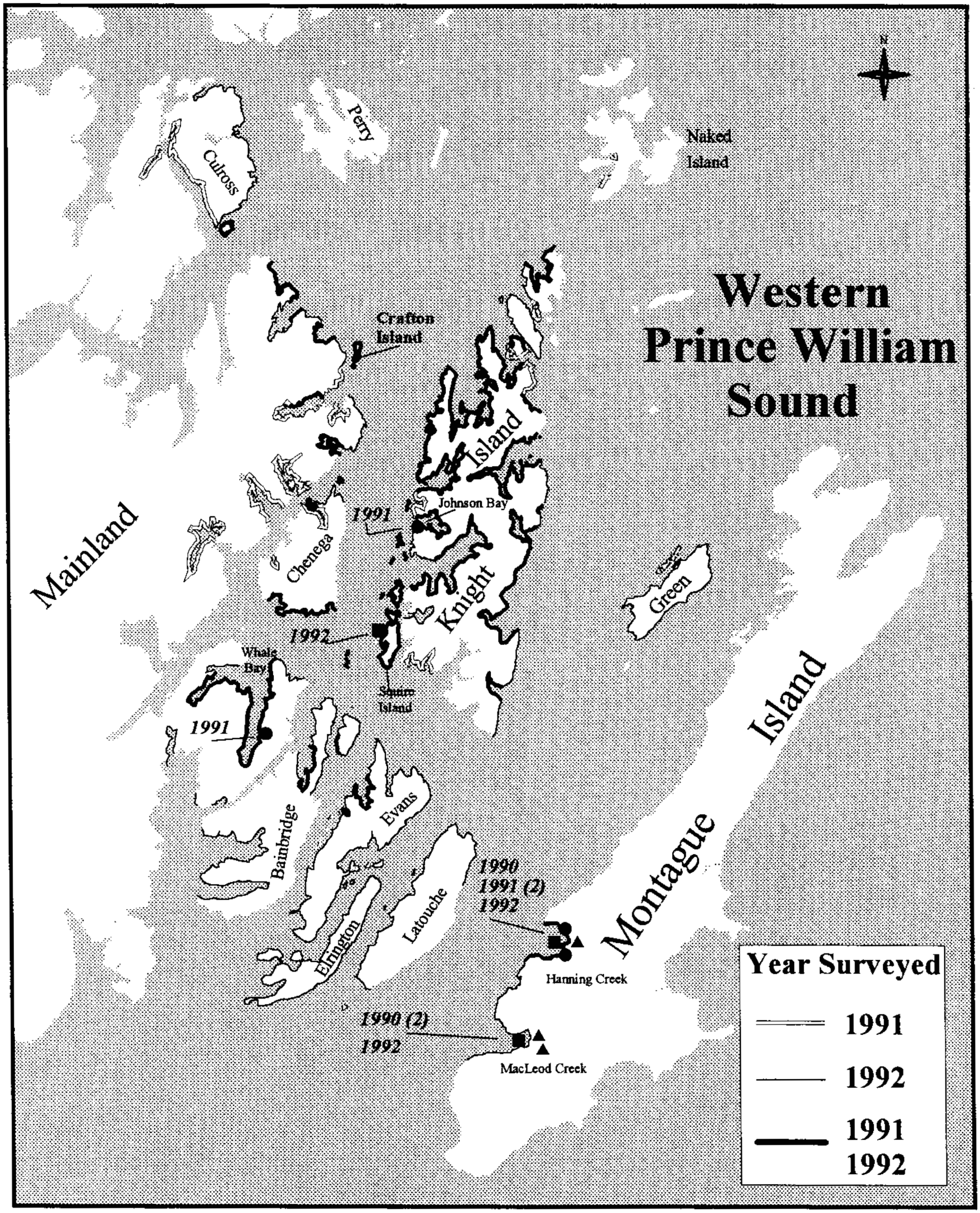

Fig. 12. Shoreline surveyed in July - August for harlequin duck broods and molting flocks, and brood locations, in western Prince William Sound, Alaska, 1991-1992. Includes broods seen on opportunistic fisheries surveys in 1990.

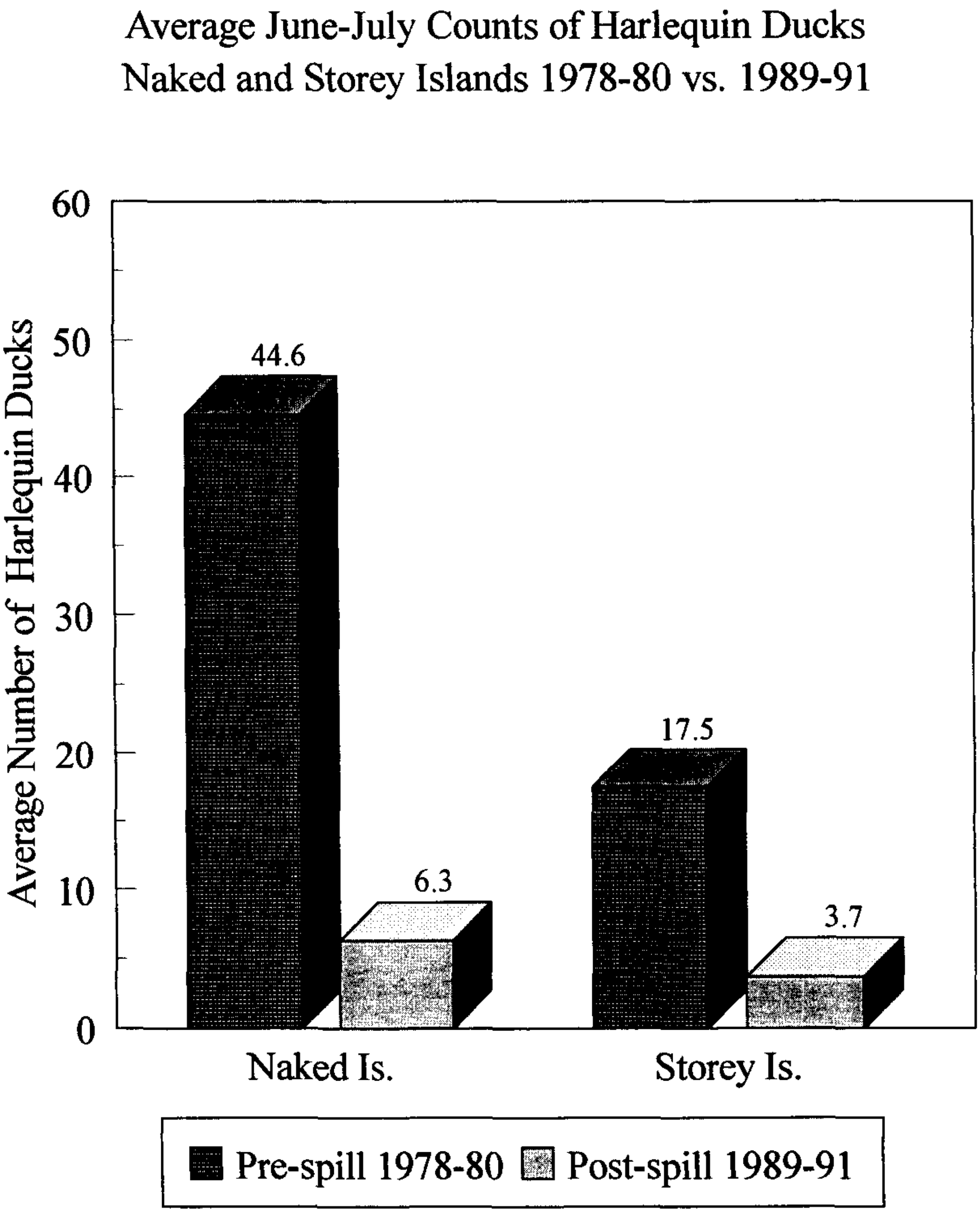

Figure 13. Average June - July counts of harlequin ducks near Naked and Storey Islands in western Prince William Sound, prior to the oil spill (1978-1980) and after (1989-1991).

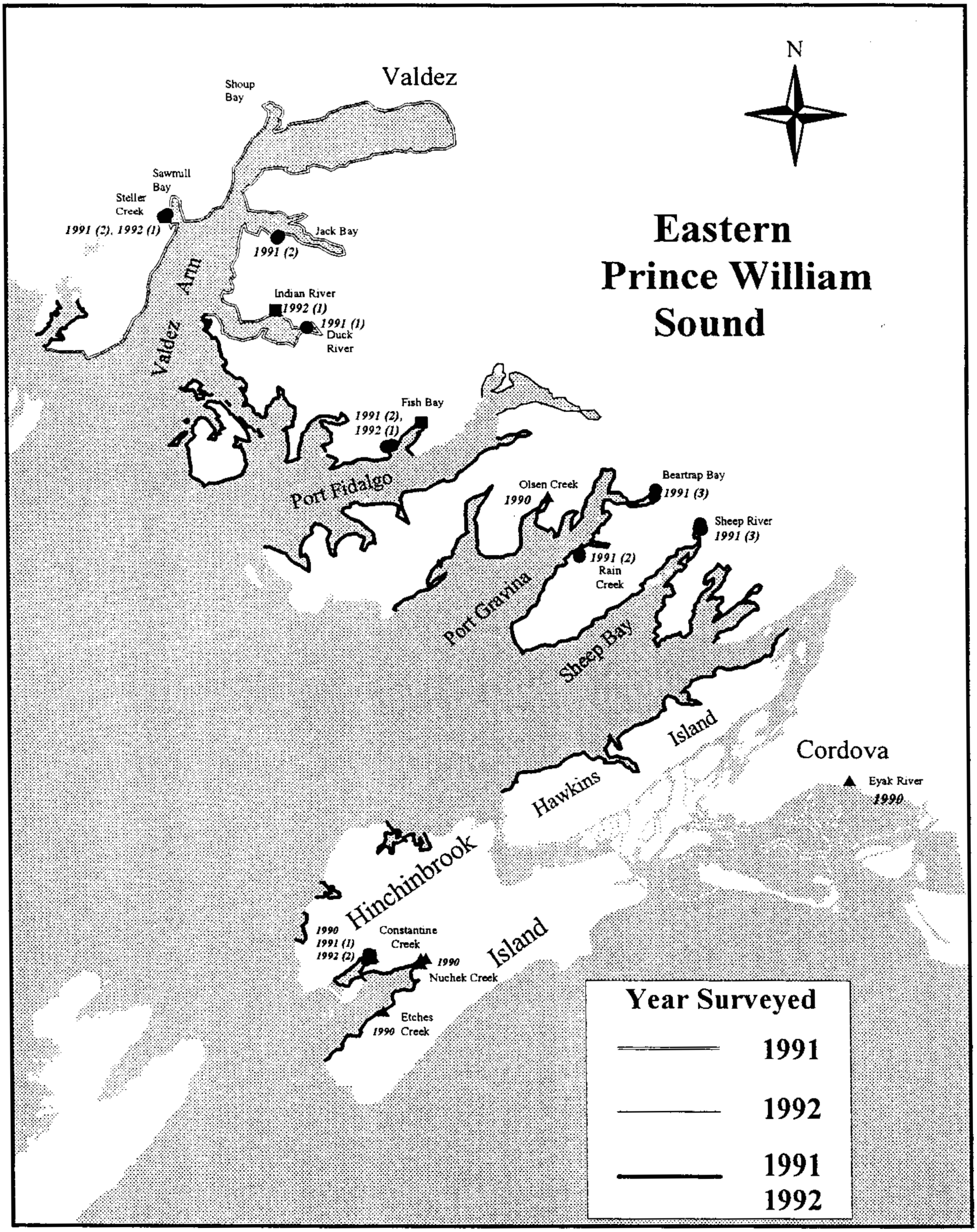

Fig. 14. Shoreline surveyed in July - August for harlequin duck broods and molting flocks, and brood locations, in eastern Prince William Sound, Alaska, 1991-1992.

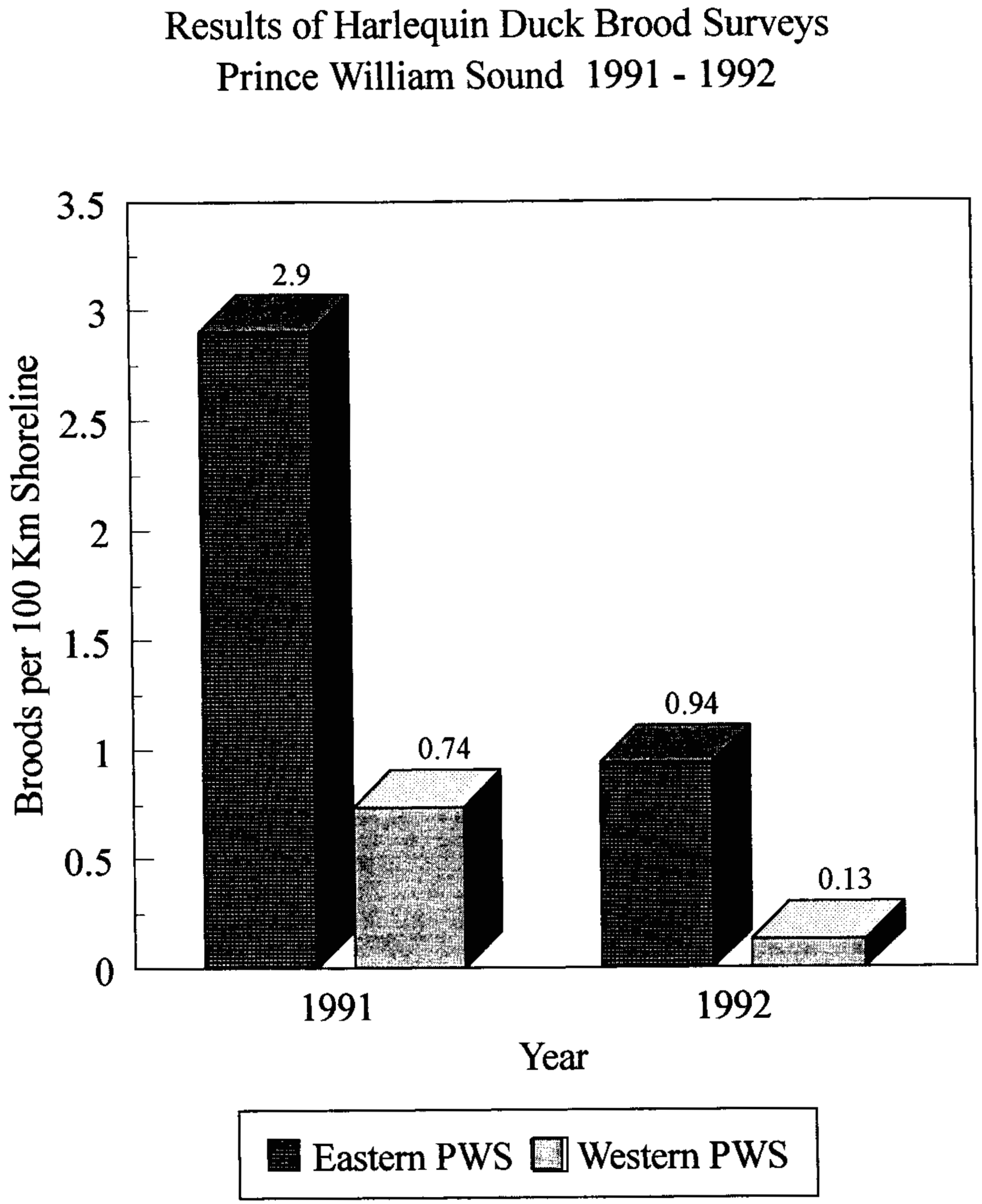

Figure 15. Linear densities (broods/100km) of harlequin duck broods observed on July - August surveys in Prince William Sound during 1991 and 1992.

APPENDIX 1

Effects of Oil Exposure on Seabirds and Waterfowl: A Literature Review

INTRODUCTION

Effects of petroleum exposure on seabirds and waterfowl were investigated and summarized because of relevance to Bird Study 11. Petroleum exposure effects were divided into two broad categories: (1) metabolic changes resulting from petroleum ingestion, and (2) reproductive effects, which are a subset of metabolic changes. Effects on reproduction may be dramatic, such as complete cessation of reproductive activity for long periods of time, or subtle, such as decreased viability of eggs. Metabolic effects of internal petroleum exposure may also be subtle, multifaceted, and synergistic. Internal exposure of birds to oil may be from either preening oiled feathers or consumption of oiled food.

METHODS

The literature on sublethal effects of petroleum hydrocarbon ingestion was sorted by physiological or reproductive aspects of exposure, then each article was summarized. Because of the large number of references, only the most relevant are indicated in the text below for ease of reading. We are grateful to Dr. D.M. Fry (Univ. of California-Davis) for access to this bibliography.

RESULTS

Wedge-tailed shearwaters breeding in Hawaii were treated with small amounts (0.1 - 2.0 ml) of weathered crude oil on upper breast feathers, or by oral doses in capsules, approximately 30 days prior to egg laying. Oil exposure did not cause birds to move to new areas but resulted in nest abandonment and reduced incubation effectiveness. Two ml of weathered oil applied externally to breast plumage resulted in greatly reduced number of eggs laid and complete hatching failure. Oral doses of oil also reduced laying and breeding success. Long-term effects of a single external application of 2.0 ml of weathered oil were demonstrated by a decreased number of birds returning to the colony in the year after dosing and reduced breeding success one year after oil exposure (Fry et al. 1986b).

Cassin's auklets breeding on Southeast Farallon Island, CA, were exposed to a single 1-ml application of weathered crude oil on breast plumage either during courtship or during mid-incubation (Fry and Addiego 1988). A high proportion of auklets dosed externally with oil prior to egg laying responded by abandoning the breeding season. Those birds remaining were delayed in egg laying by more than 20 days. Auklets exposed externally to oil in mid-incubation exhibited a high frequency of abandonment, low hatching success, and low net breeding success. Oil exposure resulted in a lower proportion of female auklets returning in the year following exposure, and reduced breeding success (Fry and Addiego 1988).

Effects of external petroleum exposure on eggs (5 species and 16 studies) indicated similar effects on a number of species. Oiling of eggs resulted in decreased hatchability (Grau et al. 1977; Ainley et al. 1979; King and Lefever 1979; Albers and Heinz 1983). Extremely small amounts of crude oil (50 microliters) exposure to the eggshell surface are toxic to the developing embryo, especially at early stages of incubation. Decreased sensitivity to petroleum exposure develops with increasing age of the embryo (Albers 1978). Subsequent retardation of chick growth may occur after hatching, as well as developmental effects such as deformed feathers, malformation of the bill, and decreased functioning of the salt gland located in the supraorbital region of the skull (Hoffman 1979a; 1979b; Hoffman et al. 1982; Sheppard et al. 1983; Hoffman and Albers 1984; Couillard and Leighton 1989; 1990).

Petroleum exposure has also led to behavioral changes such as failure of Antarctic skuas to defend nestlings. This caused complete reproductive loss, even when eggs and young were viable (Eppley and Rubega 1990).

The sublethal effects of internal petroleum exposure reported in 39 studies of 13 bird species demonstrated similar metabolic pathways in organs and organ systems. Sublethal metabolic effects of petroleum exposure result in decreased vigor of mature birds, especially when oiling is chronic at low concentrations (Holmes et al. 1979; Leighton 1983; Albers 1984; Fry and Addiego 1988). The metabolic effects of petroleum exposure may occur throughout the entire bird.

Tests for presence of petroleum in duck tissues indicate highest levels present in skin and adipose tissue, but petrochemicals are also found in liver, breast muscle, heart muscle, brain, uropygial gland, and blood (Lawler et al. 1978). Body homeostasis mechanisms, such as thermoregulation, blood oxygen levels, hormone levels, steroid metabolism, cellular transport systems, glycogen and fat storage, and oxidation/ reduction (energy release) mechanisms, are disrupted as a result of sublethal petroleum ingestion (Gorman and Milne 1970; McEwan and Whitehead 1977; Gorsline 1982; Leighton 1983; Leighton et al. 1983; Jenssen et al. 1985; Fry et al. 1986a; Khan et al. 1986; Fry and Addiego 1988).

Ingested oil causes elevated metabolic rates, initially characterized by increased feeding rates, but subsequently followed by decreased feeding rates (Gorman and Milne 1970; Lanenburg and Dein 1983). The bird may lose vigor and become hypothermic (Hartung and Hunt 1966; Hartung 1967; Jenssen 1989). The reduction of food intake by oiled ducks in conjunction with an increase in metabolic rates leads to accelerated starvation (Holmes et al. 1979; Lanenburg and Dein 1983). Internal exposure to either industrial or crude oils caused fatty livers, indicating impaired liver function and cellular necrosis (McEwan and Whitehead 1977; Peakall et al. 1983; Miller et al. 1982; Peakall et al. 1982; Leighton 1983).

Other studies showed greatly increased blood cholesterol levels of unknown consequence (Fry, et al. 1986a). Externally, oiling of even a small portion of the plumage of a waterbird leads to loss of buoyancy and the oiled area becoming an area of constant heat loss, requiring increased metabolic activity in order to maintain homeothermy (Hartung 1967; McEwan and Koelink 1973; Jenssen et al. 1985). Avoidance of oiled foods may also lead to increased metabolism. The combination of these two external effects may lead to decreased fat reserves.

Khan et al. (1986) determined that crude oil introduced to the organism via the digestive tract causes aromatic hydrocarbons (cyclic and polycyclic molecules) to block the permeability of mitochondrial membranes within cells via either electron shuttle molecules or pyruvic acid, or both. Aromatic molecules of Prudhoe Bay Crude Oil (PBCO) inhibit mitochondrial respiration and oxidative phosphorylation, principally through impairment of the mitochondrial membrane and inhibition of enzymes supported in the electron transfer activities of the respiratory chain. It appears that aromatic hydrocarbons block passage of critical components of ATP production through mitochondrial membranes (Khan et al. 1986).

Oil toxicity, internally, causes renal tubular hyperplasia, mineralization and necrosis; increased liver size, hepatocellular disassociation, and greater oxidation reaction rates as the liver attempts to lower blood toxin levels (McEwan and Whitehead 1980; Peakall et al. 1983; Peakall et al. 1982; Lee et al. 1985). Oil induced toxicity also causes hemolytic anemia, lowered immune response, and corresponding fluctuations in hormone and steroid levels related to homeostasis (Leighton et al. 1983; Rocke et al. 1983; Fry and Lowenstine 1985; Fry and Addiego 1988).

Birds exposed to ingested crude oil display lesions and bleeding in the intestinal tract (Fry and Lowenstein 1985). In nearly every case of petroleum exposure in the intestinal tract, affected birds demonstrate marked weight loss and depressed growth rates (Crocker et al. 1974; Leighton 1983; Lanenburg and Dein 1983). In some cases edema of the brain, increased spinal fluid, and swelling of other internal organs appear in seabirds after petroleum ingestion (Peakall et al. 1983; Peakall et al. 1982).

The adrenal cortex of birds is greatly affected by oiling, both in formation in the embryo stage and in function in the adult stage (Gorman and Milne 1970; Gorsline 1982; 1983; Rattner et al. 1984; Couillard and Leighton 1990). The adrenal cortex may be affected indirectly by stresses imposed on the physiology of the organism exposed to external oiling (Munck et al. 1984; Fry and Addiego 1988). When the bird is under sustained stress, the adrenal cortex may produce chronically high levels of circulating corticosterone. This will suppress normal courtship and breeding behaviors (Fry and Addiego 1988). The adrenal cortex may also be affected directly by sublethal results of petroleum ingestion (Gorman and Milne 1970; Gorsline 1982; Rattner et al. 1984). This in turn affects metabolism of glucose, causing blood sugar changes, including a diabetes-like condition (elevated blood sugar) (Gorsline 1982).

When the adrenal cortex is exposed to sublethal effects of ingested petroleum, the increased rate of corticosterone secretion, primarily responsible for maintenance of homeostasis, may inhibit development of secondary sexual characteristics in male birds by negative feedback through the pituitary (Harvey et al. 1982; Gorsline 1983). In addition, suppressive effects of ingested oil on the ovary and decreases in circulating prolactin have been associated with impaired reproductive function (Rattner et al. 1984). An oil-affected adrenal cortex may eventually be so stressed that adrenal-cortical exhaustion may occur, resulting in death (Fry and Addiego 1988).

Studies conducted on salt-water adapted seabirds and ducks indicate a reduction of mucosal water and sodium transfer in the intestinal tract after crude oil exposure (Crocker et al. 1974; Peakall et al.

1982; Fry and Addiego 1988). This causes dehydration of the bird because of lack of maintenance of proper electrolyte balance. Ducklings fed single doses of crude oil have demonstrated a lack of development of the salt gland and failure to adapt to the shift from fresh water to a salt-water environments (Holmes et al. 1978; Leighton 1983).

Some crude oils are more toxic to birds than refined oils because of the presence of aromatic hydrocarbons. Chemically dispersed crude oils also display great short-term toxicity (Albers 1984; Peakall et al. 1987; Butler et al. 1988; Jenssen 1989). Synergistic effects are important, since the toxicity of crude oil is greater than the sum of its toxic components (Miller et al. 1982; Rocke et al. 1983).

Several studies demonstrated that extremely minute amounts of oiling may lead to death of seabirds when the oiling effects are combined with stresses of severe environmental conditions such as winter weather and storms (Holmes et al. 1978; Munck et al. 1984; Fry and Addiego 1988). This may intensify effects of oil spills in arctic and subarctic environments (Levy, 1980). Subtle and multifaceted sublethal effects to birds, such as cessation of reproduction, may occur from minute amounts of oil ingestion without accompanying histopathology (Cavanaugh 1982; Fry et al 1986b; Fry and Addiego 1988). These effects may result from disruption of the adrenal cortex by alteration of pituitary hormone levels (Gorman and Milne 1970; Harvey et al. 1982; Gorsline 1983).

Bibliography on Sublethal Effects of Petroleum Exposure to Seabirds and Waterfowl: Studies Pertaining to Metabolic Effects

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Albers, P.H. 1984. Effects of oil and dispersants on birds. *In* Proceedings of the 1984 Region 9 Oil Dispersants Workshop, Santa Barbara, CA pp.101-110

Boersma, P.D. 1986. Ingestion of petroleum by seabirds can serve as a monitor of water quality. Science 231:373-376.

Butler, R.G., A. Harfenst, F.F. Leighton and D.B. Peakall. 1988. Impact of sublethal oil and emulsion exposure on the reproductive success of Leach's storm-petrels: short and long-term effects. J. Appl. Ecol. 25:125-143.

Cavanaugh, K.P. 1982. The effects of South Louisiana and Kuwait crude oils on reproduction. Aspects of avian endocrinology: practical and theoretical implications. Grad. Studies, Texas Tech. Univ. 26:371-377.

Crocker, A.D., J. Cronshaw, and W.N. Holmes. 1974. The effect of a crude oil on intestinal absorption in ducklings (*Anas platyrhynchos*). Environ. Poll. 7: 165-177.

Eppley, Z.A. and M.A. Rubega. 1990. Indirect effects of an oil spill: reproductive failure in population of South Polar skuas following the '*Bahia Paradiso*' oil spill in Antarctica. Mar. Ecol. Prog. Ser. 67:1-6.

Fry, D.M. and L.J. Lowenstein. 1985. Pathology of common murres and Cassin's auklets exposed to oil. Arch. Environ. Contam. Toxicol. 14: 725-737.

________, L.A. Addiego, S. Schwarzback and C.R. Grau. 1986a. Hematological effects of Bunker C fuel oil on common murres. PSG Gp. Bul. 13(1):28.

________, J. Swenson, L.A. Addiego, C.R. Grau, and A. Kang. 1986b. Reduced production of Wedge-tailed shearwaters exposed to weathered Santa Barbara crude oil. Arch. Environ. Contam. Toxicol. 15: 453-463.

________ and L.A. Addiego. 1988. Effects of oil exposure and stress on seabird endocrine systems. Proc. 1988 Int. Assoc. Aquat. Animal Med. 19: 60-67

Gorman, M.L. and H. Milne. 1970. Seasonal changes in the adrenal steroid tissue of the common eider *Somateria mollisima* and its relation to organic metabolism in normal and oil-polluted birds. Ibis 113:218-228.

________ and C.E. Simms. 1978. Lack of effects on ingested Forties Field Crude Oil on avian growth. Mar. Poll. Bull. 9:273-276.

Gorsline, J. 1982. The effects of South Louisiana Crude oil on adrenocortical function. Aspects of avian endocrinology: practical and theoretical implications. Grad. Studies, Texas Tech. Univ. 26:359-364.

________. 1983. Effects of petroleum hydrocarbons on adreno-cortical and ovarian function in laboratory-maintained mallard ducks (*Anas platyrhynchos*). *In* The effects of oil on birds: physiological research, clinical applications, and rehabilitation. 1982 Proceedings, Tri-State Bird Rescue and Research, Inc., Wilmington, Delaware. pp. 48-57.

Hartung, R. 1963. Ingestion of oil by waterfowl. Pap. Mich. Acad. Sci., Arts and Let. Vol. XLVIII:49-55

_______. 1967. Energy metabolism in oil-covered ducks. J. Wildl. Manage. 31(4):798-804.

________ and G.S. Hunt. 1966. Toxicity of some oils to waterfowl. J. Wildl. Manage. 30(3):564.

Harvey, S., P.J. Sharp, and J.G. Phillips. 1982. Influence of ingested petroleum on the reproductive performance and pituitary-gonadal axis of domestic ducks (*Anas platyrhynchos*). Gen. and Comp. Endocrinology 45:372-80.

Holmes, W. N., J. Gorsline, and J. Cronshaw. 1979. Effects of mild cold stress on the survival of seawater-adapted mallard ducks (*Anas platyrhynchos*) maintained on food contaminated with petroleum. Environ. Res. 20:425-444.

Jenssen, B.M. 1989. Effects of ingested crude and dispersed crude oil on thermoregulation in ducks (*Anas platyrhynchos*). Environ. Res. 48: 49-56.

_______, M. Ekker and C. Bech. 1985. Thermoregulation in a naturally oil-contaminated black-billed murre (*Uria aalge*). Bull. Environ. Contam. Toxicol. 35:9-14.

Khan, S., A.M. Rahman, J.F. Payne, and A.D. Rahimtula. 1986. Mechanisms of petroleum hydrocarbon toxicity: studies on the response of rat liver mitochondria to Prudhoe Bay Crude Oil and its aliphatic, aromatic, and heterocyclic fractions. Toxicology: 42: 131-142.

Lanenburg, J.A. and F.J. Dein. 1983. Pathology of ruddy ducks *Oxyura jamaicensis*) contaminated with spilled No. 6 Fuel Oil. *In* The effects of oil on birds: physiological research, clinical applications and rehabilitation. A multi-disciplinary symposium. 1982 Proceedings. Tri-State Bird Rescue and Research, Inc., Wilmington, DE. pp. 139-142.

Larsen, E.M. and S.A. Richardson. 1990. Some effects of a major oil spill on wintering shorebirds at Greys Harbor, Washington. Northwestern Nat. 71(3):88-92.

Lawler. G.C., W. Loong, and J.L. Laseter. 1978. Accumulation of aromatic hydrocarbons in tissues of petroleum-exposed mallard ducks (*Anas platyrhynchos*). Envir. Sci. and Tech. 12(1):51-54.

Lee, Y.Z., F.A. Leighton, D.B. Peakall, R.J. Norstrom, P.J. O'Brien, J.F. Payne and A.D. Rahimtula. 1985. Effects of ingestion of Hibernia and Prudhoe Bay Crude Oils on hepatic and renal mixed oxidase in nestling herring gulls (*Larus argentatus*). Environ. Res. 36: 248-255.

Leighton, F.A. 1983. The pathophysiology of petroleum oil toxicity in birds: a review. Pages 1-28 *in* The effects of oil on birds: physiological research, clinical applications, and rehabilitation. 1982 Proceedings, Tri-State Bird Rescue and Research, Inc., Wilmington, Delaware.

________, D.B. Peakall, and R.G. Butler. 1983. Heinz-body hemolytic anemia from the ingestion of crude oil: a primary toxic effect on marine birds. Science 220:871-873.

Levy, E.M. 1980. Oil pollution and seabirds: Atlantic Canada 1976-77 and some implications for northern environments. Mar. Poll. Bull. 11: 51-56.

McEwan, E.H. and P.M. Whitehead. 1977. Influence of weathered crude oil on liver enzyme metabolism of testosterone in gulls. Can. J. Zool. 56: 1922-1924.

________ and ________. 1980. Uptake and clearance of petroleum hydrocarbons by the glaucous-winged gull (*Larus glaucescens*) and the mallard duck (*Anas platyrhynchos*). Can. J. Zool. 58: 723-726.

________ and A.F.C. Koelink. 1973. The heat production in oiled mallards and scaup. Can. J. Zool. 51:27-31.

Miller, D.S., K.J. Hallett and D.B. Peakall. 1982. Which components of crude oil are toxic to young seabirds? Environ. Toxicol. Chem. 1:39-44.

Munck, A., P.M. Guyre, and N.J. Holbrook. 1984. Physiological functions of glucocorticoids in stress and their relation to pharmacological actions. Endo. Rev. 5:25-44.

Peakall, D.B., D.J. Hallett, D.J. Bend, J.L. Foureman, D.S. Miller. 1982. Toxicity of Prudhoe Bay Crude Oil and its aromatic fractions to nestling herring gulls. Environ. Res. 27: 206-215.

________, W.B. Kinter, and D.S. Miller. 1983. Toxicity of crude oils and their fractions to nestling herring gulls: physiological and biochemical effects. Mar. Environ. Res. 8: 63-71.

________, P.G. Wells, and D. Mackay. 1987. A hazard assessment of chemically dispersed oil spills and seabirds. Mar. Environ. Res. 22: 91-106.

Rattner, B.A., V.P. Eroschenko, G.A. Fox, D.M. Fry, and J. Gorsline. 1984. Avian endocrine responses to environmental pollutants. Jour. Exp. Zool. 232: 683-689.

Rocke, T.E., T.M. Yuill and R.D. Honsdill. 1983. Oil and related contaminant effects on waterfowl immune defenses. 1982 Proceedings. Tri-State Bird Rescue and Research, Inc., Wilmington, Delaware.

Sheppard, E.P., R.A. Wells and P.E. Georghiou. 1983. The mutagenicity of a Prudhoe Bay Crude Oil and its residues from an experimental *in situ* burn. Environ. Res. 30: 427-441.

Studies Pertaining to Effects of Petroleum Exposure to Eggs and their Development

Ainley, D.G, C.R. Grau and S.H. Morell. 1979. Influence of petroleum on egg formation and embryonic development in seabirds. OCSEAP Final Rep., Research Unit 423.

Albers, P.H. 1978. The effects of petroleum at different stages of incubation in bird eggs. Bull. Environ. Contam. Toxicol. 19:624-630.

________. 1979. Oil dispersants and wildlife. Proc. 1979 USFWS Pollution Response Workshop, St. Petersburg, Florida.

________ and G.H. Heinz. 1983. FLIT-MLO and No. 2 Fuel Oil: effects of aerosol applications to mallard eggs, on hatchability and behavior of ducklings. Environ. Res. 30: 381-388.

Cavanaugh, K. P., A.R. Goldsmith, W.N. Holmes and B.K. Follet. 1983. Effects of ingested petroleum on the plasma prolactin levels during incubation and on the breeding success of paired mallard ducks. Arch. Environ. Contam. Toxicol. 12: 335-341.

Couillard, C.M. and F.A. Leighton. 1989. Comparative pathology of Prudhoe Bay Crude Oil and inert shell sealants in chicken embryos. Fund. and Appl. Toxicol. 13:165-173.

________ and ________. 1990. The toxicopathology of Prudhoe Bay Crude Oil in chicken embryos. Fund. and Appl. Toxicol. 14:30-39.

Eastin, W.C., Jr. and D.J. Hoffman. 1978. Biological effects of petroleum on aquatic birds. *In* Proceedings of the conference on assessment of ecological impacts of oil spills. Am. Inst. Bio Sci. pp. 561-582.

Grau, C.R., T. Roudybush, J. Dobbs and J. Wathen. 1977. Altered yolk structure and reduced hatchability of eggs from birds fed single doses of petroleum oils. Science 195: 779-781.

Hartung, R. 1965. Some effects of oiling on reproduction of ducks. J. Wild. Mgmt. 29(4): 872-874.

Hoffman, D.J. 1979. Embryotoxic and teratogenic effects of petroleum in Mállards. J. Toxicol. Environ. Health 5:835-844.

________. 1979. Embryotoxic effects of crude oil containing nickel and vanadium in mallards. Bull. Environ. Contam. Toxicol. 23:203-206.

________ and P.H. Albers. 1984. Evaluation of potential embryotoxicity and teratogenicity of 42 herbicides, insecticides, and petroleum contaminants to mallard eggs. Arch. Environ. Contam. Toxicol. 13:15-27.

________, W.C. Eastin, and M.L. Gay. 1982. Embryotoxic and biochemical effects of waste crankcase oil on bird eggs. Toxicol. and Appl. Pharm. 63:230-241.

Holmes, W.N., J. Cronshaw and K.P. Cavanaugh. 1978. The effects of ingested petroleum on laying in mallard ducks (*Anas platyrhynchos*). Pages 301-309 *in* (J. Siva-Linstedt, ed.) Energy/Environment '78: Proceedings of a symposium on energy development impacts.

King, K. and C.A. Lefever. 1979. Effects of oil transferred from incubating gulls to their eggs. Mar. Poll. Bull. 10: 319-321.

Lee, Y.Z., P.J. O'Brien, J.F. Payne and A.D. Rahimtula. 1986. Toxicity of petroleum crude oils and their effects on xenobiotic metabolizing enzyme activities in the chicken embryo *in ovo.* Environ. Res. 39: 153-63.

APPENDIX 2

OIL SPILL SEA DUCK STUDY: FIELD STANDARD OPERATING PROCEDURE (S.O.P.) FOR SAMPLING

A. Collection and Field Recording

1. Select collection sites according to a field plan, if one has been developed (related to intensity of oiling or intertidal study sites).

2. Target only scoters (surf, white-winged, and black), Harlequin, and goldeneyes (unless directed to eiders or scaup), especially live birds that appear to be oiled or debilitated.

3. Observe individuals and groups for feeding activity and, as much as possible, allow birds to feed prior to collection. It is important to obtain birds with as much recently ingested food as possible.

4. Collect birds with a shotgun in the most efficient and humane manner possible; 12 gauge with heavy loads, by boat pursuit if necessary into adequate range. Try to sample some of each species at a site, keeping in mind the total desired sample for the region. Although not critical, try to balance the sex composition of the samples as opportunities arise.

5. During collections, the crew should divide responsibilities to ensure that the shooter can make clean, safe shots; the boat driver pays attention to boating hazards and crew safety; and all struck birds are observed for retrieval.

6. Field processing of birds involves:

   (a) record on a map the bird's original feeding location noted by its unique specimen code;

   (b) tie or tape the bill closed to avoid loss of food items;

   (c) affix a wire and plastic tag to one leg and annotate with pencil or indelible marker: unique specimen code (see below), species, sex, location, collector's name, date;

   (d) record this same information in a bound field log book, with notes on the site and birds present;

   (e) bag each bird in a plastic bag and store with other birds; and

   (f) keep collected birds cool and away from fuel tanks, oil cans, or other sources of hydrocarbons.

Do not put anything in the bills or open any of the birds. As long as the bill and body cavity remain closed, organ and food samples will not be contaminated from outside sources. On extended field trips or delayed transport of birds to the necropsy location, do not allow decay to set in. Although freezing will likely preclude obtaining useful tissue samples for histopathology, birds should be frozen if there is a risk of losing the birds to decomposition; chemical analysis can still be done on tissues and foods.

B. Base camp or Laboratory Processing

SPECIAL CAUTION: All internal sampling instruments must be chemically cleaned before use and if any suspected contamination has occurred (or have several sets to use). Cleaning procedures involve washing in strong detergent, water rinse, acetone soak, a final rinse in hexane, and air dried. **Acetone and hexane are highly flammable and hazardous if inhaled or come in contact with skin.** Clean instruments with these chemicals outdoors or with forced ventilation, and use gloves at all times.

1. Select a work area that is clean, with suitable lighting and ventilation, away from hydrocarbon sources (formalin, alcohol, fuels, etc.) and away from open flames (heaters, pilot lights, etc.). Clean work surfaces of dirt and debris. (See SPECIAL CAUTION)

2. Organize workspace into bird dissection, sample preparation, and instrument cleaning areas. Preparation will include:

   - Set of external dissection instruments (scalpels, scissors).
   - Several sets of chemically-cleaned internal instruments (hemostats, scalpels, forceps, small syringes w/needles).
   - Instrument cleaning pans (3) for soap and water, acetone soak, hexane rinse.
   - Chemically cleaned and sealed jars (4-12 oz.), and small amber vials (3 jars and 1 vial per bird).
   - Prepared labels, evidence tape seals, chain-of-custody sample log sheets.
   - Supplies of acetone and hexane (or methylene chloride), 10 percent neutral buffered formalin (set aside from dissection area), and cleaned aluminum foil.
   - Personal protection items (coveralls, surgical gloves).

3. At the outset on each bird, a recorder should log appropriate data on the log sheet and prepare sample labels from the leg tag and field book (see example).

4. Inspect the bird externally for signs of oil; matted feathers; wounds; lesions; exudates from eyes, nostrils, or bill; and any other unusual observations. Record notes in the logbook (do not describe damage caused during collection).

5. Using <u>external</u> instruments only, split and peel back the skin from vent to throat to get plumage out of the way (note any subdermal irregularities).

6. With scissors, open the body cavity from just forward of the vent, up one side through the ribs and shoulder, and up the throat to the base of the bill. Take special care not to touch the liver. Lay open the carcass to allow work room. Do the following steps <u>in order</u>:

7. Using clean <u>internal</u> instruments, remove the gall bladder intact with forceps or hemostats, hold it above an unsealed amber vial and puncture the bladder to collect bile. Seal and label the vial, for CHEMICAL ANALYSIS.

8. Using clean <u>internal</u> instruments, resect half the liver and place in an unsealed jar. Seal and label the jar, for CHEMICAL ANALYSIS.

9. Using clean <u>internal</u> instruments, loosen the esophagus near the throat, ensuring that food items are all in the esophagus, clamp with a hemostat and cut free above the clamp. Likewise clamp off the proventriculus at the gizzard and cut free. Over a clean jar, open the clamp on the esophageal end and strip the food contents into a clean jar. (At this point notes may be taken on kinds and number of food items present; do not touch or probe contents). Seal and label the jar, for CHEMICAL ANALYSIS.

10. Instruments may be re-used for the next operations to obtain histopathology samples (chemical cleaning not essential). The following tissues should be carefully resected and placed together in a jar or two, maintaining a 9:1 or better ratio of formalin:tissue volume:

    a. remainder of the liver
    b. kidneys
    c. spleen
    d. 2-inch sections of upper, middle, and lower intestine (do not open sections)
    e. a section of 2 neck vertebrae
    f. whole brain

11. Away from the dissecting area, fill this jar with 10 percent buffered formalin, seal and label, for HISTOPATHOLOGY. With completion of the sample log sheet, this concludes sampling of the bird.

12. Secure specimen jars and vials with seals and evidence tape. Fill out a chain of custody form for each package of samples, with the original forms in the packages and copies made for files. Skins and carcasses may be salvaged and frozen for uses unrelated to the oil spill (per direction from project leader).

SAMPLE NUMBERING SCHEME

Region:	Prince William Sound	PWS
	Kodiak Archipelago	KOD
	Juneau	JUN
Species:	Surf scoter	SS
	White-winged scoter	WS
	Black scoter	BS
	Barrows goldeneye	BG
	Common goldeneye	CG
	Harlequin (duck)	HD
Number:	Number in a series for that species and that region.	
Analysis:	Chemistry	C + number
	Histopathology	H + number

<u>Example</u>: The seventh surf scoter taken in Prince William Sound should have samples labeled:

PWS-SS-7-C1	(bile vial)	PWS-SS-7-C2	(liver)
PWS-SS-7-C3	(food contents)	PWS-SS-7-H1	(tissues in formalin)

APPENDIX 3

CONTAMINATED BLUE MUSSEL (*Mytilus*) BEDS IN PRINCE WILLIAM SOUND

INTRODUCTION

Blue mussels (*Mytilus trossulus*) are a basic prey resource for many species of marine life in Prince William Sound. Harlequin ducks, black oystercatchers and sea otters may have suffered low reproduction after the 1989 oil spill. The food item common to these three species is the blue mussel. Blue mussels are well known for their ability to concentrate and retain pollutants such as petroleum.

