Exxon Valdez Oil Spill
Restoration Project Annual Report

Comprehensive Killer Whale Investigation

Restoration Project 95012

This annual report has been prepared for peer review as part of the *Exxon Valdez* Oil Spill Trustee Council restoration program for the purpose of assessing project progress. Peer review comments **have** been addressed in this annual report.

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Comprehensive Killer Whale Investigations

Restoration Project 95012
Annual Report

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Executive Summary

Killer whales were monitored in Prince William Sound, Alaska with funding from the *Exxon Valdez* Oil spill Trustee Council in 1989, 1990, and 1991 (damage assessment) and in 1993 (restoration monitoring). The North Gulf Oceanic Society (NGOS) independently maintained a monitoring program in all other years since 1984 (Matkin et *al.* 1994). This report details the continued monitoring of killer whales in Prince William Sound in 1995. The goal of the monitoring has been to obtain identification photographs of all whales in all major resident pods and transient groups on an annual basis. Photoidentification techniques (after Bigg et *al. 1990*) were used to identify individual whales. The current photographic database includes thousands of frames of film collected from 1984-1995 used to provide individual identifications for each encounter with whales. These data have been computerized in a separate photographic database for association analysis and examination of pod structure. Companion of vital rates and a preliminary examination of pod structure were made between AB pod and all other frequently sighted resident pods based on this photographic data. Changes in the resightings of individual whales from the AT transient group were examined statistically.

Data on killer whale behavior and predation events were recorded in a standard format during all years of the monitoring program. These data include the locations and behaviors of killer whales and the tracks of the survey vessels. It is appropriate that the data be input, maintained, and analyzed in a spatial database using a Geographic Information System (GIS). Analyses of these data will help evaluate recovery, recognize changes in behavior, and estimate killer whale impact on harbor seals. A GIS system was designed and data input initiated in 1995 at the Prince William Sound Science Center. Improvements were made in the field data collection format prior to the 1995 season.

Tissue samples from individually identified, free ranging killer whales were collected in 1994 and 1995 using a biopsy dart system and field techniques developed by Barrett-Lennard et *al*. (1996). Genetic analysis using mtDNA techniques was initiated in 1995 to examine the separation of two putative populations of killer whales in Prince William Sound.

Although four calves were recruited into AB pod during the period 1992-1994, five additional mortalities were recorded in 1994 and confirmed in 1995. The pod now contains 22 individuals. Mortalities in 1994 included one reproductive female, three juveniles, and one adult male whose fin collapsed at the time of the oil spill. These deaths may be related to changes in pod structure following the 14 mortalities of 1989-91. One subgroup of six whales from AB pod has traveled with AJ pod in 1994 and 1995. These observations indicate AB pod is not recovering following the *Exxon Valdez* oil spill.

Despite substantial field effort the number of AT whales sighted each year has declined following 1989. Only 11 of the original 22 whales attributed to the AT group were photographed in 1995. The rate of encounter with members of this group has also declined. Modeling of resighting data (1984-1995) for the individual AT group whales supports the hypothesis that the missing whales are dead or have permanently emigrated from Prince William Sound.

Twelve years of systematic data collected under public and private funding are being placed in a specially designed GIS system at the Prince William Sound Science Center (PWSSC). Approximately 60% of this data was input in 1995. This database will allow examination of feeding habits and other behaviors of killer whales in a spatial context before and after the spill. An important product of this investigation will be a clarification of the relationship between killer whales and the non-recovering harbor seals in Prince William Sound.

Additional observation of killer whale predation and collection of killer whale prey items occurred in 1995. Predation information is included as part of the GIS data base and

analysis of prey items are being used to determine the specific components of the killer whale diet. Preliminary results indicate a clear dietary separation between resident (fish eating) and transient (marine mammal eating) killer whales. Harbor seals and Dall's porpoise are important prey items for transient killer whales in the April-October period comprising 30% and 44% respectively of the observed kills.

Biopsy tissue sampling for genetic analysis occurred in 1994 and 1995. A total of 48 full size samples have been collected from resident and transient killer whales. Determination of the genetic separation of resident and transient killer whales is the initial goal of this aspect of the project. From the skin samples two segments of mitochondrial DNA (mtDNA) from each sample were amplified using the polymerase chain reaction (PCR). Restriction fragment length polymorphism analysis is currently being performed on the PCR products and will discriminate any mitochondrial differences between proposed Prince William Sound killer whale populations. The analysis is being carried out concurrently with a comprehensive genetic analysis of British Columbian killer whale stocks, which will make it possible to assess relatedness of Prince William Sound killer whales to whales from other areas.

The subcutaneous portion of the 1995 biopsy samples were forwarded to Dr. Graeme Worthy for lipid/fatty acid analysis (separate report). The subcutaneous portion of the 1994 samples (collected under private funding) is being analyzed for environmental contaminants at the NMFS Environmental Contaminant Laboratory, Seattle.

Introduction

On March 31, 1989, a week after the *Exxon Valdez* Oil spill (the spill), the AB pod of resident killer whales was observed traveling through oil sheens in western Prince William Sound and six members of the pod were missing. In the two years following the spill a total of 14 whales were lost from AB pod and there was no recruitment into the pod. The rate of mortality observed in this pod after the oil spill (19% in 1989 and 21% in 1990) far exceeds rates recorded over the past 11 years for the other resident pods in Prince William Sound or over the past 20 years for 19 resident pods in British Columbia and Washington State (Balcomb et *al.* 1982, Bigg 1982, Olesiuk et *al.* 1990, Matkin et *al.* 1994). Since the time of spill the social structure within AB pod has continued to show signs of deterioration. Subgroups have traveled independently of the pod, and pod members have not consistently traveled with closest relatives. AB pod was seen less frequently following the spill. Prior to spill AB pod was the most frequently encountered resident pod in Prince William Sound (Matkin et *al.* 1994).

Nine of the 22 whales from the transient AT1 group were not observed or photodocumented from 1990 to 1994 despite extensive field effort. While mortalities in transient groups cannot be confirmed with the same certainty as for residents, there is an increasing likelihood that these whales are dead or have permanently emigrated from the Sound.

The AB pod and AT group possibly were injured due to the effects of the *Exxon Valdez* oil spill and that they do not appear to be recovering. Numbers of whales in other well-documented resident pods have increased during the same period. Annual photographic monitoring has been the most effective tool in determination of the recovery status of AB pod and the AT group and the status of the entire Prince William Sound killer whale population (Matkin et al. 1994). This project continues using photoidentification to monitor changes in resident killer whale pods (including AB pod) and the AT transient group in Prince William Sound.

Predation by killer whales may be a factor in the non-recovery of harbor seals in Prince William Sound following the *Exxon Valdez* oil spill. At least 300 harbor seals were killed at the time of spill and the harbor seal population continues to decline. It appears that there are two types of killer whales in Prince William Sound, only one (transients) has been observed preying on marine mammals. This project examines harbor seal predation parameters using historical killer whale behavioral data in a GIS framework The separation of marine mammal eating and fish eating killer whales is examined using this behavioral data and genetic analysis. Genetic material was obtained using lightweight biopsy darts (Barrett-Lennard et al 1996). Subcutaneous material collected was supplied for lipid/fatty acid analysis and/or contaminant analysis .

Results from 1995 indicate that AB pod suffered five additional mortalities in 1994 that included one reproductive female, three juveniles and adult male. Other resident pods did not demonstrate atypical mortalities or mortality rates. The whales missing from the AT transient group since 1990 remain missing. The GIS system was designed, data sheets reworked, and approximately 60% of historic data entered into the system. Preliminary tabulation of predation events indicated harbor seals and Dall's porpoise are the primary food items of transient killer whales from April to October. Resident killer whales appear to select coho salmon from mixed schools during the July to September period. Full sized biopsy samples have been obtained from 48 whales. DNA has been successfully extracted from all samples and polymerase chain reaction (PCR) products have been obtained.

Objectives

1. To monitor AB pod, the AT group and the other major resident pods in Prince William Sound and determine recovery status of AB pod and the AT group

2. To input photographic data (current and historical) on a frame by frame basis into a standard computer format for association analysis and examination of pod structure of damaged and undamaged pods.

3. To design a geographic information system (GIS) and begin input of historical killer whale behavioral (including predation) data for analysis of this data in a spatial context.

4. To continue field observations of killer whale behavior and predation

5. To estimate the rate of predation of killer whales on harbor seals

6. To collect biopsy samples for genetic analysis and for lipid/fatty acid and isotope analysis (subcutaneous samples supplied to Dr. Graeme Worthy).