An *ad hoc* interagency research team (ADEC, ADNR, NMFS, and ADF&G project staff) documented residual oil and oiled mussel beds in a number of locations in western Prince William Sound in June 1991. Not only was oil confirmed within mussel beds, but raw, unweathered oil in significant concentrations was present at certain sites in anoxic conditions beneath byssal thread mats. Wiener and Slocum (1991) presented this distribution of oiled mussel beds in PWS by segment list.

A review of the files of the U.S. Coast Guard Federal On-Scene Coordinator (USCG FOSC) in Anchorage by project staff suggested as many as 130 mussel beds in western Prince William Sound potentially retained crude oil. The potentially oiled mussel beds were identified by their beach clean-up number.

Further impetus for this work was provided by a literature review by project staff on pollution in blue mussels. The literature on pollution in blue mussels contains over 1000 references.

We developed a hypothesis that blue mussels provided a mechanism for the transmission of petroleum from the environment to higher consumers such as harlequin ducks. We were aware that oil spill clean-up monitors recorded the presence of oiled mussel beds at a number of sites in the western PWS spill area in 1989. We were also aware that oil spill clean-up policy was to avoid disturbing these mussel bed sites.

METHODS

A field survey was conducted in 1992 to determine the scope and magnitude of the oiled mussel bed problem in PWS, as related to the harlequin duck foraging. In cooperation with the NMFS blue mussel study (R103), project staff expanded the documentation of residual oil in blue mussel beds in western PWS.

Fieldwork began on July 6 and continued through August 28, 1992. We attempted to survey as many as possible of the 130 sites listed in the FOSC files. These beach segments were first surveyed from a 17-ft Boston Whaler. The mussel beds were located by visual inspection of the beach segment, using information contained in notes from the file searches. If there were any indications that the site could contain residual oil, the inspection continued on foot. Potentially oiled mussel bed sites were visited on a +3-ft or lower tide, preferably on the ebb tide. On average, of four sites were visited per day. Presence and activity (such as feeding or resting) of any harlequin ducks on the site was recorded.

In many cases, oiled mussel beds were located by visual inspection of coat and cover (CT and CV) oiling on the upper intertidal zone. The study team would then search the adjacent lower intertidal zone for mussel beds. This was considered the most expeditious method of identifying the sites. However, not all sites could be identified by residual surface oiling. If the smell of petroleum was evident, crude oil was also suspected in the intertidal. Rubbing suspected oil between thumb and forefinger provided additional cues to the presence of oil. The oil felt greasy and stained the skin surface.

The presence of oil on the mussel bed was recorded during visual inspection of the site, using appropriate oil spill terminology (see Glossary, below). A narrative and a sketch map were prepared for the site. The sketch map was drawn in relation to prominent geographical features of the beach segment. The narrative included the location of the mussel bed within the intertidal zone, and relative size and density of the mussel beds. Average length of the mussels was noted. Beach and sediment types were noted. The FOSC files already contained some sketch maps, providing a method for eventual cross-confirmation of the sites. Sites were designated by beach segment identifier code (ADEC 1989) and a Global Positioning System (GPS) unit, if available, was used to record latitude and longitude for the site.

After the mussel beds were identified, the team measured the extent of the oiling, and laid out a transect roughly parallel to the waterline, no more than 30 m in length. Along the transect, within 1 m, up to eight excavations to extant oil levels were made at random intervals. The substrate beneath the mussel bed was exposed using a trowel or clam shovel.

Approximate average depth to the oil level through the mussels and byssal thread mat was 6-10 cm. In some cases, oil was found immediately below the byssal mat, and if mussels were inadvertently stepped upon, oil would protrude through the mat and form a surface sheen.

The first sediment layer beneath the mussel bed was sampled using chemically clean jars and sterile tongue depressors to fill the jar. This sediment layer should have contained the greatest concentration of petroleum. Three samples per oiled mussel bed site were considered adequate. Oiled sediment samples were taken from the excavations, with a sample blank from each location.

The sampling sets from all sites examined were sent to the cooperating blue mussel study (RS#103) at the NOAA/NMFS Auke Bay Laboratory in Juneau. Samples were measured by fluorescence spectroscopy to determine presence/absence of oil in a laboratory screening test. Samples with evident high concentrations of petroleum components were investigated further by NOAA using a gas chromatograph. NOAA/NMFS investigators returned to a number of oiled mussel bed sites located by ADF&G in Prince William Sound in late August 1992 for further sampling of mussel tissue, byssal thread mats, and substrates.

RESULTS

We surveyed 121 mussel bed sites suspected of being oiled in western Prince William Sound during July and August 1992 (Table 1). A list of those sites with substantial amounts of oil is shown in Table 2. More particular descriptions of surveyed sites and observations are found in Table 3.

Mussel beds were described by size:

1. Small bed - less than 50 m^2
2. Medium bed - 50-300 m^2
3. Large bed - greater than 300 m^2

Density of the mussel bed was described as follows:

1. Low density - mussels were dispersed over a beach such that a person could walk through the bed without stepping on any mussels.
2. High density - impossible to walk through the mussel bed without stepping on mussels. In the most extreme cases, sediments were not visible due to the coverage of mussels. Mussels could be layered over one another.

3. Medium density - any concentration of mussels that fell between low and high density.

Thirty-two beach segments were identified by the ADF&G team as containing significant amounts of subsurface oil associated with blue mussel beds (Table 2). NOAA/NMFS investigators identified an additional 18 beach segments containing oiled mussel beds sites.

DISCUSSION

The ADF&G Sea Duck Damage Assessment Study (B11), in cooperation with the NMFS Blue Mussel Study (R103) clarified the scope and magnitude of the oiled mussel bed problem in western PWS in 1991-1992. This work led to documentation of approximately 50 oiled mussel bed sites in western Prince William Sound which remained contaminated by oil through 1992.

Buried oil was prevalent beneath gravel beaches in PWS, and spilled oil also exists beneath boulders on the so-called armored beaches in PWS. The oil under the boulders is sheltered from wave action, oxidation and dispersal, and continually exposes intertidal organisms and eventually harlequin ducks to petroleum contamination.

Toxicological analyses of blue mussels have documented levels of cumulative petroleum exposure to this bivalve in oil spill areas. NRDA Study CH1B and its complementary blue mussel Restoration Study # 103 reported levels of polynuclear aromatic hydrocarbons in mussel tissue, byssal thread mats, and underlying sediments remaining in intertidal mussel beds in Prince William Sound in 1991 - 1992. The results of analysis of petroleum derived hydrocarbons indicated very high petroleum contamination levels, with aromatic hydrocarbon contamination levels reaching 4.5 ppm in mussel tissues and 48 ppm in underlying sediments (Babcock, pers. comm.).

Bird Study 11 and its complementary Restoration Study 71 have focused on the sublethal effects of petroleum exposure to harlequin ducks, a wintering and resident breeding species in Prince William Sound. Harlequin ducks are intertidal feeders and consume a wide variety of intertidal organisms, including limpets, small clams, hermit crabs, snails, and blue mussels. Blue mussels are also taken by five other waterfowl species, including Barrow's and common goldeneyes, and three species of scoters, particularly the surf scoter, which feeds both intertidally and subtidally. These other species of sea ducks, however, do not breed in Prince William Sound, with the exception of a few Barrow's goldeneyes.

Food samples collected from sea ducks were analyzed for levels of petroleum contamination. USFWS and NMFS analyses confirmed that 5 of 151 sea duck proventriculus (gullet) samples contained oiled food items at the time of collection. Three of these five ducks contained only blue mussels in their proventriculus samples. Bile samples indicated that a larger percentage of sea ducks were contaminated with petroleum residues over time.

Experimental and field studies in the literature indicated that low levels of petroleum ingestion may result in reproductive failure in seabirds, such as murres and auklets (Cavanaugh 1982; Fry et al. 1986b; Fry and Addiego 1988). Poor production in western PWS harlequin ducks was first suspected in 1990 and was documented in 1991 and 1992. In contrast, harlequins were quite productive in unoiled eastern PWS during the same period.

Because of concerns about food chain contamination, it was initially recommended in summer 1991 that oiled mussel beds and oiled substrate be physically removed where possible, and that the mussels be disposed of in such a manner that they would not re-enter the nearshore system. Resettlement of spat was believed to be rapid and the beds naturally recolonized within several years. An appropriate time frame for this activity was postulated to be in late summer and early fall while harlequin ducks feed on salmon eggs in streams and migratory sea ducks have not arrived for the winter. Removal of residual oil from contaminated mussel beds in western PWS would assist recovery of harlequin ducks and other species by reducing their exposure rate to residual petroleum contamination. Additional work was recommended to determine the extent of the oiled mussel bed problem along the Kenai Peninsula coast, Afognak Island, and the Kodiak Archipelago.

Physically removing the obviously oiled mussel beds was believed to be an important step in reducing risk of continued oil contamination to sea ducks. However, dense blue mussel beds with complete byssal thread mats may be affected by this disturbance. Once severely damaged or perturbed, the returning intertidal community structure may be radically different from the original.

Restoration of intertidal sites will require a combination of well-designed experimental treatments and long-term monitoring to assess ecological effects. Such efforts are needed to describe both the fate of oil and the specific mechanisms by which consumers such as sea ducks, oystercatchers, and sea otters are affected. Oil contamination may be transmitted through many diverse taxa of intertidal prey items. Other food items in sea duck proventriculus samples determined to be contaminated with oil were snails (*Littorina*), small crabs (*Hyas*), a small crustacean (*Saduria*), salmon eggs, and clams (*Nuculana*). A community-level approach would provide the breadth of study necessary to examine the physical and trophic complexities of the intertidal zone.

LITERATURE

Alaska Dept. of Environmental Conservation (ADEC). 1989. Prince William Sound oil spill segment file. Alphabetical indicator by island. ADEC Oil Spill Response Office, Anchorage.

Cavanaugh, K.P. 1982. The effects of South Louisiana and Kuwait crude oils on reproduction. Aspects of avian endocrinology: practical and theoretical implications. Grad. Studies, Texas Tech. Univ. 26:371-377.

Fry, D. M., J. Swenson, L.A. Addiego, C.R. Grau, and A. Kang. 1986b. Reduced production of Wedge-tailed shearwaters exposed to weathered Santa Barbara crude oil. Arch. Environ. Contam. Toxicol. 15: 453-463.

________ and L.A. Addiego. 1988. Effects of oil exposure and stress on seabird endocrine systems. Proc. 1988 Int. Assoc. Aquat. Animal Med. 19: 60-67.

McDonald, J.H. and R.K. Koehn. 1988. The mussels *Mytilus galloprovincialis* and *M. trossulus* on the Pacific Coast of North America. Mar. Biol. 99:111-118.

Seed, R. 1992. Systematics, evolution and distribution of mussels belonging to the genus *Mytilus*: an overview. Amer. Malacol. Bull. 9(2):123-137.

Wiener, A.H. and J. Slocumb. 1991. Mussel bed study draft GIS product. Alaska Dept. Nat. Resour., Div. of Land. OS Project Office, Anchorage. 9pp.

Table 1. Beach segments in the western Prince William Sound oil spill area surveyed for oiled mussel beds by B11 project staff during July and August 1992.

Exxon beach clean-up segment alphanumeric identifier (ADEC 1989)

AE001A	CU001A	IN031A*	KN145A	MU900
AE004A	CU001B	IN031B	KN207B*	NJ001A
AE005A	CU005A	IN032A	KN500A	NY001
AE005B	CU006A	KN004A	KN500B	NY001A
AE005C	CU007A	KN005B	KN5000A	NY001B
AG001*	DA002A	KN016A	KN5001A	SL1D
AG001A	DI059A	KN021A	KN5011	SL1E
AG009*	DI066A*	KN023A	KN5012A	SQ004B
AG009A	DI067A	KN103A	LA15E	
CH001	EB002A	KN113A	LA39A	
CH002A	EB011A	KN113B	MA001	
CH002B	EL011A	KN114A	MA001A	
CH009	EL013A	KN115A	MA002A	
CH009A	EL015A	KN117A	MA002C	
CH009B	EL052A	KN118A	MA002D	
CH010A	EL052B	KN119A	MA003	
CH010B	EL053A	KN120A	MA003A	
CH010C	EL054A	KN121A	MA004A	
CH011A	EV015A	KN122A	MA005A	
CH012	EV018A	KN123;A&B	MA009	
CR001A	EV036A	KN124A	MA010	
CR002C	EV037A	KN125A	MA010A	
CR004A	EV070D	KN126A	MU001C	
CR004C	EV071A	KN127A	MU002	
CR005A	IN021A	KN127B	MU002A	
CR005B	IN022A	KN132C	MU002B	
CR005C	IN022B	KN133A	MU003	
CR005D	IN023A	KN141A	MU003A	

*sites not on any previous list

Table 2. Beach segments (32) in the western Prince William Sound spill area surveyed by B11 project staff during July and August 1992 and found to contain significant amounts of subsurface oil associated with blue mussel beds.

Exxon beach clean-up segment alphanumeric identifier (ADEC 1989)	
AE005A	KN004A
AG001A	KN103A
AG009*	KN113A
CH009	KN113B
CH010B	KN114A
CH011A	KN115A
CH012A	KN119A
CR004A	KN120A
CR005B	KN121A
DI059A	KN133A
DI066A*	KN207B*
DI067A	KN500B
EL015A	LA15E
EL052A	MA002C
EL052B	SL1D
EV036A	
IN031B	

* previously unknown oiled mussel bed sites

Table 3. Descriptions of beach segments in the western Prince William Sound oil spill area surveyed by B11 project staff during July and August 1992. Acronyms are defined in the glossary following this table.

SEGMENT	DESCRIPTION/OBSERVATIONS
AE001A	Gravel beaches northwest end Applegate Island. Foot surveyed. No oil observed in mussel beds. CV and CT found in UITZ. Medium and high-density mussel beds throughout segment.
AE004A Site A	Gravel beaches southeast end Applegate Island. Foot surveyed. No oil observed in mussel beds. CV and CT found in UITZ. Medium to high-density mussel beds throughout segment.
AEOO4A Site B	Cobble and gravel beaches southeast end Applegate Island. Foot surveyed. No oil observed in mussel beds. CT in UITZ. Large, medium to high-density mussel beds throughout segment.
AE005A	Boulder/cobble beaches east side Applegate Island. HOR oil found on large, medium density mussel bed/north-facing pocket beach at south end of segment. Gravel/sand/peat matrix. Samples collected. LSOR to HOR & OP oil found in 20 of 40 test holes in UITZ. Oil depth to 8 cm.
AE005B	Cobble/gravel beach east side Applegate Island. HOR oil found on large, medium-density mussel bed/small pocket beach, SE corner of lagoon. Gravel/sand matrix. Samples collected. SOR to 5 cm deep; mostly heavy to OP. Oil found in 8 of 25 test holes.
AE005C	Gravel/cobble beach south side of Applegate Island. Foot surveyed. No oil observed in mussel bed. Small, medium-density mussel beds in gravel/sand matrix. Larger, more dense beds on bedrock.
AG001A	Boulder/gravel beach east side Aguliak Island (North Island) in middle of segment. HOR oil found on large, low-density mussel bed on gravel/sand matrix. Samples collected. HOR, OP oil; surface to 30 cm depth. Oil found in 8 of 20 test holes in transect.
AG009	Gravel beach on east side of southern Aguliak Island. HOR and MOR oil found on medium size and medium-density bed. Gravel/sand matrix. Samples collected. MOR, HOR oil - surface to 30 cm depth. Seven test holes over 20-m transect.

Table 3. (cont.) Descriptions of beach segments surveyed during July and August 1992.

SEGMENT	DESCRIPTION/OBSERVATIONS
AG009A	Cobble/boulder beach on SW end of southern Aguliak Island. No oil observed in mussel beds. Medium size, low-density mussel bed in MITZ. CV and CT on bedrock in UITZ.
CH001	Gravel/cobble beaches on mostly bedrock island. No oil observed on segment. Large, medium to high-density mussel bed on gravel/sand substrate.
CHOO2A	Boulder bedrock beaches, NE end Chenega Island.
CH002B	No oil observed in mussel bed. No substantial sediments. Boat surveyed only. Medium to high-density mussel beds throughout segment.
CH009	Lat. 60 22.67N, Long. 147 59.66W. Cobble/gravel beach NE end Chenega Is. HOR oil found. Samples collected. Large medium-density mussel bed on bedrock and cobble/gravel near small lagoon. FL & LSOR to OP oil found along 30-m transect below bedrock face in UITZ on north side of lagoon. HOR oil to 20 cm in cobble/gravel/sand matrix. HOR to OP oil to 16 cm found along separate 10m transect on south side of lagoon below bedrock face.
CH009A	Bedrock boulder beach segment NE end Chenega Island. Foot surveyed. No oil observed in low-medium density mussel bed.
CH009B	Bedrock beach NE end Chenega Island. Boat surveyed. No oil observed. No significant mussel beds in segment.
CH010A CH010C	Northeast end Chenega Island. Boat surveyed. No oil observed. No significant mussel beds in segment.
CH011A	Lat. 60° 23.49', Long. 147° 59.54' Cobble/gravel beach on north end of island. LOR oil found on medium sized, low-density mussel bed. Sand matrix. Samples collected. LOR from surface to 20 cm depth. Oil found in 8 of 11 test holes. Six test holes on 6m transect.
CH012A	Cobble, gravel beach on north end of Chenega Island.
CH102B	Trench marked with rebar (NOAA site). Not sampled. Large, high-density mussel bed covering most of the point. Heavy SOR observed in trench and FL on standing water. No holes dug.

Table 3. (cont.) Descriptions of beach segments surveyed during July and August 1992.

SEGMENT	DESCRIPTION/OBSERVATIONS
CR001A	No significant mussel beds in segment (boat survey).
CROO2C	See Mike East field notes.
CROO4A	Lat 60° 29.62' Cobble, boulder beach on NE side of southern Crafton Island. LOR and MOR oil found in large, medium-density mussel bed on sand and clay substrate. Samples collected. LOR, MOR from surface to 10cm. Six test holes on a 7m transect.
CROO4C	Gravel, cobble beach on SW side of southern Crafton Island. No oil observed in mussel bed. Large, medium-density bed on sand and clay substrate. CT and TB on bedrock in UITZ.
CROO5A	No significant mussel beds in segment. Boat survey.
CROO5B	Boulder, cobble beach in lagoon on west side Crafton Island. MOR oil found in large, low-density mussel bed on sand and mud matrix. Samples collected. MOR and some HOR oil from surface to 16cm depth. Oil found in 8 holes along 50-m transect.
CROO5C	No significant mussel beds in segment. Boat survey.
CROO5D	No significant mussel beds in segment. Boat survey.
CU001A	Small islets SW tip of Culross Island. Foot surveyed. No oil observed in mussel bed. Large high density mussel bed on gravel tombolo from islet to Culross Island. 0.5m band of CV CT oil on bedrock face UITZ on smaller tombolo south of described bed. CU001B Gravel/cobble beaches SW end Culross Island. Foot surveyed. No oil observed. Small, low density mussel beds.
CU005A	Cobble/gravel/bedrock beaches SE end Culross Island. Boat surveyed. No oil observed. No significant mussel beds on segment.
CU006A	As above.
CU007A	As above.

Table 3. (cont.) Descriptions of beach segments surveyed during July and August 1992.

SEGMENT	DESCRIPTION/OBSERVATIONS
DA002A	Bedrock/gravel beaches on north side of Danger Island. No oil observed in low- to medium-density mussel beds on gravel substrate. ST and CT on bedrock in UITZ.
DI059A	Cobble/gravel/bedrock beach NE end Disk Island. MOR oil found; medium size, medium density mussel bed. Samples collected. MOR to OP oil found along 15-m transect in MITZ. HOR oil to 10 cm+ in gravel/sand matrix. TB, CV, & CT in UITZ along bedrock face.
DI066A	Gravel tombolo west side Disk Island. HOR oil found in large, high-density mussel bed. Heavy byssal thread mat on tombolo leading into Disk anchorage. Samples collected. HOR to OP oil to 30 cm along 30-m transect. Heavier concentrations of oil along base of bedrock face on west side of tombolo. Aromatics noticed. FL on surface water. Black mobile oil in sample holes.
DI067A	Cobble/boulder/bedrock beach next to small islet in bay on west side of Disk Island. OP oil found in medium size, medium density mussel bed between jutting bedrock in front of islet. Samples collected. OP-HOR oil along 25-m transect to 16 cm+ deep, black mobile oil on underside of boulders and puddled in water in all sample holes. Heavy aromatics noticed. FL on standing water.
EB002A	Mainland coast north of Eshamy Bay, behind Crafton Island. Foot surveyed. No oil observed in small, medium density bed on gravel/sand matrix.
EB011A	Exposed bedrock coastline. Boat surveyed. No significant mussel beds in segment.
EL011A	Boulder/cobble beach on NW side of large peninsula on SW side Eleanor Island. No oil observed in large, medium-density mussel bed. CV and CT on bedrock UITZ. No oil in test holes.
EL013A	No significant mussel beds in segment. Boat surveyed.
EL015 A	Gravel cobble beach SW side Eleanor Island. LOR oil found in large, medium density bed over large area of beach segment. Samples taken. LOR oil found in small 5-m transect of this bed. LSOR visible near largest rock directly across from Block Island. Oil to 6 cm depth. 50+ test holes dug to find oiled area.

Table 3. (cont.) Descriptions of beach segments surveyed during July and August 1992.

SEGMENT	DESCRIPTION/OBSERVATIONS
EL015 B	Gravel/cobble/boulder beach on north end of Block Island directly across from Site A. HOR oil found in large, medium- to high-density mussel bed. Spat-sized to large mussels on gravel/cobble substrate. Samples taken. SOR, MOR to OP oil along 20-m transect to 12cm in depth. FL, rainbow sheen on standing pools of water. Black mobile oil under boulders.
EL052A	Lat 60° 33.06', Long 147° 35.90". Boulder cobble beach in west arm of Northwest Bay. MOR oil found in medium size, low-density mussel bed. Samples collected. MOR with some HOR pockets in 19 of 21 test holes. Ten-meter transect with 8 test holes.
EL052B	Lat 60° 32.61', Long 147° 36.22'. Gravel beach at head of Northwest Bay, west side. MOR oil found on large, low to medium density bed in gravel/sand matrix on either side of small stream. Samples taken. LOR to HOR found from 8 cm subsurface to 18 cm+ deep along 30-m transect below bedrock face on left side of stream. 30+ test holes dug.
EL053A	No significant mussel beds in segment (boat survey).
EL054A	No significant mussel beds in segment (boat survey).
EV015A	Cobble beaches on NE side Evans Island. No oil observed on segment. Dense, large mussel bed on northernmost point of segment on cobble/gravel beach.
EV018A	Mussels on bedrock only. No oil observed (boat survey).
EV036A	Cobble and boulder beaches on NE side Evans Island. MOR oil found in medium size, high-density mussel bed on clay/sand substrate between bedrock outcrops at north end of segment. Samples collected. FL in tidal pools. MOR and some HOR in mussel bed to 5cm depth. Transect 10 m long with 6 test holes.
EV037A	Bedrock/boulder/cobble beaches on NE side Evans Island. No oil observed in mussel beds. Dense mussels primarily on large boulders and bedrock faces. LOR and CT at base of bedrock in UITZ at south end of segment.

Table 3. (cont.) Descriptions of beach segments surveyed during July and August 1992.

SEGMENT	DESCRIPTION/OBSERVATIONS
EV070D	Boulder/gravel/mud beaches on west side Evans Island. No oil observed in mussel bed. Medium size, high-density mussel bed at end of north-facing lagoon on sand/mud substrate.
EV071A	Boulder/cobble beaches in bay on west side Evans Island. No oil observed in mussel bed. Medium size, low density bed near stream mouth at end of bay on gravel/sand substrate. Scattered small pockets of LOR in UITZ.
N021A	Bedrock/cobble beaches on east side Ingot Island. No oil observed in mussel bed. Medium size, high-density mussel bed. CV and CT on bedrock in UITZ.
N022A	Small cove east end of segment. No oil observed in medium-density mussel bed.
IN022B	No substantial mussel beds in substrate. Boat survey.
IN023A	No substantial mussel beds observed. Boat survey.
IN031A	North side Ingot Island, at Foul Pass behind Disk Island. No oil observed in mussel beds. Large, high-density mussel beds.
IN031B	Rocky point connected to mainland by gravel tombolo. LSOR oil found in large low density mussel bed, on gravel sand substrate. Samples collected. LSOR from 5 test holes on 6-m transect on gravel tombolo. Five of 20 test holes contained oil.
IN032A	No significant mussel beds in segment. Boat survey.
KN004A	Gravel/cobble beach, North of Death Marsh. Near West Arm point, Bay of Isles. MOR oil found in medium size, medium-density mussel bed on cobble/gravel substrate. Samples collected. MOR oil along 20-m transect to 16 cm depth, in cobble/gravel/sand matrix. FL on pools of water and along tide line.
KN005B	Small cove SE of West Arm, Bay of Isles. No oil observed in mussel bed. MOR to OP oil found in UITZ above mussel bed, to 30cm depth. Medium-sized, medium density mussel bed.
KN016A	Bedrock coastline on small Island in Bay of Isles. No mussels in substrate. Boat survey only.

Table 3. (cont.) Descriptions of beach segments surveyed during July and August 1992.

SEGMENT	DESCRIPTION/OBSERVATIONS
KN021A	Bedrock coastline on small Island, in Bay of Isles. No substrates, mussels on bedrock only. Boat survey.
KN023A	Bedrock coastline on small island, Bay of Isles. Mussels on bedrock only. Boat survey.
KN103A	Gravel/cobble beach south side of Lower Passage, in small bay near Opal Creek. <u>MOR oil found</u> in large medium density mussel bed, near largest rock on NW side of segment, 370 m N of stream mouth. Samples collected. SOR oil along 10m transect, MOR oil to 12cm depth in gravel sand matrix. This is a small section of a very large, dispersed mussel bed. 60+ test holes dug to find this oiled section. MOR oil found near Opal Creek mouth on east side, in UITZ above mussel bed.
KN113A	Small cove on NE end of Herring Bay. MOR-HOR <u>oil found</u> in small, low density bed in boulder/cobble on right side of cove near bedrock face. Samples collected. MOR to HOR oil in small mussel bed along 20-m transect in MITZ to 12+cm deep. OP/HOR oil in UITZ along base of bedrock face in boulders above mussels.
KN113B*	Small pocket beach NE side of Herring Bay. HOR <u>oil found</u> in large, high-density mussel bed on gravel substrate behind offshore rock. HOR/OP oil found along 20M transect to 12 cm deep in gravel/sand matrix just below cobble section of beach. Black mobile oil on underside of rocks. Aromatics present. *Note: This site was reported washed out by a storm on 8/26/92.
KN114A	Small islet west of KN114A shoreline NE side of Herring Bay. HOR/OP <u>oil found</u> in large, medium to high density mussel bed mainly on bedrock and offshore rocks on NE side of islet. Samples collected. OP/HOR oil along 7-m transect only in gravel section of mussel bed at MITZ. OP oil to 40+ cm deep. Heavy aromatics/rainbow sheen at tide line. Mobile black oil on underside of rocks.
KN115A	First large bay on NE side of Herring Bay south from Lower Passage. LOR <u>oil found</u> in medium size, medium-density mussel bed on cobble boulders (*Fucus*-covered). Samples collected. LOR to MOR oil along a 20m transect in MITZ. MOR oil found higher up beach in UITZ. Abundant runoff made depth of oil difficult to determine.
KN117A	Mussels on bedrock only. No substantial beds in substrate. Boat surveyed.

Table 3. (cont.) Descriptions of beach segments surveyed during July and August 1992.

SEGMENT	DESCRIPTION/OBSERVATIONS
KN118A	North side of largest bay on NE side of Herring Bay. No oil observed in medium size, medium density mussel bed (foot surveyed).
KN119A	Lat. 60° 27.96'/ Long. 147° 41.83'. Large bay on NE side of Herring Bay. HOR oil found in large, medium density bed on cobble/gravel beach. Small stream on south end of bed. Samples collected. HOR oil found along 30-m transect to 10+cm depth. Rainbow sheen observed along tide line.
KN120A	Lat 60° 27.58'N/ Long 147° 41.87'W. Head of largest bay NE side of Herring Bay. MOR oil found in large, medium density bed at mouth of stream on gravel/cobble beach. Samples collected. MOR oil found along a 10-m transect to 12+cm depth in gravel/sand sediments. Oiled area to left of streambed.
KN121A	Lat 60° 28.6'N / Long° 147 42.70'W. Pocket beach on point at north end of segment in Herring Bay. LOR oil found in large medium density bed on small cobble/gravel beach interspersed with fucus and algae. Samples collected. LOR oil found along 7-m transect to 6cm depth in sand mud sediment. No other oil observed at this site.
KN 122A, 123A&B, 124A, 125A, 126A, 127A&B.	Segments on south end of Herring Bay. No significant mussel beds observed; mussels in sediments on bedrock only. Boat surveyed.
KN123	Tidal lagoon on island at south end of Herring Bay. No oil observed in mussels. A few TBs in HITZ. Foot surveyed.
KN132C	Camp Creek at ADF&G base camp site. No oil observed in mussels. AP/OP/MOR/HOR/CT/CV/TB/SOR found in upper HITZ in boulder and bedrock. 57 test holes dug in mussel beds.
KN133A	Lat 60° 26.76 / Long. 147° 45.54'. Gravel/sand tombolo, East side of island. MOR oil found in medium size, medium-density mussel bed on sand and crushed shell substrate. Samples collected. MOR oil found in 16 of 24 test holes from 2-10 cm in depth.
KN141A	No significant mussel beds in segment. Boat surveyed.
KN145A	No significant mussel beds in segment. Boat surveyed.

Table 3. (cont.) Descriptions of beach segments surveyed during July and August 1992.

SEGMENT	DESCRIPTION/OBSERVATIONS
KN207B	Lat 60° 23.30' / Long 147° 38.47'. Boulder/cobble beach in semi-protected embayment at east end of segment. MOR to HOR oil found in small, medium-density mussel bed on gravel/sand substrate. Samples collected. Predominately MOR oil found in 6 test holes along 20-m transect.
KN500A	Small cove NW side of Herring Point. No oil. Mussel beds on bedrock only. Boat surveyed.
KN500B	Lat 60° 28.42' / Long 147° 47.49'. Small gravel/cobble beach in cove on NW side of Herring Point. HOR to OP oil found in large, low-density mussel bed on left side of gravel/cobble beach. Small stream located in this cove. Samples collected. HOR to OP oil along 10m transect below bedrock face. HOR oil to 20cm in gravel/sand matrix. Mobile black oil on underside of rocks. Sheen visible.
KN5000A	Small cove behind islet in SE end Herring Bay. No oil observed in mussel bed. Foot surveyed. Medium to high-density mussel bed on tombolo to islet.
KN5001A	Last cove in south end of segment; SE end of Herring Bay. No oil observed in mussel bed. Foot surveyed. Large, low to medium density mussel bed.
KN5011	No substantial mussel beds observed. Boat survey only.
KN5012A	As above.
LA15E	Bedrock/boulder/cobble beach on NE side Latouche Island. NOAA site. HOR oil found. Not sampled since NOAA team had previously collected samples at site during 6/92.
LA39A	Cobble/gravel beach on west side of Latouche Island. No oil observed in mussel bed or anywhere on segment. Large, low-density mussel bed on low angle beach to south of stream at mid-segment. Mussels on gravel/sand substrate.
MA001, MA001A, MA002A	No significant mussel beds in these segments. Boat surveyed.

Table 3. (cont.) Descriptions of beach segments surveyed during July and August 1992.

SEGMENT	DESCRIPTION/OBSERVATIONS
MA002C	Largest island in east side of Foul Bay. OP oil found in large, medium-density mussel bed in lower MITZ. High exposure site. Samples collected in OP/HOR oil found along 25m transect to 20+cm depth. Rainbow sheen on standing water. SOR oil visible and high aromatics present. Black mobile OP oil on underside of rocks. Heavily oiled site.
MA002D	No significant mussel beds in segment. Boat surveyed.
MA003	As above.
MA003A	Cobble/boulder beach on exposed mainland coastline. Remainder of segment is primarily bedrock coastline. No oil observed in medium size, medium-density mussel bed at north end of segment.
MA004A	No significant mussel beds in segment. Boat surveyed.
MA005A	As above.
MA009	Mainland coast south of Main Bay. No oil observed in mussel beds. Foot surveyed. Large, high-density beds over large area including bedrock and boulder/cobble/gravel on tombolo to offshore rocks.
MA010	Mussels on bedrock only; no oil observed. Boat surveyed.
MA010A	No significant mussel beds in segment. Boat surveyed.
MU001C	Mostly bedrock coastline with small pocket beaches on west side of Mummy Island. No oil observed in two small mussel beds of medium density at north end of segment on gravel/sand substrate. 15 test holes - no oil.
MU002	No significant mussel beds in segment. Boat surveyed.
MU002A	As above.
MU002B	As above.
MU003	Small islands west of Mummy Island. No oil observed in small, high density, low exposure mussel bed on east side of northernmost Island. Foot surveyed.

Table 3. (cont.) Descriptions of beach segments surveyed during July and August 1992.

SEGMENT	DESCRIPTION/OBSERVATIONS
MU003A	No significant mussel beds in segment. Boat surveyed.
MU900	As above.
NJ001A	No significant mussel beds in segment. Boat surveyed.
NY001	No significant mussel beds in segment. Boat surveyed.
NY001A	Small islet on north end of New Year Island. No oil observed in mussels - on bedrock only. Boat surveyed.
NY001B	Larger of 2 islets off north end of New Year Island. Foot surveyed. No oil observed in large, medium to high-density mussel bed.
SL1D	Bedrock coastline with cobble/gravel pocket beaches on east side of Squirrel Island. HOR & OP oil found in medium size and medium-density mussel bed on gravel/sand substrate in peat underlayment; south end of segment. Samples collected. LSOR at edges of mussel bed grading to HOR and OP through the middle of the bed. 27 of 30 test holes were oiled. Depth of oil from surface to 20 cm. 10 test holes in 10m transect.
SL1E	Cobble/gravel beaches on southern embayment of Squirrel Island. No oil observed on segment. Small, medium density mussel bed at end of bay. 12 test holes - no oil observed.
SQ004B	Bedrock shoreline with pocket beaches on north side of island. No oil found in mussel beds. Medium size, medium-density mussel bed on north side of island on pocket beach. TB and AP in UITZ on west side of island.

GLOSSARY OF OILING TERMINOLOGY

SURFACE OIL CHARACTERS

AP ASPHALT PAVEMENT: heavily oiled beach sediments held cohesively together.

MS MOUSSE/POOLED OIL: any oil/water emulsion with a thickness greater than 1 cm.

TB TAR BALLS, PATTIES, & TAR PATTIES; small, distinct oil deposits lying on top of the beach surface; possibly binding debris, but typically not sediments.

SOR SURFACE OIL RESIDUE: significantly oil coated beach sediments in the top 5 cm; sediments do not form a cohesive layer. SOR should be described in terms of Heavy or Light.

CV COVER: oil greater than 1 mm to greater than or equal to 1 cm thick.

CT COAT: oil greater than 0.1 mm thick to greater than or equal to 1 mm thick, can be easily scratched off with fingernail.

ST STAIN: oil greater than or equal to 0.1 mm thick that cannot be easily scratched off with fingernail.

FL FILM or SHEEN: transparent or translucent film or sheen.

DB OILED DEBRIS: any oiled debris or cleanup material stranded on a shore; LG signifies oiled logs; VG signifies oiled vegetation; TR signifies clean-up related trash and/oiled trash.

NO NO OIL: no oiling observed at the location.

SURFACE OIL DISTRIBUTION

C CONTINUOUS:	area or band with 91% to 100% oil coverage
B BROKEN:	area or band with 51% to 90% coverage
P PATCHY:	area or band with 11% to 50% coverage
S SPLASH:	area or band with 1% to 10% coverage
T TRACE:	area or band with less than 1% coverage

SURSURFACE OIL DISTRIBUTION

OP OIL PORE: pore spaces are completely filled with oil, resulting in oil oozing out of the sediments - water cannot penetrate an OP zone.

HOR HEAVY OIL RESIDUE: pore spaces are partially filled with oil residue, but not generally flowing out of sediments.

MOR MEDIUM OIL RESIDUE: heavily coasted sediments: pore spaces are not filled with oil - pore spaces may be filled with water.

LOR LIGHT OIL RESIDUE: sediments lightly coated with oil.

OF OIL FILM: continuous layer of sheen or film on sediments, water may bead on sediments.

TR TRACE: discontinuous film, spots of oil on sediments, an odor or tackiness with no visible evidence of oil.

NO NO OIL OBSERVED

APPENDIX 4

SUMMARY REPORT ON HISTOPATHOLOGY OF SEA DUCK TISSUES
EXXON VALDEZ OIL SPILL: BIRD STUDY 11

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College of Veterinary Medicine

January 11, 1993

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January 11, 1993

Mr. Don Calkins
Alaska Department of Fish and Game
333 Raspberry Road
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Dear Don:

This letter is in reference to histopathology done on sea ducks collected following the Exxon Valdez oil spill. A total of 202 birds were examined histologically. That includes 29 from the Juneau region, 33 from the Cordova region, 36 from the Kodiak region and 104 from Prince William Sound. The tissues from several more birds were submitted, but their containers broke during transit and their tissues were not suitable for histological studies. The diagnoses from each individual region (Kodiak, Cordova, Juneau and Prince William Sound) will be discussed separately. All of the diagnoses found in individual birds are included in Table 1. Table 2 gives the meaning of the abbreviations used in Table 1.

Kodiak

A total of 36 birds were examined from the Kodiak region.

Nervous System -- One bird was found to have a change in the nervous system. This lesion was characterized by a mild microcavitation of the neuropile of the brain. This lesion is probably an artefact associated with fixation. No significant lesions were found in the nervous systems of birds from Kodiak.

Special Senses -- Four birds had lesions within the special senses from the Kodiak region. One bird had a mild degree of microcavitation of the poles of the lens. This lesion is most likely associated with artefact of fixation with weak formalin. Two birds had a mild microcavitation of the cornea of the eye, this, too, is most likely associated with the formalin fixation. Two birds had a mild, focal lymphoid hyperplasia within the conjunctiva. This mild lymphoplasmacytic conjunctivitis is fairly common in free-ranging animals and can be caused by numerous agents. No significant histological lesions were found in the special senses in birds from Kodiak.

Digestive System -- Numerous lesions were found in the digestive system of birds from Kodiak. The most common lesion was a mild to moderate mononuclear cellular/lymphoplasmacytic cellular reaction within the liver. These cells were especially prevalent around hepatic portal triad regions. This lesion (D-2) is most likely associated with parasitic activity. Two birds had a mild, multifocal hepatitis which was also probably associated with parasitic activity. One bird had a mild degree of lymphoid hyperplasia (follicular) within the liver parenchyma. This is a lesion similar to the mild, mononuclear lymphoplasmacytic hepatitis as described earlier. One bird had a mild, multifocal lymphoid hyperplasia present throughout the liver that was most likely associated with schistosomes (a type of trematode that is extremely common in ducks). All the lesion found in the digestive system of birds from Kodiak were probably associated with parasitic activity.

Musculoskeletal System -- Two birds had a mild infection of sarcocysts and one bird had a pyogranulomatous lesion within the skeletal muscle that was most likely associated with foreign material, probably feathers. This latter lesion is probably secondary to an old gunshot. No significant lesions were found in the musculoskeletal system in birds from Kodiak.

Urogenital System -- Three different diagnoses were found in the kidneys of birds from Kodiak. At least 14 birds had a mild to moderate, lymphoplasmacytic nephritis that was associated with trematodes and/or trematode ova. Three birds had a lymphoplasmacytic nephritis in which coccidia were found within epithelium lining the renal calyxes. Eleven birds had a lymphoplasmacytic nephritis nearly identical to the birds that either had trematodes or coccidia within the tubules. However, these specific organisms were not observed. However, this nephritis was most likely due to the parasites as mentioned previously. This lymphoplasmacytic nephritis is a condition that is common in birds and is associated with parasitic activity.

Lymphohemopoietic System -- One bird did have a mild lymphoid hyperplasia of the spleen. This is a relatively non-specific reaction and could be due to numerous agents, including parasites.

Respiratory System -- One bird had a small, focal, chronic granuloma within the lung. This was probably due to an old, healing bacterial or Aspergillus infection. One bird had a mild degree of mineralization within the lung which was also probably secondary to an old, healed area of inflammation, such as bacterial or fungal infection. No significant lesions were found in the respiratory systems of birds from Kodiak.

Parasitism -- Numerous parasites were found in various tissues of these animals. Trematodes were found in the liver of 2 birds. Trematodes were found in the small intestines of 10 birds and in the cecum in 4 birds. Cestodes were found in the small intestines of 7 birds and in the cecum of 2 birds. Nematodes were found in the small intestines of 1 bird and coccidia were found in the kidneys of at least 3 birds. The number and types of parasites found in these birds are normally found within free-ranging waterfowl.

No Histological Lesions -- No histological lesions were found in the tissues from 1 bird.

Cordova

Histological studies were done on 33 birds from Cordova. No lesions were found in the nervous system, eyes, lymphohemopoietic system, endocrine system or the skin.

Digestive System -- Nineteen birds did have mild to moderate, lymphoplasmacytic accumulations within the liver. This form of mild lymphocytic plasmacytic hepatitis was probably associated with parasitic activity. Three birds had a mild lymphoid follicular hyperplasia within the liver of which 2 birds showed cross-sections of schistosomes; schistosomes were not found in the third, but the lesions were highly suggestive of a schistosome infection. Four birds had a mild degree of mineralization within the mucosa of the small intestines. This is probably a chronic, healed lesion, most likely associated with schistosomes. One animal had a mild inflammatory reaction within the ducts of the pancreas. This, too, was most likely due to pancreatic flukes. However, flukes were not found.

Urogenital System -- Thirty birds had a mild to moderate, lymphoplasmacytic nephritis, primarily within the renal calyxes. This lesion is most likely associated with parasites. Trematodes were found within the kidney associated with this inflammatory response in 6 birds and coccidia in 1. This nephritis is extremely common in waterfowl and is usually associated with either trematodes or coccidia.

Respiratory System -- One bird had a mild degree of mineralization of the lung, another bird had a mild, focal area of lymphoid hyperplasia. These lesions are probably areas of a previous infection. One bird had a mild degree of lymphoplasmacytic and heterophilic infiltration of the lung, suggesting a small focus of active pneumonia. Birds had numerous parasites, including cestodes, trematodes and coccidia in various organs, including the small intestines, large intestines, liver. The degree of parasitism in these birds from Kodiak were well within normal limits.

Juneau

A total of 29 birds were examined from the Juneau area.

Digestive System -- Fifteen birds from Juneau had a similar lymphoplasmacytic/mononuclear hepatitis that was most likely associated with mild parasitism. Two birds had mild, focal mineralization within the small intestine.

Urogenital System -- Twenty-five birds had a lymphoplasmacytic nephritis. Five of these birds had trematodes associated with this inflammation. Twenty birds had the inflammatory process, but parasites were not observed.

Lymphohemopoietic System -- One bird had a mild degree of lymphoid depletion within the spleen.

Respiratory System -- One bird had a mild degree of lymphoid proliferation within the lung. Two birds had small, focal areas of active pneumonia. These lesions are not unusual in free-ranging birds.

Parasitism -- These birds had numerous parasites that were similar in number and type as observed in all other birds.

No Histological Lesions -- One bird did not have histological lesions.

Prince William Sound

A total of 104 birds were examined from Prince William Sound.

Nervous System -- Four birds had lesions in the nervous system. However, these lesions were highly suggestive of artefactual changes associated with fixation.