7. To determine the behavioral and genetic separation of the two putative populations of killer whales in Prince William Sound (residents and transients)

Methods

Most field work for the 1985 photoidentification study was conducted from the *Whale 2* , a 7.9m live-aboard vessel powered by a 165 hp diesel engine with inboard/outboard drive. This vessel centered its range in Montague Strait and lower Knight Island Passage but also made occasional searches in northwestern PWS and Upper Knight Island Passage (Figure 1). The 12.8 m vessel *Lucky Star* and an 5.1 m console skiff with 60 hp outboard were used as a mobile research platform and supply boat, collecting biopsy samples, predation data, and conducting photoidentification studies as well as supplying food and fuel to the *Whale 2* .

N.G.O.S. biologists on the *Whale 1*(a 15.5m cabin skiff with 85hp outboard) and *Auklet* (18m inboard diesel powered vessel) also photographed killer whales and kept data sheets during surveys directed at humpback whale photoidentification. The field time and killer whale encounters for these vessels were included in the GIS data base and used in our analysis.

Researchers attempted to maximize the number of contacts with each killer whale pod to insure sufficient photographs of each individual within the pod. Searches for whales were not random, but based on current and historical sighting information.

An encounter was defined as the successful detection, approach and taking of identification photographs. Accounts of whales from other mariners (generally by VHF radio were termed "reports". Although reports were used to select areas to be searched, all identifications were made from photographs taken during encounters.

Searches were centered in areas that had produced the most encounters with killer whales in the past. In all years whales were found visually, or by listening for killer whale calls with a directional hydrophone, or by responding to VHF radio calls from other vessels. Regular requests for recent killer whale sightings were made on hailing Channel 16 VHF. Photographs for individual identification were taken of the port side of each whale showing details of the dorsal fin and white saddle patch. Photographs were taken at no less than 1/1000 sec using Ilford HP5, a high speed black and white film, exposed at 1600 ASA. A Nikon 8008 autofocus camera with internal motor drive and a 300 mm f4.5 autofocus lens was used. When whales were encountered, researchers systematically moved from one subgroup (or individual) to the next keeping track of the whales photographed. If possible individual whales were photographed several times during each encounter to insure an adequate identification photograph. Whales were followed until all whales were photographed or until weather and/or darkness made photography impractical

A vessel log and chart of the vessel track were kept for each day the research vessels operated (LOG, Appendix 1). Similar logs were kept for all previous study years will be used in the GIS format to estimate effort. On these logs the elapsed time and distance traveled were recorded and vessel track was plotted. Record was made of time and location of all whale sightings and weather and sea state noted at regular intervals.

Specifics of each encounter with killer whales were recorded on standardized data forms that have been used since 1984. These forms were modified in 1995 to improve collection of data for GIS input (ENCOUNTER, Appendix 2). Data recorded included date, time, duration, and location of the encounter. Rolls of film exposed and the estimated number of whales photographed also were recorded. A chart of the whales' trackline during the encounter was completed and the distance traveled by the vessel with the whales calculated. Specific group and individual behaviors (i.e. feeding, resting, traveling, socializing, milling) were recorded by time and location when possible. Only one or a few sightings were recorded on any field day, but encounters with whales averaged from 3-6 hours, providing considerable behavioral information (travel rates, duration of feeding bouts, etc.). On each sheet the path of the vessel (LOG) or whales (ENCOUNTER) was recorded on a sketch map. These tracklines were entered by hand into the GIS database along with associated tabular data against a background map of the coastline. In all cases, location data was stored as the trackline, rather than as tabular arrays of point locations.

The GIS (Arc/Info) can produce such coordinate arrays if from the tracklines if needed. Comments on the data sheets regarding the specific locations of events such as feeding activity or changes in the weather were recorded in the comments fields.

The data entry system was designed and written using the ESRI Advanced Macro Language for Arc/Info. Complete procedures for entering the data are described in Appendix 5. The user proceeds through a series of menus and fills in the designated field for each tabular data item. When all data for a particular boat or whale path has been entered, the user clicks on "Add Record" and is prompted to enter the path of the associated boat or whale. Once this is entered, the macro attends to relating the tabular and vector data and processing the data layer to maintain its spatial structure in Arc/Info.

Directed observations of feeding behavior and identification and collection of prey of killer whales were made from all vessels as a part of the 1995 fieldwork. Opportunistic prey identification and collection from prior years was also available and used in our analysis. Only events that provided positive evidence of a kill were categorized as predation. Evidence included prey observed in the mouth of the whale, bits of hair or other parts, or oil slicks with bits of blubber. Incidents of harassment of potential marine mammal prey were also collected. This included instances where evidence was not observed but a kill was suspected or when potential prey exhibited fright or flight response or other strong behavioral reaction to killer whales. Harassment was demonstrated by behaviors such as flipper slapping and lobtailing by humpback whales and fleeing behavior by small cetaceans, pinnepeds, or mustelids. When predation on fish was observed, fish scales from the site of fish kills by killer whales were collected and later identified by species. Slides were individually mounted and identifications were made by a laboratory specializing in fish scale aging and identification. Fish scales and marine mammal remains were collected with a fine mesh net on an extendible handle (5 m. maximum extension). The pod or group of killer whales and specific individuals present at the kill or harassment incidents were recorded on the encounter data sheets (Appendix 2).

Tissue samples were collected from killer whales in Prince William Sound using a pneumatic rifle and custom-designed biopsy darts (biopsy system as described in Barrett-Lennard et al. 1996). A small dart was fired from a specially outfitted rifle powered by air pressure from a.22 caliber blank cartridge. The setup is similar to that used to deliver tranquilizing drugs to terrestrial mammals in wildlife research. A lightweight plastic dart (approx. 10 cm long by 1.2cm dia.) was fitted with a beveled tubular sterile stainless steel tip that took a small core of skin and blubber (approximately 1.6cm long and 0.5cm dia.). The sterilized dart is fired from a range of 16-20m. The dart hit the animal in the upper back, excised a small tissue sample and bounced off. The dart floated with sample contained until retrieved.

From the biopsy samples the epidermis, which was heavily pigmented, was separated aseptically from the other layers with a scalpel as soon as the dart was retrieved from the water. The dermal sample was used as a source of DNA, and was stored at 4 deg C. in a sterile 1.7 ml cryovial containing 1.2 ml of an autoclaved solution of 20% DMSO and 80% sodium chloride saturated double distilled water (for properties of storage solution see Amos and Hoelzel, 1991). The dermis and hypodermis were made up primarily of collagen and lipid, respectively, and were frozen in autoclaved, solvent-washed vials for fatty acid and contaminant analysis.

Data Analysis

All photographic negatives were examined under a Wild M5 stereo microscope at 9.6 power. Identifiable individuals in each frame were recorded. When identifications were not certain, they were not included in the analysis. Unusual wounds or other injuries were noted.

The alphanumeric code used to label each individual was based on Leatherwood et. *al.* (1984) and Heise et *al.* (1992). The first character in the code is "A" to designate Alaska, followed by a letter (A-Z) indicating the individual's pod. Individuals within the pod receive sequential numbers. For example, AB3 is the third whale designated in AB pod. New calves were identified with the next available number.

Individual identifications from each roll of film were computerized on a frame by frame basis using a specially designed data entry program. The actual number of whales identified from photographs and pods of whales present for each encounter was extracted from the photographic database and included with each encounter entered in the GIS database.

New calves were already present when fieldwork began and exact birth dates could not be determined. We followed the method of Olesiuk et *al.* (1990) and placed the birth of all calves in January for calculation of vital rates. Thus, birth rates could not be measured, and recruitment rates represent the survival of calves to about 0.5 years of age.

The determination of mothers of new calves was based on the consistent close association of calves with an adult female. Although young calves may travel with other individuals at times, a majority of time is spent with the mother as demonstrated by association analysis of identification photographs from repeated encounters (Bigg et *al.* 1990). The white saddle patch of calves generally does not develop for several years, but other scars and marks including the shape of the white eye patch are used to reliably re-identify calves.