Digestive System -- Forty-eight birds had a lymphoplasmacytic/mononuclear infiltration within the adventitia of the hepatic portal triads which is considered a mild degree of hepatitis. This lesion is extremely non-specific and most likely due to parasitism. Five birds had a mild degree of lymphoid hyperplasia of the liver in which cross-sections of schistosomes were found. One bird had a mild degree of mineralization of the small intestine which was probably associated with parasitic activity. One bird had mild dilatation of sinusoids which is not uncommon and is of little significance. One bird had a mild degree of necrotizing pancreatitis. The cause of this lesion was not determined. One bird had a mild degree of lymphoid hyperplasia within the small intestine. This is probably associated with parasitic activity. One bird had a mild degree of fatty degeneration of the liver. This may be dietary because the bird may have been fairly fat and had not eaten for several days, associated with migration. There

are many dietary causes of fatty degeneration. This fatty degeneration is fairly non-specific and is of little importance.

Musculoskeletal System -- Four birds were found to have sarcocysts within the skeletal muscle.

Urogenital System -- Seventy-seven birds were found to have a mild to moderate degree of lymphoplasmacytic nephritis, primarily surrounding renal calyxes. Of these animals, 4 of them were found to have a trematode or trematode eggs within the lumen of calyxes and 7 were found to have coccidia within renal epithelium. The remaining 67 birds had the typical inflammatory response, however, specific organisms were not found. One bird had a mild degree of lymphoid hyperplasia within the testes. Two birds had a mild degree of interstitial cell hyperplasia within the testes.

Lymphohemopoietic System -- Five birds had a mild to moderate degree of lymphoid hyperplasia within the follicles of the spleen and 3 birds had a lymphoid depletion within lymphoid follicles of the spleen.

Respiratory System -- Two birds had a mild degree of lymphoid hyperplasia within the lungs. One bird had a small, focal area of pneumonia.

Parasitism -- Numerous cestodes, trematodes, coccidia and schistosomes were found within small intestines, large intestines, liver and kidney of tissues from these birds. The degree of parasitism in the birds from Prince William Sound were no different from the parasites that were found in the birds from Cordova, Juneau or Kodiak.

No Histological Lesions -- No histological lesions were found in the submitted tissues from 6 birds.

<u>Summary</u>

In summary, 202 birds were examined in detail histologically in search of histological lesions that may have been associated with oil contamination. Numerous lesions were found in these birds, but they were all considered to be relatively common lesions found in free-ranging waterfowl. The majority of these lesions were associated with parasites or mild bacterial infections. No specific lesions that could be associated with oil toxicity were found in submitted tissues from these sea ducks.

Sincerely,

Terry R. Spraker
DVM/Ph.D.

APPENDIX 5

COMPARATIVE DATA ON BLUE MUSSEL CONTAMINATION

Blue mussels (*Mytilus trossulus*)[1] are an important sea duck food species and are well known for their ability to concentrate pollutants at high levels. We obtained data from other investigators on contamination levels of sea duck food species.

ADEC (1989) collected samples of blue mussels in the oil spill area of western PWS in May and June 1989. Mussel tissues, but not shells or byssal threads, were analyzed for PAH and TPH (total petroleum hydrocarbons) by Enseco-Erco Laboratory. Samples were taken from the following sites: Esther Island, Wilson Bay, Shelter Bay, Herring Bay, Block Island, Bay of Isles, and Northwest Bay. Esther Island was an unoiled reference control site. Wilson Bay was a lightly oiled site. Shelter Bay was a moderately oiled site. Herring Bay, Block Island, and Bay of Isles were heavily oiled.

Data on petroleum hydrocarbon levels in blue mussels at sites in PWS was also obtained from NRDA Coastal Habitat Study 1B and its complementary Restoration Study 103 (the NOAA Auke Bay blue mussel study). The intensity of petroleum hydrocarbon contamination of oiled mussel beds was determined by measuring amounts of polynuclear aromatic hydrocarbons (PAHs) in mussel tissue, in mussel byssal thread mats, and in underlying sediments.

Mussel tissue samples collected from a control site at Esther Island had few polynuclear aromatic hydrocarbons detected. Total petroleum hydrocarbons were barely above detection limits or not detected. Mussel tissue samples from Wilson Bay, a lightly impacted site, had low levels of polynuclear aromatic hydrocarbons and low or not detectable levels of total petroleum hydrocarbons. Mussel tissue samples collected by ADEC from Shelter Bay, a moderately impacted site, had elevated levels of pristane and phytane, and C19, C20, and C25 petroleum hydrocarbon analytes. Mussel tissues also had elevated levels of C3- and C4-naphthalenes, C3-fluorene, C1-, C2-C3- and C4-phenanthrenes/anthracenes, and C1, C2-, C3-dibenzothiophenes (ADEC, 1989).

The mussel tissue samples from heavily oiled sites at Block Island, Herring Bay, Northwest Bay, and Bay of Isles had elevated levels of C17, pristane, C19, C21, C23, C24, and C25 analytes (ADEC 1989). The mussel tissue samples also had particularly elevated levels of C2-, C3-, and C4-naphthalenes, C1-, C2-, and C3-fluorenes, C1-, C2- and C3-phenanthrene/anthracenes, and C1-, C2- C3-dibenzothiophenes.

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[1] For a discussion of the taxonomy of this species in the Pacific Northwest see McDonald and Koehn (1988) and Seed (1992).

The general tendency with increasing site oiling is for a greater number of petroleum hydrocarbon analytes to appear in the mussel tissue analysis, with elevated levels (in ug/kg dry weight) of polynuclear aromatic hydrocarbon exposure.

NMFS (NOAA) collected more than 500 fish and shellfish samples from the track of the EVOS in July, August, and September 1989 (Varanasi 1990). Tissue samples (edible flesh for a subsistence survey) were analyzed for aromatic contaminants (ACs) from petroleum (alkylated and unsubstituted aromatic hydrocarbons with 2-7 benzenoid rings and dibenzothiophenes). Intertidal molluscs (mussels, clams, chitons, and snails) from Chenega Bay in PWS, Windy Bay on the southern Kenai Peninsula, Kodiak City, and Old Harbor on Kodiak Island consistently had more than 100 ppb aromatic contaminants, with levels in mussels from Windy Bay and Kodiak as high as 12,000 to 18,000 ppb.

NMFS analyzed edible flesh of an additional 28 composite mussel samples from the track of the EVOS in early 1990 (Varanasi 1990). NMFS analyzed a total of 20 further samples of edible flesh of mussels in summer 1990 (Varanasi 1990). Most of the occurrences of high AC levels were for mussels from Windy Bay.

High aromatic contaminant (ACs) levels in summer 1990 were from mussels in the upper intertidal, which exhibited visible signs of oil. Mussel samples collected in the lower intertidal zone had much lower levels of ACs. The 1990 winter sampling also had high AC levels in mussels from the upper intertidal zone but not in those from the lower intertidal. The results indicate continued exposure of mussels to ACs at Windy Bay, with highest levels found in the intertidal zone. Additionally, mussels from Chenega Bay were exposed to a well-weathered oil. At both of these sites, there was little evidence of a substantial decrease in the exposure of mussels to ACs by 1990. Varanasi et al. (1993) collected an additional 75 samples of shellfish during April 1991 at Windy Bay. High concentrations of ACs were present in mussel samples collected in the upper intertidal zone in the winter and summer of 1990. Concentrations of ACs at this site in the spring of 1990 and spring of 1991 were much lower. Continued investigation of this site should indicate whether the decrease over time is actual or a seasonal phenomenon.

NOAA investigators Karinen and Babcock (1991) reported high levels of total petroleum aromatics and selected hydrocarbon groups in mussels sampled by an interagency team (including B11 researchers) in several locations in western Prince William Sound in June 1991. Analysis of 24 samples collected in 1991 indicated very high petroleum contamination levels, with aromatic hydrocarbon contamination levels reaching 4.5 ppm in mussel tissues and 48 ppm in underlying sediments. Levels of phenanthrenes, dibenzothiopenes, and chrysenes in mussels at beds in Bay of Isles, at Latouche Island and Eleanor Island were particularly high.

The high levels of aromatics reported in the laboratory study confirm field observations by ADFG, ADEC, and NOAA of unweathered crude oil remaining in mussel beds in Prince William Sound through 1992. Blue mussels are the most probable source of transmission of petrochemicals through the sea duck food chain.

LITERATURE

Alaska Dept. of Environmental Conservation (ADEC). 1989. Prince William Sound oil spill segment file. Alphabetical indicator by island. ADEC Oil Spill Response Office, Anchorage.

Karinen, J.F. and M. M. Babcock. 1991. Pre-spill and post-spill concentrations of hydrocarbons in sediments and mussels at intertidal sites within Prince William Sound and the Gulf of Alaska. NRDA Draft Status Report, Coastal Habitat Study No. 1B. Nat. Mar. Fish. Serv., Auke Bay Lab., Auke Bay, Alaska.

McDonald, J.H. and R.K. Koehn. 1988. The mussels *Mytilus galloprovincialis* and *M. trossulus* on the Pacific Coast of North America. Mar. Biol. 99:111-118.

Seed, R. 1992. Systematics, evolution and distribution of mussels belonging to the genus *Mytilus*: an overview. Amer. Malacol. Bull. 9(2):123-137.

Varanasi, U. 1990. Survey of subsistence finfish and shellfish for exposure to oil spilled from the *Exxon Valdez*: the first year. NOAA, NMFS. Northwest Fisheries Center, Env. Cons. Div. Seattle. Memorandum F/NWC 191. 151pp.

________, T. Hom, D.G. Burrows, C.A. Sloan, L.J. Field, J.E. Stein, K.L. Tilbury, B.B. McCain, and S.-L. Chan. 1993. Survey of Alaskan subsistence fish, marine mammal and invertebrate samples collected 1989 - 1991 for exposure to oil spilled from the *Exxon Valdez*. NOAA Technical Memorandum NMFS-NWFSC. National Technical Information Service. U.S. Dept. Commerce. 5285 Port Royal Rd., Springfield VA 22161. 40pp. + appendices.

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

Assessment of Injury to Sea Ducks from Hydrocarbon Uptake in Prince William Sound and the Kodiak Archipelago, Alaska, Following the *Exxon Valdez* Oil Spill

Vol. II. Supplements

Bird Study Number 11
Final Report

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February 2000

PREFACE

The work in this Supplement originated as part of the State - Federal response to the 1989 *Exxon Valdez* oil spill. During the development of Natural Resources Damage Assessment (NRDA) Bird Study 11 (B11), the necessity for documenting the oiling and clean-up history of known (and potential) harlequin duck habitats in western Prince William Sound became evident. This documentation was initially driven by legal reasons, i.e. in order to determine the degree of injury to the species. However, it also was intended to compile information resources for future scientific work on spill-related topics or regional ecological studies.

A chronology of oiling in three major habitat types was correlated with compiled observations of harlequin ducks at sites keyed to the Exxon beach segment identifier system (ADEC 1989). The beach segment identifier system enables cross-referencing to agency files containing the oiling history of each site, as well as the subsequent clean-up treatments (manual, mechanical, and chemical) applied to segments during 1989 - 1991. Because harlequin ducks breed on streams and there was no use of suitable streams by pairs in most of western Prince William Sound during the nesting seasons of 1991 and 1992, additional oiling and clean-up information was compiled for streams.

Supplement 1

B11 project staff researched agency oil spill files in Anchorage during 1991 for documentation of oiling to four harlequin duck habitat types in western Prince William Sound. This effort was conducted in order to provide a synopsis of *Exxon Valdez* oiling of offshore rocks, bays and lagoons, mussel beds with known harlequin use, and streams with potential harlequin duck use. The most productive searches were conducted at the Oil Spill Public Information Center (OSPIC) library and at the U.S. Coast Guard Federal On-Scene Coordinator (FOSC) offices. This research provided a detailed history of oiling of important harlequin duck habitats.

Supplement 2

B11 project staff also compiled and summarized extensive supporting information on oiling of anadromous fish streams in western Prince William Sound where harlequins would be expected to nest. Staff utilized all available sources of oiling information compiled 1989 - 1991 by ADFG, Habitat Division. This information was keyed to the numbered streams in the Anadromous Stream Catalog (ASC) (ADFG 1990). The information was supplemented with ADEC stream data, ADFG Commercial Fisheries and Sport Fisheries surveys, videotapes, and other data on stream oiling from the combined government/Exxon surveys. Surface and subsurface oiling conditions along streams were summarized and reported. This effort resulted in a highly detailed and lengthy portrayal of the oiling of anadromous fish streams in western Prince William Sound.

Supplement 3

Supplement 3 summarizes use of Inipol and other chemical treatments in the oil spill clean-up in western Prince William Sound 1989 - 1991. Chemical composition, application schedules, and site descriptions are described for uses of oleophilic fertilizer (Inipol EAP22), slow release fertilizer (Customblen), and soluble spray fertilizers. Many areas treated with these chemicals were sites with known harlequin use. Although we have no direct evidence of harlequin duck mortality associated with the use of these fertilizers, potential toxicity of these fertilizers is discussed. Primarily, these treatment histories may contribute future insights into changes in harlequin duck habitat use or the intertidal communities upon which they depend. At the least, application of these fertilizers was considered a major disturbance event to sites with known harlequin duck use.

References:

Alaska Dept. of Environmental Conservation (ADEC). 1989. Prince William Sound oil spill segment file. Alphabetical indicator by island. ADEC Oil Spill Response Office, Anchorage.

Alaska Department of Fish and Game (ADFG). 1990. An atlas to the catalog of waters important for spawning, rearing or migration of anadromous fishes. ADFG Habitat Division, Southcentral Region, Anchorage. 131pp.

SUPPLEMENT 1

HARLEQUIN DUCK HABITAT OILING IN WESTERN PRINCE WILLIAM SOUND

During September - November 1991, we searched oil spill agency files in Anchorage for EVOS clean-up and response data. This research provided extensive documentation of oiling to four harlequin habitat types in western Prince William Sound: (a) offshore rocks, (b) bays and lagoons, (c) mussel beds, and (d) potential breeding streams. The file searches were keyed to the Exxon beach clean-up segment identifier system (ADEC 1989; 1990; 1991). The most productive searches were conducted at the Oil Spill Public Information Center (OSPIC) library and at the U.S. Coast Guard Federal On-Scene Coordinator (FOSC) offices (USCG 1989; 1990; 1991). Beach segments selected for research were those with documented harlequin use, based on 1989 - 1991 field observations. Terminology of the degree of oiling changed from 1989 to 1991 because the amount of oil on the surface along the shorelines varied. Differences in oil on shorelines were caused by weathering, storm surf, movement into substrate, and clean-up activities.

Oiling History of Harlequin Habitats in Western PWS

The following is a synopsis of *Exxon Valdez* oiling of offshore rocks, mussel beds, bays and lagoons, and streams in western PWS in 1989, 1990, and 1991 (Tables 1 - 3). There was documented use of these habitats by harlequins, except streams. In the case of streams, it was potential use. Sources of information and criteria for oiled stream habitats are presented in Supplement 2. Offshore rocks, mussel beds and sites in bays and lagoons were identified by Exxon beach clean-up segment number (ADEC 1989). Streams were identified by Alaska Stream Catalog (ASC) number (ADF&G 1990) and/or Exxon beach segment number.

Oiling of Offshore Rocks

Offshore rocks in western Prince William Sound, generally located in protected bays and lagoons with good intertidal food sources, were used molting harlequins in July and early August as safe roosts, feeding sites, and as locations for primary feather regrowth. Harlequin molting sites in eastern PWS by comparison were generally located on nearshore rocks along exposed coastlines (Crowley and Patten 1996).

Oiling history of offshore rocks occupied by harlequins in western Prince William Sound in 1989-91 is summarized in Tables 1 - 3. Offshore rocks were identified by location and Exxon beach segment number (ADEC 1989). Oiled offshore rocks with documented use by harlequins included those near Evans Island, Iktua Bay, Bainbridge Passage Bay, Applegate Island, Pleiades Islands, Junction Island, Knight Island, Crafton Island, Flemming Island, Naked Island, Perry Island, and near mainland sites at Foul Bay and Eshamy Bay.

Table 1 (1989) describes oiling of offshore rocks using the following criteria: quantity of oil, oil types, and width of oil band. These offshore rocks received amounts of oil ranging from heavy to light in 1989. Heavy oiling of offshore rocks (>50% coverage) in June 1989 generally decreased to medium oiling (10% - 50% coverage) by September (Table 1). Oil types encountered on offshore rocks included fresh oil, free oil, pooled oil, oil coating, mousse, tar, asphalt, and buried oil. Oil bands, where documented on offshore rocks, varied in width from 0.25m (light) at the southern tip of Flemming Island to 25m (heavy) at Applegate Island (Table 1).

Table 2 (1990) excludes description of oil quantities and width of oil band because other oil characteristics became more important within a year after oil spill. Fresh oil and free oil were not present, but surface oil residue, asphalt, tarballs, tar cover, buried oil and oil saturated gravel were prevalent. Buried oil in saturated gravels can potentially release petroleum hydrocarbons at high tide levels, and thus serve as a continued source of contamination. Buried oil is considered anoxic until released by tidal action.

Additional information was available for 1990 on oiling of offshore rocks at Green Island, Gibbon Anchorage and N.W. side, Applegate Island, Delenia Island, Junction Islands, Foul Passage, Aguliak Island, Mummy Island, and Squirrel Island. Each oil evaluation presented in Table 2 also represented a disturbance event requiring a site visit by boat or helicopter. For instance, Table 2 includes notation of an Exxon cultural resource evaluation conducted by a hovering helicopter on May 17, 1990. All offshore rocks and islands in Gibbon Anchorage, Green Island were surveyed. This site had documented usage by harlequin ducks.

Table 3 (1991) resembles locations in Table 2 (1990), but buried oil residues and surface oil residues are widespread. During the course of time, surface oiling became less evident, but buried oil persisted. Petroleum continued to bleed from buried oil under certain tidal conditions.

Oiling of Mussel Beds

Since mussel beds serve as important feeding sites for harlequin ducks, an initial list of specific oiled mussel beds was developed from a 1991 file search of clean-up assessment team reports. Mussel beds were identified by location and Exxon beach segment number (Table 4). Tables 1-3 also contain general references to mussel beds in western PWS. Appendix 5 of the final report (Volume I) contains results of contaminant sampling of blue mussels on many of these sites.

Oiling of mussel beds used by foraging harlequin ducks ranged from heavy (>50% coverage) in June at Latouche LA015, to medium (10% to 50% coverage) in July at Guguak Cove Lagoon EV070, to light (1% - 10% coverage) in October 1989 at Evans Island EV015. No oil was observed at the Point Bainbridge mussel bed in October 1989 (Table 1), although it may have become buried. Oil types in these mussel beds in 1989 included fresh oil, free oil, pooled oil, mousse, tar, asphalt, and buried oil. Oil in mussel beds by 1990 tended to assume mousse, tar, and asphalt forms, or become buried.

In 1991, two years after the oil spill, unweathered crude oil was located in pools beneath rocks and in contaminated substrates in mussel beds in western Prince William Sound (Table 3). During June 28-30, 1991, investigators from ADEC, ADNR, ADF&G, and NOAA (Restoration Study 103) observed substantial remaining petroleum contamination of sediments among byssal threads underlying mussel beds, even in fairly exposed rocky shores (examples are segments KN0136A; EL013A; ER020B; FI004A; DI067A; LA015E; Table 3).

Established mussel beds in protected areas formed dense byssal thread mats. Contaminated sediments trapped beneath these byssal thread mats were found in potentially anoxic conditions. These sediments, however, continued to leak relatively unweathered petroleum hydrocarbons into the mussel beds, contaminating filter-feeding mussels for unknown lengths of time.

Oiling of Bays and Lagoons

Harlequin ducks used bays and lagoons in Prince William Sound as feeding, resting, and pairing sites. Oiling history of bays and lagoons in western PWS in 1989 is summarized in Table 1. Oiled bays and lagoons with documented harlequin use included Iktua Bay and Iktua Lagoon, Block Island Lagoon, Cabin Bay and Outside Bay on Naked Island, Otter Cove and Mallard Bay on Knight Island and Eshamy Bay on the mainland. The bays and lagoons were identified by location and Exxon beach segment number. Oiling condition of these bays and lagoons in 1989 ranged from heavy (>50% coverage) in May at Otter Cove in Bay of Isles, Knight Island, to moderate (10% to 50% coverage) in June at Iktua Bay, and to a trace tar band in June at Mallard Bay in Drier Bay, Knight Island. Oil types encountered in bays and lagoons in 1989 included fresh oil, free oil, oil coating, mousse, tar, asphalt, and buried oil (Table 1).

Table 3 also includes 1991 observations of harlequin ducks by Exxon SSAT (Spring Shoreline Assessment Team) contract biologists. These harlequin observations were most often made in bays and lagoons. Although buried oil and surface oil residue persisted in 1991 (Table 3), no treatment orders (N/T) were issued by the FOSC. Since harlequin ducks spend much time throughout the year feeding in bays and lagoons, the petroleum bleeding from buried oil may have continued to contamination of intertidal food chains for some time (Table 3).

Oiling of Streams

Table 1 includes 1989 oiling conditions of those streams in western PWS potentially used by harlequins for nesting. Stream mouths were identified in this table by location and Exxon beach segment number (ADEC 1989). The table was keyed to locations where harlequin ducks were observed during the 1991 field season. Streams on Naked Island (NA) and Eleanor Island (EL), where harlequins may have bred (Oakley and Kuletz 1979), were also included in this table. Although no harlequin pairs were trapped at any stream mouth during the spring and summer of 1991 in the oil spill area of western PWS, harlequins were regularly trapped at streams with similar profiles in eastern PWS (Crowley 1994). Harlequin ducks were, however, present in bays, lagoons and on offshore rocks near stream mouths in the oil spill area. Streams were incorporated in Tables 1 - 3 if harlequins were observed in the vicinity or if they were potential breeding streams chosen for mist-net sampling.

The sample of 1989 oiling conditions described in Table 1 included stream sites with the following notations: a heavy 50-m band of fresh oil and mousse at a stream mouth (LA018) in Sleepy Bay Lagoon became asphalt, tar, and buried oil by the time of the ADEC Fall Walk; a moderate band (3m to 10m) of pooled oil and fresh oil in April at a stream mouth (EL052) in Northwest Bay, Eleanor Island (a previously documented harlequin breeding site) became buried oil and tar and asphalt by September; a light 0.5-m band of mousse and tar at a stream mouth (EV008) at Iktua

Bay Lagoon in June became asphalt by October; the stream mouth (KN018) at Otter Cove, Bay of Isles, had a heavy coating of fresh and free oil, oil coating of rocks, and mousse in May 1989, which became tar by September 1989.

The two Naked Island streams ASC 222-40-12960 at Cabin Bay and 222-40-12950 in Outside Bay (NA-25) were relatively small (Table 1). However, harlequin broods were reported by Oakley and Kuletz (1979) at Naked Island and Eleanor Island. Harlequin broods around Naked Island were mentioned also by Dzinbal (1982). No harlequin broods were observed at Naked Island nor Eleanor Island in 1989, 1990, or 1991 (Kuletz, pers. comm.). The Naked Island beach segment (NA-25) was documented as moderately oiled in 1989 (Table 1). Segments NA024-026 contained areas of pooled oil, tar coating, tar balls and oil mousse in 1990 (Table 2). In 1991 NA024-026 contained asphalt, tarballs, tar cover and mousse, although these segments were excluded in 1991 cleanup plans.

REFERENCES

Alaska Dept. of Environmental Conservation (ADEC). 1989a. Prince William Sound oil spill segment file. Alphabetical indicator by island. ADEC Oil Spill Response Office, Anchorage.

________. 1990. Cleanup Monitoring Standard Operating Procedures Manual. Abbreviations/codes version 3.8.90. ADEC EVOS Center, Anchorage.

________. 1991. Cleanup Monitoring Standard Operating Procedures Manual. ADEC EVOS Center, Anchorage.

Alaska Dept. of Fish and Game. 1990. An atlas to the catalog of waters important for spawning, rearing or migration of anadromous fishes. ADF&G Habitat Division, Southcentral Region, Anchorage. 131pp.

Crowley, D.W. 1994. Breeding habitat of harlequin ducks in Prince William Sound, Alaska. M.S. thesis. Department of Wildlife Sciences. Oregon State Univ., Corvallis. 61pp.

________, and S.M. Patten. 1996. Harlequin duck restoration and monitoring in Prince William Sound, Alaska. Final Report. *Exxon Valdez* Oil Spill Restoration Study No. 71. Alaska Dept. Fish and Game, Div. Wildl. Conserv., Anchorage. 75pp.

Dzinbal, K.A. 1982. Ecology of harlequin ducks in Prince William Sound, Alaska, during summer. M.S. thesis. Department of Wildlife Sciences. Oregon State Univ., Corvallis. 89pp.

Oakley, K.L. and K.J. Kuletz. 1979. Summer distribution and abundance of marine birds and mammals in the vicinity of Naked Island, Prince William Sound, Alaska in 1978 and aspects of the reproductive ecology of the pigeon guillemot. Unpubl. Rep. U.S. Fish and Wildl. Serv., Special Studies, Anchorage. 95 pp.

U. S. Coast Guard. 1989. Prince William Sound Oil Spill Segment File. Alphabetical indicator by island. USCG Federal On-Scene Coordinator (FOSC), Anchorage.

________. 1990. Prince William Sound Oil Spill Segment File. Alphabetical indicator by island. USCG Federal On-Scene Coordinator (FOSC), Anchorage.

________. 1991. Prince William Sound Oil Spill Segment File. Alphabetical indicator by island. USCG Federal On-Scene Coordinator (FOSC), Anchorage.

Table 1. 1989 oiling conditions in Harlequin Duck habitats, Prince William Sound.

LOCATION	HARLEQUIN DUCK HABITAT	SEGMENT	TYPE SURVEY	DATE	DEGREE OF OIL CONTAMINATION	DESCRIPTION OF OILING	BAND WIDTH
EVANS ISLAND	MUSSEL BED SAMPLE SITE OFFSHORE ROCKS	EV015	SCAT	6/17/89	MOD> LT	MOUSSE, TAR	
			USCG SIGN OFF	8/29/89	MOD> LT		
			DEC FALL WALK	10/14/89	HVY> LT	TAR, AP, MS, ST BURIED OIL	
IKTUA BAY, LAGOON	POTENTIAL BREEDING AREA STREAM NET SITE	EV008	SCAT	6/6/89	LT>	MOUSSE, TAR	.5 Meters
			USCG SIGN OFF	7/28/89	MOD>		
			DEC FALL WALK	10/13/89	LT>	AP, STAIN	
IKTUA BAY	ADJACENT OFFSHORE ROCKS MOLTING AREA	EV010	SCAT	6/16/89	MOD>	MOUSSE, TAR	
			USCG SIGN OFF	7/28/89	LT>		
			DEC FALL WALK	10/13/89	LT>	TAR	
GUGUAK COVE, LAGOON	MUSSEL BED SAMPLE SITE PROBABLE BREEDING STREAM	EV070	SCAT	7/19/89	MOD>	POOLED OIL MS, TAR, FR	
	USCG SIGN OFF DOES NOT EXIST FOR EV070 1989						
		EV070	DEC FALL WALK	10/13/89	VERY LIGHT	NO	
NORTH TIP ELRINGTON ISLAND	MUSSEL BED SAMPLE SITE	ER020	SCAT	7/1/89	HEAVY>	FO, MS, TAR	
			USCG SIGN OFF	9/13/89	HEAVY>	BURIED OIL	
			USCG SIGN OFF	9/17/89	LIGHT	BURIED OIL	
			DEC FALL WALK	10/1/89	HEAVY>	BURIED OIL	
			USCG SIGN OFF	10/2/89	HEAVY>	BURIED & MOBILE OIL	
LATOUCHE, NORTH TIP	MUSSEL BED SAMPLE SITE	LA015	SCAT	6/16/89	HEAVY	OP, FR, MS, TAR BURIED OIL	
			USCG SIGN OFF	9/14/89	HEAVY> LIGHT		

LOCATION	HARLEQUIN DUCK HABITAT	SEGMENT	TYPE SURVEY	DATE	DEGREE OF OIL CONTAMINATION	DESCRIPTION OF OILING	BAND WIDTH
			DEC FALL WALK	10/3/89	HEAVY> LIGHT	MS,TAR,AP,ST BURIED OIL	
LA TOUCHE ISLAND SLEEPY BAY	MUSSEL SAMPLE SITE PROBABLE BREEDING STREAM	LA018	SCAT	6/14/89	HEAVY	FRESH OIL MOUSSE	50 Meters
			USCG SIGN OFF	7/16/89	MODERATE>	BURIED OIL	
			DEC FALL WALK	6/3/89	HEAVY	MS,AP,TAR BURIED OIL	
BLOCK ISLAND LAGOON & HELIPORT	MUSSEL BED SAMPLE SITE	EL013A	SCAT	9/15 /89	HEAVY	MS,ST,TAR	3 to 6 Meters
			USCG SIGN OFF	7/4/89	LIGHT		
			DEC FALL WALK	9/15/89	HEAVY	BURIED OIL	
POINT BAINBRIDGE	MUSSEL BED SAMPLE SITE	BA004	SCAT	7/30/89	MODERATE> LIGHT	TAR,ASPHALT	
			USCG SIGN OFF	9/6/89	MODERATE		
			DEC FALL WALK	10/2/89	NO OIL		
BAINBRIDGE PASSAGE	MOLTING SITE, OFFSHORE ROCKS	BA006	SCAT	7/23/89	NO OIL		
			USCG SIGN OFF	8/10/89	LIGHT	BURIED OIL	
			DEC FALL WALK	10/12/89	MODERATE> LIGHT	TAR,ASPHALT	
NORTHWEST BAY	PROBABLE BREEDING STREAM & FEEDING AREA	EL052	SCAT	4/22/89	MODERATE>	POOLED OIL FREE OIL	3 to 10 Meters
			USCG SIGN OFF	6/14/89	MODERATE> LIGHT	BURIED OIL	
			DEC FALL WALK	9/19/89	MODERATE> LIGHT	TAR,ASPHALT	
APPLEGATE ISLAND	MOLTING & FEEDING AREA	AE004	SCAT	5/25/89	HEAVY>	MS,TAR CT	25 Meters
			USCG SIGN OFF	5/25/89	LIGHT		

LOCATION	HARLEQUIN DUCK HABITAT	SEGMENT	TYPE SURVEY	DATE	DEGREE OF OIL CONTAMINATION	DESCRIPTION OF OILING	BAND WIDTH
			DEC FALL WALK	9/14/89	HEAVY>	MOUSSE, TAR STAIN	
APPLEGATE ISLAND	MOLTING & FEEDING OFFSHORE ROCKS	AE004	SCAT	5/25/89	HEAVY>	MOUSSE, TAR COAT	25 Meters
			SIGN OFF	8/4/89	LIGHT	BURIED OIL	
			DEC FALL WALK	9/13/89	MODERATE> LIGHT	MS, TAR, ST BURIED OIL	
APPLEGATE ISLAND, LAGOON	MOLTING & FEEDING AREA OFFSHORE ROCKS	AE005	SCAT	5/26/89	HEAVY>	MOUSSE, TAR ASPHALT	15 Meters
			USCG SIGN OFF	8/26/89	HEAVY> MODERATE		
			DEC FALL WALK	9/13/89	HEAVY> LIGHT	MS, TAR, AP, ST BURIED OIL	
FOUL BAY	MOLTING & FEEDING SITES OFFSHORE ROCKS	MA002	SCAT	5/22/89	HEAVY> MODERATE	MOUSSE FREE OIL	15 Meters
			USCG SIGN OFF	8/24/89	MODERATE> LIGHT		
			DEC FALL WALK	9/13/89	MODERATE> LIGHT	MS, TAR BURIED OIL	4 to 30 Meters
NORTH ENTRANCE BAY OF ISLES	ROOSTING & FEEDING SITES	KN020	SCAT	5/12/89	MODERATE>	FRESH	15 Meters
			USCG SIGN OFF	8/1/89	LIGHT>	BURIED OIL	
			DEC FALL WALK	9/20/89	MOD>	TAR	
BAY OF ISLES, ENTRANCE	MOLTING, FEEDING, ROOSTING AREAS OFFSHORE ROCKS	KN022	SCAT	5/12/89	HEAVY> MODERATE	FREE OIL MOUSSE	2 to 3 Meters
	NO FURTHER SURVEYS CONDUCTED AT KN022 1989						
BAY OF ISLES, OTTER COVE	PROBABLE BREEDING AREA STREAM NET SITE	KN018	SCAT	5/11/89	HEAVY>	FREE OIL CT, MS, FS	
			USCG SIGN OFF	8/1/89	LIGHT		
			DEC FALL WALK	9/20/89	MODERATE> LIGHT	TAR	
DEATH LAGOON BAY OF ISLES	MUSSEL BED SAMPLE SITE	KN136A	SCAT	5/4/89	HEAVY>	100% MOUSSE	
			USCG SIGN OFF	7/19/89	LIGHT		

LOCATION	HARLEQUIN DUCK HABITAT	SEGMENT	TYPE SURVEY	DATE	DEGREE OF OIL CONTAMINATION	DESCRIPTION OF OILING	BAND WIDTH
			DEC FALL WALK	10/1/89	HEAVY	MOUSSE, TAR ST, APSHALT	
WEST ARM, BAY OF ISLES LAGOON	PROBABLE BREEDING & FEEDING SITE STREAM NET SITE	KN201	SCAT	5/22/89	LIGHT	TAR, MOUSSE	
			USCG SIGN OFF	7/7/89	MODERATE>		
			DEC FALL WALK	10/1/89	LIGHT	TAR, MOUSSE BURIED OIL	
PLEIADES ISLANDS	MOLTING & FEEDING, OFFSHORE ROCKS	PL001	SCAT	8/2/89	HEAVY	TAR	15 M
	LAST SURVEY CONDUCTED AT THIS SITE						
JUNCTION ISLAND	MOLTING & FEEDING AREA OFFSHORE ROCKS	CH011	SCAT	7/6/89	HEAVY	TAR, MOUSSE FS, FR, CT	
			USCG SIGN OFF	8/3/89	MODERATE> LIGHT		
			DEC FALL WALK	10/19/89	HEAVY> MODERATE	MOUSSE, TAR ASPHALT	
CHENEGA ISLAND, KAKE COVE	PROBABLE BREEDING & FEEDING AREA STREAM NET SITE	CH017	SCAT	7/18/89	LIGHT	TAR	.25 Meters
	NO RECORD OF THIS SITE BEING SIGNED OFF BY USCG						
			DEC FALL WALK	10/2/89	VERY LIGHT	STAIN	
CHENEGA ISLAND, NORTH TIP	MUSSEL SAMPLE SITE	CH010	SCAT	7/4 & 7/5/89	HEAVY	FRESH OIL, CT MS, TAR, OF	
			USCG SIGN OFF	8/3/98	MODERATE>	BURIED OIL	
			DEC FALL WALK	9/19/89	HEAVY>	MS, TAR, AP, ST BURIED OIL	
DELENIA ISLAND DANGEROUS PASSAGE	MOLTING AREA	THIS SEGMENT WAS NOT SURVEYED UNTIL THE 1991 MAYSAP SURVEYS					
KNIGHT ISLAND, WEST SHORE	FEEDING & ROOSTING AREAS OFFSHORE ROCKS	KN500	SCAT	6/5/89	MODERATE	FRESH OIL, TAR, MS, CT, T	
			USCG SIGN OFF	7/23/89	LIGHT		
			DEC FALL WALK	9/26/89	HEAVY> LIGHT	TAR, ASPHALT BURIED OIL	
HERRING POINT	MOLTING & FEEDING AREA OFFSHORE ROCKS	KN300	SCAT	5/2/89	MODERATE	FRESH OIL	

LOCATION	HARLEQUIN DUCK HABITAT	SEGMENT	TYPE SURVEY	DATE	DEGREE OF OIL CONTAMINATION	DESCRIPTION OF OILING	BAND WIDTH
			USCG SIGN OFF	6/3/89			
			DEC FALL WALK	9/16/89	HEAVY> LIGHT	TAR BURIED OIL	
SOUTH TIP CRAFTON ISLAND	MOLTING & FEEDING AREA OFFSHORE ROCKS	CR004	SCAT	5/7/89	MODERATE>	MOUSSE	20 Meters
			USCG SIGN OFF	8/17/89	LIGHT	BURIED OIL	
			DEC FALL WALK	9/12/89	MODERATE> LIGHT	OP,MS,TAR,AP BURIED OIL	
SNUG HARBOR	FEEDING AREA & STREAM NET SITE	KN401	SCAT	6/11/89	HEAVY> MODERATE	POOLED OIL MOUSSE, TAR	2 to 20 Meters
			USCG SIGN OFF	8/20/89	HEAVY> MODERATE	BURIED OIL	
			DEC FALL WALK	9/30/89	HEAVY>	MOUSSE,TAR STAIN	
LOG JAM BAY	FEEDING & MOLTING AREA	KN211	SCAT	5/24/89	HEAVY	FRESH OIL MOUSSE, TAR	1 to 75 Meters
			SIGN OFF	9/13/89	HEAVY	BURIED OIL	
			DEC FALL WALK	9/20/89	HEAVY> BURIED OIL	POOLED OIL MOUSSE,AP,ST	
FLEMMING ISLAND	MUSSEL SAMPLE SITE	FL004	SCAT	7/15/89	HEAVY>	OP,MS,TAR	10M
			USCG SIGN OFF	8/9/89	MODERATE>		
			USCG SIGN OFF	8/10/89	LIGHT>		
			DEC FALL WALK	10/17/89	HEAVY> BURIED OIL	MOUSSE,TAR ASPHALT	
FLEMMING ISLAND SOUTH TIP	MOLTING & FEEDING AREA OFFSHORE ROCKS	FL003	SCAT	7/12/89	LIGHT	TAR	.25 Meters
			USCG SIGN OFF	7/28/89	LIGHT		
			DEC FALL WALK	10/19/89	LIGHT	TAR,STAIN	
HERRING BAY	MOLTING & FEEDING AREA OFFSHORE ROCKS	KN141	SCAT	7/12/89	HEAVY> LIGHT	MOUSSE,TAR FREE OIL	16 Meters
			SIGN OFF	8/28/89	MODERATE> LIGHT		

LOCATION	HARLEQUIN DUCK HABITAT	SEGMENT	TYPE SURVEY	DATE	DEGREE OF OIL CONTAMINATION	DESCRIPTION OF OILING	BAND WIDTH
			DEC FALL WALK	9/15/89	HEAVY> LIGHT	ASPHALT	
NORTH SHORE HERRING BAY	MUSSEL BED SAMPLE SITE	KN113	SCAT	5/1/89	HEAVY		5 to 10 Meters
			USCG SIGN OFF	8/2/89	HEAVY>		
			USCG SIGN OFF	8/30/89	MODERATE>		
			DEC FALL WALK	9/16/89	HEAVY> BURIED OIL	MOUSSE, STAIN TAR	
HERRING BAY ADF&G CAMP	PROBABLE BREEDING & FEEDING AREA STREAM HABITAT	KN132	SCAT	5/4/89	MODERATE	TAR	2 to 30 Meters
		NO RECORD OF SIGN OFF BY USCG					
			DEC FALL WALK	9/16/89	HEAVY> LIGHT	TAR BURIED OIL	
NAKED ISLAND, CABIN BAY	PROBABLE BREEDING & FEEDING AREA	NA024	SCAT	8/15/89	LIGHT	MOUSSE, TAR	3 Meters
			USCG SIGN OFF				
			DEC FALL WALK	9/26/89	LIGHT	MS, TAR, AP BURIED OIL	
NAKED ISLAND, OUTSIDE BAY	PROBABLE BREEDING & FEEDING AREA	NA026	SCAT	8/15/89	LIGHT	COAT, TAR	
			USCG SIGN OFF				
			DEC FALL WALK	9/25/89	MODERATE> LIGHT	TAR BURIED OIL	
FOUL PASSAGE	MOLTING & FEEDING AREA OFFSHORE ROCKS	DI059	SCAT	4/26/89	HEAVY> MODERATE	TAR BURIED OIL	
			USCG SIGN OFF	7/19/89	MODERATE>	BURIED OIL	
			DEC FALL WALK	9/15/89	HEAVY> LIGHT	ASPHALT BURIED OIL	
WHALE BAY, SOUTH ARM	PROBABLE BREEDING & FEEDING AREA STREAM NET SITE	WH502	THIS SEGMENT WAS NOT SURVEYED UNTIL THE SPRING OF 1990				
WHALE BAY, MAINLAND	MOLTING & FEEDING AREAS OFFSHORE ROCKS & STREAM AREA	WH003	SCAT	8/1/89	NO OIL		

LOCATION	HARLEQUIN DUCK HABITAT	SEGMENT	TYPE SURVEY	DATE	DEGREE OF OIL CONTAMINATION	DESCRIPTION OF OILING	BAND WIDTH
	SCAT ON 8/1/89 WAS THE ONLY SURVEY OF WH003 IN 1989 LATER SURVEYS IN 1990 REVEALED EXTENSIVE OILING TO THIS AREA						
WHALE BAY, WEST ARM	PROBABLE BREEDING & FEEDING AREA STREAM NET SITE	WH504	THIS SEGMENT WAS NOT SURVEYED UNTIL THE SPRING OF 1990				
PADDY BAY	BREEDING & FEEDING AREAS STREAM NET SITE	PA001	SCAT	7/19/89	LIGHT	TAR	.5 Meter
			USCG SIGN OFF	8/11/89	VERY LIGHT		
		NO FURTHER SURVEYS OF THIS SEGMENT					
ESHAMY BAY, SOUTH ARM	MOLTING & FEEDING AREA	EB009	SCAT	5/27/89	LIGHT	FRESH OIL	
			USCG SIGN OFF	8/4/89	LIGHT		
		NO FURTHER SURVEYS OF THIS SEGMENT					
AGULIAK ISLAND	MOLTING & FEEDING AREA OFFSHORE ROCKS	AG001	SCAT	6/21/89	HEAVY	TAR	3 to 6 Meters
			USCG SIGN OFF	7/20/89	LIGHT	BURIED OIL	
			DEC FALL WALK	9/28/89	LIGHT	TAR, ASPHALT	
AGULIAK ISLAND	MOLTING & FEEDING AREA OFFSHORE ROCKS	AG009	SCAT	8/21/89	HEAVY> MODERATE	MOUSSE, TAR	2 Meters
			USCG SIGN OFF	8/30/89	MODERATE>	BURIED OIL	
MUMMY ISLAND	FEEDING & MOLTING AREA OFFSHORE ROCKS	MU900	SCAT	8/21/89	HEAVY>	FREE OIL MOUSSE, TAR	2 Meters
			USCG SIGN OFF	8/30/89	VERY LIGHT		
SQUIRREL ISLAND	MOLTING & FEEDING AREA OFFSHORE ROCKS	SL001	SCAT	6/24/89	HEAVY	TAR	
			SIGN OFF	8/3/89	MODERATE>	TAR BURIED OIL	
			DEC FALL WALK	10/2/89	HEAVY> LIGHT	TAR BURIED OIL	
DRIER BAY, MALLARD BAY	PROBABLE BREEDING & FEEDING AREA STREAM NET SITE	KN575	SCAT	6/8/89	TRACE TAR BAND		
			USCG SIGN OFF				
			DEC FALL WALK	9/29/89	VERY LIGHT	TAR, STAIN	

LOCATION	HARLEQUIN DUCK HABITAT	SEGMENT	TYPE SURVEY	DATE	DEGREE OF OIL CONTAMINATION	DESCRIPTION OF OILING	BAND WIDTH
PERRY ISLAND, SOUTH TIP	MOLTING & FEEDING AREA OFFSHORE ROCKS	PR003	SCAT	5/18/89	MODERATE>	FREE.OIL MOUSSE	
			USCG SIGN OFF	6/13/89	LIGHT	BURIED OIL	
			DEC FALL WALK	9/12/89	HEAVY> LIGHT	MS,TAR,AP,ST BURIED OIL	
GREEN ISLAND NORTH COAST	MUSSEL BED SAMPLE SITE & PROBABLE FEEDING AREA	GR101	SCAT	5/16/89	MODERATE>	MOUSSE & TAR	10 & 20 Meters
			DEC FALL WALK	10/3/89	HEAVY> BURIED OIL	TAR,ASPHALT STAIN	
CHANNEL ISLAND	MOLTING AREA	GR004A	SCAT	5/2/89	TRACE AMOUNT	STAIN	
GR004 WAS RECOMMENDED FOR NO TREATMENT AND A N/T ORDER WAS SIGNED BY FOSC 5/4/89							
GREEN ISLAND SOUTH END	MOLTING AREA	GR300A	SCAT	8/11/89	VERY LIGHT	STAIN	3cm
			DEC FALL WALK	10/2/89	VERY LIGHT	ASPHALT (SPORADIC)	
GR300A WAS RECOMMENDED FOR NO TREATMENT AND A N/T ORDER WAS SIGNED BY THE FOSC							
DISK ISLAND	MUSSEL SAMPLE SITE	DI067A	SCAT	6/16/89	HEAVY BURIED OIL	POOLED OIL,FM MOUSSE,TAR	
			USCG SIGN OFF	6/16/89	HEAVY>		
			DEC FALL WALK	9/16/89	HEAVY>	MS,TAR BURIED OIL	
PERRY ISLAND SOUTH SHORE	MOLTING & FEEDING AREA OFFSHORE ROCKS	PR002	SCAT	5/18/89	HEAVY>	FREE OIL MOUSSE, COAT	20 Meter
			USCG SIGN OFF	8/27/89	HEAVY	BURIED OIL	
			DEC FALL WALK	9/13/89	HEAVY>	TAR, BURIED OIL	

ST	Stain	T	Tar	CT	Oil Coating
OF	Oil Film	FS	Fresh Oil	M	Meter measurement
MS	Mousse	AP	Asphalt	FR	Fresh Crude Oil
OP	Pooled Oil	SUB	Subsurface Oil	>	Decreasing

HEAVY/MODERATE/LIGHT Relative oiling conditions

SCAT Shoreline Cleanup Assessment Team's initial survey of oiling conditions after the spill.
USCG SIGN OFF Coast Guard release saying further cleanup not necessary.
DEC FALL WALK Department of Environmental Conservation's last shoreline oiling evaluation in the 1989 season.

NOTE: All surveys are considered a source of disturbance particularly ones conducted by helicopter.
* This table incorporates locations of Harlequin Ducks observations during the 1991 field season.

Table 2. 1990 harlequin duck habitat oiling conditions in Prince William Sound.

LOCATION	HARLEQUIN DUCK HABITAT TYPE	SEGMENT	TYPE SURVEY	DATE	OIL DESCRIPTION
EVANS ISLAND	MUSSEL BED SAMPLE SITE OFFSHORE ROCKS	EV015A	SSAT	4/20/90	AP,MS
			DEC	8/7/90	OP,MS,BURIED OP & OR
			ASAP	8/7/90	CT,ST,MS
IKTUA BAY LAGOON	STREAM NET SITE POTENTIAL BREEDING AREA	EV008	THIS SEGMENT WAS NOT INCLUDED IN SURVEY OR CLEANUP PLAN FOR 1990		
IKTUA BAY	ADJACENT OFFSHORE ROCKS, MOLTING AREA	EV010	SSAT	4/23/90	CT,CT,TAR PATTIES
			DEC	6/5/90	OP,TB,ST,CT
			ASAP	8/6/90	ST,MS, TAR PATTIES
GUGUAK COVE, LAGOON	MUSSEL BED SAMPLE SITE & PROBABLE BREEDING STREAM SITE	EV070	SSAT	4/6/90	CV,ST,TAR PATTIES, BURIED OR & OF OIL
			ASAP	8/3/90	SOR,CV,TAR PATTIES
ELRINGTON ISLAND NORTH TIP	MUSSEL SAMPLE SITE	ER020B	SSAT	4/7/90	AP,CV,CT,ST BURIED OP,OR & OF
			ASAP	9/7/90	TARMATS,ASPHALT,MOUSSE
LATOUCHE	MUSSEL BED SAMPLE SITE	LA015E	SSAT	4/1/90	CT,ST BURIED OR
			ASAP		
SLEEPY BAY	MUSSEL SAMPLE SITE, PROBABLE BREEDING STREAM	LA018	SSAT	4/24/90	OP,AP,MS,CV,ST BURIED OR & OP OIL
			ASAP	8/21/90	AP,SOR,CT,ST BURIED OR OIL
GREEN ISLAND, N.W. SIDE	MUSSEL SAMPLE SITE, OFFSHORE ROCKS	GR101	SSAT	4/7/90	CT,ST BURIED OR & OP
			ASAP	8/14/90	HEAVY CT,AP,SOR
GREEN ISLAND GIBBON ANCHORAGE	MOLTING AREA, OFFSHORE ROCKS	GR015A	SSAT	4/7/90	TAR COAT, STAIN
	EXXON CULTURAL RESOURCE EVALUATION SURVEY CONDUCTED BY HOVERING HELICOPTER*			5/17/90	(ALL ISLANDS SURVEYED)
			DSA	7/15/90	COAT & STAIN
GREEN ISLAND, SOUTH END	MOLTING AREA	GR300A	SSAT	4/8/90	STAIN ONLY
		N/T ORDER WAS SIGNED FOSC & CLEANUP ACTIVITIES CEASED 4/26/90			
CHANNEL ISLAND	MOLTING AREA	GR004A	SSAT	4/8/90	STAIN ONLY
		N/T ORDER WAS SIGNED FOSC & CLEANUP ACTIVITIES CEASED 4/26/90			

LOCATION	HARLEQUIN DUCK HABITAT TYPE	SEGMENT	TYPE SURVEY	DATE	OIL DESCRIPTION
POINT BAINBRIDGE	MUSSEL BED SAMPLE SITE	BA004	SSAT	3/31/90	POOLED OIL, CV, CT
		N/T ORDER WAS SIGNED FOSC & CLEANUP ACTIVITIES CEASED 4/5/90			
BAINBRIDGE PASSAGE, BAY	MOLTING SITE, OFFSHORE ROCKS	BA006B&C	SSAT	4/24/90	AP,CT,ST, BURIED OR OIL
			ASAP	8/4/90	MS,SOR
WEST COVE, DISK ISLAND	MUSSEL SAMPLE SITE	DI067A	SSAT	4/19/90	AP,CT,FM BURIED OR
			ASAP	8/20/90	SOR,CV,CT,ST,TAR PATTIES BURIED OP & OR
NORTHWEST BAY ELEANOR ISLAND	PROBABLE BREEDING HABITAT & FEEDING AREA	EL052	SSAT	4/4/90	AP,TB,CV,ST BURIED OP & OR OIL
			ASAP	8/8/90	SOR,CV,CT,ST BURIED OP,OR,OF OIL
BLOCK ISLAND LAGOON & HELIPORT	FEEDING & MOLTING HABITAT	EL015	SSAT	4/8/90	AP,CB,CT,TB,TAR PATTIES POOLED OIL
			ASAP	8/12/90	AP,CT,ST,SOR,TAR
BLOCK ISLAND LAGOON & HELIPORT	MUSSEL SAMPLE SITE	EL013A	SSAT	4/8/90	ASPHALT, POOLED OIL BURIED OR OIL
			ASAP	8/2/90	AP,SOR,CV,CT BURIED OR OILING
APPLEGATE ISLAND	MOLTING & FEEDING & OFFSHORE ROCKS	AE004 A&B	SSAT	5/12/90	MS,AP,SOR,CV,CT,POOLED OIL BURIED OR & OF
			ASAP	8/22/90	AP,SOR,CV,CT BURIED OP & OR OIL
APPLEGATE ISLAND, LAGOON	MOLTING & FEEDING HABITAT, OFFSHORE ROCKS	AE005 A,B&C	SSAT	4/3/90	AP,MS,CV,POOLED OIL BURIED OP,OR,SF OIL
		DURING THIS SURVEY 4 MALE & 3 FEMALE HARLEQUIN DUCKS WERE OBSERVED BY SSAT BIOLOGIST			
			DEC FALL WALK	9/13/90	MS,TAR,AP,ST BURIED OIL
FOUL BAY,ISLANDS & OFFSHORE ROCKS	MOLTING & FEEDING SITES	MA002A	SSAT	4/06/90	AP & BURIED OR OIL (OCCURING ON ALL ISANDS)
		SURVEYED DURING CLEANUP		6/7/90	MS,CV,CT,ST BURIED OR & OF
OTTER COVE, BAY OF ISLES	PROBABLE BREEDING & FEEDING SITE STREAM NET SITE	KN018	SSAT	4/2/90	CT,CV
NORTH ENTRANCE TO BAY OF ISLES	MOLTING & FEEDING AREAS	KN020	SSAT	4/25/90	CT ONLY

LOCATION	HARLEQUIN DUCK HABITAT TYPE	SEGMENT	TYPE SURVEY	DATE	OIL DESCRIPTION
OFFSHORE ROCKS, ENTRANCE TO BAY OF ISLES	MOLTING, FEEDING & ROOSTING HABITAT	KN022	THESE ISLANDS WERE NOT INCLUDED IN THE SHORELINE CLEANUP OR SURVEYS DURING THE 1990 SEASON		
	A N/T ORDER WAS SIGNED BY THE FOSC & CLEANUP ACTVITIES CEASED ON 4/27/90				
BAY OF ISLES DEATH LAGOON	MUSSEL SAMPLE SITE	KN136A	SSAT	3/30/90	AP,CV,CT,ST BURIED OP & OR
			ASAP	8/10/90	AP,SOR,CT,ST BURIED OR OIL
WEST ARM, BAY OF ISLES LAGOON	PROBABLE BREEDING & FEEDING SITE STREAM NET SITE	KN201	SSAT	9/9/90	TB,AP,CT TAR PATTIES
			ASAP	8/9/90	AP,CT,ST,MS TAR PATTIES
PLEIADES ISLANDS	MOLTING & FEEDING OFFSHORE ROCKS	PL001	SSAT	4/1/90	CT, OP BURIED OF OIL
	A N/T ORDER WAS SIGNED BY THE FOSC & CLEANUP ACTIVITES CEASED ON 4/11/90				
DELENIA ISLANDS	OFFSHORE ROCKS AND MUSSEL SAMPLE SITE	DE001	THIS SITE WAS NOT INCLUDED IN CLEANUP UNTIL 1991		
CHENEGA ISLAND, NORTH TIP	MUSSEL SAMPLE SITE & FEEDING AREA	CH010B	SSAT	4/5/90	OP,TAR PATTIES BURIED OP & OR OILING
		3 HARLEQUIN DUCKS OBSERVED DURING SSAT BY TEAM BIOLOGIST			
			ASAP	8/4/90	CT,ST,FM BURIED OR
JUNCTION ISLANDS	MOLTING & FEEDING OFFSHORE ROCKS	CH011	SSAT	4/5/90	AP,OP BURIED OP OIL
		DURING THIS SURVEY 2 MALE AND 1 FEMALE HARLEQUIN DUCKS WERE OBSERVED BY SSAT BIOLOGIST			
			SSAT NO.2	4/23/90	AP,OP,TAR PATTIES, BURIED OP OIL
		DURING THIS SURVEY 20 HARLEQUIN DUCKS WERE OBSERVED BY SSAT BIOLOGIST			
			ASAP	8/4/90	SOR,MS,BURIED OR OILING
KAKE COVE	PROBABLE BREEDING & FEEDING AREA STREAM NET SITE	CH017	THIS SEGMENT WAS EXCLUDED FOR THE 1990 CLEANUP PLANS		
KNIGHT ISLAND WEST SHORE	FEEDING & ROOSTING AREAS, OFFSHORE ROCKS	KN500	SSAT	4/8/90	CV,AP,CT BURIED OR OILING
			ASAP	8/3/90	SOR,CT,FM BURIED OR OILING
HERRING POINT	MOLTING & FEEDING AREA OFFSHORE ROCKS	KN300	SSAT	3/3/90	AP,CT BURIED OR OIL
			ASAP	8/10/90	SOR,CT,CV, BURIED OR OILING

LOCATION	HARLEQUIN DUCK HABITAT TYPE	SEGMENT	TYPE SURVEY	DATE	OIL DESCRIPTION
SOUTH TIP, CRAFTON ISLAND	MOLTING & FEEDING AREA, OFFSHORE ROCKS	CR004	SSAT	4/4/90	POOLED OIL,CV,CT,FM
		DURING THIS SURVEY 4 HARLEQUIN DUCKS WERE OBSERVED BY SSAT BIOLOGIST			
	A N/T ORDER WAS SIGNED BY THE FOSC & CLEANUP ACTIVIES CEASED ON 4/25/90				
SNUG HARBOR	PROBABLE BREEDING & FEEDING AREA STREAM NET SITE	KN401	SSAT	4/7/90	AP,MS,CV,CT, POOLED OIL TAR PATTIES
			ASAP NO.1	8/2/90	AP,CT,MS
			ASAP NO.2	9/19/90	AP,SOR,MS,ST
LOG JAM BAY	FEEDING & MOLTING AREA, STREAM HABITAT	KN211C&D	SSAT	4/2/90	CV,CT, TAR BALLS
	A NO TREATMENT ORDER WAS SIGNED BY THE FOSC AND CLEANUP ACTIVIES CEASED ON 5/9/90				
FLEMMING ISLAND	MUSSEL SAMPLE SITE	FL004A	SSAT	4/9/90	AP,CV BURIED OP & OR
			ASAP	8/5/90	AP,OP,SOR
FLEMMING ISLAND SOUTH TIP	MOLTING & FEEDING AREA, OFFSHORE ROCKS	FL003	SSAT	4/21/90	CT,TB, TAR PATTIES
	A N/T ORDER WAS SIGNED BY THE FOSC & CLEANUP ACTIVITES CEASED ON 5/18/90				
HERRING BAY	MOLTING & FEEDING AREA	KN141A&B	SSAT	3/31/90	CV,CT,ST,FM BURIED OP/OR/OF
			ASAP	8/11/90	SOR,CT, BURIED OR OIL
HERRING BAY	MUSSEL SAMPLE SITE	KN113B	SSAT	5/5/90	CT,ST BURIED OP & OR
			ASAP	8/2/90	SOR,CT BURIED OR
HERRING BAY ADF&G CAMP	PROBABLE BREEDING & FEEDING AREA STREAM HABITAT	KN132	SSAT	3/31/90	AP,CT BURIED OP OILING
			ASAP	8/10/90	SOR,CT,CV BURIED OR OILING
NAKED ISLAND, CABIN BAY	PROBABLE BREEDING & FEEDING AREA	NA024A&F	SSAT	4/3/90	POOLED OIL,CT,MS
			ASAP	8/9/90	MOUSSE
NAKED ISLAND, OUTSIDE BAY	PROBABLE BREEDING & FEEDING AREA	NA026B	SSAT	4/5/90	OP,TB,CT,TAR PATTIES
			ASAP	8/9/90	NO OIL OBSERVED
FOUL PASSAGE	MOLTING & FEEDING AREA, OFFSHORE ROCKS	DI059	SSAT	4/20/90	CT,TB, BURIED OR & OP OIL
		THIS WAS THE LAST SURVEY OF THIS SEASON			
WHALE BAY, SOUTH ARM	PROBABLE BREEDING & FEEDING AREA STREAM NET SITE	WH502	DEC	10/12/90	TAR,AP,ST VERY LIGHT

LOCATION	HARLEQUIN DUCK HABITAT TYPE	SEGMENT	TYPE SURVEY	DATE	OIL DESCRIPTION
WHALE BAY, MAINLAND	MOLTING, FEEDING & OFFSHORE ROCKS STREAM HABITAT	WHOO3	SSAT	4/1/90	CT,AP,ST,FM BURIED OR & OF OILING
			ASAP	8/5/90	SOR,CT BURIED OIL
WHALE BAY, WEST ARM	PROBABLE BREEDING & FEEDING AREA STREAM NET SITE	WH504	DEC	10/12/90	NO OIL OBSERVED
PADDY BAY	BREEDING, FEEDING STREAM NET SITE	PA001	NO INFORMATION FOR THIS SEGMENT IN 1990		
ESHAMY BAY, SOUTH ARM	MOLTING & FEEDING AREA	EB009	SSAT	4/10/90	CT,TAR BALLS
	A N/T ORDER WAS SIGNED BY THE FOSC & CLEANUP ACTIVITES CEASED ON 4/25/90				
AGULIAK ISLAND	MOLTING & FEEDING AREA, OFFSHORE ROCKS	AG001	SSAT	4/6/90	CT,CV,ST
	A N/T ORDER WAS SIGNED BY THE FOSC AND CLEANUP ACTIVITIES CEASED ON 4/21/90				
AGULIAK ISLAND	MOLTING & FEEDING AREA, OFFSHORE ROCKS	AG009 A&B	SSAT	4/25/90	MS,AP,TB,CV,CT,TB BURIED OR OILING
			ASAP	8/17/90	SOR,CV,CT BURIED OR OILING
MUMMY ISLAND	FEEDING & MOLTING AREA, OFFSHORE ROCKS	MU900	SSAT	4/2/90	AP,CT TAR PATTIES
SQUIRREL ISLAND	MOLTING & FEEDING AREA, OFFSHORE ROCKS	SL001 ABC&D	SSAT	4/5/90	AP,CV,CT BURIED OP,OF OILING
			ASAP	8/6/90	SOR,CV,AP BURIED OR,OF OILING
MALLARD BAY, DRIER BAY	PROBABLE BREEDING & FEEDING AREA STREAM NET SITE	KN575	SSAT	4/22/90	CT,TAR PATTIES TARBALLS
		DURING THIS SURVEY 5 HARLEQUIN DUCKS WERE OBSERVED BY THE SSAT BIOLOGIST			
	A N/T ORDER WAS SIGNED BY THE FOSC & CLEANUP ACTIVITIES CEASED ON 4/30/90				
SOUTH TIP, PERRY ISLAND	MOLTING & FEEDING AREA, OFFSHORE ROCKS	PR003	SSAT	3/30/90	CT,AP,CV
			ASAP	8/21/90	SOR,CV,AP,MS BURIED OP,OR OILING
PERRY ISLAND SOUTH SHORE	MOLTING & FEEDING AREA, OFFSHORE ROCKS	PR002	SSAT	4/30/90	MS,CV,CT,ST BURIED OP & OF OILING
			DEC	6/20/90	ST,OF BURIED OR OILING
			ASAP	8/21/90	CT,ST BURIED OR,OP,OF OILING

Abbreviations

MS	oil mousse (thick fresh brown oozing tar)
OP	pooled oil (where has pooled on surface or into a freshly dug pit)
ST	oil stain (where oil has left stain on bedrock or boulders)
SOR	surface oil residue (any oil on the surface of beach area, similar to asphalt)
N/T	no treatment
AP	asphalt
TB	tarballs (generally small areas of thick surface tar or asphalt)
CV	tar cover (bedrock or boulders that are covered with tar)
OR	oil residue (oil saturated gravel)
CT	tar coating (bedrock or boulders that are coated with weathered tar)
OF	oil film (film of oil coating subsurface gravel or surface gravel)

SSAT Spring Shoreline Assessment Team's initial survey of oiling conditions after the spill.

ASAP August Shoreline Assessment Program

DEC Department of Environmental Conservation's shoreline oiling evaluation survey.

FOSC Federal On Scene Coordinator (in charge of cleanup) Usually the USCG Admiral.

TAG Technical Advisory Group (consisting of USCG FOSC, DEC, EXXON, NOAA)

* This table incorporates locations of Harlequin Ducks observed and documented during the 1990 Spring Shoreline Assessment Program.

* All surveys may also be considered a source of disturbance to Harlequin duck habitat particularly when conducted by helicopter.

WP51/TOM/90FORM3.TWC

Table 3. 1991 harlequin duck habitat oiling conditions in Prince William Sound.

LOCATION	HARLEQUIN DUCK HABITAT TYPE	SEGMENT	TYPE SURVEY	DATE	OIL TYPE
EVANS ISLAND	MUSSEL BED SAMPLE SITE OFFSHORE ROCKS	EV015A	MAYSAP	4/30/91	AP,CV,ST BURIED HOR & MOR
	A N/T ORDER WAS ISSUED BY THE COAST GUARD AND ALL CLEANUP ACTIVIES CEASED ON 5/20/91				
IKTUA BAY LAGOON	STREAM NET SITE, POTENTIAL BREEDING AREA	EV008B	MAYSAP	4/27/91	SOR
A N/T ORDER WAS ISSUED BY THE FOSC AND ALL CLEANUP ACTIVITES CEASED 5/13/91					
IKTUA BAY	ADJACENT OFFSHORE ROCKS, MOLTING AREA	EV010	THIS SEGMENT WAS EXCLUDED FROM THE 1991 CLEANUP PLANS		
GUGUAK COVE, LAGOON	MUSSEL BED SAMPLE SITE & PROBABLE BREEDING STREAM SITE	EV070E	MAYSAP	5/25/91	AP,SOR,CT BURIED LOR
			SVPSR	7/25/91	SOR, BURIED HOR,MOR & LOR
ELRINGTON ISLAND NORTH TIP	MUSSEL SAMPLE SITE	ER020B	MAYSAP	5/23/91	AP,MS,SOR,CV,CT,ST BURIED OP,HOR
			SVPSR	7/10/91	MS & BURIED HOR
LATOUCHE	MUSSEL BED SAMPLE SITE	LA015E	MAYSAP	5/23/91	AP,MS,TB,SOR,CV,ST BURIED OP,HOR,MOR,LOR,OF
			SVPSR	7/15/91	BURIED HOR & MOR
SLEEPY BAY	MUSSEL SAMPLE SITE, PROBABLE BREEDING STREAM	LA018	MAYSAP	5/3/91	AP,SOR BURIED MOR & OP OIL
			SVPSR	8/3/91	AP,MS,SOR BURIED OP,HOR,MOR,TR
GREEN ISLAND, N.W. SIDE	MUSSEL SAMPLE SITE, OFFSHORE ROCKS	GR101 A&B	MAYSAP	5/2/91	SOR,CT,TB BURIED MOR,LOR & HOR
N/T ORDERS WERE ISSUED BY THE FOSC. ALL CLEANUP ACTIVITIES CEASED 6/8/91					
		A	SVPSR	6/28/91	HSOR,CV,CT,ST
		B	SVPSR	8/20/91	AP,HSOR,LOR,OP
GREEN ISLAND GIBBON ANCHORAGE	MOLTING AREA, OFFSHORE ROCKS	GR015A	THIS SEGMENT WAS EXCLUDED FROM THE 1991 CLEANUP PLANS		
GREEN ISLAND, SOUTH END	MOLTING AREA	GR300A	THIS SEGMENT WAS EXCLUDED FROM 1991 CLEANUP PLANS		
CHANNEL ISLAND	MOLTING AREA	GR004A	THIS SEGMENT WAS EXCLUDED FROM 1991 CLEANUP PLANS		
POINT BAINBRIDGE	MUSSEL BED SAMPLE SITE	BA004A	MAYSAP	5/26/91	AP,MS,SOR,CT
		N/T ORDER WAS SIGNED FOSC & CLEANUP ACTIVITIES CEASED 6/8/91			
			SVPSR	6/24/91	MS,SOR,TB,CV,CT,ST,OP BURIED MOR

LOCATION	HARLEQUIN DUCK HABITAT TYPE	SEGMENT	TYPE SURVEY	DATE	OIL TYPE
BAINBRIDGE PASSAGE, BAY	MOLTING SITE, OFFSHORE ROCKS	BA006C	MAYSAP	5/21/91	AP,MS,TB,SOR,CV,CT BURIED OP
		SUBSEGMENT B	SVPSR	5/12/91	AP,MS,TB
WEST COVE, DISK ISLAND	MUSSEL SAMPLE SITE	DI067A	MAYSAP	5/22/91	TB,SOR,CT,ST BURIED HOR,MOR
A N/T ORDER WAS ISSUED BY THE FOSC AND ALL CLEANUP ACTIVITIES CEASED 6/30/91					
NORTHWEST BAY ELEANOR ISLAND	PROBABLE BREEDING HABITAT & FEEDING AREA	EL052 A	MAYSAP	5/21/91	DV,ST BURIED MOR & LOR
		SUBSEGMENT B	MAYSAP	4/27/91	SOR BURIED HOR,MOR & OF
BLOCK ISLAND LAGOON & HELIPORT	FEEDING & MOLTING HABITAT	EL015	MAYSAP	4/30/91	SOR,CV,CT,ST BURIED HOR & OF
A N/T ORDER WAS ISSUED BY THE FOSC AND ALL CLEANUP ACTIVITIES CEASED 5/15/91					
BLOCK ISLAND LAGOON & HELIPORT	MUSSEL SAMPLE SITE	EL013A	MAYSAP	4/30/91	TB,SOR,CV,ST,CT BURIED HOR,MOR
			SVPSR	5/4/91	AP,HSOR BURIED HOR
APPLEGATE ISLAND	MOLTING & FEEDING & OFFSHORE ROCKS	AE004 A&B	MAYSAP	5/2/91 and 5/5/91	MS,AP,TB,SOR,CT BURIED OF & TR
			2 HARLEQUIN DUCKS OBSERVED DURING MAYSAP SURVEY		
A N/T ORDER WAS ISSUED BY THE FOSC AND ALL CLEANUP ACTIVITIES CEASED 5/2/91 FOR SUBSEGMENT A AND 5/25/91 FOR SUBSEGMENT B					
APPLEGATE ISLAND, LAGOON	MOLTING & FEEDING HABITAT, OFFSHORE ROCKS	AE005 A,B&C	MAYSAP	5/2/91	MS,CT BURIED OF
A N/T ORDER WAS ISSUED BY THE FOSC AND ALL CLEANUP ACTIVITIES CEASED ON 5/20/91					
FOUL BAY,ISLANDS & OFFSHORE ROCKS	MOLTING & FEEDING SITES	MA002A	MAYSAP	5/22/91	AP,SOR,MS,CT
		2 HARLEQUIN DUCKS WERE OBSERVED DURING MAYSAP SURVEY			
NORTH SHORE ENTRANCE TO BAY OF ISLES	FEEDING AND ROOSTING AREA	KN020	THIS SEGMENT WAS NOT INCLUDED IN THE 1991 CLEANUP PLANS		
OFFSHORE ROCKS, ENTRANCE TO BAY OF ISLES	MOLTING, FEEDING & ROOSTING HABITAT	KN022	THESE ISLANDS WERE NOT INCLUDED IN THE SHORELINE CLEANUP OR SURVEYS DURING THE 1991 SEASON		
	A N/T ORDER WAS SIGNED BY THE FOSC & CLEANUP ACTVITIES CEASED ON 4/27/91				
		KN018	THIS SEGMENT WAS EXCLUDED IN 1991 CLEANUP PLANS		

LOCATION	HARLEQUIN DUCK HABITAT TYPE	SEGMENT	TYPE SURVEY	DATE	OIL TYPE
BAY OF ISLES DEATH LAGOON	MUSSEL SAMPLE SITE	KN136A	MAYSAP	5/4/91	TARMATS,AP,SOR,CV,CT,ST BURIED HOR,MOR,LOR
			SVPSR	7/17/91	AP,SOR,CV,CT,ST BURIED HOR,MOR,LOR
WEST ARM, BAY OF ISLES LAGOON	PROBABLE BREEDING & FEEDING SITE STREAM NET SITE	KN201	MAYSAP	5/2/91	SOR,TAR PATTIES
	A N/T ORDER WAS ISSUED BY THE FOSC AND ALL CLEANUP ACTIVIIES CEASED ON 5/25/91				
PLEIADES ISLANDS	MOLTING & FEEDING OFFSHORE ROCKS	PL001	THIS SEGMENT WAS EXCLUDED FOR THE 1991 CLEANUP PLAN		
	A N/T ORDER WAS SIGNED BY THE FOSC & CLEANUP ACTIVITES CEASED ON 4/11/91				
DELENIA ISLANDS	OFFSHORE ROCKS, FEEDING AND MOLTING AREA	DE001	MAYSAP	5/2/91	TB,SOR,CV,ST
CHENEGA ISLAND, NORTH TIP	MUSSEL SAMPLE SITE & FEEDING AREA	CH010B	MAYSAP	5/1/91	SOR,TARMAT
A N/T ORDER WAS SIGNED BY THE FOSC AND ALL CLEANUP ACTIVITIES CEASED 5/21/91					
			SVPSR	7/11/91	HSOR, BURIED HOR & MOR
JUNCTION ISLANDS	MOLTING & FEEDING OFFSHORE ROCKS	CH011	MAYSAP	5/1/91	SOR,CT,AP,TAR
			SVPSR	7/1/91	SOR,CT,ST,TB
KAKE COVE	PROBABLE BREEDING & FEEDING AREA STREAM NET SITE	CH017	THIS SEGMENT WAS EXCLUDED FOR THE 1991 CLEANUP PLANS		
KNIGHT ISLAND WEST SHORE	FEEDING & ROOSTING AREAS, OFFSHORE ROCKS	KN500 A&B	MAYSAP	4/30/91	SOR,CV BURIED HOR,MOR,LOR
		A	SVPSR	6/10/91	BURIED HOR & MOR
		B	SVPSR	8/1/91	BURIED HOR & LOR
HERRING POINT	MOLTING & FEEDING AREA OFFSHORE ROCKS	KN300 A	MAYSAP	9/30/91	SOR BURIED OP & HOR
			SVPSR	4/80/91	SOR,CT,CV, BURIED OR OILING
SOUTH TIP, CRAFTON ISLAND	MOLTING & FEEDING AREA, OFFSHORE ROCKS	CR004 AB&C	MAYSAP	5/20/91	SOR,CV,CT,ST,OP BURIED HOR
		A	SVPSR	7/2/91	MS,OP
		B	SVPSR	7/20/91	SOR,CV,ST,MOR,LOR
SNUG HARBOR	PROBABLE BREEDING & FEEDING AREA STREAM NET SITE	KN401 B&C	MAYSAP	4/26/91	AP,TB,SOR,CT
LOG JAM BAY	FEEDING & MOLTING AREA, STREAM HABITAT	KN211C&D	MAYSAP	4/2/91	SOR,CT,TAR BALLS
A N/T TREATMENT ORDER WAS SIGNED BY THE FOSC AN CLEANUP ACTIVIES CEASED ON 4/29/91 FOR SUBSEGMENT C AND 6/6/91 FOR SUBSEGMENT D					
FLEMMING ISLAND	MUSSEL SAMPLE SITE	FL004A	MAYSAP	5/12/91	AP,SOR,CV,CT BURIED OP,HOR,MOR

LOCATION	HARLEQUIN DUCK HABITAT TYPE	SEGMENT	TYPE SURVEY	DATE	OIL TYPE
FLEMMING ISLAND SOUTH TIP	MOLTING & FEEDING AREA, OFFSHORE ROCKS	FL003	THIS SEGMENT WAS EXCLUDED FROM THE 1991 CLEANUP PLAN		
HERRING BAY	MOLTING & FEEDING AREA	KN141A&B	MAYSAP	5/19/91	SOR,CV,CT,ST,FM BURIED MOR,LOR,TR
A N/T ORDER WAS ISSUED BY THE FOSC AND ALL CLEANUP ACTIVITIES CEASED ON 5/31/91					
HERRING BAY	MUSSEL SAMPLE SITE	KN113B	MAYSAP	4/29/91	BURIED HOR/MOR
A N/T ORDER WAS ISSUED AND ALL CLEANUP ACTIVITIES CEASED 5/14/91					
			SVPSR	7/19/91	STAIN ONLY
HERRING BAY ADF&G CAMP	PROBABLE BREEDING & FEEDING AREA STREAM HABITAT	KN132B	MAYSAP	5/1/91	AP,SOR BURIED OIL
		D	MAYSAP	5/24/91	SOR,ST,CV BURIED HOR,MOR,LOR
		B (STREAM)	SVPSR	8/1/91	AP,SOR BURIED HOR,MOR,LOR
NAKED ISLAND, CABIN BAY	PROBABLE BREEDING & FEEDING AREA	NA024 A&F	MAYSAP	5/1/91	AP,TB
N/T ORDERER SIGNED BY THE FOSC ALL CLEANUP ACTIVITIES CEASED AS OF 5/25/91					
		A	SVPSR	5/14/91	MS,CV,CT
NAKED ISLAND, OUTSIDE BAY	PROBABLE BREEDING & FEEDING AREA	NA026B	THIS SEGMENT WAS EXCLUDED IN 1991 CLEANUP PLANS		
FOUL PASSAGE	MOLTING & FEEDING AREA, OFFSHORE ROCKS	DI059	THIS SEGMENT WAS EXCLUDED IN 1991 CLEANUP PLANS		
WHALE BAY, SOUTH ARM	PROBABLE BREEDING & FEEDING AREA STREAM NET SITE	WH502	MAYSAP	5/2/91	CV,CT
A N/T ORDER WAS SIGNED BY THE FOSC AND ALL TREATMENT CEASED 6/10/91					
WHALE BAY, MAINLAND	MOLTING, FEEDING & OFFSHORE ROCKS STREAM HABITAT	WH003	SSAT	4/1/91	CT,AP,ST,FM BURIED OR & OF OILING
			ASAP	8/5/91	SOR,CT BURIED OIL
WHALE BAY, WEST ARM	PROBABLE BREEDING & FEEDING AREA STREAM NET SITE	WH504	DEC	10/12/91	NO OIL OBSERVED
PADDY BAY	BREEDING & FEEDING AREA STREAM NET SITE	PA001	THIS SEGMENT WAS EXCLUDED FOR TREATMENT IN 1991		
ESHAMY BAY, SOUTH ARM	MOLTING & FEEDING AREA	EB009	MAYSAP	4/29/91	TAR BALLS, VERY LIGHT
	A N/T ORDER WAS SIGNED BY THE FOSC & CLEANUP ACTIVITES CEASED ON 5/15/91				
AGULIAK ISLAND	MOLTING & FEEDING AREA, OFFSHORE ROCKS	AG001 A&B	SSAT	6/8/91	AP,MSOR BURIED OP OIL
	A N/T ORDER WAS SIGNED BY THE FOSC AND CLEANUP ACTIVITIES CEASED ON 7/8/91				

LOCATION	HARLEQUIN DUCK HABITAT TYPE	SEGMENT	TYPE SURVEY	DATE	OIL TYPE
AGULIAK ISLAND	MOLTING & FEEDING AREA, OFFSHORE ROCKS MUSSEL BED AREA	AG009 A	MAYSAP	5/4/91	LSOR,OP BURIED OP, MOR
			2 HARLEQUIN DUCKS OBSERVED DURING SURVEY		
MUMMY ISLAND	FEEDING & MOLTING AREA, OFFSHORE ROCKS	MU900	MAYSAP	5/19/91	SOR BURIED OP/MOR
A N/T ORDER WAS ISSUED BY THE FOSC AND CLEANUP ACTIVITIES CEASED ON 6/8/91					
SQUIRREL ISLAND	MOLTING & FEEDING AREA, OFFSHORE ROCKS	SL001 ABCD&E	MAYSAP	5/4/91	TB,SOR,CT,ST
A N/T ORDER WAS ISSUED BY THE FOSC AND ALL CLEANUP ACTIVITIES CEASED 5/20/91					
MALLARD BAY, DRIER BAY	PROBABLE BREEDING & FEEDING AREA STREAM NET SITE		THIS SEGMENT WAS EXCLUDED IN THE 1991 CLEANUP PLAN		
SOUTH TIP, PERRY ISLAND	MOLTING & FEEDING AREA, OFFSHORE ROCKS	PR003 ACD	MAYSAP	5/4/91	AP,MS,SOR,CT
			4 HARLEQUIN DUCKS WERE OBSERVED DURING MAYSAP SURVEY		
PERRY ISLAND SOUTH SHORE	MOLTING & FEEDING AREA, OFFSHORE ROCKS	PR002	MAYSAP	4/26/91	SOR,CT BURIED HOR,MOR,TR
			DEC	6/20/91	ST,OF BURIED OR OILING
			ASAP	8/21/91	CT,ST BURIED OR,OP,OF OILING

Abbreviations

MS	Oil Mousse (weathered thick brown tar)
OP	Pooled Oil (surface or buried mobile oil)
ST	Oil Stain
N/T	No Treatment
AP	Asphalt (weathered mousse or tar that is lying on the substrate surface cementing it together)
TB	Tarballs (small localized areas of mousse)
CV	Tar Cover (boulders or bedrock covered with tar)
CT	Tar Coating (boulders or bedrock coated with tar)
OF	Oil Film
HOR	Heavy Oil Residue (buried oil that has heavily permeated gravel)
MOR	Moderate Oil Residue (buried oil that has moderately permeated gravel)
LOR	Light Oil Residue (buried oil that has lightly permeated gravel)
SOR	Surface Oil Residue (any oil that is on surface of a beach substrate, similar to asphalt)
HSOR	Heavy Surface Oil Residue
MSOR	Moderate Surface Oil Residue
LSOR	Light Surface Oil Residue

DESCRIPTIONS IN ( ) ARE AN UNOFFICIAL ATTEMPT TO CLARIFY OILING DEFINITIONS.

MAYSAP	May Shoreline Assessment Program (1991)
SVPSR	State Vessels Progress Status Report (1991)
DEC	Department of Environmental Conservation's shoreline oiling evaluation survey.
FOSC	Federal On Scene Coordinator (in charge of cleanup) Usually the USCG Admiral.
TAG	Technical Advisory Group (consisting of USCG FOSC, DEC, EXXON, NOAA)
*	This table incorporates locations of Harlequin Ducks observed and documented during the 1991 Spring Shoreline Assessment Program.
Note:	Definitions and description of oiling change with the individual and agency making the observations. Most observations are general.

WP51/TOM/91FORM.TWC

SUPPLEMENT 2

SOURCES OF INFORMATION AND CRITERIA FOR OILED STREAM HABITATS

Much supporting documentation existed on oiling of anadromous fish streams in western PWS where harlequin ducks would be expected to nest. Habitat Division, ADF&G, compiled 1989-91 oiling information for PWS streams potentially used by harlequin ducks. Table 1 lists oiling observations and their sources by location and date for harlequin duck streams. Table 1 also describes the selection of streams, sources of oiling data, criteria used for summarizing oiling information, and availability of supplemental data.

The stream oiling in Table 1 was sorted by ADEC segment number, sub-segment, anadromous stream catalog number (ASC) (ADF&G 1990), and date. For each stream, the stream number, location and oiling summary information was listed under a sub-heading. Where the ASC number could not be clearly identified, the information was listed by segment and sub-segment numbers minus oiling summaries. Segment MA002 was included in Table 1, since it consisted of four small islands frequented by harlequin ducks offshore from potential nesting streams.

Sources of Information

All available data sources produced by ADF&G Habitat Division on anadromous streams in western PWS were used in Table 1. This information was supplemented with ADEC data, sketches from ADF&G Commercial Fisheries and Sport Fisheries surveys, and data from the combined government/Exxon surveys.

Habitat Division data sources on oiling of anadromous streams were PWS 1989 logs, treatment and oiling summary reports, data forms and sketches associated with ANADSCAT (1990 Anadromous Stream Cleanup Assessment Team), Pre-ASAP (Habitat pre-screening for the 1989 August Shoreline Assessment Program), MAYSAP (1991 May Shoreline Assessment Program), treatment monitoring, the 1989/1990 winter study data, and miscellaneous surveys conducted by the Habitat Division in conjunction with other agencies. This information was supplemented with data from photographs, videotapes, and sediment sample databases when necessary. In some cases videotapes were reviewed and abstracted to further document oiling conditions.

Sources for 1989 oiling conditions included oiling categories from the SCAT (Shoreline Cleanup Assessment Program, the earliest 1989 survey) and the ADEC Fall Beach Survey (Fall Walk-a-thon). Where Habitat Division oiling information seemed insufficient or oiling descriptions covered a wide range, ADEC Gundlach transect data, ADEC monitoring reports, references to descriptive ADEC photos, and detailed SCAT descriptions were used.

Oiling Categories

The comments section included 1989 information from the SCAT survey, and the 1989 ADEC Fall Survey, containing oiling conditions from the DEC computer maps at stream mouths. The 1990 and 1991 oiling conditions were from ANADSCAT and MAYSAP surveys conducted by an interagency team from Exxon, Coast Guard, NOAA, and ADF&G.

Caution is urged in evaluating these comments, however, since oiling classifications varied among years, agencies and, to some extent, among observers. The comments are intended to provide general information for comparative purposes. The following section summarizes Habitat Division criteria in evaluating oiling conditions from the compiled comments.

Oiling Criteria

Assigning oiling categories by year to the compiled stream information was not a simple task because the quality and detail of observations varied widely (especially in 1989). Both oiling criteria and the character of the oiling itself changed during 1989-91. Thus 1989 criteria largely ignored subsurface oiling. Although streams were monitored with some attention to subsurface contamination in 1990, this problem was not fully addressed until the 1991 MAYSAP survey.

The Habitat Division EVOS group jointly reviewed individual oiling comments for all harlequin duck streams and assigned oiling categories generally as described in the following paragraph:

> "The SCAT and ADEC Fall Beach surveys were used as comparisons for all other observations. They were not included in the Habitat oiling summaries. Whenever there were no Habitat Division observations for a given stream within a year, or when information was considered insufficient, the Habitat summary was considered N/A. For each year, oiling was summarized with emphasis on the earliest and most detailed information of the season in order to reflect untreated conditions. In cases where only late-season observations were available, no attempt was made to extrapolate oiling back to previous surveys such as SCAT or the 1989/1990 Winter Study."

A combination of oiling criteria were used in an attempt to standardize oiling categories throughout the three years. This standardization was heavily dependent upon field sketches of oiling conditions and dimensions of oiled areas. In determining oiling criteria, a "sifting process" applied major criteria first, then adjusted using further considerations (ADF&G Habitat Division, Anchorage).

The primary consideration consisted of a combination of oil band width and percent coverage criteria from the ADEC Shoreline Field Treatment Manual (1989) and the ADEC Cleanup Monitoring Standard Operating Procedures Manuals (1990, 1991). Within that framework, the proximity to the stream and mobility of the oiled area were considered, using a 50-m radius as the limit. Alternatively, such as in the case of segment KN 134, geographical features such as tombolos or rocky outcrops that may form a barrier to oil reaching the stream were taken into account.

As subsurface oiling became evident, its extent and type was considered in application of the categories. Although surface oiling was greatly reduced in 1991, subsurface oiling continued to persist (Table 1). The 1991 oiling categories reflected a greater emphasis on type and percent of subsurface oiling. The oiling summary values were noted as "subsurface" where the amount of subsurface oiling affected the oiling category. The persistence of oiling was best demonstrated in individual descriptions of 1991 subsurface oiling conditions (Table 1).

For example, in EL052 (ASC 226-10-16902), heavy surface oil coverage at this Eleanor Island stream mouth was documented in an ADEC photograph taken in mid-April 1989 (Table 1). Eight days later, however, the survey crew found considerably less surface oiling in a detailed survey. Persistent subsurface oiling, however, was found in this segment during the next two years. The area would have qualified as medium oiling according to band width/coverage criteria established later in 1989, but Habitat Division classified this oiling as heavy based on the initial photograph. The 1990 data indicate medium oiling and some penetration. The 1991 classification is considered as light oiling, according to the main criteria, but this is qualified by the "subsurface" notation, according to MAYSAP documentation.

Photographs and videos documenting oiling information on the anadromous streams included in Table 1 are available from ADF&G Habitat and Restoration Division, Anchorage.

REFERENCES

Alaska Dept. of Environ. Conserv. (ADEC). 1989. EVOS Shoreline Field Treatment Manual. ADEC Oil Spill Response Office, Anchorage.

________. 1990. Cleanup Monitoring Standard Operating Procedures Manual. Abbreviations/codes version 3.8.90. ADEC EVOS Center, Anchorage.

________. 1991. Cleanup Monitoring Standard Operating Procedures Manual. ADEC EVOS Center, Anchorage.

Alaska Dept. of Fish and Game (ADF&G). 1990. An atlas to the catalog of waters important for spawning, rearing or migration of anadromous fishes. ADF&G Habitat Division, Southcentral Region, Anchorage. 131pp.

Table 1. Selected information on oiling of harlequin duck streams from detailed reports.