If a whale from a resident pod is not photographed swimming alongside other members of its maternal group during repeated encounters over the course the summer field season it is considered missing. If it is again missing during the repeated encounters in the following summer season it is considered dead. No individual resident whale consistently missing during repeated encounters with its pod and maternal group over the course of a summer season has ever returned to its pod or appeared in another pod in all the years of research in Canada and the United States (Bigg et *al.* 1990, Matkin et *al.* 1994). Subgroups of resident pods may travel separately from the pod for a season or longer; however, this has not been observed for individuals. In a few instances missing whales have been found dead on beaches, but strandings of killer whales are infrequent events and most missing whales are never found. During 1975 to 1987 only six killer whales were found on beaches throughout the entire Gulf of Alaska (Zimmerman 1991). One explanation for the lack of recorded dead killer whales comes from the observations of early Soviet researchers. Killer whales that were shot for specimens were reported to sink. (Zenkovich 1938).

Immigration and emigration may occur among groups of transient whales. In British Columbia, infrequently sighted transients missing from their original groups for periods ranging from several months to several years or more have been resighted swimming with other groups of transient whales (Ellis, unpub. data). For this reason, transient whales missing from a particular group for several years cannot necessarily be considered dead. However, members of the AT group of transients have been resighted consistently in Prince William Sound since 1983.

Finite annual mortality rates (MR) and reproductive rates (RR) for resident pods were calculated as follows:

where: NM = number of whales missing from a pod in given year
NP = number of whales present in a pod at end of previous year
NR = number of calves recruited to 0.5 years in a pod in a given year
then: Mortality rate = NM/NP and Reproductive rate = NR/NP

If the year a mortality or recruitment occurred could not be determined it was split between the possible years. A mean weighted mortality and reproductive rate for all pods for all years was determined by pooling the data for all pods for all years.

The sex and age class of missing whales were determined from data collected prior to their disappearance when possible. In some cases sex had been determined by viewing the ventral side of the whale. Reproductive females were identified by the presence of offspring. Whales of adult conformation at the beginning of the study that had not calved since 1983 and were not accompanied by a juvenile(s) were considered as possibly post-reproductive. Exact ages of whales could be determined only for whales born since 1983. Juveniles born before 1984 were given approximate ages by comparing the relative size of the whale and development of saddle patch and dorsal fin in photographs from 1984. Males are readily identified at about 15 years of age as their dorsal fin grows taller and less falcate than females. At sexual maturity fin height will exceed width by at 1.4 times (Olesiuk et. *al.* 1990). The fin continues to grow until physical maturity (about 21 years of age).

Subgroupings of whales within resident pods were determined from repeated examination of photographic data as well as from field observations of travel patterns. Cole's Association Index dendrograms are being used to clarify the subgroups and relationships within them.

The effect of the oil spill on the probability of resighting AT group whales was examined using log-linear models (PROC CATMOD of SAS; SAS 1988). For each year, each individual AT whale was classified as either having been seen or not seen in that year. Data from 1987 were excluded from the analysis because of low effort in that year. Two effects were included in the analysis: year, and whether the year was in the category 1984-1989 or 1990-1995. We tested three log-linear models in our analyses. Two of these models treated year as a continuous variable; i.e. these models assumed that there was continuous and systematic variation in the probability of sighting whales through time. Year was treated as a continuous variable in order to test whether the probability of re-sighting whales was decreasing through time, irrespective of the oil spill. The third model treated year as a categorical variable, assuming that probability of sighting whales could vary among years, but that the variation did not have to be systematic.

(1) Probability = Intercept + Pre 1990 or post 1989 + Year (year continuous)
(2) Probability = Intercept + Pre 1990 or post 1989 x Year " "
(3) Probability = Intercept + Pre 1990 or post 1989 + Year (year categorical)

Where: Probability = probability of sighting a given AT whale
Intercept = a constant with variation caused by:
(a) year falling pre or post 1989, (b) the specific year,
(c)the interaction of the year and being pre 1990 or post 1989

The most appropriate model was decided upon on the basis of the overall goodness-of-fit of the model, and the match between observed and predicted values.

Graphical display and query tools were developed for the GIS database. These allow users that may be unfamiliar with Arc/Info to output summary statistics about the data and to create simple maps showing the locations of selected data records. Simple routines were developed to categorize and tabulate behavioral data after entry into the GIS system. Data was summarized by behavioral category, number of occurrences and duration. Data from most pre-spill years has not been entered and tabulation is not complete, however killer whale predation data was tabulated and presented graphically.