LOCATION	SEGMENT STREAM#	DATE	COMMENTS
BAINBRIDGE ISLAND	BA006 A 2264016269	07/23/89	NO OIL OBSERVED IN SEGMENT.
BAINBRIDGE ISLAND	BA006 A 2264016269	08/10/89	GENERAL - 1% LIGHT & 2% VERY LIGHT SURFACE OIL FOR SEGMENT OCCASIONAL TAR PATTIES, SUBSURFACE OIL. (GENERAL FOR ENTIRE SEGMENT).
BAINBRIDGE ISLAND	BA006 A 2264016279	07/23/89	NO OIL OBSERVED IN SEGMENT.
BAINBRIDGE ISLAND	BA006 A 2264016279	08/10/89	GENERAL - 1% LIGHT & 2% VERY LIGHT SURFACE OIL FOR SEGMENT OCCASIONAL TAR PATTIES, SUBSURFACE OIL. (GENERAL FOR ENTIRE SEGMENT).
CHENEGA ISLAND, NORTH	CH001 2262016280	06/29/89	NORTH BANK: 12' WIDE OIL BAND ALONG STREAM BANK, WITH SOME PENETRATION, WIDENING TO 30-40' FARTHER NORTH ALONG BEACH. MOUSSE/SAND TARMATS DEPOSITED IN UITZ ADJACENT TO BAND. THE 30-40' WIDE OIL BAND BEGINS 50' NORTH OF STREAM. SOUTH BANK: SOUTH OF STREAM, THE BEACH APPEARS UNOILED BUT CLEAN SHALE IS BEING DEPOSITED OVER A RELATIVELY NARROW BAND OF MOUSSE WHICH APPEARS TO END 25' AWAY FROM STREAM. SKETCH. (VALDEZ OFFICE FIELD LOG ENTRY ON PAGES 60-61).
CHENEGA ISLAND, NORTH	CH001 2262016280	06/29/89	MAPS. SOUTH OF STREAM, NARROW BAND OF MOUSSE ENDS APPROXIMATELY 25FT FROM STREAM. ON THE NORTH SIDE OF THE STREAM TIP A 30-40FT WIDE BAND STOPS APPROXIMATELY 50FT NORTH OF STREAM. MOUSSE, SAND/TARMATS HAVE BEEN DEPOSITED IN UITZ. OIL IS PRESENT ON NORTH BANK IN 12FT WIDE AREA.
CHENEGA ISLAND, NORTH	CH001 2262016280	07/02/89	HEAVY OIL NORTH OF STREAM, MOD IMMEDIATELY ADJACENT STREAM BEACH ON SOUTH SIDE OF STREAM. LIGHT 1-2M BAND, BEACH ON TIP NORTH SIDE OF STREAM MODERATE 5-6M WIDE BAND. SKETCH.
CHENEGA ISLAND, NORTH	CH001 2262016280	07/26/89	BEACH HEAVILY OILED UP TO STREAM BANK.
CHENEGA ISLAND, NORTH	CH001 2262016280	07/26/89	BEACH HEAVILY OILED, BUT STREAM AND ADJACENT SUBSTRATE ONLY MOD TO LIGHTLY OILED.

CHENEGA ISLAND, NORTH	CH001 2262016280	07/28/89	AT MOUTH - THICK, NARROW BAND OF OIL/MOUSSE JUST NORTH OF STREAM MOUTH.
CHENEGA ISLAND, NORTH	CH001 2262016280	08/13/89	MODERATELY OILED. OILED TAR MOUSSE BAND, MAP 19.
CHENEGA ISLAND, NORTH	CH001 2262016280	10/01/89	(NOTE: DAY OF DATE NOT AVAILABLE). WEST OF STREAM: OIL ON ROCKS IN A 30 FT WIDE ZONE. AREA ON EAST HAS DEEPER PENETRATION IN VICINITY OF ADEC STATION. A 20 FT WIDE BAND OF MOUSSE AND OILY DEBRIS IS 30 FT NORTH OF STREAM. OILED ZONE VARIES 3-75 FT WIDE WITH INTERMITTENT COVERAGE AND PENETRATION.
CHENEGA ISLAND, NORTH	CH001 2262016280	10/14/89	HIGH EXPOSURE. HEAVY TO MODERATE OILING.
CHENEGA ISLAND, NORTH	CH001 2262016280	12/09/89	MAPS. 1 X 30M OIL BAND ON SOUTH BANK - MITZ >75% COVERAGE, 13CM PENETRATION. 8 X 50M OIL BAND ON NORTH BANK <1%. FILM ON SURFACE.
CHENEGA ISLAND, NORTH	CH001 2262016280	04/13/90	SMALL BAND OF ASPHALT ON RIGHT SIDE OF STREAM, 2 FEET WIDE, 30 FEET LONG. OIL ON STREAM BANK.
CHENEGA ISLAND, NORTH	CH001 2262016280	04/25/90	SMALL AREA OF TARMAT IS ONLY SIGN THAT THIS BEACH HAS BEEN OILED. OIL ON STREAM BANK.
CHENEGA ISLAND, NORTH	CH001 2262016280		TRANSECT NORTH OF STREAM. AVERAGE OIL DEPTH = 5CM, AVERAGE THICKNESS .05CM. BAND WIDTH 25M ON 04/08/89. SUMMARY: JULY 89: BEACH WITH REALTIVELY NARROW BAND OF OILING. 04/08/89: 6-9M WIDE BAND WITH 60-95% COVERAGE. 05/22/89: 25M WIDE OILED ZONE WITH 5-98% COVERAGE.
CHENEGA ISLAND, NORTH	CH002 B 2262016180	05/25/89	AERIAL PHOTO OF OIL BAND BY STREAM.
CHENEGA ISLAND, NORTH	CH002 B 2262016180	06/02/89	HEAVY OIL BAND UP TO 20M WIDE ON WEST SIDE OF STREAM. 25CM PENETRATION. EAST SIDE OF STREAM HAS OIL BAND 1 TO 10M WIDE. GOOD SKETCH.
CHENEGA ISLAND, NORTH	CH002 B 2262016180	06/29/89	WEST BANK: OIL BAND VARIES FROM 3-12' WIDE, INTERMITTENT, THEN TO 75' WIDE, INTERMITTENT COVERAGE WITH PENETRATION. OILY DEAD FUCUS MATS ADJACENT TO CHANNEL. EAST BANK: 10-30' WIDE CLEAN AREA ALONG STREAM CHANNEL, WITH <10-20' WIDE OIL/MOUSSE BAND ADJACENT TO IT. OIL COMES TO WITHIN 10 FT OF STREAM CHANNEL IN AN OILED CHANNEL BANK. DEEPER PENETRATION ON EAST SIDE. (IN VALDEZ OFFICE FIELD LOG ON PAGES 59-60).

CHENEGA ISLAND, NORTH	CH002 2262016180	B	07/05/89	COBBLE & GRAVEL BEACH CONTAINS OIL AND SOME MOUSSE, DEPOSITS 12" WIDE, OIL COVERAGE 80-90%. LOOKS LIKE REOILING.
CHENEGA ISLAND, NORTH	CH002 2262016180	B	07/05/89	AREA TO WEST HAS A WIDE BAND OF OILED COBBLE (50-75FT WIDE) WITH MOUSSE PATTIES IN PATCHES. AREA RE-OILED: 2X40' AREA OF OILED SEDIMENTS ALONG WESTERN STREAM BANK (PER SKETCH), MOUSSE, OILED DEBRIS AND SEDIMENTS SHOWN ON EAST SIDE.
CHENEGA ISLAND, NORTH	CH002 2262016180	B	07/09/89	MOD-HEAVY 12FT WIDE.
CHENEGA ISLAND, NORTH	CH002 2262016180	B	07/11/89	BAND OF OIL ON WEST BANK EXTENDS AROUND EDGE OF COVE.
CHENEGA ISLAND, NORTH	CH002 2262016180	B	07/11/89	POST TREATMENT. OIL IN STREAM CHANNEL SUBSTRATE, WEST BANK STILL LOTS OF OIL - 8" OR MORE. EAST BANK - OILED SEDIMENTS, HALF REMOVED.
CHENEGA ISLAND, NORTH	CH002 2262016180	B	07/26/89	STREAM ITSELF APPEARED TO BE OIL-FREE, HOWEVER, NORTH BANK HAD A HEAVY BAND OF MOUSSE - ABOUT 25-30' WIDE X 150YDS LONG.
CHENEGA ISLAND, NORTH	CH002 2262016180	B	07/26/89	ENTIRE AREA MODERATELY TO HEAVILY OILED.
CHENEGA ISLAND, NORTH	CH002 2262016180	B	07/28/89	OILED SEDIMENTS HAD BEEN REMOVED FROM 40FT LONG X 2-3FT WIDE BAND ON EAST BANK. WEST BANK AND STREAM DELTA HAD WIDE BAND OF OIL. PENETRATION TO >8". (IT IS) LIKELY THAT OIL HAD ENTERED STREAM CHANNEL SUBSTRATE DUE TO PENETRATION. SOME MANUAL (TREATMENT) HAD BEEN DONE.
CHENEGA ISLAND, NORTH TIP	CH002 2262016180	B	07/31/89	MOUTH OF STREAM HEAVILY OILED.
CHENEGA ISLAND, NORTH	CH002 2262016180	B	08/05/89	DETAILED SUMMARY OF OIL PENETRATION ON STREAM SITE.
CHENEGA ISLAND, NORTH	CH002 2262016180	B	08/13/89	HEAVILY OILED. SAMPLE 89RLG009V, MAP #18.
CHENEGA ISLAND, NORTH	CH002 2262016180	B	09/07/89	APPEARS MODERATELY OILED. POST TREATMENT ASSESSMENT.
CHENEGA ISLAND, NORTH	CH002 2262016180	B	10/14/89	HEAVY OILING. RICK GUSTIN HAS GOOD BASIC INFO FROM JULY SURVEY.

CHENEGA ISLAND, NORTH	CH002 2262016180	B	11/02/89	HEAVY BAND IN MID TO UITZ ON LEFT BANK. MODERATE TO HEAVY ON RIGHT BANK. OIL INTO STREAM BED. 11 X 45M OIL BAND ON LEFT BANK. 7.6 X 67M OIL BAND ON RIGHT BANK.
CHENEGA ISLAND, NORTH	CH002 2262016180	B	04/13/90	HEAVILY OILED. SEE WINTER PROJECT MAP. OIL ON STREAM BANKS.
CHENEGA ISLAND, NORTH	CH002 2262016180	B	04/26/90	WEST SIDE OF STREAM: 2x30M BAND AP IN UITZ AND 20X30M AREA OF SPORADIC TARMAT LYING ADJACENT TO IT IN MITZ 6CM THICK. EAST BANK UPSTREAM: 6X4M BROKEN AP 3CM THICK IN GRASSY AREA AND A 2X60M SPORADIC AP IN UITZ 6CM THICK. AP BAND PARTIALLY BURIED ON WEST SIDE.
CHENEGA ISLAND, NORTH	CH002 2262016180	B	08/06/90	WEST SIDE OF STREAM: 2 BANDS OF OIL: A 44M LONG X 1M WIDE BAND OF PATCHY TARMAT/OR SEDIMENTS IN THE UITZ - BELOW THE SWASH ZONE. A 32M LONG X 3-5M WIDE BAND IN THE LUITZ OF BROKEN TARMAT/OR SEDIMENTS. EAST SIDE: SPORADIC PATCHES TARMAT/OP/OR SEDIMENTS 4M FROM THE STREAM CHANNEL IN THE MITZ. REASSESS IN SPRING.
CHENEGA ISLAND, NORTH	CH002 2262016180	B	05/05/91	PER OG SKETCH. EAST BANK: AT MOUTH, 2X20M 1% AP BAND. FURTHER UPSTREAM SMALL PATCHES OF .2X2M 15% CV, 1X3M 10% SOR AND .2X5M 1% HSOR ADJACENT TO STREAM BANK. WEST BANK: HEAVIEST OILING IN VICINITY OF STREAM IS 8X22M BAND WITH 2% AP AND 5% HSOR. REST IS SMALL PATCHES OF CV AND AP WELL REMOVED FROM STREAM. MAD FORM LISTS 20CM PENETRATION AND MOR FOR THE OIL BAND.
CHENEGA ISLAND, NORTH	CH002 2262016180	B	06/13/91	WORK ORDER WAS FOLLOWED. SUGGEST THAT ADF&G REASSESS THIS SITE AT A LATER DATE FOR RE-TILLING TREATMENT. "MOST ALL OF THE OILING WAS TILLED WITH VERY LITTLE REMOVAL. IT WAS 80% LOR AND 20% MOR".
CHENEGA ISLAND, NORTH	CH002 2262016180	B	08/22/91	HEAVIEST REMAINING OIL IS A 1 X 3 METER PATCH OF HOR/OP LOCATED IN AREA B ON THE WEST SIDE OF THE STREAM. COVERED BY CLEAN SEDIMENT. IT MISSED TREATMENT IN 1991. DUE TO ITS DISTANCE FROM THE STREAM, IT DOES NOT APPEAR TO POSE A THREAT TO THE STREAM. OTHER AREAS OF SURFACE OIL ARE LIGHT. NO REASSESSMENT NECESSARY IN 1992. LOTS OF PINKS IN STREAM AND BAY.
CHENEGA ISLAND, PRESTON COVE	CH010		08/01/89	RAT VISIT TO ASSESS TREATMENT. HEAVY TO MOD OIL.
CHENEGA ISLAND, KAKE COVE	CH017 2262016262	A	07/11/89	TRACE OF RANDOM TAR DROPS ON COBBLES & PEBBLE IN MID ITZ. LIGHT SHEEN OBSERVED ON SMALL POOLS IN TIDAL STREAM CHANNELS. (SKETCH)
CHENEGA ISLAND, KAKE COVE	CH017 2262016262	A	08/08/89	KAKE COVE AREA WAS OILED VERY LIGHTLY. STREAM ON WESTERN EDGE HAD 300 PINKS AT MOUTH.

CHENEGA ISLAND, KAKE KOVE	CH017 A 2262016262	08/13/89	89RLG008V, #16260 MAP #20, APPEARED LITTLE TO NO OIL IN AREA AT STREAM MOUTH.
CHENEGA ISLAND,	CH017 A 2262016270	07/11/89	"RANDOM DROPS ON BOULDERS" FROM SKETCH.
CHENEGA ISLAND, KAKE COVE	CH017 A 2262016270	07/26/89	VERY LIGHT OILING.
CHENEGA ISLAND, KAKE COVE	CH017 A 2262016270	08/08/89	KAKE COVE AREA WAS OILED VERY LIGHTLY. 1000 PINKS AT MOUTH. WALKED STREAM UP TO SMALL LAKE.
CHENEGA ISLAND, KAKE COVE	CH017 A 2262016270	08/25/89	LIGHT OILING IN COVE, NONE IN STREAM, TAR MOUSSE BAND IN UITZ.
CHENEGA ISLAND, KAKE COVE	CH017 A 2262016270	09/11/89	NO OIL SIGHTED.
CHENEGA ISLAND, KAKE COVE	CH017 A 2262016270	01/05/90	"NO OILING VISIBLE"
CHENEGA ISLAND, KAKE COVE	CH017 A CANNOT ID	08/13/89	KAKE COVE: 2 VISITS IN 1 DAY TO SAMPLE.
CRAFTON ISLAND	CR004	07/30/89	BEACH HEAVILY TO MODERATELY OILED. TREATMENT OCCURRING, VISIT BY RAT.
MAINLAND, ESHAMY BAY, NORTH OF MOUTH, LOOMIS CREEK	EB001 A 2253015060	05/22/89	MODERATELY OILED, SKETCH MUSSEL BED AT STREAM MOUTH HAS HIGH CONCENTRATION OF OIL COATING, HEAVILY OILED FUCUS NORTH SIDE OF STREAM ON OUTCROP. (WAS LISTED AS EB002).
MAINLAND, ESHAMY BAY, NORTH OF MOUTH, LOOMIS CREEK	EB001 A 2253015060	06/06/89	REPORTED OILED MUSSEL BED NOT CONFIRMED (TIDE TOO HIGH).
MAINLAND, ESHAMY BAY, NORTH OF MOUTH, LOOMIS CREEK	EB001 A 2253015060	06/06/89	NO HEAVY OILING OBSERVED.
MAINLAND, ESHAMY BAY, NORTH OF MOUTH, LOOMIS CREEK	EB001 A 2253015060	07/31/89	ISOLATED PATCHES OF OIL FROM LIGHT TO MODERATE, SOME MOUSSE OIL LANDED NEAR LOW TIDE. (WAS LISTED AS EB002).
MAINLAND, ESHAMY BAY, NORTH OF MOUTH, LOOMIS CREEK	EB001 A 2253015060	08/21/89	MAP #2, 89RLG078V, NO OIL SAMPLE FOUND.

MAINLAND, ESHAMY BAY, NORTH OF MOUTH, LOOMIS CREEK	EB001 A 2253015060	01/05/90	"NO OILING VISIBLE" (SEGMENT IN LOG IS EB002).
MAINLAND, ESHAMY BAY, BELOW GUNBOAT LAKES	EB007 A 2253015070	05/30/89	NO SPECIFICS ON STREAM AREA, NO SKETCH WITH PACKET. GENERAL = VERY LIGHT OILING, RARE SMALL TAR BALLS. >1%.
MAINLAND, ESHAMY BAY, BELOW GUNBOAT LAKES	EB007 A 2253015070	08/04/89	2% MED SURFACE OIL FOR SEGMENT 2% LIGHT SURFACE OIL.
MAINLAND, ESHAMY BAY, BELOW GUNBOAT LAKES	EB007 A 2253015070	09/06/89	BOOMED IN FRONT OF CREEK. VERY LITTLE OIL IN ESHAMY; A FEW LIGHTLY OILED SPOTS ON THE SOUTH SIDE NEAR THE MOUTH OF THE BAY, ANADROMOUS STREAM LOOKED GOOD.
MAINLAND, ESHAMY BAY, BELOW GUNBOAT LAKES	EB007 A 2253015070	09/11/89	VERY LIGHT TO NO OIL SHOWN FOR SEGMENT IN GENERAL. NO DESIGNATION MADE FOR SALMON STREAM AREA - PERHAPS BECAUSE A BOOM ACROSS THE COVE KEPT THEM OUT. SURVEY BY SKIFF AND FOOT.
MAINLAND, ESHAMY BAY, SOUTHEAST	EB009 A 2253015160	08/21/89	SORBENT BOOM BLOCKING FISH PASSAGE.
MAINLAND, ESHAMY BAY, SOUTHEAST	EB009 A 2253015160	08/21/89	RAT MOVED BOOM AT EB THAT WAS BLOCKING FISH PASSAGE.
MAINLAND, ESHAMY BAY, SOUTHEAST	EB009 A 2253015160		RARE TAR BALLS (FOR SEGMENT). HAND CLEAN.
MAINLAND, ESHAMY BAY	EB009 2253015140	06/06/89	NO OILING EVIDENT EXCEPT OILED FUCUS IN STORM BERM AND TAR BALLS. NO VISIBLE OILING ADJACENT TO STREAM. OILED FUCUS IN HIGH TIDE STORM BERM WEST OF STREAM, AND VERY SPOTTY TAR BALLS. NO SHEEN IN CHANNEL WITH AGITIATION. AREA BELKOW BANK HAS OILY FUCUS AND DEBRIS, INCLUDING ONE DEAD HEAVILY OILED BIRD. PER PHOTO: OIL APPEARS TO BE WITHIN 50M OF STREAM.
MAINLAND, ESHAMY BAY	EB009	05/30/89	NO OIL OBSERVED. SKETCH NOT WITH PACKET.
MAINLAND, ESHAMY BAY, EB009, EB012, EB013	EB009 A	07/29/89	RAT VISIT TO SITES TO PREASSESS FOR CLEANUP.
ELEANOR ISLAND, UPPER PASSAGE	EL015 A 2261016906	04/15/89	MOD TO LIGHT, PATCHY OIL BAND 30% COVERAGE, 1CM PENETRATION 0.5CM THICKNESS, NO SKETCH WITH PACKAGE.
ELEANOR ISLAND, UPPER PASSAGE	EL015 A 2261016906	09/14/89	SKETCH HAS LABEL "VERY LIGHT" OIL BAND ON BOTH SIDES OF STREAM IN UITZ, YET QUALIFIES AS 'LIGHT' DUE TO THE AREA OF OILING SHOWN.

ELEANOR ISLAND, UPPER PASSAGE	EL015 A 2261016906	09/15/89	REFERRED TO AS "EL010". A "VERY LIGHT" DESIGNATION WAS GIVEN TO THE STREAM AREA.
ELEANOR ISLAND, UPPER PASSAGE	EL015 A 2261016906	11/06/89	REFERRED TO AS "EL010". DISCUSSES TREATMENT TO SEGMENT. GUNDLACH STUDY SITE #7. NO SPECIFICS ON STREAM.
ELEANOR ISLAND, UPPER PASSAGE	EL015 A 2261016906	04/13/90	BANDS OF ASPHALT AND MOUSSE AT UPPER INTERTIDAL ON BOTH SIDES OF CREEK. PENETRATION 2". SHOVEL/STEAM.
ELEANOR ISLAND, UPPER PASSAGE	EL015 A 2261016906	04/23/90	OIL PRESENT INCLUDES A 100M X 1 M WIDE BAND OF INTERMITTENT TAR PATTIES RUNNING THE LENGTH OF THE UITZ ON NORTH SIDE OF STREAM. A 2M WIDE LIGHTLY OILED BAND IN M & UITZ ON SOUTH SIDE OF STREAM & OILED ORGANIC DEBRIS ON SOUTH SIDE IN SWASH ZONE, OILED LOG. OIL 1-2CM THICK.
ELEANOR ISLAND, UPPER PASSAGE	EL015 A 2261016906	06/21/91	LSOR IN CRUMBLE STAGE. AREA K BROKEN UP. AREA C BROKEN UP. AREA AROUND TOMBOLO NOT SURVEYED, FOUND TO HAVE LSOR ALSO BROKEN UP. NOT RECOMMENDED FOR FUTURE REASSESSMENT. REMAINING OIL IS CT AND ST ON SURFACE; LOR AND OF IN SUBSURFACE.
ELEANOR ISLAND, NORTHWEST BAY	EL052 B 2261016902	04/13/89	HEAVILY OILED. 40M WIDE OIL BAND WITH OVER 50% COVERAGE. TRANSECT CROSSES STREAM.
ELEANOR ISLAND, NORTHWEST BAY	EL052 B 2261016902	04/13/89	EARLY AERIAL PHOTO OF OILING. SHOWS WIDE OIL COVERAGE.
ELEANOR ISLAND, NORTHWEST BAY	EL052 B 2261016902	04/22/89	MODERATE OILING LISTED 3-10M WIDE BAND OVER 100% OF SEGMENT. LIGHT OILING ON MOST OF INNERMOST COVE, AREA. NO SKETCH WITH PACKET.
ELEANOR ISLAND, NORTHWEST BAY	EL052 B 2261016902	05/02/89	LIGHT TO MODERATELY OILED SHORELINE, 2 STREAMS APPEAR CLEAN. (SECOND STREAM IS UNCATALOGUED).
ELEANOR ISLAND, NORTHWEST BAY	EL052 B 2261016902	09/14/89	HEAVY OILING SHOWN ON SKETCH FOR STREAM AREA. 100% OIL COVERAGE.
ELEANOR ISLAND, NORTHWEST BAY	EL052 B 2261016902	09/14/89	MODERATELY OILED.
ELEANOR ISLAND, NORTHWEST BAY	EL052 B 2261016902	01/04/90	(FROM MAP) CT/ST APPROX. 50% COVERAGE IN UFTZ APPROX. 20M WIDE X 145M LONG THROUGH STREAM. EXTENDS HIGHER UP ALONG STREAM. APPROX. 60M ON EITHER SIDE OF STREAM. THE UPPER PORTION OF UITZ COVERED BY SNOW.

ELEANOR ISLAND, NORTHWEST BAY	EL052 2261016902	B	04/13/90	LARGE OILED SECTION SURROUNDING BOULDERS NEAR STREAM IN UPPER INTERTIDAL AND MID INTERTIDAL. SOMEWHAT COVERED A NEW ADVANCING STORM GENERATED GRAVEL BAR. GRAVEL AND LARGE BOULDERS COATED: 1- 2" DEEP IN SEDIMENTS. SHOVEL/STEAM. SCATTERED SPOTS OF OIL UPPER INTERTIDAL. OIL ON STREAM BANKS.
ELEANOR ISLAND, NORTHWEST BAY	EL052 2261016902	B	04/24/90	UPPER INTERTIDAL IS SPORADICALLY DOTTED WITH MOUSSE PATTIES, SOME OF WHICH PENETRATE 2-3 CM. NO OILED DEBRIS WAS NOTICED IN THE SUPRATIDAL OR ABOVE. THE SALMON STREAM EDGE AND BANK APPEARED UNOILED/NO SHEEN WAS KICKED UP IN STREAM SEDIMENTS EXCEPT A LIGHTLY SHEENED AREA IN THE LOWER SECTION OF THE MIDDLE ITZ. THE SINGLE LARGEST AREA OF OILING IS IN THE MIDDLE INTERTIDAL ZONE, NEAR SEVERAL LARGE BEDROCK BOULDERS. IT APPEARS A LARGE SEGMENT OF OIL WAS DEPOSITED HERE AND PENETRATED AT LEAST 4 CM, POSSIBLE DEEPER IN AREAS. THIS OIL APPEARS TO BE HIGHLY MOBILE AND IF DISTURBED PUTS OUT HEAVY SHEEN. ITS NEARNESS TO THE SALMON SPAWNING GRAVELS IS CAUSE FOR CONCERN. NO OIL ON STREAM BANKS.
ELEANOR ISLAND, NORTHWEST BAY	EL052 2261016902	B	08/06/90	WEST SIDE OF STREAM: A 11M LONG X 6M WIDE PATCH OF HEAVY TO MOD 'OR' SEDIMENTS IN MITZ - 1 M WEST OF STREAM CHANNEL. 62M WEST OF CHANNEL: A 7M WIDE X 10M LONG AREA OF 'OR' SEDIMENT IN MITZ IN STREAM SEEP - GIVES OFF RAINBOW SHEEN WHEN DISTURBED. EAST SIDE: A 3M LONG X 2M WIDE PATCH OF 'OR' SEDIMENT - 17.5M FROM STREAM CHANNEL MITZ - SEVERAL SMALLER PATCHES SAME AREA. MITZ COULD CONTAIN A LENSE OF OIL, RUNNING THE LENGTH. REASSESS NEXT SPRING. PAIR OF HERON APPEAR TO BE NESTING NEARBY. SEVERAL PINKS SEEN JUMPING FAR OFFSHORE. NO OIL SIGHTED ON STREAM BANKS.
ELEANOR ISLAND, NORTHWEST BAY	EL052 2261016902	B	04/27/91	RECOMMEND MANUAL TILLING OF BURIED 'HOR' IN SEEP ALONG WITH MOPPING OIL WITH POMPOMS. RETURN TO THIS SEGMENT 4/28/91 TO FINISH OG MAPPING. VERY MINUTE AMOUNTS OF SURFACE OIL WERE VISIBLE. RETURN 4/30/91 TUESDAY.
ELEANOR ISLAND, NORTHWEST BAY	EL052 2261016902	B	05/28/91	THE WORK ORDER WAS SATISFACTORILY COMPLETED, HOWEVER, WE WERE UNABLE TO LOCATE 'HOR' SEDIMENT NEAR PIT 5. AREA OF PITS 8 & 9 RECEIVED A VERY THOROUGH TILLING WITH A NATURAL WATER FLUSH ASSISTING THE PROCESS. PIT 4 WAS TILLED WITH RAINBOW & SILVER SHEEN RELEASED. AREA A WAS RAKED, BEING SO WEATHERED THAT IT DID NOT WARRANT REMOVAL. NO OIL RECOVERY WAS ATTEMPTED. STREAM IS IN GOOD SHAPE NOW, BUT WARRANTS A FINAL ASSESSMENT BY ADF&G IN AUGUST TO DETERMINE REMAINING OIL & APPLY ANY FINAL TREATMENT.

EVANS ISLAND, IKTUA BAY	EV007 A 2264016550	06/16/89	GENERAL OILING LIGHT FOR SEGMENT, NO OIL OBSERVED BY STREAM. A PAIR OF HARLEQUIN DUCKS SIGHTED.
EVANS ISLAND, IKTUA BAY	EV007 A 2264016550	07/23/89	NO OIL OBSERVED.
EVANS ISLAND, IKTUA BAY	EV007 A 2264016550	02/19/90	INDIRECT OBSERVATION; MENTIONS THAT THIS STREAM WAS TO BE OUR UNOILED CONTROL FOR MFO SAMPLES.
EVANS ISLAND, IKTUA BAY	EV008 B 2264016543	06/16/89	MOUSSE BAND 0.5M WIDE & PATCHES AT HIGH ITZ-SKETCH. SEMI-CONTINUOUS BAND OF MOUSSE/DEBRIS AT MID-TIDE BETWEEN STREAMS.
EVANS ISLAND, IKTUA BAY	EV008 B 2264016543	07/22/89	FLOCK OF HARLEQUIN DUCKS, LITTLE OIL SEEN - RAT VISIT.
EVANS ISLAND, IKTUAL BAY	EV008 B 2264016543	07/23/89	THE STREAM BANKS APPEAR UNOILED, SHORELINE BETWEEN (STREAMS), ESPECIALLY THE FAR WESTERN ONE (16543), CONTAINED SCATTERED MOUSSE PATCHES WHICH NEED TREATING.
EVANS ISLAND, IKTUA BAY	EV008 B 2264016543	08/16/89	SEMI-CONTINUOUS BAND (.5M WIDE) OF MOUSSE/DEBRIS AT MID-TIDE. OVERALL OILING FOR SEGMENT IS LIGHT TO NO OIL.
EVANS ISLAND, IKTUA BAY	EV008 B 2264016543	08/31/89	NO OIL SAMPLE FOUND, MAP #9 #16590.
EVANS ISLAND, IKTUA BAY	EV008 B 2264016545	06/16/89	MOUSSE BAND 0.5M WIDE & PATCHES AT HIGH ITZ-SKETCH. SEMI-CONTINUOUS BAND OF MOUSSE/DEBRIS AT MID-TIDE BETWEEN STREAMS.
EVANS ISLAND, IKTUA BAY	EV008 B 2264016545	07/22/89	LITTLE OIL SEEN. FLOCK OF HARLEQUINS OBSERVED.
EVANS ISLAND, IKTUA BAY	EV008 B 2264016545	07/22/89	LIGHT OIL AT HEAD OF BAY.
EVANS ISLAND, IKTUA BAY	EV008 B 2264016545	07/23/89	THE STREAM BANKS APPEAR UNOILED, SHORELINE BETWEEN (STREAMS), ESPECIALLY THE FAR WESTERN ONE (16543), CONTAINED SCATTERED MOUSSE PATCHES WHICH NEED TREATING.
EVANS ISLAND, IKTUA BAY	EV008 B 2264016545	10/13/89	NO STREAM 2264016546 ON MAP. 2264016545 SHOWS VERY LIGHT OIL BOTH SIDES OF STREAM.
EVANS ISLAND, GUGAK COVE	EV070 G 2264016509	07/18/89	07/18/89 AND 07/19/89 LIGHT OILING RECORDED NEAR STREAM VIA SKETCH. SEGMENT CONTAINS HEAVY TO LIGHT OIL.

EVANS ISLAND, GUGAK COVE	EV070 G 2264016509	08/19/89	STREAM INSIDE THIS LAGOON HAS PINKS. THICK OIL SHEEN AND FREE FLOATING MOUSSE IN THE STREAM ENTRANCE.
EVANS ISLAND, GUGUAK COVE	EV070 G 2264016509	09/18/89	3MM MOUSSE AND OIL SHEEN FLOATING OVER THIS STREAM AREA.
EVANS ISLAND, GUGUAK COVE	EV070 G 2264016509	04/11/90	SMALL PATCH OF TAR/ASPHALT RIGHT SIDE OF STREAM FACING DOWN STREAM. EASY SHOVEL AND BAG REMOVAL. OIL ON STREAM BANKS.
EVANS ISLAND, GUGUAK COVE	EV070 G 2264016509	04/21/90	VERY SPORADIC STAIN, ASPHALT, TAR, AND BURIED MOUSSE. OIL QUANTITY AND DISTRIBUTION RELATIVE TO STREAM, DO NOT PLACE SALMON OR OTHER ORGANISMS AT RISK. NO TREATMENT IS RECOMMENDED. NO OIL ON STREAM BANKS, BUT WITHIN ONE MILE OF STREAM.
EVANS ISLAND, GUGUAK BAY,	EV070 H 2264016498	09/09/89	SITE Y, ON EVANS, NO VISIBLE OIL 89RLG186V.
MAINLAND, EWAN BAY, HEAD OF LAGOON	EW001 2262016030	07/28/89	LIGHT OIL PRESENT IN SEGMENT, NO SKETCH, NO SPECIFICS ON STREAMS.
MAINLAND, EWAN BAY, WEST SIDE	EW001 2262016036	07/28/89	LIGHT OIL PRESENT IN SEGMENT, NO SKETCH, NO SPECIFICS ON STREAMS.
GREEN ISLAND, GIBBON ANCHORAGE	GR103 A 2272017880	05/16/89	MODERATE OILING, 10-25M WIDE CONTINUOUS OIL BAND OVER 80% OF SEGMENT, 12CM THICK.
GREEN ISLAND, GIBBON ANCORAGE	GR103 A 2272017880	06/29/89	10FT X 25FT OIL PATCH IN STREAM DELTA, 20FT X 30FT PATCH WEST SIDE OF STREAM, 30FT WIDE OIL BAND ON EAST SIDE OF STREAM. POOLED OIL.
GREEN ISLAND, GIBBON ANCHORAGE	GR103 A 2272017880	07/08/89	WEST BANK: MODERATE, 35' X 15' X 10CM. EAST BANK: HEAVY.
GREEN ISLAND, GIBBON ANCHORAGE	GR103 A 2272017880	07/10/89	25' X 10' OILED AREA IN STREAM DELTA, 30' X 20' OILED AREA ON WEST BANK. 30' WIDE OILED BAND ON EAST SIDE OF STREAM.
GREEN ISLAND, GIBBON ANCHORAGE	GR103 A 2272017880	07/10/89	POST ASSESSMENT OF TREATMENT. HEAVY PATCH OF OIL 50' X 250' MITZ IN UPENDED BEDROCK ON NORTH SIDE OF STREAM.
GREEN ISLAND, GIBBON ANCHORAGE	GR103 A 2272017880	07/11/89	WAS REOILED; ABOUT 9.5 MILE BAND RANGING FROM 10' TO +50' WIDE; 20' X 8' OIL PATCH.
GREEN ISLAND, GIBBON ANCHORAGE	GR103 A 2272017880	07/11/89	25' X 10', STILL 2+" OF PENETRATION.

GREEN ISLAND, GIBBON ANCHORAGE	GR103 2272017880	A	07/28/89	30FT WIDE OILED ZONE, EAST SIDE OF STREAM. 20' X 30' AREA ON WEST BANK AND A 25' X 10' OILED AREA BETWEEN THE 2 CHANNELS. 30-40 BAGS REMOVED FROM THOSE 2 AREAS. 2+" PENETRATION. VERY DEEP OIL PENETRATION IN CREVICES OF SLATE SUBSTRATE, EAST SIDE OF STREAM.
GREEN ISLAND, GIBBON ANCHORAGE	GR103 2272017880	A	08/08/89	THE STREAM APPEARED TO HAVE FLUSHED MOST OF THE VISIBLE OIL FROM THE STREAM BED, IN CONTRAST TO THE HEAVILY OILED BEACHES ON EITHER SIDE OF THE STREAM. (INFO ALSO IN RAT DAILY LOG ON DISKETTE).
GREEN ISLAND, GIBBON ANCHORAGE	GR103 2272017880	A	08/08/89	OILED ON NORTH SIDE OF STREAM. TARRY COATING ON THE ROCKS 2-3MM THICK. (STREAM) HAD OIL ADJACENT TO IT IN A LARGE COBBLE/BOULDER/FRACTURED SHALE SETTING.
GREEN ISLAND, GIBBON ANCHORAGE	GR103 2272017880	A	04/12/90	THIS IS THE NE TIP OF GREEN ISLAND WHICH WAS LITERALLY HOSED DOWN WITH LIQUID INIPOL ON AUGUST 8, 1989, AGAINST EPA PROTOCOL. IT WAS HEAVILY OILED AND EXPOSED TO ALL WINTERS STORMS. HIGH EXPOSURE TO NEW NW SHEENS AND OILED DEBRIS. STILL HEAVY TO MODERATE OIL IN THE CREEK AND ON BANKS, ESPECIALLY NORTH AND EAST OF CREEK. THICK TAR AND AP MUCH LARGER ROCK. OIL SEEMS WORSE IN UITZ EXTENDING DOWN INTO UPPER HALF OF MITZ. SHEENS VISIBLE IN POOLS OF WATER.
GREEN ISLAND, GIBBON ANCHORAGE	GR103 2272017880	A	04/23/90	TARMAT PRESENT ON WEST SIDE STREAM BANK 10M X 4M X 10CM. TAR PATTIES INTERSPERSED IN SHALE BEDROCK ON EAST BANK OF STREAM. OIL COAT & STAIN ON SHALE BEDROCK IN MID & UPPER ITZ. OILED GRASS & SCATTERED TARBALLS IN UIT & SWASH ZONE. SOME SHEEN ON WATER WHEN AGITATED.
GREEN ISLAND, GIBBON ANCHORAGE	GR103 2272017880	A	08/12/90	2000-3000 PINKS IN THE STREAM, 1000 OFF THE MOUTH, 2 PINK CARCASSES. SEVERAL LIVE COHO IN THE STREAM. NORTH SIDE OF STREAM - 3 INTERMITTENT BANDS OR/OP SEDIMENTS MOSTLY EMBEDDED IN UPTURNED SHALE BEDROCK: ONE JUST ABOVE FUCUS LINE, ONE IN UMITZ AND ONE IN UITZ JUST BELOW GRASS LINE. SOUTH SIDE - A 13M LONG X 5-7M WIDE AREA OF LIGHT TO MOD 'OR' SEDIMENTS ON THE STREAM BANK AND EXTENDING INTO THE STREAMBED - LOCATED 21M DOWN THE BEACH FROM GRASS LINE. ALSO A BROKEN BAND OF 'OR' SEDIMENTS AT THE GRASS LINE. REC - REASSESSMENT NEXT SPRING.
GREEN ISLAND, GIBBON ANCHORAGE	GR103 2272017880	A	04/26/91	EAGLE ON NEST. SITE #1 - 'H & MSOR' SEDIMENTS TRAPPED IN BEDROCK INTERSTICES, SHEEN RAINBOW & SILVER WHEN DISTURBED. SITE #2 - 'AP' 5 METERS FROM STREAM BANK. SITE #3 - 'AP, HSOR', ALONG GRASSLINE.

INGOT ISLAND,	IN024		05/12/89	COREXIT 7664 TEST SITE HEAVILY OILED AND BOUNDED BY FRESHWATER STREAM.
INGOT ISLAND,	IN024		09/13/89	"BEACH AT SOUTH END OF SEGMENT. 30FT BAND OF HEAVILY OILED SURFACE-SUBSURFACE IS AT LEAST 10", HITZ-MITZ." NORTHWEST
INGOT ISLAND, FOUL PASSAGE	IN031 2261016916	A	04/17/89	HEAVY OILING, CENTRAL PORTION OF SEGMENT (STREAM LOCATION) IS FINES WITH GRASS FLATS, THE OIL WIDTH IS 7-50M WITH 10CM PENETRATION.
INGOT ISLAND, FOUL PASSAGE	IN031 2261016916	A	09/02/89	HEAVILY OILED EITHER SIDE OF STREAM.
INGOT ISLAND, FOUL PASSAGE	IN031 2261016916	A	09/12/89	HIGH TIDE. 10FT SOUTH OF STREAM, LONG PATCH MOD TO HEAVY OILED GRAVEL 2" DEEP. BEACH WAS MOST LIKELY TREATED UP TO STREAM BANK.
INGOT ISLAND, FOUL PASSAGE	IN031 2261016916	A	09/13/89	BEACH MED TO HEAVILY OILED. SOME OIL IN STREAM GRAVEL. EGGS IN OILED GRAVELS. SUBSURFACE OILING.
INGOT ISLAND, FOUL PASSAGE	IN031 2261016916	A	09/15/89	HEAVILY OILED 15M WIDE X 75M LONG OIL BAND BOTH SIDES OF STREAM PER SKETCH. OIL CONTINUES TO STREAM BANKS.
INGOT ISLAND, FOUL PASSAGE	IN031 2261016916	A	09/15/89	HEAVILY OILED 15M X 75M BAND.
INGOT ISLAND, FOUL PASSAGE	IN031 2261016916	A	09/22/89	SAMPLE WITH OIL AREA A, 89TWC257V.
INGOT ISLAND, FOUL PASSAGE	IN031 2261016916	A	09/22/89	STILL MOD TO HEAVILY OILED IN A WIDE BAND (30-40FT) AT U & MITZ HEAVY SUBSURFACE OILING NEAR PRESENT TIDE LINE.
INGOT ISLAND, FOUL PASS	IN031 2261016916	A	01/04/90	WAS CALLED "16106", "HEAVY TO MODERATE".
INGOT ISLAND, FOUL PASSAGE	IN031 2261016916	A	01/04/90	10 X 50M+ HEAVY OIL BAND ON LEFT SIDE OF STREAM. 20 X 30M HEAVY OIL BAND ON RIGHT SIDE OF STREAM. 80 % COVERAGE, 1-2" THICK. 18-25M WIDE BAND OF LIGHT OIL IN LITZ - 1-2" THICK.
INGOT ISLAND, FOUL PASSAGE	IN031 2261016916	A	04/13/90	HEAVILY OILED SEDIMENTS IN AND OUTSIDE OF STREAM. 3-4" PENETRATION DOWN TO GROUND WATER. OIL IN UPPER AND MID INTERTIDAL.

INGOT ISLAND, FOUL PASSAGE	IN031 A 2261016916	04/24/90	SOME VERY THIN TARMATS ALONG EAST BANK OF STREAM. SHEEN FROM GRAVELS IN STREAM ITSELF. UITZ: OILED GRAVELS AND ROCK PRIMARILY UNDER SIDE ON WEST SIDE STREAM. MITZ: TARMAT AND OIL ON STREAM BANKS. THIN CRUST OF OILED MAT AND VEGETATION ALONG EAST SIDE OF STREAM IN MIDDLE & UPPER ITZ. OILED GRAVELS AND SANDS ON WEST SIDE OF STREAM EDGE. AREAS WHERE SHEENS OCCUR IN THE STREAMBED. THIN PATCHES OF OILED MATS IN UPPER ITZ ON WEST SIDE OF STREAM. PATCHES OF TARMAT ON EAST SIDE OF THE STREAM IN MIDDLE ITZ AREA.
KNIGHT ISLAND, BAY OF ISLES OTTER BAY	KN018 A 2263016880	05/11/89	OILING GENERALLY LIGHT TO MOD WITH 2 HEAVILY OILED AREAS IN SEGMENT, BUT CANNOT IDENTIFY LOCATION, AS NO SCAT SKETCH IS AVAILABLE. WAS SEGMENT KN042. RECOMMEND HAND-WIPE.
KNIGHT ISLAND, BAY OF ISLES OTTER BAY	KN018 A 2263016880	09/20/89	NO OILING DETERMINATION MADE FOR STREAM AREA ON SKETCH. VERY LIGHT OILING RECORDED FOR ADJACENT AREA.
KNIGHT ISLAND, LOUIS BAY	KN103 A 2261016922	04/29/89	MODERATE OIL BAND DIRECTLY EAST OF STREAM (SKETCH) 3-10M BAND WIDTH - 55% SEGMENT. MODERATE OILING FOR STREAM AREA.
KNIGHT ISLAND, LOUIS BAY	KN103 A 2261016922	10/20/89	OIL BAND 56' X 5'. OIL DEPTH 2" 80% COVERAGE. MOUSSE, COATED, TARRY. OIL BAND 25-30%; MOUSSE, STAIN, COATED, TARRY.
KNIGHT ISLAND, LOUIS BAY	KN103 A 2261016922	10/20/89	MODERATE BAND OF OIL BECOMES HEAVY ALONG UITZ ON RIGHT SIDE OF STREAM. LEFT SIDE LIGHT TO MODERATE. RIGHT BANK 6.8M X 120M BAND. LEFT SIDE: 1.5 X 17.1M.
KNIGHT ISLAND, LOUIS BAY	KN103 A 2261016922	11/04/89	HEAVY COATING ON BEDROCK. MOUSSE COATED COBBLES. SOME IMPROVEMENT.
KNIGHT ISLAND, LOUIS BAY	KN103 A 2261016922	11/07/89	OILING EXTENT INFO, LIGHT TO HEAVY. NO OIL DETECTED IN STREAMBED GRAVEL.
KNIGHT ISLAND, LOUIS BAY	KN103 A 2261016922	04/12/90	HEAVY DEPOSITS OF ASPHALT/MOUSSE. PENETRATION 3-4". MOUSSE PATTIES, OILED SANDS. MAY TAKE DREDGING TO CLEAN UP THIS. OIL ON STREAM BANKS.
KNIGHT ISLAND, LOUIS BAY	KN103 A 2261016922	04/21/90	SHALLOW SURFACE(50CM - 1M WIDE) OILED BAND ON EAST SIDE OF STREAM IN UITZ. WHEN CRUST IS BROKEN OIL APPEARS DARK BLACK/BROWN AND VERY MOBILE. SPORADIC 30CM WIDE BAND RUNNING IN LUITZ ON WEST SIDE - NO PENETRATION. OIL ON STREAM BANKS.

KNIGHT ISLAND, LOUIS BAY	KN103	A 2261016922	05/01/91	THE SMALL AMOUNT OF REMAINING 'AP/HOR' SEDIMENTS WERE REMOVED DURING THE SURVEY. REMAINING 'LSOR' SEDIMENTS WERE TILLED. NO SUBSURFACE OIL DETECTED. NO TREATMENT RECOMMENDED.
KNIGHT ISLAND, LOUIS BAY	KN106	E 2261016890	04/29/89	LIGHT OR NO OIL. MOST OF SEGMENT IS CLEAN OR HAS ONLY A SMALL BAND OF LIGHT OIL AT HIGH TIDE LEVEL. NO SKETCH OR SPECIFICS ON STREAM.
KNIGHT ISLAND, LOUIS BAY	KN106	E 2261016890	05/17/89	VERY LIGHT OR NO OIL.
KNIGHT ISLAND, LOUIS BAY	KN106	E 2261016890	07/24/89	POST TREATMENT OIL: 1.5% LIGHT, 98.5% NONE FOR SEGMENT.
KNIGHT ISLAND, LOUIS BAY	KN106	E 2261016890	09/18/89	NO OIL FOUND. NO CARCASSES OR LIVE FISH OBSERVED. OTHER STREAMS IN THIS SEGMENT WERE UNOILED AND NO SIGN OF SALMON WAS OBSERVED.
KNIGHT ISLAND, LOUIS BAY	KN106	E 2261016890	04/27/90	VERY RICH INTERTIDAL ZONE. VERY LIGHT OILING. SEVERAL SMALL MOUSSE PATTIES WERE NOTED ON THE WEST SIDE OF STREAM IN A .5X.5 M AREA. ONE PATTY ON EAST SIDE. NO OIL ON STREAM BANKS.
KNIGHT ISLAND, HERRING BAY WEST SIDE	KN132	B 2261016982	05/04/89	3 BEACHES IN SEG - ALL MOD OILED, STREAM IN BEACH #3 CONTINUOUS 2-30M OILED BAND. OIL PENETRATION 5 CM. MODERATE OIL WITH SOME MOUSSE 200M UPSTREAM.
KNIGHT ISLAND, HERRING BAY, WEST SIDE	KN132	B 2261016982	05/17/89	HEAVY OILING TO NORTH, ALONG ROCKS. (REFERRED TO AS #692).
KNIGHT ISLAND, HERRING BAY WEST SIDE	KN132	B 2261016982	06/12/89	MEDIUM TO HEAVY OILING. EXXON STUDY SITE.
KNIGHT ISLAND, HERRING BAY WEST SIDE	KN132	B 2261016982	06/20/89	SHORELINE NEAR STREAM HAS NOT BEEN TREATED. HEAVY OILING OIL PATTIES MADE IT WELL INTO THE STREAM. MAIN AREA OF CONCERN IS ENTRY. MOUTH HAS NOT BEEN BOOMED OFF. (REFERRED TO AS #16910).
KNIGHT ISLAND, HERRING BAY, WEST SIDE	KN132	B 2261016982	07/13/89	BOOMING AROUND STREAM, RAT DISCUSS TREATMENT WITH USCG.
KNIGHT ISLAND, HERRING BAY WEST SIDE	KN132	B 2261016982	07/28/89	RECORDED AS 2261016920. RAT HAD RECOMMENDED NO TREATMENT. WEST BANK UNTREATED PER DAMES AND MOORE. SUBSEQUENTLY ONE AREA FLAGGED AND MANUALLY REMOVED (AS SEEN FROM HELICOPTER). LATER RAT REQUESTED ADDITIONAL MANUAL REMOVAL.
KNIGHT ISLAND, HERRING BAY WEST SIDE	KN132	B 2261016982	08/04/89	HEAVILY OILED ON THE RIGHT BANK. LIGHT TO MOD 150M UPSTREAM SITE #4 4.

KNIGHT ISLAND, HERRING BAY WEST SIDE	KN132 2261016982	B	08/04/89	OILED BAND IS PROBABLY 400-500 YARDS WIDE FROM LOW TIDE TO UPPER LINE, HEAVILY OILED.
KNIGHT ISLAND, HERRINFG BAY, WEST SIDE	KN132 2261016982	B	09/02/89	HEAVILY OILED. MAP.
KNIGHT ISLAND, HERRING BAY, WEST SIDE	KN132 2261016982	B	09/16/89	HEAVILY OILED. MAP.
KNIGHT ISLAND, HERRING BAY WEST SIDE	KN132 2261016982	B	10/16/89	"MOUSSE & HEAVY SHEEN ON WATER. WIND BLOWING DIRECTLY INTO COVE AND BLOWING OIL UPSTREAM."
KNIGHT ISLAND, HERRING BAY WEST SIDE	KN132 2261016982	B	11/05/89	MAPS, DATASHEETS. HEAVILY OILED IN MID TO UITZ ON LEFT BANK. LIGHT OIL AND TAR PATCHES IN LITZ. 17 X 41.3M OIL BAND ON LEFT BANK - 100% COVERAGE. 14.4M LONG BAND ON RIGHT BANK WITH 70% COVERAGE.
KNIGHT ISLAND, HERRING BAY WEST SIDE	KN132 2261016982	B	11/05/89	USEFUL VISUAL/AUDIO DESCRIPTION OF VERY HEAVY OILING FROM AIR AND GROUND WITH PIT INFORMATION & SURVEY FROM BEACH. #1 IN VIDEO LOG 4941-5220.
KNIGHT ISLAND, HERRING BAY, WEST SIDE	KN132 2261016982	B	11/05/89	DESCRIPTION OF OILING BY TRANSECT PLOT. LIGHT TO HEAVY.
KNIGHT ISLAND, HERRING HERRING BAY WEST SIDE	KN132 2261016982	B	04/21/90	HEAVIEST OILING OCCURS IN A 60M LONG X 10M WIDE BAND IN THE MID AND UPPER ITZ ON THE WEST BANK OF THE STREAM. OIL ON STREAM BANKS. A THIN LAYER OF ANGULAR ROCKS/COBBLE COVERS THE OIL SATURATED FINES. THE UNDER SIDES OF THE SURFACE ROCKS HAVE A SPORADIC OIL COAT. SCATTERED TARBALLS ARE PRESENT WITHIN THE GRASSY TIDE POOL AREA AND UPSTREAM ON THE EAST SIDE OF THE STREAM.
KNIGHT ISLAND, HERRING BAY, WEST SIDE	KN132 2261016982	B	07/12/90	VIOLATION OF 100M BUFFER FROM STREAM BY EXXON FOR INIPOL APPLICATION.
KNIGHT ISLAND, HERRING BAY WEST SIDE	KN132 2261016982	B	08/14/90	SOME SCATTERED PATCHES OF MOUSSE AND 'OR' REMAIN ON LEFT SIDE OF STREAM ABOVE CONSTRUCTION AT WEIR. PRIMARY REMAINING OIL IS ON THE 70M RIGHT BANK BELOW WEIR. IT CONSISTS OF HEAVY 'OR' WHICH IS TURNING TO ASPHALT ON THE BEACH (WHICH HAS BEEN TILLED AND BIO'D). OIL OBSERVED ON STREAM BANKS.

KNIGHT ISLAND, HERRING BAY WEST SIDE	KN132 2261016982	B	05/01/91	TWO PINK FRY IN STREAM. STREAM/BEACH AREA IS IMPROVING BUT STILL IN NEED OF TREATMENT. ADF&G PERSONNEL REPORTED THAT WHEN THE SUN COMES OUT, THE OIL LIQUIFIES & STARTS OOZING TOWARDS THE STREAM. OG'S ESTIMATES ON % COVERAGE INCLUDES ALL THE ROCK & BOULDER SURFACES IN THE OILED AREA. SO IT IS A DECPTIVELY LOW FIGURE. FYKE NET ACROSS STREAM - ADF&G PERSONNEL HAD FRY CAUGHT TO CODED-WIRE TAG. MAXIMUM OIL DEPTH FOUND - 15CM.
KNIGHT ISLAND, HERRING BAY WEST SIDE	KN132 2261016982	B	06/04/91	THE WEATHER CONDITIONS WERE NOT CONDUCIVE TO LAYING OUT BOOM TO CONTAIN SHEENING. I PHONED DEC BASE AND ASKED FOR THIS TO BE WAIVED. ERNIE PIPER GAVE ME PERMISSION TO USE MY DISCRETION. SHEENS WERE NOT FREQUENT AND WIND/WAVE ACTION GUARANTEED THAT ANYTHING RELEASED WOULD BE DISPERSED QUICKLY. CARE WAS TAKEN NEAR THE ANAD SITE. CUSTOMBLEN WAS NOT APPLIED NEAR THE STREAM. ADF&G PERSONNEL WERE ON SITE TAGGING FISH. THEY WERE INFORMED OF OUR ACTIVITY AND GIVEN MSDS'S ON CUSTOMBLEN. RECOMMENDED FOR FUTURE REASSESSMENT.
KNIGHT ISLAND, HERRING BAY WEST SIDE	KN132 2261016982	B	06/07/91	AREAS IN MITZ AND UITZ REMAIN OILED. OILING CONDITIONS RANGE FROM 'OP/AP', 'HSOR' AND SUBSURFACE 'MOR'. WORK ORDERS FOR THIS AREA MAY HAVE BEEN FOLLOWED, HOWEVER, SERIOUS AMOUNTS OF OIL REMAIN ADJACENT TO THIS ANADROMOUS STREAM. FISH & GAME REPRESENTATIVES WERE NOT PRESENT WHEN THE CLEANUP EFFORT WAS CONDUCTED. THIS SURVEY WAS DONE DURING A HOT SUNNY PERIOD WHEN OILING CONDITIONS WERE EASILY OBSERVED. THE ENTIRE SEGMENT SMELLED OF CRUDE OIL. SUGGESTION IS THAT THIS STREAM BE REASSESSED BY THE TAG FOR POSSIBLE MECHANICAL TILLING AS MANUAL WORK APPEARS TO BE INADEQUATE.
KNIGHT ISLAND, HERRING BAY, WEST SIDE	KN132 2261016982	B	08/01/91	SURFACE OIL (AP/HSOR) LOCATED THROUGHOUT SEGMENT FROM THE WEST SIDE OF STREAM NORTH TO THE FIRST BEDROCK OUTCROP. SUBSURFACE OIL (MOR TO LOR) LOCATED NEAR GRASSY POINT, SOUTHWEST END ADJACENT TO STREAM. HOR LOCATED IN SEGMENT FROM FIRST RUN OFF STREAM (ENTRANCE TO CAMP), NORTH TO BEDROCK OUTCROP. PINKS OBSERVED JUMPING NEAR THE MOUTH, BUT NO PINKS HAVE MOVED PAST THE WEIR. *SURVEY FOCUSED ON DOCUMENTED OILING TREATED IN 1991. DIMENSIONS: 8X10M 5% AP/HSOR, 21X10M 30% AP/HSOR, 36X5M 35% AP/HSOR, 40X5M 40% AP/HSOR, 30X5M 40% AP/HSOR, 1X1M 100% AP ON SURFACE. SUBSURFACE: 20X5M MOR-LOR, 5X36M HOR-MOR, 5X40M HOR-MOR, 6X6M HOR.
KNIGHT ISLAND HERRING BAY, WEST SIDE	KN132 2261016982	B		AERIAL PHOTO OF WIDE OIL BAND BY STREAM. (1989)

KNIGHT ISLAND, HERRING BAY WEST SIDE	KN132 2261016982	B		TRANSECT RUNS ADJACENT TO STREAM, THEN CROSSES STREAM. FROM SUMMARY: OCTOBER 1989: ESTIMATED SURFACE COVERAGE OF 80% IN MITZ TO UITZ. ASPHALT PAVEMENT COMMON THROUGHOUT UPPER ZONE. ASPHALT PENETRATION 5-10CM. 06/06/89: 14 M WIDE OIL BAND.
KNIGHT ISLAND BAY OF ISLES SOUTH ARM	KN134 2263016865	A	05/03/89	HEAVY OIL, OVER 100% OF SEGMENT SKETCH, 10-85M WIDE BAND 90% MOUSSE.
KNIGHT ISLAND SOUTH ARM BAY OF ISLES	KN134 2263016865	A	05/17/89	AERIAL PHOTO SHOWING WIDE OIL BAND BY STREAM.
KNIGHT ISLAND, BAY OF ISLES SOUTH ARM	KN134 2263016865	A	08/31/89	RECENTLY BIOREMEDIATED. 20 YD BUFFER LEFT ADJACENT TO STREAM. WAS HEAVILY OILED AND WAS MECHANICALLY TREATED PRIOR TO BIOREMEDIATION. LITTLENECK CLAMS OILED, STILL ALIVE.
KNIGHT ISLAND, BAY OF ISLES SOUTH ARM	KN134 2263016865	A	08/31/89	OILED FROM HITZ DOWN 100FT TO LITZ.
KNIGHT ISLAND, BAY OF ISLES SOUTH ARM	KN134 2263016865	A	09/10/89	MAP OF OILING, MOD TO HEAVY, SOME SUBSURFACE OILING. APPEARS RE-OILED. BIOREMEDIATION APPEARED INEFFECTIVE.
KNIGHT ISLAND, BAY OF ISLES, SOUTH ARM	KN134 2263016865	A	09/10/89	APPEARS REOILED. BIOREMEDIATION APPEARED INEFFECTIVE.
KNIGHT ISLAND, BAY OF ISLES SOUTH ARM	KN134 2263016865	A	09/10/89	REOILING MAY HAVE OCCURRED. BEACH WORSE THAN EARLIER IN FULL SUN. MOUSSE HAD HARDENED.
KNIGHT ISLAND, BAY OF ISLES SOUTH ARM	KN134 2263016865	A	01/02/90	HEAVILY OILED. A 35 X 5M BAND OF 4-6 IN THICK ASPHALT IS ALONG THE WEST BANK WITH 80% COVERAGE. IMMEDIATELY ADJACENT TO THAT (5M FROM STREAM) IS A 20 X 20M HEAVY OIL BAND (4 IN THICK WITH 90% COVERAGE). SNOW MAY BE COVERING MORE OIL. EAST BANK IN STREAM GRAVEL BAR HAS LIGHT OIL.
KNIGHT ISLAND, BAY OF ISLES SOUTH ARM	KN134 2263016865	A	04/12/90	AREA IS HEAVILY OILED WITH LARGE AREAS OF ASPHALT MOUSSE. PENETRATION 4-6", POSSIBLY MORE IN (OTHER) AREAS. THICK COATINGS ON BEDROCK- PROTRUSIONS CARPETED WITH NEEDLES. OIL ON STREAM BANKS.

KNIGHT ISLAND BAY OF ISLES SOUTH ARM	KN134 2263016865	A	04/22/90	(UITZ) PRIMARY OIL OF CONCERN IS FLAT ON NORTH SIDE OF CREEK, 3-4 CM THICK TARMATS, VERY MOBILE ON UNDERSIDE. SOME 1-2 MM COATINGS ON BEDROCK. SOME MOUSSE PATTIES 40 YARDS NORTH IN MITZ. SOME OILED GRASSES & DEBRIS IN UITZ. NO OIL NOTED IN STREAM OR AT STREAM'S EDGE. TOP OF KNOLL NORTH OF STREAM HAS 2 PARTIALLY OILED TREES (STUMP & ROOTS) ALSO OILED GRASSES/KELP/DEBRIS. THE UITZ AND SUPRA ITZ ARE STILL PARTLY COVERED IN SNOW AND HAVE THICK AREAS OF OILED DEBRIS/MOUSSE ETC. MAJORITY OF TARMATS LIE IN MIDDLE TO UPPER
KNIGHT ISLAND, BAY OF ISLES SOUTH ARM	KN134 2263016865	A	08/15/90	OILING CONDITIONS ARE PRIMARILY ON THE NORTH BANK OF THE STREAM. THEY CONSIST OF REMNANTS OF ONCE LARGE TARMATS, SOME OF WHICH ARE STILL PRESENT. THERE ARE POCKETS OF HEAVY 'OR' SEDIMENTS AND SOME 'OP' IN THE CREVICES OF THE LARGER BEDROCK RIB THAT SEPARATES THE STREAM FROM THE BEACH SEGMENT. REASSESSMENT SPRING 1991. OIL OBSERVED ON STREAM BANKS.
KNIGHT ISLAND, BAY OF ISLES SOUTH ARM	KN134 2263016865	A	05/13/91	OILING OF CONCERN CONSISTS OF 2 PATCHES OF REMNANT TARMAT IN DEPRESSION ON NORTH SIDE OF STREAM. AREA RECEIVED THOROUGH TILLING BY LOCAL RESPONSE GROUP IN FALL 90. TARMAT HAS REFORMED OVER WINTER. REMAINING H/MSOR SEDIMENTS.
KNIGHT ISLAND, BAY OF ISLES SOUTH ARM	KN134 2263016865	A	06/08/91	WORK ORDER WAS COMPLETED TO MY SATISFACTION. A CREW OF 2-3 PEOPLE & MYSELF WORKED FROM 1700-1815 REMOVING THE REMAINING 'AP' & 'SOR' FROM LOCATIONS A & B. A THOROUGH TREATMENT WAS ACCOMPLISHED. ALL AGENCY REPS AGREED THAT THE APPLICATION OF CUSTOMBLEN WAS UNNECESSARY DUE TO THE SMALL AMOUNT OF RESIDUAL OIL REMAINING. I WAS NOT PRESENT WHEN THE CREW TREATED OILED COVE TO THE WEST, WHICH IS IN THE SAME SUBSEGMENT, THAT AREA HOWEVER DOES NOT APPEAR TO POSE A THREAT OF CONTAMINATION TO THE STREAM.
KNIGHT ISLAND, BAY OF ISLES, WEST ARM	KN201 2263016869	A		REASONABLY CLEAN; SOME SPOTS OF OIL, MOUSSE CONCENTRATION AREA.
KNIGHT ISLAND, BAY OF ISLES WEST ARM	KN201 2263016870	A	04/26/89	LIGHT OILING - BAND OF OILY VEG 1-2M WIDE BOTH SIDES OF STREAM IN UITZ 50M LONG. BLOTCHES SEVERAL FEET WIDE AND LONG ALL THROUGHOUT, ITZ, OIL IN SUBSTRATE WITHIN THE STREAM.
KNIGHT ISLAND, BAY OF ISLES WEST ARM	KN201 2263016870	A	04/26/89	BAND OF OILY VEGETATION 1-5' WIDE. BLOTCHES SEVERAL FEET WIDE AND LONG ALL THROUGHOUT AREA.

KNIGHT ISLAND, BAY OF ISLES WEST ARM	KN201 A 2263016870	05/22/89	PATCHES OF MODERATELY AND LIGHTLY OILED ALGAE AND PEBBLES BETWEEN STREAMS "PER SKETCH" MANUAL REMOVAL OF OILED GRAVEL AND DEBRIS. GREEN-WINGED TEAL IN PROBABLE SALMON STREAM FLOOD PLAIN. EXERCISE CARE IN ADJACENT GRASSY AREA - CUT OILED GRASSES BY HAND. SCOOP & SHOVEL PATCHES OF OILED SOIL/GRAVEL.
KNIGHT ISLAND BAY OF ISLES WEST ARM	KN201 A 2263016870	05/22/89	STREAM OUTLET FLOWED INTO SHALLOW BASIN. OUTLET WAS BOOMED. OIL IN BASIN WAS MOSTLY OILY DEBRIS OR MOUSSE. ENTRANCE HEAVILY OILED OUTSIDE BOOM.
KNIGHT ISLAND, BAY OF ISLES WEST ARM	KN201 A 2263016870	06/06/89	ONE OILED ADULT SEAL IN LAGOON. OILING IN UITZ IN QUANTITIES WHERE MECHANICAL TREATMENT COULD BE USED, APPROXIMATELY 300 FT FROM CHANNEL.
KNIGHT ISLAND, BAY OF ISLES WEST ARM	KN201 A 2263016870	07/11/89	TREATMENT RECOMMENDATIONS - ADDITIONAL WORK NEEDED. NEW OILING AT HIGH TIDE LINE OVER 300 M FROM MOUTH. (PHOTO).
KNIGHT ISLAND, BAY OF ISLES WEST ARM	KN201 A 2263016870	07/28/89	BOOMED LAGOON. MODERATE TO HEAVILY OILED SEGMENT, NORTH AND SOUTH OF LAGOON MOUTH.
KNIGHT ISLAND, BAY OF ISLES, WEST ARM	KN201 A 2263016870	08/30/89	"LIGHT TO MODERATE OILING ALONG LARGE BOULDERS. NO CLEANUP HERE."
KNIGHT ISLAND, BAY OF ISLES, WEST ARM	KN201 A 2263016870	09/10/89	3 X 3FT PATCH OF TARRY MOUSSE.
KNIGHT ISLAND, BAY OF ISLES WEST ARM	KN201 A 2263016870	06/01/90	LIGHT OILING - SCATTERED TAR PATTIES, OILED GRASSES, BROKEN TARMATS IN UITZ TO LITZ IN RANDOM PATCHES. NO ANADSCAT.
KNIGHT ISLAND, BAY OF ISLES, WEST ARM	KN201 A 263016872	05/22/89	LIGHT OILING.
KNIGHT ISLAND, BAY OF ISLES, WEST ARM	KN201 A 2263016872	07/14/89	STREAM REASONABLY CLEAN, A COUPLE OF SPOTS OF OIL.
KNIGHT ISLAND, BAY OF ISLES WEST ARM	KN201 A 2263016872	04/12/90	MOUSSE PATTIES FOUND ON EITHER SIDE OF STREAM, UPPER INTERTIDAL ZONE TO EDGE OF LOW TIDE STREAM CHANNEL. PATCHES OF MOUSSE OILED FINESAND GRAVELS. SOME OILED VEGETATION, PENETRATION 2-3". OIL ON STREAM BANKS, POSSIBLY IN STREAM BED. OIL IN STREAMBED: POSSIBLY

KNIGHT ISLAND, BAY OF ISLES WEST ARM	KN201 2263016872	A	04/22/90	PRIMARY AREA OF OILING IN UPPER INTERTIDAL ON BOTH SIDES OF STREAM E & W. THIN BROKEN RANDOM TARMATS 2-4 CM THICK. NO APPARENT OIL IN STREAM. SMALL SCATTERED MOUSSE PATTIES RIGHT DOWN TO LOW TIDE (0.3), 10 SQUARE METER AREA OF MOUSSE PATTIES. OIL ON STREAM BANKS, NOT IN STREAM BED.
KNIGHT ISLAND WEST ARM BAY OF ISLES	KN201 2263016870		05/22/89	LIGHT OIL - SMALL PATCHES OF OIL ARE IN GRAVEL OF STREAM FLOOD PLAIN.
KNIGHT ISLAND, BAY OF ISLES SOUTH ARM	KN205 2263016860	B	05/22/89	MODERATE TO LIGHT OILING. SKETCH. THICK MOUSSE BY BOTH STREAMS. 2M X 5M BLACK POOL 2-4CM DEEP IN GRASS ADJACENT TO STREAM.
KNIGHT ISLAND, BAY OF ISLES, SOUTH ARM	KN205 2263016860	B	05/22/89	OILING TAPERS OFF TO WEST OF STREAM. SOME MOUSSE PATTIES.
KNIGHT ISLAND, BAY OF ISLES, SOUTH ARM	KN205 2263016860	B	05/23/89	SPOT CLEANING OF MOUSSE PATTIES.
KNIGHT ISLAND, BAY OF ISLES, SOUTH ARM	KN205 2263016860	B	05/27/89	THE PINK STREAM RECEIVED LIGHT OILING. FRY TRAP.
KNIGHT ISLAND, BAY OF ISLES SOUTH ARM	KN205 2263016860	B	06/08/89	SKETCH SHOWS BAND OF POOLED MOUSSE ON WEST SIDE OF STREAM, ALONG STREAM BANK AND THEN CONTINUING WEST. 95% OIL COVERAGE IN BAND.
KNIGHT ISLAND, BAY OF ISLES, SOUTH ARM	KN205 2263016860	B	01/02/90	"NOT CONSIDERED" (FOR FUTURE TREATMENT).
KNIGHT ISLAND, BAY OF ISLES SOUTH ARM	KN205 2263016860	B	04/12/90	PATCHY AREAS OF MOUSSE & ASPHALT. MOSTLY S & E OF STREAM. OIL ON STREAM BANKS.
KNIGHT ISLAND, BAY OF ISLES SOUTH ARM	KN205 2263016860	B	04/27/90	A LARGE, FLAT ROCK/COBBLE BEACH. OIL NOTED INCLUDES A NARROW BAND OF SCATTERED TARBALLS AND PATTIES ON THE EAST SIDE OF STREAM ALONG THE MITZ AND AN INTERMITTENT TAR BAND, 50M X 2M 4CM DEEP, ALONG THE UITZ ON THE WEST SIDE OF THE STREAM. INCLUDED IN THIS BAND ON ITS NEAR STREAM EDGE IS AN AREA OF CONTINUOUS SOFT ASPHALT PAVEMENT - APPROX 4MX 1M X 6CM DEEP. SNOW IS COVERING THE SITZ ON THE EAST SIDE OF STREAM, COULD NOT CHECK FOR OILING. OIL ON STREAM BANKS.

KNIGHT ISLAND, LOG JAM BAY BAY OF ISLES	KN211 2261016880	C	05/24/89	HEAVILY OILED, 13-15M WIDE OIL BAND CONTINUOUS, 3M WIDE MODERATELY OILED, 10M WIDE LIGHT OILING, 12CM PENETRATION.
KNIGHT ISLAND, LOG JAM BAY BAY OF ISLES	KN211 2261016880	C	08/24/89	BEACH APPEARS HEAVILY OILED. OIL SAMPLES TAKEN (SUBSEGMENT AND STREAM# FROM CHEMDATA INFO).
KNIGHT ISLAND, LOG JAM BAY BAY OF ISLES	KN211 2261016880	C	09/06/89	3' WIDE - 6" DEEP BAND OF MOUSSE/GRAVEL IN STORM BERM. POST TREATMENT.
KNIGHT ISLAND, LOG JAM BAY FROM BAY OF ISLES	KN211 2261016880	C	09/06/89	5-6 LARGE TAR BALLS WITHIN 10FT OF STREAM. HEAVILY OILED 3' WIDE BAND OF MOUSSEY GRAVEL (6" DEEP) RAN LENGTH OF BEACH IN UITZ - STORM BERM. AN OIL SHEEN AROSE IN WATER BY SHORELINE AS WE WALKED ALONG. POST TREATMENT.
KNIGHT ISLAND, LOG JAM BAY BAY OF ISLES	KN211 2261016880	C	09/20/89	4M BAND MOUSSE FROM GRASS LINE TO BEACH ON CLIFF BAND. 1.5-4M WIDE BAND SOUTH SIDE OF STREAM ON CLIFF. THICK MOUSSE BAND COATING MUSSELS. PHOTO DESCRIPTIONS. NO OIL FOUND IN STREAM BED. LIGHT BAND OF OIL (RUNS) ENTIRE BEACH FROM HT-LMT.
KNIGHT ISLAND, LOG JAM BAY BAY OF ISLES	KN211 2261016880	C	04/12/90	"THICK BANDS 1-2MM THICK FROM STREAM EDGE TO 16' HIGH ON CLIFFS (NEEDLES, OIL, MOUSSE)." PER SKETCH, EAST BANK OF STREAM IS PARALLELED BY OIL BAND THAT EXTENDS TO CLIFFS. FURTHER UPSTREAM, OIL APPEARS TO BE IN LOG JAM THAT SPANS STREAM. NO OIL IS SHOWN ON WEST BANK. NO DIMENSIONS PROVIDED.
KNIGHT ISLAND, LOG JAM BAY BAY OF ISLES	KN211 2261016880	C	04/22/90	IN LOG JAM AT CREEK - AT OILED POM-POM CAUGHT IN LOGS. PITS DUG IN UITZ SHOWED NO OIL. IT APPEARS THAT THE UITZ WAS WORKED OVER BY STORMS. OIL ON EAST CLIFF FACES IS WEATHERED AND STICKY. NO OIL NOTICED ON LOGS IN JAM. SMALL AMOUNTS OF OIL SCATTERED OVER SURFACE OF BEACH. SOME BURIED OIL IN UITZ (LIGHT). THIN DISTRIBUTION OF OILED PEBBLES, FUCUS AND ROCK CLUMPS OVER 50-60% OF BEACH LENGTH. ADDITIONAL FROM OG SHEET: NON-OILED UITZ PITS WERE DUG ON WEST SIDE OF STREAM. "TRACE OF SURFACE OIL AND COAT/STAIN ON STEEP ROCK WALLS AND 2 MOUSSE BALLS AT SUPRA ITZ BERM ON BEACH".
KNIGHT ISLAND, LOG JAM BAY NORTH BAY OF ISLES	KN211 2261016875	E	05/24/89	HEAVILY OILED, 10-50M. WIDE CONTINUOUS OIL BAND - 200M LONG, SKETCH - BEACH 4.

KNIGHT ISLAND, NORTH FROM BAY OF ISLES	KN211 2261016875	E	06/26/89	BP1100X TEST OBSERVATIONS: "TEST SITE MODERATELY TO HEAVILY OILED IN A 15-20M BAND ABOVE 'GREEN LINE'." MALFUNCTION DURING BP1100X APPLICATION CAUSED TIDE TO COVER 3/4 OF TREATMENT PLOTS BEFORE WASHING RESUMED, RESULTING IN OIL THROUGHOUT THE WATER COLUMN WITHIN THE INNER BOOM. THE OIL RE-COALESCED AND WAS REDEPOSITED ON BEACH. DID NOT OBSERVE ANY RECOVERY OF OIL. AFTERMATH: "ROCK SURFACES APPEARED CLEANER, BUT MUCH OIL STILL IN SEDIMENTS".
KNIGHT ISLAND, LOG JAM BAY	KN211 2261016875	E	06/30/89	AERIAL PHOTO SHOWING WIDE OIL BAND COVERING MOST OF ITZ.
KNIGHT ISLAND, LOG JAM BAY BAY OF ISLES	KN211 2261016875	E	04/12/90	THIS COVE WAS SLATHERED AND NEVER PROPERLY DEALT WITH. HEAVILY OILED BAND OF DRIFT WOOD AND DEBRIS CHOKING STREAM AS IT CROSSES BEACH TO OCEAN FROM SMALL LAKE.
KNIGHT ISLAND, LOG JAM BAY BAY OF ISLES	KN211 2261016875	E	04/22/90	OUTLET OF LAKE IS CHOKED WITH OILED LOGS, NEEDLES, KELP, MOUSSE, SHEEN ON CREEK. THICK LAYERS OF OILED VEGETATION/FUCUS ETC. SOME SHEEN DOWN STREAM FROM LOG JAM IN BRAIDED STREAM ON BEACH. (COPPER SHEEN) OILED DEBRIS CONTINUES IN UITZ ON BOTH SIDES OF CREEK 30-35 METERS EAST OF CREEK/ 15-20 METERS WEST OF CREEK.
KNIGHT ISLAND, BAY OF ISLES	KN211 2261016875	E	04/22/90	LARGE HEAVILY OILED LOG JAM IN STREAM. 25 X 25M STREAMBED AND BANK AREA HEAVILY OILED (>45CM PENETRATION). MITZ AND LITZ STREAMBED CONTAINS MOUSSE AND SUBSURFACE OIL - STEADY SHEEN. ADJACENT BEACH HAS .25 X 10M HEAVY OIL WITH 34CM PENETRATION. THICK LAYERS OF OILED VEGETATION IN SUPRATIDAL ALONG BEACH TO EAST. (THIS INFO WAS TAKEN FROM OG SKETCH IN ANADCAT AND SUPPLEMENTS THE COMMENTS OF THE MAD FORM).
KNIGHT ISLAND, LOG JAM BAY BAY OF ISLES	KN211 2261016875	E	05/24/90	A HUGE PILE OF DRIFTWOOD LOGS IN STREAM IS SOAKED WITH OIL AND MUCH OIL IS IN THE STREAM AND INTERTIDAL SUBSTRATE.
KNIGHT ISLAND, LOG JAM BAY BAY OF ISLES	KN211 2261016875	E	08/04/90	STREAM BANKS AND STREAM BED STILL HEAVILY OILED: 30M LONG X 25M WIDE AREA OF STREAM BED HAS HEAVY TO MOD 'OR' - BLACK BEADS AND RAINBOW SHEEN IN PITS DUG IN SPAWNING AREA. STREAM BANKS ADJACENT TO POOL ARE 'OR' SEDIMENTS WITH OILED ORGANICS. OILED LOGS THAT HAD BEEN PUSHED ASIDE ARE ALREADY MIGRATING TO STREAM BED. SUBSURFACE OIL LENSE IN STORM BERM ON EAST SIDE. POSSIBLE HEAVY OIL UNDER PILED UP LOGS ON BANKS. REASSESS NEXT SPRING.

KNIGHT ISLAND, NORTH FROM BAY OF ISLES	KN211 E 2261016875	05/01/91	THIS BEACH/STREAM AREA CONTAINED A LOT OF NEW MATERIAL (I.E: GRAVELS) ON TOP OF THE OLD, DUE TO STORM ACTIVITY OVER WINTER. GRAVELS HAVE FILLED IN THE STREAM CHANNEL COMING OUT OF THE POND - SITE OF LOG JAM. THERE WAS A BAND OF NEWLY DEPOSITED OILY DEBRIS (ORGANIC) IN THE SWASH ZONE ALONG THE BEACH. THIS WAS THE ONLY OIL WE DETECTED OTHER THAN A SLIGHT SILVER SHEEN ON THE STREAM AS IT RAN OVER & BETWEEN THE ROCKS & COBBLE. TO TRULY ASSESS OIL PRESENT, DEEPER PITS NEED TO BE DUG IN STORM BERMS, ETC. NO TREATMENT WAS RECOMMENDED FOR THIS STREAM AREA BECAUSE WE COULD FIND LITTLE OIL THAT WAS ACCESSIBLE TO TREAT. IT IS SUCH A HIGH ENERGY BEACH THAT IT WAS EITHER FLUSHED OUT OR BURIED, PROBABLY BOTH.
KNIGHT ISLAND, LOG JAM BAY BAY OF ISLES	KN211 E 2261016875		BEACH HEAVILY OILED DURING FIRST WEEK OF SPILL. TRANSECT SOUTH OF STREAM. OIL BAND 18M WIDE. BY AUGUST 89, TOTAL BEACH HAS 65% SURFACE OIL COVERAGE, SUBSURFACE COVERAGE INCREASED. GRAVEL AROUND STREAM IS CLEAN, MAYBE LIGHT STAINING.
KNIGHT ISLAND, LOG JAM BAY	KN211	09/20/89	2 FRESHWATER STREAMS, HEAVILY OILED, MAP. HEAVY OIL SEDIMENTS IN STREAM BED. BOTH STREAMS HAVE WATERFALLS.
KNIGHT ISLAND, LOG JAM BAY	KN211	09/08/89	OVERFLIGHT - OBSERVED HEAVY MOUSSE AND SHEEN IN WATER.
KNIGHT ISLAND, RUA COVE	KN213 B 2263016853	06/01/89	LIGHTLY OILED. 30% COVERAGE OF TOTAL BEACH. DRIED MOUSSE, STAIN ON BOULDERS. NO OIL AT DEPTH OR UNDERNEATH BOULDERS.
KNIGHT ISLAND, RUA COVE	KN213 B 2263016853	08/16/89	HEAVILY OILED AT MOUTH 2-6" LAYER OF MOUSSE, 25' X 30' OIL BAND ON SOUTH SIDE.
KNIGHT ISLAND, RUA RUA COVE	KN213 B 2263016853	08/17/89	2-6" THICK LAYER OF MOUSSE & OILED ORGANIC DEBRIS IN M & UITZ - 25 X 30 FT.LONG BEACH.
KNIGHT ISLAND, RUA COVE	KN213 B 2263016853	08/24/89	OIL SAMPLE, HEAVY OIL, 89RLG106V.
KNIGHT ISLAND, RUA RUA COVE	KN213 B 2263016853	08/29/89	MAP & DESCRIPTIONS OF LIGHT TO HEAVY OILING, TREATMENT CONSIDERATIONS.
KNIGHT ISLAND, RUA COVE	KN213 B 2263916853	09/06/89	THE STREAM BANKS HAD BEEN HEAVILY OILED UP TO THE SWASH LINE. MOUSSE/GRAVEL ERODED INTO STREAM.
KNIGHT ISLAND, RUA COVE	KN213 B 2263016853	09/08/89	OIL LINE STILL HEAVY AT HIGH TIDE LINE. BEACH NORTH OF STREAM HAS HEAVY OILING.

KNIGHT ISLAND, RUA RUA COVE	KN213 2263016853	B	09/13/89	THICK AP, MOBILE OIL AND HEAVILY OILED DEBRIS. NORTHERN SECTION ABOVE STILL VERY HEAVILY OILED.
KNIGHT ISLAND, RUA RUA COVE	KN213 2263016853	B	01/20/90	40 X 40M HEAVY OIL BAND ON SOUTH BANK OF STREAM - 6" THICK. 40 X 2M HEAVY OIL BAND ON NORTH BANK.
KNIGHT ISLAND, RUA COVE	KN213 2263016853	B	04/12/90	PENETRATION VARIED FROM 1-2MM TO 4-6" OR NONE. LARGE PATCHES OF MOUSSE ON SOUTH SIDE OF STREAM. HEAVILY OILED CLIFFS ON NORTH TAR LIKE WITH NEEDLES COMPRESSED ON THEM. OIL ON STREAM BANKS.
KNIGHT ISLAND, RUA COVE	KN213 2263016853	B	04/27/90	VERY HEAVY OILING REMAINS AT THIS SITE.
KNIGHT ISLAND, RUA COVE	KN213 2263016853	B	04/27/90	NOTE: LARGE EAGLE NEST LEFT SIDE OF CREEK. OIL ON STREAM BANKS. TREATMENT RECOMMENDATIONS.
KNIGHT ISLAND, RUA COVE	KN213 2263016853	B	08/04/90	5000 PINKS OFF MOUTH AND IN STREAM, SOME SPAWNERS. TARMAT REFORMING IN TARMAT AREAS. RECENT STORM EXPOSED 'OR' SEDIMENTS IN UPPER STORM BERM ON SOUTHERN STREAM BANK - ERODING INTO STREAM. SHEEN ON POOL. LOWER STORM BERM HAS BURIED OIL LENSE, PART OF WHICH WAS REMOVED. REASSESS NEXT SPRING.
KNIGHT ISLAND, RUA COVE	KN213 2263016853	B	05/13/91	AREA LOOKS 100% IMPROVED FROM 1 YEAR AGO. RESIDUAL TARMAT/MOUSSE STILL PRESENT IN SITE #1 AND SHOULD BE REMOVED. SITE #3 ON STREAM BANK CONTAINS 'LOR' SEDIMENTS WHICH SHOULD BE MANUALLY TILLED. 'HSOR' SEDIMENT IN SITE #5 THAT ARE ACCESSIBLE SHOULD BE REMOVED. SITE #6 CONTAINS ACCESSIBLE 'HOR' SEDIMENTS WHICH, IF NOT REMOVED, WILL REMAIN BECAUSE THEY ARE IN SHELTERED AREA. I WAS UNABLE TO LOCATE OIL IN STORM BERMS THAT I SAW LAST FALL. ACTIVE BERM AREA: GRAVELS HAD BEEN REMOVED & NEW LOGS DEPOSITED BY STORMS. IMPOSSIBLE TO TILL AREA NEAR STREAM - STREAM COULD MIGRATE. UNDISCOVERED RESIDUAL 'HSOR' SEDIMENTS TO RIGHT OF SITE #3 MAY BECOME APPARENT WHEN WEATHER WARMS OR SOME ROCKS ARE TURNED.
KNIGHT ISLAND, RUA COVE	KN213 2263016853	B	06/19/91	TREATMENT TO THIS STREAM AREA WAS VERY THOROUGH. IT INCLUDED NEW OILED AREAS NOT IDENTIFIED IN MAYSAP 91. 5X5M HMOR/OP SOUTH OF STREAM REMAINS. I TILLED THE AREA OF SUBSURFACE OIL ALONG THE STREAM BANK. THIS OIL IS CHARACTERIZED AS GLOBS OF MOUSSE UNDERNEATH AND BETWEEN ROCKS. THE AREA OF SITE 6 (H & I ON OG MAP) STILL CONTAINS HEAVY OILING AND SHOULD BE REASSESSED. AREA OF SUBSURFACE ON STREAM BANK COULD BE RETILLED AT THE SAME TIME. SURFACE OIL CHARACTERISTICS ALSO INCLUDED 'DB'.

KNIGHT ISLAND, RUA COVE	KN213 2263016853	B	06/25/91	THE AREA ALONG SOUTHERN STREAM BANK COULD BE RETILLED, BUT IT IS "SPOTTY" AND MIGHT NOT BE NECESSARY. THE 'HOR' IN SITE 6 COULD BE REMOVED IF THE STATE VESSEL WAS IN THE AREA. WE DID LOOK AT 213C, JUST NORTH AROUND THE CORNER AND NOTED SOME MOUSSE AND FLOWING OIL AMONGST THE BOULDER FIELD. OVERALL 213C HAD BEEN CLEANED AS BEST AS COULD BE EXPECTED. MAY HAVE HAD MORE MANUAL REMOVAL - DSA, JEFF GINNALIAS, DEC - WORKED AFTER DFG SURVEY.
KNIGHT ISLAND RUA COVE	KN213 2263016853	B	08/02/91	NEW AREA OF SUBSURFACE OIL DISCOVERED ALONG CLIFF EDGE - SITE D. SUBSURFACE OIL ALONG STREAM BANK IMPROVED (SITE E) - SLIGHT SILVER SHEEN IN 2 PITS ONLY. SMALL 'HSOR' PATCH ON NORTH STREAM BANK - SITE C - SHOULD BE RETILLED. SITE F CONTAINS A 2 X 18 PATCH H/MOR WHICH SHOULD BE REMOVED. THIS OIL IS LOCATED IN SHELTERED LOCATION - VERY SLOW DEGRADATION RATE. AREAS F AND C WARRANT REASSESSMENT IN 1992. STREAM AREA IS IN RELATIVELY GOOD SHAPE. *SURVEY FOCUSED ON DOCUMENTED OIL TREATED IN 1991.
KNIGHT ISLAND, RUA COVE	KN213 2263016853	B		AERIAL PHOTO SHOWING OIL BAND.
KNIGHT ISLAND, RUA COVE	KN213 2263016853	B		TRANSECT LOCATED APPROXIMATELY 125M NORTH OF STREAM. PER SUMMARY: VERY HEAVILY OILED SITE. AUGUST 89: 100% OIL COVERAGE OF BEACH WITH POOLED MOUSSE BETWEEN BOULDERS. NOVEMBER 89: ASPHALT COVERED 40% OF BEACH SURFACE IN DRAINAGE AREA TO SOUTH OF TRANSECT (ADJACENT TO STREAM).
KNIGHT ISLAND, SNUG HARBOR	KN401 2263016820	B	06/10/89	SKETCH LISTS "SOME VERY SCATTERED SPOTS OF MOUSSE ON BEACH". SKETCH DOES NOT SHOW OIL LOCATION.
KNIGHT ISLAND, SNUG HARBOR	KN401 2263016820	B	06/11/89	MODERATE OILING. AT MOUTH OF RIVER: 100X10M HEAVY OILING BAND WITH SOME POOLING IN SU. LOCALLY HEAVY. LIGHT OILING ON BEDROCK, NORTH SIDE OF STREAM.
KNIGHT ISLAND, SNUG HARBOR	KN401 2263016820	B	06/17/89	STREAM IS BOOMED, AREA OUTSIDE BOOM IS OILED ON THE SOUTH SIDE.
KNIGHT ISLAND, SNUG HARBOR	KN401 2263016820	B	08/04/89	HEAVILY OILED THICK MOUSSE, GRASSY FLAT HIT HARD, VISIT TO STREAM VIA CHOPPER.
KNIGHT ISLAND, SNUG HARBOR	KN401 2263016820	B	08/06/89	SALMON STREAM ON BORDER 1M X 100M BAND OF HEAVY OILING, WITH SOME POOLING IN SUPRA-INTERTIDAL.
KNIGHT ISLAND, SNUG HARBOR	KN401 2263016820	B	08/15/89	OIL IN PATCHES IN GRASS VEGETATION.

KNIGHT ISLAND, SNUG HARBOR	KN401 2263016820	B	08/16/89	LIGHT OIL SHEEN ON STREAM BANK WHERE WE WALKED. 1-3FT OILED BAND WITH SOME MOUSSE IN UITZ.
KNIGHT ISLAND, SNUG HARBOR	KN401 2263016820	B	08/16/89	1-3FT WIDE BAND OF OIL ON SOUTH BANKS OF STREAM. WE CAUSED A SHEEN IN WATER BY BOOM.
KNIGHT ISLAND, SNUG HARBOR	KN401 2263016820	B	09/06/89	ADVISED THAT MANUAL TREATMENT HAD OCCURRED TO STREAM AREA.
KNIGHT ISLAND, SNUG HARBOR	KN401 2263016820	B	09/30/89	SKETCH SHOWS VERY LIGHT OILING FOR NORTH STREAM BANK AREA.
KNIGHT ISLAND, SNUGB HARBOR	KN401 2263016820	B	09/30/89	KN401/402. SKETCH SHOWS "LIGHT TO VERY LIGHT" OILING AREA ALONG SOUTH STREAM BANK. 4M WIDE OIL BAND IN "LIGHT" AREA.
KNIGHT ISLAND, SNUG HARBOR	KN401 2263016820	B	04/12/90	SOME SHEEN/STICKY FILM VISIBLE. SHOVEL REMOVAL. OIL ON STREAM BANKS.
KNIGHT ISLAND, SNUG HARBOR	KN401 2263016820	B	04/27/90	RECOMMENDATIONS. CHECK THE AREA NOW COVERED BY SNOW. NO OIL ON STREAM BANKS, BUT WITHIN ONE MILE OF STREAM (MAP). PER OG SKETCH: SOUTH BANK OF STREAM PARALLELED AT APPROXIMATELY 10M DISTANCE BY BAND OF SCATTERED TAR MATS AND PATTIES (70X4M, 3CM THICK), FURTHER UPSTREAM POCKET OF OILED VEGETATION FAIRLY DISTANT FROM STREAM. FURTHER UPSTREAM, 2 OILED LOGS IN STREAM. NO OILING IS INDICATED FOR SOUTH BANK. PITS REVEALED NO SUBSURFACE OILING.
KNIGHT ISLAND, SNUG HARBOR	KN401 2263016820	B	08/15/90	PRIMARY AREA OF OILING CONSISTS OF A THIN BAND OF TARMAT ON THE LEFT BANK AS YOU FACE UPSTREAM. IT IS IN THE UPPER ITZ, BUT IT IS DOWN NEAR THE LOWER ITZ MOUTH AREA OF THE STREAM. SOME LARGE PATCHES 1 X 1M OF TARMAT STILL REMAIN NEAR AND IN SMALL FEEDER STREAM CHANNEL. UNSATISFACTORY WORK WAS DONE ON REMOVAL OF REMAINING TARMAT STRIP. SUGGEST REASSESSMENT SPRING 1991. OIL OBSERVED ON STREAM BANKS.
KNIGHT ISLAND, SNUG HARBOR	KN401 2263016820	B	04/26/91	STREAM AREA LOOKS IN GOOD SHAPE. THE MAJORITY OF THE HSOR WAS REMOVED FROM SITE #1 DURING SURVEY. THE OIL IS LOCATED IN & JUST BELOW THE GRASSY SWASH ZONE & SHOULD RECEIVE TREATMENT BEFORE THE GRASS HIDES IT.
KNIGHT ISLAND, SNUG HARBOR	KN401 2263016820	B	05/28/91	WORK ORDER COMPLETED. AREA ADRESSED ON WORK ORDER QUITE A DISTANCE FROM CATALOGUED STREAM AND NOT A THREAT TO STREAM. OIL REMAINING NEAR STREAM RELATIVELY INSIGNIFICANT BUT ITS PRESENCE AND CONDITION SHOULD BE ASSESSED BY ADF&G IN AUGUST 1991.

KNIGHT ISLAND, HOGAN BAY	KN411 2263016810	A	06/21/89	LIGHT OIL BAND AT HIGH TIDE ON EAST SIDE OF STREAM INSIDE ADF&g MARKER. 100+ METERS FROM STREAM DELTA. SKETCH.
KNIGHT ISLAND, HOGAN BAY	KN411 2263016810	A	08/15/89	NO SIGN OF OIL.
KNIGHT ISLAND, HOGAN BAY	KN411 2263016810	A	08/15/89	NO BANK SAMPLE TAKEN AS NO OIL SLICK OR PATCHES SEEN.
KNIGHT ISLAND, HOGAN BAY	KN411 2263016810	A		BAY APPEARED TO BE MOSTLY OILED WITH OCCASIONAL HEAVILY OILED SEGMENT. BOOM STILL IN PLACE NEAR THE STREAM MOUTH. (BOOM STATEMENT APPARENTLY REFERS TO #16810).
KNIGHT ISLAND, NORTHWEST TIP	KN500 2261016992	A	06/05/89	OVERALL OILING CONDITIONS ARE MODERATE. <5M WIDE OIL BAND - 50+% COVERAGE, 0-10CM OIL PENETRATION.
KNIGHT ISLAND, NORTHWEST TIP	KN500 2261016992	A	09/26/89	HEAVY OILING PER SKETCH. "72M BAND, STICKY/TARRY 3-4MM THICK, MITZ OVER 15 CM DEEP."
KNIGHT ISLAND, NORTHWEST TIP	KN500 2261016992	A	01/02/90	"HEAVILY OILED".
KNIGHT ISLAND, NORTHWEST TIP	KN500 2261016992	A	04/12/90	DEAD OILED DEBRIS EVERYWHERE. REEKS OF OIL. HEAVY OIL BANDS ON CLIFFS. OIL ON STREAM BANKS.
KNIGHT ISLAND, NORTHWEST TIP	KN500 2261016992	A	04/21/90	OILED AREA THAT NEEDS THE MOST ATTENTION IS ON THE NORTH BANK OF THE STREAM NEAR THE MOUTH IN THE UITZ. A SMALL STREAM COMING FROM THE NORTH AND CONNECTING WITH MAIN STREAM CONTAINS MODERATELY OILED GRAVELS WHICH WHEN AGITATED PRODUCE A SILVER TO BROWN SHEEN. THIS FLOW LIKELY FEEDS A SALMON SPAWNING/REARING AREA. OIL ON STREAM BANKS. MODERATE OILING ON NORTH SIDE OF STREAM, LIGHT ON SOUTH SIDE.
KNIGHT ISLAND, NORTHWEST TIP	KN500 2261016992	A	08/15/90	OIL NEAR STREAM IS PRIMARILY ON THE NORTH BANK - SOME TARMAT REMAINS NEAR STREAM. LARGE UPPER ITZ BOULDERS PACKED WITH 'OP' AND MOUSSE ON SOUTH SIDE. 2 SMALL COVES ON NORTH SIDE OF STREAM HAVE BURIED SUBSURFACE OIL. IT STILL REMAINS. NO FISH PRESENT. OIL OBSERVED ON STREAM BANKS.
KNIGHT ISLAND, NORTHWEST TIP	KN500 2261016992	A	04/30/91	BURIED OIL IN SITE #1 & 2. SITE # 2 IS IN AND DIRECTLY ADJACENT TO THE STREAM FLOW THROUGH THE INTERTIDAL AREA. SITE #2 RECOMMEND THOROUGH TILLING IN AND AROUND STREAM FLOW. SITE #1 ALSO RECOMMEND TILLING TO BRING OILED DEPOSITS TO THE SURFACE. (SEE MAP FOR SITES) NOTE: SITE #1 WAS NOT RECORDED ON OG MAP AS EXXON ADVISOR DID NOT WANT IT FOR DATA.

KNIGHT ISLAND, NORTHWEST SIDE	KN500 2261016996	B	06/05/89	OVERALL OILING CONDITIONS ARE MODERATE. >5M WIDE OILED BAND WITH 50+% COVERAGE.
KNIGHT ISLAND, NORTHWEST SIDE	KN500 2261016996	B	09/26/89	OILING HEAVY PER SKETCH. "100% COVER. > 1M BAND IN HITZ AND MITZ. OVER 15CM DEEP. ASPHALT".
KNIGHT ISLAND, NORTHWEST SIDE	KN500 2261016996	B	01/02/90	"HEAVILY OILED".
KNIGHT ISLAND, NORTHWEST SIDE	KN500 2261016996	B	01/04/90	HEAVY OIL THROUGHOUT ITZ. NORTH BANK HAS 80M X 30 TO 40M BAND OF HEAVY OIL. SOUTH BANK HAS 70 X 70M BAND OF HEAVY OIL, 6-24 IN PENETRATION WITH 100% COVERAGE.
KNIGHT ISLAND, NORTHWEST SIDE	KN500 2261016996	B	04/12/90	A DISASTER, THICK OIL EVERYWHERE. OIL ON STREAM BANKS.
KNIGHT ISLAND, NORTHWEST SIDE	KN500 2261016996	B	04/24/90	OILED HEAVILY IN NORTH SIDE SPOTS (UPPER LITZ), MID-ITZ CENTER OF COVE NEAR STREAM, UPPER ITZ: OIL MATS & OIL ALONG STREAM. SOUTH SIDE OF COVE: UPPER ITZ LARGE TARMATS/LIGHT OILED BOULDER. MID ITZ SOUTH SIDE TARMAT (210 FEET 2/3 LENGTH OF STREAM CHANNEL OILED DOWN TO WATER) . OG SKETCH INDICATES HEAVY OILING IN UITZ, MITZ AND LITZ ON NORTH SIDE OF STREAM AND IN MITZ ON SOUTH SIDE OF STREAM. OIL PRESENT ALONG STREAM BANKS.
KNIGHT ISLAND, NORTHWEST SIDE	KN500 2261016996	B	08/15/90	BOTH SIDES OF THIS STREAM HAVE EXTENSIVE AREAS OF OILING. THE NORTH SIDE HAS POCKETS OF HEAVY-MODERATE 'OR' IN THE MID TO LOWER ITZ NEAR CLIFFS. THIS MAY REFORM INTO LENSE OF OIL DURING THE WINTER. THE UPPER ITZ ON THE NORTH SIDE HAS THE REMNANTS OF A LARGE TARMAT. OILING PERSISTS INTO STREAM CHANNEL APPROX 20 FEET DOWN FROM POINT WHERE STREAM CHANNEL CUTS THE BERM. THE SOUTH SIDE HAS LARGE AREAS OF MOD TO LIGHT 'OR' STRETCHING FROM UPPER ITZ TO THE UPPER 1/4 OF THE LITZ. NO FISH PRESENT.
KNIGHT ISLAND, NORTHWEST SIDE	KN500 2261016996	B	09/04/90	"KN500, HERRING BAY, SOUTHERN COVE HEAVILY OILED".
KNIGHT ISLAND, HERRING BAY	KN500 2261016996	B	09/08/90	SKETCH SHOWS HEAVY OILING ON BOTH SIDES OF STREAM IN MITZ AND LITZ. TRANSECT RUNS PARALLEL AND ADJACENT TO STREAM ON SOUTH.
KNIGHT ISLAND, NORTHWEST SIDE	KN500 2261016996	B	04/30/91	ALL PIT INFORMATION WAS RECORDED BY OG IN THE FIELD SITE. OBVIOUSLY ALL SITES ON THIS MAP DESCRIBE A VERY LARGE AREA THAT REMAINS OILED. ALL GRAVEL SEEMS TO BE SATURATED WITH OIL INCLUDING THE FIRST 6CM ON THE SURFACE.

KNIGHT ISLAND, NORTHWEST SIDE	KN500 2261016996	B	06/07/91	AREAS OF SUBSURFACE OIL,(HOR AND MOR), ADDRESSED IN WORK ORDER WERE HOPEFULLY DEGRADED TO LOR AND SOME MOR. OTHER AREAS OF LOR NOT ADDRESSED BY WORK ORDER REMAIN. AREA OF CONCERN IS LOR IN STREAM BED ON SOUTH SIDE. SHOULD BE RE-EVALUATED. IT IS LOCATED DIRECTLY ADJACENT TO LOWER MID STREAM GRAVEL BAR.
KNIGHT ISLAND, NORTHWEST SIDE	KN500 2261016996	B	06/25/91	AIMEE STATED THAT THE CLEANUP WENT WELL, ACCORDING TO THE WORK ORDER BUT THE LOR - MOR IN AREA ADJACENT TO THE STREAM NEEDED TO BE WORKED. MECHANICAL TILLING WAS SUGGESTED FOR THE H - MOR AREA AT THE NORTH SIDE OF THE COVE.
KNIGHT ISLAND, NORTHWEST SIDE	KN500 2261016996	B	07/11/91	NOT TILLED WITH INCOMING TIDE. BACKHOE PEELED THE OILED SEDIMENT (LOR TO HOR, OP) BACK AWAY FROM THE STREAM CHANNEL AND SPREAD IT OUT TO INCREASE THE SURFACE AREA AVAILABLE FOR DEGRADATION. OIL OBSERVED TO 18" (DEEP). THE LARGER AREA WAS TILLED WITH THE INCOMING TIDE. PORTIONS OF THIS AREA CONTAINED BLACK OIL AT 4-8" DEPTH WHICH HAD NOT BEEN TOUCHED BY THE 1990 TILLING OPERATION). A SIGNIFICANT QUANTITY OF OIL WILL CONTINUE TO BE PRESENT ON KN500B. SNARE BOOM WITH POMPOMS DRAPED ON IT WAS SET IN PLACE. ADDITIONAL BOOM WAS DEPLOYED BEYOND THE PRIMARY AREA BECAUSE SHEEN AND BLACK OIL WAS ESCAPING THE BOOM AREA, PORTION OF THE BOOM WAS SATURATED BLACK WITH OIL.
KNIGHT ISLAND, NORTHWEST SIDE	KN500 2261016996	B	08/01/91	MECHANICALLY TILLED AREAS C AND D, STILL WITH OIL (NO OIL LENSE IN ITS DUE TO MIXING). EXPOSED HOR TO MOR, SHEENING, BLACK BEADING WHEN DISTURBED. NO SURFACE OIL TO SPEAK OF OTHER THAN COATS OR STAINS ON BEDROCK. NEW TARMAT POSSIBLY TO BE FORMED FROM OIL EXPOSED FROM TILLING. NEEDS TO BE REASSESSED IN SPRING OF 1992. NO PINKS OBSERVED. *SURVEY FOCUSED ON DOCUMENTED OILING TREATED IN 1991. DIMENSIONS: LOR: 10X7M. MOR-HOR: 8X5M, 8X10M, 13X46M. THE LATTER 2 AREAS WERE MECHANICALLY TILLED IN JUNE 91.
KNIGHT ISLAND, NORTHWEST SIDE	KN500 2261016996	B	08/26/91	TAG MEMBERS INSPECTED THE SITE IN RESPONSE TO ADF&G SURVEY DATED 8/1/91. TAG MEMBERS MANUALLY TILLED, EXPOSED, RELOCATED AREA ON SOUTH SIDE OF BEACH. EXXON AGREED TO TREAT REMAINING 2 AREAS WITH DON BOLLINGER BIO CREW. CLEANUP FROM 0945 TO 1130. RECOMMENDED FOR FUTURE REASSESSMENT.
KNIGHT ISLAND, NORTHWEST SIDE	KN500 2261016996	B	08/26/91	TAG DECIDED IN FAVOR OF FURTHER TREATMENT TO STREAM SITE THIS YEAR. WHILE ON SITE, WE MANUALLY TILLED PARTS OF AREAS A AND B ON SOUTH SIDE OF STREAM. TILLING WAS WITHOUT THE TIDE AND NO ATTEMPT WAS MADE AT OIL RECOVERY.

KNIGHT ISLAND, NORTHWEST SIDE	KN500 2261016996	B	08/29/91	MANUALLY TILLED SITE 1 (NORTH END BY BEDROCK WALL) AND SITE 2 (SOUTH STREAM BANK). SITE 1 BEGAN W/HIGH TIDE AND TILLED H2O AREA, CHASING SHEEN DOWN TO BOOM. EFFECTIVE: BROWN SHEEN TURNED TO RAINBOW. STILL A WIDE AREA OF SHEEN REMAINED. AREA TREATED: 40M X 15M. AT SITE 2, RELOCATED ABOUT A 12-15M LENGTH OF SEDIMENT ALONG STREAMBED. AREA SHEENED HEAVILY, MORE SO THAN SITE 1. BROWN SHEEN TO RAINBOW. MOSTLY RAINBOW WHEN COMPLETE. SOME DISTURBANCE OF STREAMBED OCCURRED FROM RELOCATION. MORE OIL STILL IN SEDIMENTS, BUT DIMINISHED. CUSTOMBLEN APPLIED AT SITE 1 ONLY. SOME COAT/STAIN ON BEDROCK AT SITE 1.
KNIGHT ISLAND, LOWER HERRING BAY	KN551 2262016846		09/23/89	#89TWC273V. NO OIL, AREA D.
KNIGHT ISLAND, LOWER HERRING BAY	KN551 2262016862		09/22/89	#89TWC264V. NO OIL, AREA H.
KNIGHT ISLAND, LOWER HERRING BAY	KN551 2262016868		09/23/89	#89TWC268V. NO OIL, AREA L.
KNIGHT ISLAND, LOWER HERRING BAY	KN551 2262016881. N/A		06/07/89	NO OIL OBSERVED IN BAY. STREAMS# 2262016862, 2262016846, 2262016868,
KNIGHT ISLAND, LOWER HERRING BAY,	KN551 N/A		07/28/89	VERY LIGHT OILING - 1% FOR WHOLE BAY.
KNIGHT ISLAND, LOWER HERRING BAY	KN552 2262016895	A	09/23/89	#89TWC270V. NO OIL, AREA S.
KNIGHT ISLAND, JOHNSON BAY	KN554 2262016940		06/22/89	NO OIL OBSERVED NEAR STREAM, LIGHT OIL AT ENTRANCE OF BAY.
KNIGHT ISLAND, DRIER BAY MALLARD BAY	KN575 2262016980		06/13/89	NO OIL LISTED FOR MALLARD BAY. NO TREATMENT RECOMMENDED. GOLDEN EYE OBSERVED.
KNIGHT ISLAND, MUMMY BAY	KN602 2264016851	B	07/30/89	LIGHT OILING. A 1-4M WIDE BROWN OIL BAND PASSES THROUGH STREAM CHANNELS AND CONTINUES ON BOTH SIDES OF STREAM. 5 CM OIL PENETRATION IN STREAM - SHEEN PRODUCED. LOCALS SAY THAT IT MAY NOT BE EXXON VALDEX OIL. GOOD SKETCH. STREAM# WAS 2264016820 AT TIME OF SURVEY.
KNIGHT ISLAND, MUMMY BAY	KN602 2264016851	B	04/12/90	OIL FOUND ON SOUTH SIDE OF STREAM (RIGHT FACING IN) DRIP LINE OF TAR ON CLIFFS NEXT TO STREAM. 1MM PENETRATION. OIL ON STREAM BANKS.

KNIGHT ISLAND, MUMMY BAY	KN602 2264016851	B	04/27/90	VERY LIGHT OIL: A 1X2M TAR PATTY 2CM THICK RESIDES BETWEEN STREAM CHANNELS IN DELTA AREA. SPORADIC STAIN ON ROCKS ON BOTH SIDES OF STREAM. OIL ON STREAM BANKS.
KNIGHT ISLAND, THUMB BAY	KN605 2264016797		06/30/89	(DATE WAS 06/31/89). NO OIL OBSERVED IN SEGMENT.
KNIGHT ISLAND, THUMB BAY	KN605 2264016797		08/15/89	NO OIL OBSERVED, OLD CANNERY.
KNIGHT ISLAND, THUMB BAY	KN605 2264016797		08/15/89	MAP 33, 89TWC033V, NO BANK SAMPLE TAKEN AS NO OIL OBSERVED AT SITE.
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	04/24/89	SKETCH SHOWS HEAVY OILING IN LARGE BAND ALONG STREAM ON EAST SIDE, HEAVY OILING IN SMALLER BAND ALONG WEST SIDE, AND HEAVY OILING WITHIN STREAM CHANNEL BELOW MERGER OF CHANNELS.
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	06/02/89	LIGHT TO MODERATE OILING. MODERATE AT STREAM MOUTH ONLY. 10% OF OILING CONTINUOUS IN 10-12M BAND. 90% SPORADIC OILING. SKETCH SHOWS CREEK BED AS OIL-FREE.
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	06/17/89	10-12' X 1/2-3/4 MILE OIL BAND ON EAST BANK OF EASTERN CH WEST BANK OF EASTERN CHANNEL HAD A 6X30' BAND OF OIL. GRAVELS WERE SATURATED TO A DEPTH OF 3-5" AND BROWN MOUSSE SLUMPED DOWN TO BELOW CHANNEL AT HIGH TIDE. MAP.
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	06/17/89	NO VISIBLE OIL TO WEST OF STREAM. EAST SIDE OF STREAM HAS WEATHERED OIL AND MOUSSE IN AN AREA OF 10 X 2M. GRAVELS ARE SATURATED TO 3-5".
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	07/02/89	DEPTH OF OIL ON EAST BANK: TOOK DEPTH EVERY 10 CM AND MEASURED 5-6CM DEEP MOUSSE.
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	07/05/89	ONGOING TREATMENT - OIL/MOUSSE WAS SEEPING OUT OF SEDIMENTS INTO STREAM. CRITCHLOW SAID STREAM LOOKED DIFFERENT THAN WHEN HE CLASSIFIED IT PRIORITY 2 - OILED STUMP HAD NOT BEEN IN STREAM CHANNEL THEN.
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	07/05/89	CONTINUOUS 6-8' BAND OF MOUSSE.
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	07/06/89	SHORELINE HEAVILY COVERED WITH A COATING OF MOUSSE, WITH 1/2 DEEP POCKETS.
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	07/08/89	HEAVY, 90% COVERAGE. (SEGMENT WAS KN035 IN LOG).

KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	07/10/89	PER SKETCH. WEST BANK, EAST CHANNEL: 2M WIDE MOUSSE BAND, 2-5CM PENETRATION. OIL-SOAKED FUCUS AND DEBRIS NEAR STUMP. SPORADIC MOUSSE PATTIES IN M,LITZ. EAST BANK, EAST CHANNEL: STARTING UP STREAM IN SUPRA ITZ, A 10-12X4M MOUSSE BAND, 1-5 CM THICK FOLLOWED BY A 4M WIDE OILED BAND, 1-3CM THICK IN UITZ. ADJACENT TO THIS IN MITZ IS A <1CM THICK OIL COATING OVER SEDIMENT AND IN LITZ. OCCASIONAL MOUSSE PATTIES. MOUSSE FLOWS DOWN-SLOPE INTO STREAM, AND IS IN STREAM AT HIGHER TIDE LEVELS.
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	07/11/89	SOME REMOVAL OF MOUSSE AND SEDIMENTS. HOWEVER, SEEPAGE CONTINUES ON BOTH BANKS.
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	07/12/89	5-6CM PENETRATION OF BROWN, RUNNY MOUSSE MEASURED FOR 25M. MOUSSE COVERS BOULDERS IN STREAM CHANNEL. LARGE VERY HEAVILY OILED DRIFT LOG IN STREAM.
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	07/26/89	POST TREATMENT - RESIDUE MOUSSE PATTIES, OILED FUCUS, POOLED MOUSSE 4MM DEEP PENETRATION ON STREAM BANK.
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	07/26/89	HEAVILY OILED, MAP. POST TREATMENT ASSESSMENT. EASTERN BANK: APPROX. 6M WIDE BAND OF MOUSSY OIL IS STILL PRESENT ALONBG STREAM BANK IN UITZ AND MITZ. IN PLACES OIL CONTINUES INTO STREAM ITSELF. 7MM PENETRATION RECORDED 8" FROM STREAM ON EAST SIDE. MOUSSE FLOWS TOWARDS STREAM CHANNEL WITHIN 6". WESTERN BANK ALSO CONTAINED A THIN COATING OF MOUSSE. PART OF OILED STUMP REMAINS.
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	07/26/89	50YDS X 100FT AREA OF MOUSSE IN PATCHES ABOUT 4MM DEEP, MOUSSE GOES DOWN INTO CREEK.
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	07/28/89	MOUSSE 5~6CM DEPTH; THE LENGTH OF THE CONTAMINATED AREA WAS CONTINUING TO SEEP INTO STREAM (MOUSSE HAD BEEN RAKED). FURTHER WORK NEEDED.
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	08/02/89	POOLS OF MOUSSE ON BOTH BANKS, SHEEN. FISH AT STREAM MOUTH.
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	08/03/89	MID TREATMENT. OIL SHEEN EXTENDING 50FT INTO BAY. 150 BAGS OF OILED GRAVEL REMOVED JULY 4-6TH. EXTENDED PERMIT ISSUED.
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	08/08/89	20' X 150' BAND OF MOUSSE MIXED WITH FINE GRAVELS .5~2" THICK - OOZING TOWARDS STREAM. LEFT BANK - PATCHES OF MOUSSE, LARGE OILED BOULDERS AND OILED STUMP IN STREAM.

KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	08/08/89	STREAM HEAVILY OILED. OIL COVERAGE EXTENDS FROM HIGH TIDE AT VEGETATION LINE TO STREAM CHANNEL AT LOW TIDE.
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	08/10/89	THE EAST BEACH WAS OILED THROUGHOUT ITS ENTIRE LENGTH WITH AN AVERAGE OIL DEPTH OF 2-3 INCHES, MAXIMUM 6-8 INCHES. 14 BAGS OF OILED SEDIMENT REMOVED AT 1800.
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	08/11/89	"STREAM IS ONE OF THE MORE HEAVILY OILED ONES. THE ORIGINAL SCAT LISTED MODERATE TO LIGHT; I THINK IT SHOULD HAVE BEEN MODERATE TO HEAVY. OIL IN THE STREAM. SEDIMENTS ARE TOTALLY COVERED BY WATER MOST OF THE TIME."
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	08/11/89	AERIAL OBSERVATION: "STREAM SEEMED TO BE PROGRESSING WITH SHOVELS. SLICK WAS COMING OFF ISLAND AND NOT BEING CONTAINED, HEADED TOWARD STREAM.
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	08/15/89	PHOTOS SHOW HEAVY OILING ON STREAM, WRITTEN INFO IS GENERAL.
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	08/15/89	20' X 100' AREA HAD OILY SEDIMENTS REMOVED. LEFT BANK STILL HAS QUITE A BIT OF OIL. OILED STUMP WAS WINCHED UP THE BANK.
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	08/16/89	MAP #33, HEAVY OIL IN GRAVEL 89RLG050V.
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	08/28/89	PARTIALLY TREATED. "LOWER PART OF BANK STILL QUITE HEAVILY OILED."
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	08/29/89	BIOREMEDIATE ON WEST SIDE ONLY.
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	08/29/89	MAP SHOWS HEAVILY OILED AREAS ON EAST AND WEST BANKS OF EASTERN STREAM CHANNEL.
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	08/29/89	MAP OF TREATED VS. UNTREATED PORTIONS, SHEENING. TIDE HIGH.
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	09/08/89	"LOOKS GOOD - NO SHEEN ON WATER."
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	09/13/89	"BEACH BELOW RICK'S MANUAL CLEANING TURNED INTO 2-3" THICK AP. NO SIGN OF DIFFERENCE FROM BIOREMEDIATION. APPEARS REOILED - VERY THICK".

KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	09/30/89	COVERS WHOLE SEGMENT. OILING L, VL, H WITH MAX PENETRATION 8 CM, THICKNESS 40-60 MM. MOUSSE, STICKY, TARRY AND ASPHALT. ALTHOUGH THE TICK MARK IN THE SKETCH SHOWS THE STREAM MOUTH TO BE WITHIN THE VL REGION, THE ASSOCIATED NOTES ON THE SKETCH INDICATE THAT THE STREAM'S MOUTH IS WITHIN THE HEAVILY OILED REGION.
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	10/20/89	TREATMENT REPORT FOR AUGUST 10-12, 1989, WITH EMPHASIS ON PROBLEMS OCCURRING THROUGHOUT TREATMENT. MOST OF 200M LENGTH OF EAST BANK IS OILED WITH THICK PATCHES OF MOUSSE. FREE OIL IN POOLS. LARGE OIL-SOAKED LOG IN STREAM.
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	10/20/89	DATA FORMS AND MAPS. EAST BANK: HEAVY OILING ALONG BANK AND BEACH, APPROXIMATELY 12X15M AND 20X1 M ALONG STREAM. WEST BANK: MODERATE OILING ADJACENT TO STREAM, HEAVY OILING WITHIN 4M FROM STREAM EXTENDING TO 8M FROM STREAM. (APPROXIMATIONS WERE TAKEN OFF MAP).
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	12/08/89	HEAVY CONTAMINATION NOTED DURING MFO SAMPLING.
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	04/13/90	THIS PLACE IS A DISASTER - IT NEEDS SHOVEL/STEAM. SEE MAP #KN701684LH: NOTHING HAS CHANGED, IT LOOKS WORSE THAN IT DID AFTER WE FINISHED SHOVEL REMOVAL AUGUST 12.
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	04/27/90	TAKEN FROM OG SKETCH TO SUPPLEMENT MAD DATABASE. EAST BANK: 10X25M STAIN ON AREA CLEANED IN 89 IN LITZ/MITZ, AND 1X24M AP IN SAME AREA IN UITZ. THEN A 4X35M AP AREA FOLLOWED BY A 2X20M AP AREA. WEST BANK: 1X12M OILED GRASS FOLLOWED BY A 5X15M AP/OP AREA. KEN CRITCHLOW: "THIS STREAM SITE IS VERY HEAVILY OILED, PARTICULARLY ALONG THE LEFT BANK IN THE ENTIRE INTERTIDAL". "THE AP ON LEFT BANK IS THICK AND SHOWED SIGNS OF MOBILITY EVEN AT NEAR FREEZING TEMPERATURES".
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	04/27/90	THE STREAM BANKS APPEARED IN MUCH THE SAME CONDITION AS THEY WERE LAST FALL AFTER TREATMENT. OIL ON BANKS. SEE MAP AND RECOMMENDATION FOR OILING CONDITIONS.
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	04/27/90	VERY HEAVILY OILED. SOME NATURAL CLEANING OCCURRED OVER WINTER. HE EXPECTS INCREASED OIL MOBILITY IN SUMMER, MORE CONTAMINATION.
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	07/01/90	THICK MOBILE OIL IN BAND IN UITZ ON EASTERN BANK, RUNNING INTO STREAM. SURFACE AND SUBSURFACE OIL ON BOTH BANKS. SHEENING INTO STREAM FROM BOTH BANKS.

KNIGHT ISLAND, MARSHA MARSHA BAY	KN701 2263016840	B	07/23/90	ADDITIONAL INFO ON OILING FOR WORK ORDER MODIFICATION. HEAVIEST ACCUMULATIONS OF OILING OCCUR IN THE UITZ IN A 1X50M AREA AMONG LARGE ROCKS BY GRASS LINE. SKETCH.
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	07/27/90	TREATMENT DESCRIPTIONS FROM MAY 26 TO JULY 27, 1990.
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	08/12/90	3000-4000 (SALMON) SIGHTED AT MOUTH AT HIGH TIDE ON 8/11/90, NO SPAWNERS. WEST BANK: SPORADIC ASPHALT/MOUSSE/OR IN AN AREA 26M LONG X 1-7M WIDE. OIL EXTENDS INTO STREAM BED WHICH SHEENS INTO STREAM WHEN AGITATED. EAST BANK: SPORADIC TAR BALLS/LIGHT TO MOD 'OR' IN AN AREA 44M LONG X 1-9M WIDE FROM TOP OF OILED ZONE. A 146M LONG X 1-8M WIDE AREA OF BROKEN TARMAT/MOUSSE/OP/OR SEDIMENTS - MAINLY IN THE UITZ WITH SOME IN THE MITZ.
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	09/13/90	"OILING NEARLY AS EXTENSIVE AS THE FIRST OILING BAT MAP INDICATED." MAP.
KNIGHT ISLAND, MARSHA MARSHA BAY	KN701 2263016840	B	05/05/91	TWO SEASONS OF TREATMENT HAVE GREATLY AIDED THE RECOVERY OF THIS ONCE HEAVILY OILED STREAM. DUE TO THE RELATIVELY STEEP SLOPE OF THE STREAM BANKS, THE TENDENCY OF THE OIL TO LIQUIFY AND FLOW TO THE STREAM AND THE PRESENCE OF OILED SEDIMENTS UP TO THE STREAM BED. AREA B OG MAP SITE 2 IS WHERE EXXON REP DUMPED BUCKETS OF OILED GRAVEL THAT HAD BEEN REMOVED FROM AREA B1 BY TOM & RICK. HE CLAIMED THEY WERE CLEAN (IN 1990). TWO SMALL PATCHED 'AP' LOCATED ON WEST BANK (SITE 3) NOT ON OG MAP. OILED AREA UPSTREAM, WEST BANK LARGER THAN DESCRIBED BY OG, IT IS MORE LIKE 1X6M, INSTEAD OF 1X3M.
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	05/05/91	ADDITION TO MAYSAP: OILING AREAS PER OG SKETCH. AREA A = 8X20M AP 10-15%. AREA B = 9X20M HSOR <10%. AREA B1 = 1X3M < 5% HSOR, AP. AREA C: .5X1M LSOR IN GRASS ROOT MAT. PITS IN AND NEAR AREAS A AND B12 SHOWED NO SUBSURFACE OILING.
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	06/20/91	A CREW OF 10 LABORED FOR 7.5 HOURS ON THE STREAM BANK AREA, REMOVING 5 SUPER SACKS OF OILED SEDIMENTS & MOUSSE. OIL COVERAGE WAS MORE EXTENSIVE THAN INDICATED ON MAYSAP 1991. THE HSOR SEDIMENTS OF AREA B (OG SKETCH) WERE IN REALITY 'AP' TURNING INTO PURE MOUSSE IN THE M & LITZ. THIS 2-3CM LENS OF MOUSSE WAS COVERED BY 2-3CM OF CLEAN MATERIAL AS WELL AS SOME MUSSELS, BARNACLES AND GREEN ALGAE. AREA B1 WAS THOROUGHLY WORKED AND TILLED AT THE STREAMS EDGE. AREAS WORKED WERE LEFT "OPEN" TO FACILITATE FLUSHING OF RESIDUAL OILED SEDIMENTS. THE LARGER ROCKS CAN BE PLACED BACK ON THEM

KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	08/02/91	AREA A H/MSOR MIXED WITH ORGANICS OVER OP TO HOR (AREA E), WEST BANK AREA HAS HOR BURIED OIL SEDIMENTS ALONG STREAM EDGE WHEN DISTURBED. ALONG EAST BANK OF STREAM (AREA C), SCATTERED AP/MS UNDER A CM OR SO OF CLEAN SEDIMENTS. AP/MS IN AREA D SPORADIC IN BOULDER/COBBLE FIELD. NO PINKS OBSERVED AT THE MOUTH, BUT PINKS OBSERVED IN MARSHA BAY. THIS STREAM SHOULD BE REASSESSED IN SPRING OF 1992. *SURVEY FOCUSED ON DOCUMENTED OILING TREATED IN 1991.
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B	08/26/91	TAG VISIT / NO TREATMENT. AT MY REQUEST TAG AGREED TO 20 MINUTES OF MANUAL TILLING ON THE SITE WHILE WE WERE THERE. SUBSTRATE TILLED WAS MAINLY IN AREA C (POST ASSESSMENT 1991 MAP). OILING WAS SPORADIC OP LENSE IN THE LITZ AND MITZ, EAST STREAM BANK. COVERED BY 1-2CM OF CLEAN GRAVEL, THE LENSE WAS 1-2CM THICK. SOME TARMAT IN AREA D WAS ALSO BROKEN UP. TREATMENT WAS NOT THOROUGH, BUT OBVIOUS OILED AREAS WERE BROKEN UP. TILLING OCCURRED WITHOUT TIDE FLUSH. NO ATTEMPT WAS MADE TO COLLECT OR CONTAIN OIL. AREA WILL MOST LIKELY RELEASE A SHEEN FOR SEVERAL TIDE CYCLES. LIVE AND DEAD PINK SALMON PRESENT IN THE STREAM IN ABUNDANCE.
KNIGHT ISLAND, MARSHA BAY	KN701 2263016840	B		UNDATED, HANDWRITTEN NOTE. EAST BANK: SMALL PATCH OF OILED GRASS, 1X25M BAND OF OIL, 35X4M 5 CM THICK ASPHALT BAND, 20X2M BROKEN PAVEMENT. WEST BANK: 12X1M OILED GRASS, 15X15M BROKEN ASPHALT/TAR PATTIES.
KNIGHT ISLAND, MARSHA BAY	KN704 2263016844	A	05/26/89	NO OIL SIGHTED.
KNIGHT ISLAND, MARSHA BAY	KN704 2263016844	A	06/23/89	LIGHT OR NO OIL LISTED FOR SEGMENT. OCCASIONAL MOUSSE PATTIES. NO SKETCH.
KNIGHT ISLAND, MARSHA BAY	KN704 2263016844	A	06/29/89	NO VISIBLE OIL.
KNIGHT ISLAND, MARSHA BAY	KN704 2263016844	A	08/16/89	MAP #38, OILED ONLY IN PATCHES. 89TWC058V.
KNIGHT ISLAND, MARSHA BAY	KN704 2263016844	A	04/11/90	RECOMMEND ANADSCAT. THE ENTIRE COVE AND MUCH OF THE STREAM & STREAMBED , BANKS, ETC. WERE COVERED WITH A THIN SHEET OF ICE PREVENTING A GOOD DETERMINATION OF OILING. SUGGEST RETURNING IN A WEEK OR TWO. OIL WAS FOUND HERE LAST AUGUST AND THIS IS AN EXTREMELY PROTECTED COVE. NEEDS TO BE U RESURVEYED, TWC 5/8/91.

KNIGHT ISLAND, MARSHA BAY	KN704 A 2263016844	04/27/90	VERY LIGHT OILING. 3 TAR BALLS FOUND IN UITZ ON WEST SIDE OF STREAM.
KNIGHT ISLAND, MARSHA BAY	KN704 A 2263016844 2263016850	08/04/89	VERY LIGHT OIL NEAR THE STREAM.
KNIGHT ISLAND, MARSHA BAY	KN704 A 2263016850	04/26/89	SMALL SPLOTCHES (OF OIL) ON ROCKS THROUGHOUT THE INTERTIDAL AREA.
KNIGHT ISLAND, MARSHA BAY	KN704 A 2263016850	05/26/89	A FEW STRAY SPLASHES OF MOUSSE NEAR IT.
KNIGHT ISLAND, MARSHA BAY	KN704 A 2263016850	06/23/89	LIGHT OR NO OIL LISTED FOR SEGMENT. OCCASIONAL MOUSSE PATTIES. NO SKETCH.
KNIGHT ISLAND, MARSHA BAY	KN704 A 2263016850	06/29/89	ONLY FEW MOUSSE SPLATTERS IN FLOOD PLAIN.
KNIGHT ISLAND, MARSHA BAY	KN704 A 2263016850	06/29/89	OIL IMMEDIATELY TO EAST OF ESTUARY AREA IN BAND.
MAINLAND, FOUL BAY	MA002 C	09/13/89	MUSSELS APPEAR DEAD IN MIDDLE TIDE POOL, SOUTH END (WAS IMPACTED WITH OIL). SE SIDE MODERATELY OILED, FUCUS DOES NOT LOOK HEALTHY (WHAT IS NOT DEAD). LIMPETS DEAD.
MAINLAND, FOUL BAY, ISLANDS (SUBSEGMENTS A-D)	MA002	05/22/89	ISLANDS IN BIGHT NORTH OF FOUL BAY RECEIVED MODERATE TO HEAVY OILING IN MITZ-UITZ. ISLAND 1: WEST SIDE HAS 14M WIDE OIL BAND WITH LIGHT TO MODERATE OIL AND MOUSSE CONCENTRATION. ISLAND 2: EAST SIDE HAS MODERATE TO HEAVY OILING > 30 CM PENETRATION. ISLAND 3: NORTH SIDE IS EXTENSIVELY OILED (WITH SOMEWHAT LESS OIL ON SOUTH SIDE) THROUGHOUT UITZ. ISLAND 4: MODERATELY TO HEAVILY OILED IN PORTIONS OF UITZ.
MAINLAND, FOUL BAY	MA002	07/31/91	HEAVY OIL-SATURATION TO 24". TREATMENT OCCURRING TO BEACH.
MAINLAND, FOUL BAY	MA003 A 2251015003	05/24/89	LARGE SEGMENT. INFO TAKEN FROM SITE "P" DESCRIPTION (WHICH COVERS STREAM). LIGHT CONTINUOUS OIL COATING, PENETRATION < 5CM MID TO HIGH INTERTIDAL. STORM BERM MODERATELY TO HEAVILY OILED WITH TAR AND MOUSSE AT DEPTH. WIDTH OF OILED BEACH IS 16M. HEAVIEST OILING CONSISTS OF MOUSSE AND TAR DEPOSITS IN CLUMPS UP TO 5M LONG.
MAINLAND, FOUL BAY	MA003 A 2251015003	09/13/89	OILING N, VL, L. SUPRA- TO MID INTERTIDAL, MAX PENETRATION 15 CM. 15% OF WHOLE SEGMENT OILED. STREAM AREA WAS NOT SURVEYED.

MAINLAND, FOUL BAY	MA003 A 2251015003	10/10/89	ABOVE FOUL BAY, NE TIP OF MAINLAND, MODERATELY OILED AT THE HIGH TIDE MARK.
MAINLAND, FOUL BAY	MA003 2251015003	01/05/90	"NO OILING VISIBLE". (SEGMENT IN LOG WAS MA001).
MAINLAND, FOUL BAY	MA003 2251015010	09/13/89	HEAD OF BAY, STREAM BLOCKED. INTERTIDAL SPAWNING, NO OIL EVIDENT. SOME BROWN SHEEN FLOATING IN FOUL BAY.
NAKED ISLAND, CABIN BAY	NA024 2224012960	08/15/89	SKETCH SHOWS "NO OIL NEAR STREAM". TRACE TO NO OIL. LIGHT OIL SHOWN SEGMENT IN GENERAL.
NAKED ISLAND, CABIN BAY	NA024 2224012960	09/11/89	STREAM ON HEAD OF BAY NOT OILED. BEACHES ON SOUTH SHORE OF CABIN BAY HAVE STAIN AT HIGH TIDE MARK.
NAKED ISLAND, CABIN BAY	NA024 2224012960	09/26/89	NO OIL RECORDED FOR STREAM AREA. LIGHT OR VERY LIGHT OIL RECORDED ELSEWHERE IN SEGMENT. SMALL PATCHES WITH HEAVIER OILING.
NAKED ISLAND, CABIN BAY	NA024	04/02/89	TRANSECT 3. NOT CLEAR WHETHER BY STREAM. "WHOLE SOUTH SHORELINE OF CABIN BAY OILED IN 90% ON 5' SLOPE".
NAKED ISLAND, OUTSIDE BAY	NA026 2224012950	08/15/89	PER SKETCH NEAREST OBSERVED OIL IS 2,000FT FROM STREAM.
NAKED ISLAND, OUTSIDE BAY	NA026 2224012950	09/11/89	NO MENTION OF OILING.
NAKED ISLAND, OUTSIDE BAY	NA026 2224012950	09/22/89	SAMPLE 89TWC256V, NO OIL, AREA H.
NAKED ISLAND, OUTSIDE BAY	NA026 2224012950	09/23/89	NO OILING DETERMINATION FOR STREAM AREA. VERY LIGHT OIL RECORDED FOR ADJACENT AREA.
NAKED ISLAND, OUTSIDE BAY	NA026 2224012950	04/26/90	NO OIL OR OILED DEBRIS NOTED. APPEARS TO HAVE SELF CLEANED OVER WINTER. NO OIL FOUND WITHIN ONE MILE OF STREAM.
MAINLAND, PADDY BAY	PA001 2262016010	07/19/89	NO OIL WAS SEEN ON THE BANKS OF EITHER FISH STREAM & THE ABSORBENT BOOM CROSSING BOTH STREAMS WERE FREE OF OIL. LIGHT OIL 1/3 MILE FROM STREAM - PER SKETCH.
MAINLAND, PADDY BAY,	PA001 2262016010	08/22/89	1-2" WIDE BATHTUB RING AROUND BOULDERS AT MOUTH OF BAY. BUT STREAM AT END OF BAY.

SQUIRREL ISLANDS	SL001	D	07/27/89	MODERATE OIL, VISIT TO SEGMENT - TREATMENT OCCURRING.
MAINLAND, WHALE BAY, CLAW PEAK POINT	WH003 2262016322	B	08/01/89	NO APPARENT OIL WAS OBSERVED.
MAINLAND, WHALE BAY, CLAW PEAK POINT	WH003 2262016322	B	09/25/89	HEAVY OIL - OILED BAND UITZ 6" PENETRATION (WAS WB003). COVE "A" BELOW CLAW PEAK CONTAINS HEAVY OIL. (VIDEO 960-1074). EGGS IN OILED SEDIMENT (VIDEO 89RLG009V, METER# 1074-1125). OILED BAND AT UPPER INTERTIDAL (1125-1156) CONTAINS OVERVIEW. 6" PENETRATION DOCUMENTED ON 1125-1226. SED SAMPLES 89TWC278V, VD.
MAINLAND, WHALE BAY, CLAW PEAK POINT	WH003 2262016322	B	04/12/90	NO OIL. NOTE: THIS STREAM WAS LATER DISCOVERED TO HAVE AN OILED BAND OP 1M WIDE 20M LONG. OIL PRESENT UNDER SNOW AT TIME OF SURVEY. ADDENDUM WRITTEN TO WORK AREA.
MAINLAND, WHALE BAY, CLAW PEAK POINT	WH003 2262016322	B	04/27/90	NO OIL. DETERMINATION MADE FROM PRE-ANADSCAT SURVEY.
MAINLAND, WHALE BAY, CLAW PEAK POINT	WH003 2262016322	B	07/08/90	SKETCH SHOWS FORMER LOCATION OF AP BAND: 1.5X27M, 3-6CM THICK, ON WEST SIDE OF STREAM. EAST SIDE HAD INTERMITTENT AP BAND OF SIMILAR WIDTH. SPORADIC TAR PATTIES WERE PRESENT IN STREAM CHANNEL. OIL REMAINING INCLUDED LIGHT OR/OF RUNNING 27M LONG ON WEST SIDE AND SOME IN BOULDERS ON EAST SIDE.
MAINLAND, WHALE BAY, CLAW PEAK POINT	WH003 2262016322	B	08/05/90	OILING CONSISTS OF COAT ON COBBLE/BOULDERS AND ROCK WITH SOME MODERATE SOR WHERE TAR MATS WERE REMOVED. OILING NONE TO LIGHT. SKETCH SHOWS 1-2X60M BAND OF SOR.
MAINLAND, WHALE BAY, CLAW PEAK POINT	WH003 2262016322	B	08/08/90	OIL BAND OF GRAVEL IN UITZ. OIL SOAKED WALNUT SIZED GRAVEL OP/OR AND TARMAT. OIL OBSERVED ON STREAM BANKS AND IN STREAM BED. ANADROMOUS FISH OBSERVED AT MOUTH OF STREAM. SKETCH SHOWS 50 M LONG TAR MAT BAND ON EAST SIDE OF STREAM AND 40 M LONG AT WEST SIDE OF STREAM.
MAINLAND, WHALE BAY, CLAW PEAK POINT	WH003 2262016322	B	08/14/90	RECOMMENDS FOR REASSESSMENT IN 1991. SMALL AMOUNTS OF SOR AND HOR REMAIN. THIS STREAM HAD NOT BEEN SURVEYED ON ANADSCAT DUE TO SNOW COVER DURING PRE-ANADSCAT.
MAINLAND, WHALE BAY, CLAW PEAK POINT	WH003 2262016321	C	08/01/89	NO APPARENT OIL OBSERVED. DUCKS SIGHTED SOMEWHERE ON SEGMENT DURING SURVEY.
MAINLAND, WHALE BAY, CLAW PEAK POINT	WH003 2262016321	C	09/25/89	TOOK VIDEOS OF (AERIAL) INTERTIDAL (89RLG009V METER# 1267-1274). SAMPLE 89TWC279V. NO OIL FOUND.
MAINLAND, WHALE BAY, CLAW PEAK POINT	WH003 2262016321	C	04/12/90	NO OIL OBSERVED.

MAINLAND, WHALE BAY	WH003	01/05/90	"NO OILING VISIBLE" (SEGMENT# IN LOG WAS CH020).
(GENERAL)	N/A	04/04/89	FWS AERIAL SURVEY INDICATES LOONS, GREBES, HARLEQUINS AND MURRELETS LESS IMPACTED THAN GOLDENEYE, SCOOTERS, MERGANSERS, GULLS.
(GENERAL)	N/A	05/28/89	TERRY CAMPBELL (D&M) - *SMOLT TRAPS IN HERRING BAY, SNUG HARBOR*, PORT ETCHER, BAY OF ISLES, MCLEOD HARBOR, PRESENTED AT SCIENCE MEETING.

NOTE: This table documents oiling conditions at Harlequin habitat areas. It also reveals the vast amount of areial activity as almost every survey report was conducted by landing a helicopter at the mouth of a stream.

WPDUCKS.TWC

SUPPLEMENT 3

INIPOL AND OTHER CHEMICAL TREATMENTS FOR OIL SPILLS

Bioremediation is the process of removing pollutants from the environment using microorganisms to degrade the polluting chemicals into (harmless) byproducts, i.e. biodegradation. Bioremediation involves, in many cases, enhancing natural biodegradation processes by optimizing specific environmental conditions (e.g. through fertilization). It is not the intent here to delve into the toxicity of these chemical treatments, but simply to document their use in harlequin duck habitats. Site descriptions, dates, and applications in 1989 are listed in Table 1. Three types of bioremediation were tested by Exxon from the summer of 1989 through 1991: oleophilic fertilizer (Inipol EAP22); slow release fertilizer (Customblen), and soluble spray fertilizers. The mixtures resemble the liquid or pelletized fertilizers purchased for application to lawns.

Oleophilic fertilizers

Oleophilic fertilizers contain oleic acid which is added to a liquid base to soften the target oil. This enables the fertilizer to adhere to the oil more effectively. Inipol EAP22 is a oleophilic fertilizer purchased from the French company Elf Aquitane (a major oil company). Over 500 metric tons were delivered in 1989. Inipol is a liquid material designed to dissolve nitrogen and phosphorus nutrients into spilled crude oil. Chemically, Inipol is described as a mixture of an oily substance (oleic acid, a fatty acid) commonly found in fats and oils, a phosphate containing shampoo-like material (laurel phosphate, a surfactant), and a garden fertilizer (urea). Inipol notably also contains polyethylene glycol ether -- 2-butoxy-1-ethanol (ethylene glycol monobutyl ether, butyl cellosolve or 2-butoxyethanol). This glycol ether, a substance similar to antifreeze, is used as an oil dispersant and solvent. The composition of Inipol EAP22 is approximately:

oleic acid	26% surfactant
urea	16%
laurel phosphate	23% surfactant
water	24%
2-butoxy-1-ethanol	11% solvent/dispersant

The nitrate/phosphate urea fertilizer fosters bacterial breakdown of crude oil. Inipol was applied to oiled beaches in a pressurized spray based on the square footage of the oiled area; 0.0075 gallons/sq ft were intended to be applied. Personnel applying Inipol wore full protective gear.

Slow Release Fertilizers (Customblen)

These slow release fertilizers consist of ammonium nitrate and phosphate salts packed in an inert material (mineral or vegetable in nature) that allows slow release of the nutrients over time. The major chemical used was urea fertilizer granules about the size of BB shot, produced by Sierra Chemicals. The granules were broadcast by a hand crank fertilizer spreader at the rate of 0.0033lb/ft^2.

Soluble Spray

Nitrogen and phosphorous in the form of ammonium nitrate and sodium phosphate were mixed with sea water to produce a fertilizer solution that was applied to the beaches via a sprinkler system at low tide. This allowed deep penetration of nutrients into the beach sediments. During the actual test of this system at Passage Cove, six pounds of nitrogen and five pounds of phosphorous fertilizer were applied per hectare.

Bacterial Requirements

Bacteria which are capable of breaking down hydrocarbons (oil) require the following:

1. Oxygen for respiration.

2. Nitrogen and phosphorus were needed for conversion of oil hydrocarbons into cellular components such as DNA, proteins, and carbohydrates. The beaches of PWS lack nitrogen and phosphorous in the large quantities required by bacteria. The addition of fertilizers containing ammonia and phosphate balanced the amount of oil hydrocarbons available to the bacteria and, in theory, increased the rate of oil degradation.

3. Temperature: The optimal temperature for bacterial growth and oil degradation is 70°F, with lower temperatures slowing growth and breakdown (Pritchard 1990). However, according to Sirvins and Angles (1986), temperature is not a limiting factor with acclimated bacteria, even in Antarctica at temperatures of 3°C.

4. Oil Susceptibility: Not all types of oil are biodegradable. Tarry asphaltene residues contain many degradable materials, but lack of solubility makes asphaltenes difficult for bacteria to degrade. The extreme form of this is asphalt pavement (a common occurrence on PWS beaches) which is not degraded. Oil softeners, surfactants, dispersants, and emulsifiers can be used to soften these asphaltenes, but their toxicity to vertebrates renders extreme treatments impractical.

Toxicity of Slow-Release Customblen

Slow-release Customblem and soluble spray fertilizers have ammonia flush toxicity. Sixty percent of the applied fertilizer is released as urea, microbially converted to ammonia. Ammonia can be especially harmful to aquatic species in areas where poor tidal flushing prevents rapid dilution. Ammonia at concentrations of 1 ppm is toxic to invertebrates, including mussel larvae. However, this chemical must remain at that concentration for a sustained period of 48 to 96 hours before it will affect indigenous species (Pritchard 1990). Ammonia and urea are well known substances. There is little conflict among agencies regarding toxicity. Possible problems could result from an incoming tide or a contrary current carrying the ammonia up a salmon stream over the spawning beds, into a sensitive marsh area, or by foraging birds ingesting Customblen pellets. LD50 studies on bobwhite quail indicated 5gm of pellets per quail caused death within 8hrs of dosage. Fifty percent of the quail dosed with 1gm of pellets (40 pellets) died within 36 hrs. None of the birds dosed with 0.2 gm of pellets died (Fairbrother 1990).

Inipol Composition and Toxicity

A basic supposition regarding Inipol toxicity is that once Inipol mixes with water it becomes nontoxic. This is difficult to prove, however, since there are no analytical methods to quantify Inipol in seawater (Clark 1990). When sprayed directly on intertidal organisms above the water level, Inipol kills most of them (Viteri 1990). The most toxic component of Inipol is 2-butoxyethanol ethylene glycol monobutyl. This is an oil dispersant and industrial solvent. In humans this solvent can cause dizziness, respiratory irritation, unconsciousness, and even death. Inipol can be absorbed directly through the skin and can cause blood and kidney damage (EPA MSDS comparison 1989).

Inipol may injure birds which feed upon it before it dissolves (EPA MSDS comparison 1989). In the worst case scenario developed by EPA, the pulse of Inipol in the nearshore water was estimated at 293 ppm. This is above the LC50 values for herring, sticklebacks, mussel larvae, oyster larvae, and mysid shrimp larvae. However, the accuracy of the 293 ppm is questionable because the same paper states "There is no proven analytical method to quantify Inipol in seawater" (Pritchard 1990). Inipol is toxic at concentrations of 35 to 100 mg/l (Pritchard 1990). Lauryl sulfate, used as a "witness product" for laurel phosphate, which makes up 23% of Inipol, has LC50 toxicities of 300 ppm for shrimp and 15 ppm for cockles (Sirvins and Angles 1986), but we found no known documentation on the toxicity of laurel phosphate.

Inipol was <u>not</u> intended to be sprayed in anadromous stream mouths, but entire sections of shorelines of SE Knight Island from Hogan Bay to Point Helens and other oiled areas of Knight Island were sprayed with Inipol (Table 1). Inipol was used extensively throughout the three years of oil spill cleanup (1989-1991). Excessive use of Inipol by Exxon personnel on island beaches and stream mouths (KN115) in Herring Bay, Knight Island, resulted in a citation from ADEC (August 31, 1989). This was before additional anadromous streams were included in the ASC catalog (ADFG 1990). Non-documented salmon streams (e.g. EL052) were sprayed with Inipol in 1989 (Table 1).

Table 2 contains 1990 bioremediation application by segment and by habitat type, and Table 3 gives 1991 applications. In 1990, site DI067a on Disk Island was used as a bioremediation products test site. This mussel bed has documented harlequin duck use. Site ER20b on Elrington Island was a liquid fertilizer test site for ten days in 1990. An anadromous fish stream on Knight Island (KN132b) was an Inipol test site with subsequent sampling by helicopter.

During the 1989-1991 clean-up period, several chemicals were applied to the shorelines of Prince William Sound. The toxic effects of chemicals such as urea and ammonia are well documented, while the effect on wildlife of other chemicals, such as laurel phosphate (23% of Inipol), were almost completely unknown. Many of the areas receiving chemicals (such as test site KN211E where three different dispersants were applied in 1989) were areas with documented harlequin duck use (Table 1). Two of the chemicals selected for extensive application were Inipol and Customblen, both bioremediation enhancers. Following are examples of quantities of Inipol and Customblen applied to the PWS environment 1989-1991.

Total Inipol and Customblen applied in Prince William Sound in 1989:

Inipol	60,896 gallons
Customblen	14,412 pounds

Total Inipol and Customblen applied to representative, documented harlequin habitat sites in 1989:

Inipol	7,361 gallons
Customblen	1,288 pounds

Total Inipol and Customblen applied to representative, documented harlequin habitat sites in 1990:

Inipol	3,318 gallons
Customblen	11,587 pounds

Total Inipol and Customblen applied to selected harlequin habitat sites in 1991:

Inipol	991 gallons*
Customblen	983 pounds *

* Incomplete figures; partial records kept by USCG and ADEC (1989-1991).

REFERENCES

Alaska Department of Fish and Game. 1990. An atlas to the catalog of waters important for spawning, rearing or migration of anadromous fishes. ADFG Habitat Division, Southcentral Region, Anchorage. 131pp.

Clark, J. 1990. Wildlife toxicity data for bioremediation.U.S. EPA, Environ. Research Lab., Sabine Is., Florida.

Fairbrother, A. 1990. Fertilizer Pellet LD50 Study. U.S. Environ. Prot. Agency, Environ. Res. Lab., Corvallis OR.

Pritchard, P.H. 1990. Oil spill bioremediation project---summary. U.S. Envir. Prot. Agency, Office of Res. and Devel.

Sirvins, A. and M. Angles. 1986. Biodegradation of petroleum hydrocarbons. Elf Aquitane 1986:358-404. Washington D.C.

Viteri, Alex. 1990. Memorandum: April 27, 1990. Environmental Engineer, Alaska Dept. Envir. Conserv. (ADEC). Habitat Div., ADF&G EVOS Library, Anchorage.

Table 1. 1989 Daily summary of summer bioremediation with granular INIPOL (EAP 22) on important harlequin duck sites.

ISLAND	SEGMENT	DATE	AVE.LN. FEET	AVE.WDH FEET	GALS. USED	SEGMENT	AVE.LN. FEET	AVE.WD FEET	LBS. USED	SEASON HABITAT SITE
APPLEGATE	AE004	AUG 28	2349	47	715					SUMMER\OFFSHORE ROCKS
APPLEGATE	AE004	AUG 29	825	24	145					SUMMER\OFFSHORE ROCKS
APPLEGATE	AE005	AUG 29	30	6	2					SUMMER\ BAYS & LAGOONS\POSSIBLE NONTRAPPED STREAM INFLUENCE
BAINBRIDGE	BA006	AUG 19								SUMMER\ OFFSHORE RK\MUSSEL BED FOSC\ISCC AUTHORIZED BIO\NO DATA AVAIL.
BAINBRIDGE	BA004	AUG 19								SUMMER\ MUSSEL BED\FOSC & ISCC AUTHORIZED BIO\NO DATA AVAIL.
CHENEGA	CH010	AUG 20	2103	10	171					SUMMER\ MUSSEL BED
CHENEGA	CH011	AUG 20	2139	11	170					SUMMER\ OFFSHORE ROCKS
CRAFTON	CR004	AUG 28	1197	31	247					SUMMER\OFFSHORE ROCKS
ELEANOR	EL013	AUG 31	231	10	21	EL013	231	10	35	SUMMER\MUSSEL BED
ELEANOR	EL015	AUG 31	138	12	11	EL015	138	12	15	SUMMER\MUSSEL BED
ELEANOR	EL052	AUG 21	2580	26	520					SUMMER\STREAM
EVANS	EV070	AUG 19	441	9	33					SUMMER\MUSSEL BED
FLEMING	FL004	AUG 19	288	10	18					SUMMER\MUSSEL BED
GREEN	GR101	AUG 08	600	120	531					SUMMER\OFFSHORE ROCKS
GREEN	GR101	AUG 09	1950	42	650					SUMMER\OFFSHORE ROCKS
GREEN	GR101	AUG 11	1947	33	464					SUMMER\OFFSHORE ROCKS
KNIGHT	KN113	AUG 30	909	17	110					SUMMER\MUSSEL BED
KNIGHT	KN113	AUG 31	1119	22	180					SUMMER\MUSSEL BED
KNIGHT	KN115	AUG 30	120	42	40	KN115	120	42	25	SUMMER\KN115 MANDAYS DATA SHOWING SEVERE DISTURBANCE
KNIGHT	KN115	AUG 31	2184	13	230					SUMMER\KN115 MANDAYS DATA SHOWING SEVERE DISTURBANCE
KNIGHT	KN300	AUG 29	8571	14	918	KN300	8571	14	300	SUMMER\MUSSEL BED
KNIGHT	KN500	AUG 31	1587	27	300					SUMMER\BAYS&LAGOONS\POSSIBLE NONTRAPPED STREAM INFLUENCE
MAINLAND	MA002	AUG 28	1263	51	408					SUMMER\MUSSEL BED
				TOTAL GALS.	5884			TOTAL LBS.	375	

AVE.LN.IN FEET......AVERAGE LENGTH OF OIL BAND
AVE.WDH.IN FEET.....AVERAGE WIDTH OF OIL BAND

Table 2. 1989 daily summary of fall bioremediation with granular INIPOL (EAP 22) on important harlequin duck sites.

ISLAND	SEGMENT	DATE	AVE.LN. FEET	AVE.WDH FEET	GALS. USED	SEGMENT	AVE.LN. FEET	AVE.WD FEET	LBS. USED	SEASON HABITAT SITE
CHENEGA	CH010	SEPT 3	60	6	3					FALL\MUSSEL BED
DISK	DI059	SEPT 6	240	15	30	DI059	240	15	25	FALL\BAYS&LAGOONS\POSSIBLE NONTRAPPED STREAM INFLUENCE
DISK	DI067	SEPT 2	1800	9	120	DI059	1800	9	5	FALL\MUSSEL BED
EVANS	EV015	SEPT 6	420	20	53	EV015	420	20	75	FALL\MUSSEL BED
EVANS	EV070	SEPT 6	420	36.9	110	EV070	420	36.9	25	FALL\MUSSEL BED
KNIGHT	KN141	SEPT 2								TOTAL BIO AMTS. FOR THIS DAY NOT BROKEN INTO AMTS.\SEGMENT
KNIGHT	KN401	SEPT 6	3633	5	80	KN401	3633	5	150	FALL\STREAMS
KNIGHT	KN401	SEPT 7	3633	19.5	85					FALL\STREAMS
KNIGHT	KN402	SEPT 6				KN402	195	6	20	THIS SEGMENT IS IMMEDIATELY ADJACENT TO KN401 IN A CONFINED POCKET COVE
KNIGHT	KN402	SEPT 7	195	6	25					THIS SEGMENT IS IMMEDIATELY ADJACENT TO KN401 IN A CONFINED POCKET COVE
NAKED	NA024	SEPT 10	399	40	125	NA024	399	39.9	100	FALL\BAYS&LAGOONS\POSSIBLE NONTRAPPED STREAM INFLUENCE
NAKED	NA024	SEPT 10				NA024	1170	10.5	75	FALL\BAYS&LAGOONS\POSSIBLE NONTRAPPED STREAM INFLUENCE
NAKED	NA026	SEPT 10	2340	11	125	NA026	2340	10.8	150	FALL\BAYS&LAGOONS\POSSIBLE NONTRAPPED STREAM INFLUENCE
NAKED	NA026	SEPT 10				NA026	300	29	50	FALL\BAYS&LAGOONS\POSSIBLE NONTRAPPED STREAM INFLUENCE
PERRY	PR002	SEPT 4	996	41.7	200	PR002	996	41.7	230	FALL\OFFSHORE ROCKS
PERRY	PR003	SEPT 5	225	9.9	25					FALL\BAYS&LAGOONS\POSSIBLE NONTRAPPED STREAM INFLUENCE
SQUIRREL	SL001	SEPT 3	1452	20	215					FALL\OFFSHORE ROCKS
SQUIRREL	SL001	SEPT 4	825	28.8	281					FALL\OFFSHORE ROCKS
LATOUCHE	LA015									PART OF SEGMENT WAS SETASIDE\MUCH MANUAL-MECH. WORK HOWEVER NO DOCUMENTATION FOR BIOREMEDIATION
KNIGHT	KN132 KN211									THESE SEGMENTS WERE BOTH APPROVED FOR INIPOL BY THE ISCC AND FOSC 8\18\89 BUT NO RECORD OF THEIR TREATMENT EXISTS
				TOTAL	1477			TOTAL	905	

Table 3. 1990 daily summary of bioremediation with INIPOL (EAP 22) on important harlequin duck sites.

ISLAND	SEGMENT SUBSEGMENT	DATE SEASON	MANDAYS	AVG.LNG METERS	AVG.WDH METERS	GALS.USED	SEGMENT SUBSEGMENT	AVE.LNG METERS	AVE.WDH METERS	LBS	HABITAT TYPE
BAINBRIDGE	BA006C	7\25 SUMMER	8				BA006C			75	MB
BAINBRIDGE	BA006C	7\26 SUMMER	8				BA006C	50	7.5	75	MB
BAINBRIDGE	BA006C	7\27 SUMMER	8				BA006C	25	7.5	35	MB
BAINBRIDGE	BA006C	8\11 SUMMER	8				BA006C			76.5	MB
CHENEGA	CH010B	6\19 SUMMER	8				CH010B			25	MB
CHENEGA	CH010B	7\3 SUMMER	8			32	CH010B			132	MB
CHENEGA	CH010B	8\7 SUMMER	8			5	CH010B			182	MB
DI067A ON DISK ISLAND WAS A BIOREMEDIATION PRODUCTS TEST SITE JULY (1,5,9,13,25,90)											
ELEANOR	EL013A	8\7 SUMMER	8			9	EL013A			21	MB
ELEANOR	EL013A	8\29 SUMMER	8			5	EL013A			87	MB
ELEANOR	EL015A	8\27 SUMMER	8			17	EL015A			36	MB
ELEANOR	EL015A	8\29 SUMMER	8			5	EL015A			2.5	MB
ER020B ON ELRINGTON WAS A LIQUID FERTILIZER TEST SITE (JUNE 28) (JULY 1,2,3,6,7,11,12,15,16)											
ELRINGTON	ER020B	8\12 SUMMER	8			3.5	ER020B			1.5	MB
EVANS	EV015A	6\6 SUMMER	8			5	EV015A			2.5	MB
EVANS	EV015A	8\31 SUMMER	8			3	EV015A			1.5	MB
EVANS	EV070E	6\12 SUMMER	8				EV070E	5 8	20 17	20.5 28	MB
EVANS	EV070E	9\1 FALL	8				EV070E			10	MB
EVANS	EV070F	6\12 SUMMER	8				EV070F			48.5	MB
EVANS	EV070F	9\1 FALL	8				EV070F			31	MB
FLEMING	FL004A	6\29 SUMMER	8			42.5	FL004A			104	MB
FLEMING	FL004A	6\30 SUMMER	8			19	FL004A			21	MB
FLEMING	FL004A	8\11 SUMMER	8			47.5	FL004A			125	MB
FLEMING	FL004A	9\12 FALL	8			126	FL004A			253	MB
KNIGHT	KN113B	7\19 SUMMER	8				KN113B	50	9	93	MB
KNIGHT	KN136A	7\4 SUMMER	8								

Table 3. (cont.) 1990 daily summary of bioremediation with INIPOL.

ISLAND	SEGMENT SUBSEGMENT	DATE SEASON	MANDAYS	AVG.LNG METERS	AVG.WDH METERS	GALS.USED	SEGMENT SUBSEGMENT	AVE.LNG METERS	AVE.WDH METERS	LBS	HABITAT TYPE
KNIGHT	KN136A	8\2 SUMMER	8				KN136A	56 45	10 18	22 32	MB
KNIGHT	KN136A	8\3 SUMMER	8	56 45	10 18	44 64	KN136A	17	8	27	MB
KNIGHT	KN136A	9\5 FALL	8	56 45	10 18	44 64	KN136A	56 45 17	10 18 8	22 32 27	MB
KNIGHT	KN300	7\11 SUMMER	8			43.5	KN136A			574	MB
KNIGHT	KN300	8\14 SUMMER	8			62.5	KN136A			595	MB
MAINLAND	MA002A	6\7 SUMMER	8			2	MA002A	6.5 25.5	21 58	28 56.3	MB
MAINLAND	MA002A	8\14 SUMMER	8			1.5	MA002A			41	MB
MAINLAND	MA002A	8\28 SUMMER	8				MA002A			50	MB
		TOTAL	168		TOTAL	645			TOTAL	2993	
		MANDAY			GAL.				LBS.		
											HABITAT MB = MUSSEL BED
APPLEGATE	AE005A	6\14 SUMMER	8	195	41.5	104	AE005A	299	41.5	49	B&L
APPLEGATE	AE005A	6\15 SUMMER	8			12	AE005A			32	B&L
APPLEGATE	AE005A	6\17 SUMMER	8			104	AE005A			49	B&L
APPLEGATE	AE005A	8\2 SUMMER	8			126	AE005A			288	B&L
APPLEGATE	AE005A	9\10 FALL	8			79	AE005A			230	B&L
APPLEGATE	AE005B	7\8 SUMMER	8			18	AE005A			12.3	B&L
APPLEGATE	AE005B	8\28 SUMMER	8			9	AE005A			11.8	B&L
APPLEGATE	AE005C	6\15 SUMMER	8	24	20	18	AE005C	24	20	36	B&L
DISK	DI059	5\27 SPRING	8			15	DI059			71	B&L
DISK	DI059	8\4 SUMMER	8				DI059			36	B&L
DISK	DI059	9\1 FALL	8			5.5	DI059			418	B&L
GREEN	GR015A	7\15 SUMMER	8	133	8.4	23.5	GR015A	133	82.2	434	B&L
GREEN	GR015A	8\16 SUMMER	8			15	GR015A				B&L
KNIGHT	KN211C	9\8 FALL	8	265	73	222	KN211C				B&L

Table 3. (cont.) 1990 daily summary of bioremediation with INIPOL.

ISLAND	SEGMENT SUBSEGMENT	DATE SEASON	MANDAYS	AVG.LNG METERS	AVG.WDH METERS	GALS.USED	SEGMENT SUBSEGMENT	AVE.LNG METERS	AVE.WDH METERS	LBS	HABITAT TYPE
KNIGHT	KN500A	7\6 SUMMER	8				KN500A			100	B&L
KNIGHT	KN500A	8\24 SUMMER	8			3	KN500A			135	B&L
KNIGHT	KN500A	9\11 FALL	8				KN500A			76	B&L
KNIGHT	KN500B	7\6 SUMMER	8				KN500B			25	B&L
KNIGHT	KN500B	7\7 SUMMER	8				KN500B	100	13	100	B&L
KNIGHT	KN500B	7\20 SUMMER	8	215	82	614	KN500B	246	99	354	B&L
KNIGHT	KN500B	7\22 SUMMER	8	33	4.8	6.7	KN500B	146	18.5	131	B&L
KNIGHT	KN500B	8\24 SUMMER	8				KN500B			1110	B&L
KNIGHT	KN500B	9\11 FALL	8				KN500B			568	B&L
LATOUCHE	LA018A	7\17 SUMMER	8			200	LA018A			95	B&L
LATOUCHE	LA018A	8\25 SUMMER	8			200	LA018A			95	B&L
LATOUCHE	LA018A	8\26	8				LA018A			476	B&L
LATOUCHE	LA018A	9\9 FALL	8				LA018A	150	4	60	B&L
NAKED	NA024F	7\10 SUMMER	8				NA024F	9	10	5	B&L
PERRY	PR003A	7\6 SUMMER	8			30	PR003A			54	B&L
PERRY	PR003A	8\1 SUMMER	8				PR003A			54	B&L
PERRY	PR003A	9\10 FALL	8				PR003A			54	B&L
PERRY	PR003B	7\6 SUMMER	8			19	PR003B			7.5	B&L
PERRY	PR003B	9\2 FALL	8				PR003B			2	B&L
PERRY	PR003C	7\6 SUMMER	8				PR003C			197	B&L
PERRY	PR003D	7\6 SUMMER	8				PR003D			1.5	B&L
		TOTAL	288		TOTAL GAL.	1788			TOTAL LBS.	5367	
HABITAT B&L = BAYS & LAGOONS\POSSIBLE UNTRAPPED STREAM INFLUENCE											
APPLEGATE	AE004A	6\14 SUMMER	8	4	1	0.3	AE004A	82	9	63.2	OR
APPLEGATE	AE004A	6\15 SUMMER	8				AE004A			1	OR
APPLEGATE	AE004A	8\2 SUMMER	8			41	AE004A			82	OR

Table 3. (cont.) 1990 daily summary of bioremediation with INIPOL.

ISLAND	SEGMENT SUBSEGMENT	DATE SEASON	MANDAYS	AVG.LNG METERS	AVG.WDH METERS	GALS.USED	SEGMENT SUBSEGMENT	AVE.LNG METERS	AVE.WDH METERS	LBS	HABITAT TYPE
APPLEGATE	AE004B	6\9 SUMMER	8	0.5	1.5	1.1	AE004B	1	1	3.3	OR
APPLEGATE	AE004B	6\10 SUMMER	8				AE004B	14	8	3.5	OR
APPLEGATE	AE004B	6\13 SUMMER	8	UNKNOWN			AE004B		UNKNOWN		OR
APPLEGATE	AE004B	6\14 SUMMER	8	4	3	0.95	AE004B			1	OR
APPLEGATE	AE004B	6\15 SUMMER	8			2.3	AE004B			69	OR
APPLEGATE	AE004B	8\2 SUMMER	8			46.5	AE004B			148	OR
AGULIAK	AG001A	7\15 SUMMER	8			18	AG001A			51	OR
AGULIAK	AG001A	8\10 SUMMER	8				AG001A			86	OR
AGULIAK	AG009A	5\13 SPRING	8				AG009A			1	OR
AGULIAK	AG009A	7\14 SUMMER	8				AG009A			123	OR
AGULIAK	AG009A	8\12 SUMMER	8				AG009A			63	OR
CHENEGA	CH011A	7\19 SUMMER	8				CH011A			27	OR
CHENEGA	CH011A	7\20 SUMMER	8	9	5	3.5	CH011A	43	15	95	OR
CHENEGA	CH011A	8\7 SUMMER	8			2.5	CH011A			104	OR
GREEN	GR101A	7\30 SUMMER	8	168	23	100	GR101A	278	30	206	OR
GREEN	GR101B	7\30 SUMMER	8	152	42	67.5	GR101B	242	N\A	88	OR
KNIGHT	KN141A	7\1 SUMMER	8			22.5	KN141A			88	OR
KNIGHT	KN141A	7\29 SUMMER	8			21.5	KN141A			93	OR
MUMMY	MU900	7\13 SUMMER	8				MU900			N\A	OR
PERRY	PR002A	7\6 SUMMER	8			52.5	MU900			25.3	OR
PERRY	PR002A	7\6 SUMMER	8			28.5	PR002A			34.8	OR
PERRY	PR002A	9\7 FALL	8				PR002A			18	OR
SQUIRREL	SL001B	7\14 SUMMER	8				SL001B			90	OR
SQUIRREL	SL001B	8\12 SUMMER	8				SL001B			257	OR
SQUIRREL	SL001C	8\24 SUMMER	8				SL001C			40.5	OR

Table 3. (cont.) 1990 daily summary of bioremediation with INIPOL.

ISLAND	SEGMENT SUBSEGMENT	DATE SEASON	MANDAYS	AVG.LNG METERS	AVG.WDH METERS	GALS.USED	SEGMENT SUBSEGMENT	AVE.LNG METERS	AVE.WDH METERS	LBS	HABITAT TYPE
SQUIRREL	SL001D	7\15 SUMMER	8			40	SL001D			276	OR
SQUIRREL	SL001D	8\12 SUMMER	8				SL001D			237	OR
SQUIRREL	SL001E	7\14 SUMMER	8				SL001E			20	OR
SQUIRREL	SL001E	9\12 SUMMER	8				SL001E			20	OR
WHALE BAY	WH003B	7\8 SUMMER	8				WH003B			5	OR
		TOTAL MANDAY	256		TOTAL GAL.	449			TOTAL LBS.	2420	
HABITAT OR = OFFSHORE ROCK											
ELEANOR	EL052B	6\28 SUMMER	8			3.1	EL052B			65	STRM
ELEANOR	EL052B	6\30 SUMMER	8				EL052B			31.5	STRM
ELEANOR	EL052B	8\21 SUMMER	8				EL052B			192	STRM
ELEANOR	EL052B	9\4 SUMMER	8				EL052B			32	STRM
ELEANOR	EL052A	6\28 SUMMER	8			14	EL052B			101	STRM
ELEANOR	EL052A	7\31 SUMMER	8				EL052A			121	STRM
KN132B INIPOL TEST SITE APPLIED (7\12&8\11) HELO SAMPLING (8\1&7\15)											
KNIGHT	KN132B	6\2 SUMMER	8	206	23.8	171	KN132B	206	23.8	102	STRM
KNIGHT	KN132B	7\12 SUMMER	8	36	18	51	KN132B	36	18	24	STRM
KNIGHT	KN132B	8\24 SUMMER	8			160	KN132B			80	STRM
KNIGHT	KN201A	6\20 SUMMER	8			18.2	KN201A			9.1	STRM
KNIGHT	KN201A	6\21 SUMMER	8			18.2	KN201A			9.1	STRM
KNIGHT	KN201A	8\29 SUMMER	8				KN201A			14	STRM
KNIGHT	KN201A	9\6 FALL	8				KN201A	70	2	14	STRM
KNIGHT	KN401B	9\7 FALL	8				KN401B	13	17	12	STRM
		TOTAL MANDAY	112		TOTAL GAL.	436			TOTAL LBS.	807	
N\A NOT AVAILABLE										HABITAT STRM = STREAM	

Table 4. 1991 daily summary of bioremediation with granular INIPOL (EAP 22) on important harlequin duck sites.

ISLAND	SEGMENT SUBSEGMENT	DATE SEASON	MANDAYS	AVE LNG METERS	AVE WDH METERS	GAL	SEGMENT SUBSEGMENT	AVE WDH METERS	AVE LNG METERS	LBS	HABITAT TYPE
BAINBRIDGE	BA006C	7\1 SUMMER	8	47	244	18	BA006C	47	244	7.8	MUSSEL BED
BAINBRIDGE	BA006C	7\28 SUMMER	8			18	BA006C			7.8	MUSSEL BED
BAINBRIDGE	BA006C	8\26 SUMMER	8			18	BA006C			7.8	MUSSEL BED
DISK	DI067A	6\21 SUMMER	8			6	DI067A				MUSSEL BED
DISK	DI067A	7\10 SUMMER	8			25	DI067A			3.5	MUSSEL BED
DISK	DI067A	8\15 SUMMER	8			N\A	DI067A			N\A	MUSSEL BED
ELRINGTON	ER020B	7\8 SUMMER	8	45	465	38	ER020B	45	465	17	MUSSEL BED
ELRINGTON	ER020B	8\10 SUMMER	8			N\A	ER020B			N\A	MUSSEL BED
EVANS	EV070E	7\2 SUMMER	8				EV070E			48	MUSSEL BED
EVANS	EV070E	7\27 SUMMER	8			9	EV070E			3.5	MUSSEL BED
EVANS	EV070E	8\27 SUMMER	8			5	EV070E			2	MUSSEL BED
FLEMING	FL004A	6\28 SUMMER	8				FL004A			20	MUSSEL BED
KNIGHT	KN136A	6\17 SUMMER	15	235	N\A	143	KN136A	235	N\A	63	MUSSEL BED
KNIGHT	KN136A	7\23 SUMMER	N\A			N\A	KN136A			N\A	MUSSEL BED

ISLAND	SEGMENT SUBSEGMENT	DATE SEASON	MANDAYS	AVE LNG METERS	AVE WDH METERS	GAL	SEGMENT SUBSEGMENT	AVE WDH METERS	AVE LNG METERS	LBS	HABITAT TYPE
KNIGHT	KN136A	8\20 SUMMER	N\A			N\A	KN136A			N\A	MUSSEL BED
KNIGHT	KN300A	6\5 SUMMER	8				KN300A			25	MUSSEL BED
KNIGHT	KN300A	7\11 SUMMER	4			44	KN300A			67	MUSSEL BED
KNIGHT	KN300A	8\16 SUMMER	4			27	KN300A			15	MUSSEL BED
LATOUCHE	LA015E	7\7 SUMMER	18			282	LA015E			122	MUSSEL BED
LATOUCHE	LA015E	8\11 SUMMER	8			277	LA015E			126	MUSSEL BED
MAINLAND	MA002A	8\17 SUMMER	8				MA002A			N\A	MUSSEL BED
		TOTAL MANDAYS	161		TOTAL GAL	910			TOTAL LBS	535	
APPLEGATE	AE005A	5\2 SPRING	8				AE005A			N\A	BAYS&LAGOONS\POSSIBLE UNTRAPPED STREAM INFLUENCE
APPLEGATE	AE005A	6\1 SUMMER	8				AE005A			2.8	BAYS&LAGOONS\POSSIBLE UNTRAPPED STREAM INFLUENCE
APPLEGATE	AE005A	7\19 SUMMER	8			20	AE005A			8.8	BAYS&LAGOONS\POSSIBLE UNTRAPPED STREAM INFLUENCE
APPLEGATE	AE005A	8\18 SUMMER	8			42	AE005A			19	BAYS&LAGOONS\POSSIBLE UNTRAPPED STREAM INFLUENCE
APPLEGATE	AE005B	7\19 SUMMER	8			9.4	AE005B			6	BAYS&LAGOONS\POSSIBLE UNTRAPPED STREAM INFLUENCE
APPLEGATE	AE005B	8\16 SUMMER	8			8	AE005B			10	BAYS&LAGOONS\POSSIBLE UNTRAPPED STREAM INFLUENCE
KNIGHT	KN500A	6\7 SUMMER	8				KN500A	35	N\A	183	BAYS&LAGOONS\POSSIBLE UNTRAPPED STREAM INFLUENCE
KNIGHT	KN500A	8\29 SUMMER	8				KN500A			40	BAYS&LAGOONS\POSSIBLE UNTRAPPED STREAM INFLUENCE

ISLAND	SEGMENT SUBSEGMENT	DATE SEASON	MANDAYS	AVE LNG METERS	AVE WDH METERS	GAL	SEGMENT SUBSEGMENT	AVE WDH METERS	AVE LNG METERS	LBS	HABITAT TYPE
KNIGHT	KN500B	8\29 SUMMER	8			N\A	KN500B			N\A	BAYS&LAGOONS\POSSIBLE UNTRAPPED STREAM INFLUENCE
LATOUCHE	LA018A	6\28 SUMMER	24				LA018A			27	BAYS&LAGOONS\POSSIBLE UNTRAPPED STREAM INFLUENCE
LATOUCHE	LA018A	7\3 SUMMER	4			N\A	LA018A			N\A	BAYS&LAGOONS\POSSIBLE UNTRAPPED STREAM INFLUENCE
LATOUCHE	LA018A	7\29 SUMMER	8			1.4	LA018A			53	BAYS&LAGOONS\POSSIBLE UNTAPPED STREAM INFLUENCE
LATOUCHE	LA018A	7\30 SUMMER	8			N\A	LA018A			N\A	BAYS&LAGOONS\POSSIBLE UNTRAPPED STREAM INFLUENCE
LATOUCHE	LA018A	8\27 SUMMER	8			N\A	LA018A			N\A	BAYS&LAGOONS\POSSIBLE UNTRAPPED STREAM INFLUENCE
		TOTAL MANDAYS	124		TOTAL GAL	81			TOTAL LBS	350	BAYS&LAGOONS\POSSIBLE UNTRAPPED STREAM INFLUENCE
APPLEGATE	AE004A	6\1 SUMMER	10				AE004A			2.8	OFFSHORE ROCKS
AGULIAK	AG009A	7\10 SUMMER	17			N\A	AG009A			N\A	OFFSHORE ROCKS
		TOTAL MANDAYS	27		TOTAL GAL	N\A			TOTAL LBS	2.8	
KNIGHT	KN132B	6\4 SUMMER	15				KN132B			75	STREAMS
KNIGHT	KN132B	6\8 SUMMER	15				KN132B			10	STREAMS
KNIGHT	KN401	5\28 SPRING	5				KN401			10	STREAMS
		TOTAL MANDAYS	35		TOTAL GAL	N\A			TOTAL LBS	95	

DEFINITIONS OF TERMS:

N\A..........................THIS INDICATES TREATMENT OCCURRED, BUT SPECIFIC DATA WAS NOT AVAILABLE.
TOTAL MANDAYS................THE SUMMATION OF INDIVIDUAL MAN DAYS (MANDAY=ONE MAN WORKING AN 8 HOUR DAY) BY HABITAT TYPE
TOTAL GAL....................THE TOTAL NUMBER OF GALLONS OF INIPOL SPRAYED ON THAT SUBSEGMENT HABITAT SITE DURING 1991
TOTAL LBS....................THE TOTAL NUMBER OF POUNDS OF CUSTOMBLEN DRY FERTILIZER APPLIED TO THAT SUBSEGMENT DURING 1991
AVE LNG......................AVERAGE LENGTH OF THE TREATED OIL BAND IN METERS
AVE WDH......................AVERAGE WIDTH OF THE TREATED OIL BAND IN METERS

ALL THE DATA COMPILED FOR THESE TABLES CAME FROM THE FOLLOWING SOURCES:

ALASKA DEPT. OF ENVIRONMENTAL CONSERVATION: OIL SPILL RESPONSE OFFICE, 4241 B STREET SUITE 304 ANCHORAGE ALASKA 99503 (PRINCE WILLIAM SOUND SEGMENT FILE ALPHABETICAL BY ISLAND)

UNITED STATES COAST GUARD FOSC: (1989,1990,1991) PRINCE WILLIAM SOUND OIL SPILL SEGMENT FILE. ALPHABETICAL INDICATOR BY ISLAND. KEY BANK BLDG. 601 W 5TH. AVE. 4TH FLOOR SUITE 401 ANCHORAGE ALASKA