For genetic analysis approximately 30 mg of skin from each biopsy sample was minced finely with a scalpel, and ground for one minute on ice in a glass tissue grinder. It was then combined with 400 ul of proteinase K buffer (Sambrook et al. 1989) and 0.3 mg of proteinase K enzyme, and incubated for 48 hr at 65 degrees C. This solution was combined with a similar volume of 25:24:1 phenol:chloroform: isoamyl alcohol, mixed gently by inversion for 5 minutes, and centrifuged at 10,000 g for 2 min. The DNA-containing aqueous phase was then removed with awide bore pipette. The phenol: chloroform: isoamyl alcohol extraction was repeated twice, and followed by a single extraction with 24:1 chloroform: isoamyl alcohol. The aqueous phase was then combined with 2 volumes of 95% ethanol, and incubated at -20 degrees C for 1 h. This solution was centrifuged at 13,000 g for 15 minutes. The precipitate was washed twice with 70% ethanol, and dried overnight at room temperature. The DNA precipitate was then dissolved in 100 ul of TE buffer to make a stock solution (Sambrook et al 1989). The concentration and purity of DNA was determined by UV photospectrometry (Sambrook et al 1989). The mean yield of DNA from 30 mg of skin was 98 ug (range 41 to 257 ug). Aliquots of DNA stock solution were added to sterile distilled water to make up standard solutions of 50 ng/ul DNA for use in polymerase chain reaction (PCR).

Two segments of mitochondrial DNA (mtDNA) from each sample were amplified using the PCR. The first was approximately 2,350 base pairs long and contained the D-loop and cytochrome b regions, The other was approximately 2,450 base pairs and contained NADH dehydrogenase, subunits 5 and 6 (ND5/6). The first segment includes the most variable part of the mitochondrial genome, the latter is more conserved. Primers for the PCR reactions were custom-designed based on published sequences in similar species (eg Arnason et al. 1991). For the cytochrome b/ D-loop amplification the following primer sequences were used (5'-3'): GACATGAAAAATCATCGTTGT and CTAATAGAAAGGCTGGGACC; for ND5/6 the primer sequences were ACAACGATGATTTTTCATGTC and GTAGTTATCCATTGGTCTTAGG. After experimental optimization, the following protocol was used: (1) 50 ul reactionmixes were prepared containing 75 ng of template DNA, 10 mM Tris-HCl (pH8.3), 50 mM KCl, 0.3 mM each dNTP, 1 uM each primer, 1.5 mM MgCl, and 1 unit of Taq DNA polymerase; (2) each reaction mix was cycled once for 3:00 min at 94 deg C, 1:00 min at 60 deg, and 3:00 at 72 deg.; 30 times for 45 s at 94 deg, 1:00 min at 60 deg, and 3:00 min at 72 deg; and once for 45 sec at 94 deg, 1:00 min at 60 deg, and 12:00 min at 72 deg.

Results

The *Lucky Star* completed 39 survey days (three weather days) and five partial non-survey days supplying field operations for the *Whale 2* . The *Whale2* completed 64 survey days with four weather days . The *Whale 1* completed 20 survey days and *Auklet* completed two survey days A total of 125 survey days (LOG entries) were entered in the GIS database for 1995 (Table 1).

Killer whales were encountered on 63 occasions in 1995 (ENCOUNTER entries, Appendix 6), with 43 encounters with resident pods, 13 encounters with the AT transient group and seven encounters with other transients. Researchers traveled approximately 1514 km with whales during these encounters. A total of 162 identifiable killer whales were photographed in 1995. Of these, 132 were resident whales that were attributed to pods. Nine resident whales were photographed that could not be placed in designated pods. Additionally, 21 different transient whales were identified in 1995.

The transient AT group was most frequently photographed in the April-June and September-October periods while resident whales were most frequently encountered in July and particularly August. Consistent sightings of resident pods in southwestern Prince William Sound did not occur in September 1995 as has been the case in many other years. Resident whales were not observed in October. The most killer whale encounters (22), occurred in August and were primarily with resident pods. All encounters of three or more resident pods ("superpods") occurred in late July or August.

Resident Pods

The total number of whales in well-documented resident pods other than AB pod has increased from 78 to 83 whales from 1992 through 1995, while AB pod has declined from 26 whales to 22 whales in that same time period (Figure 2)

Since the last accounting accounting of AB pod killer whales in 1993 (Dahlheim, 1994), five mortalities were recorded in this pod. All of these deaths occurred during the winter of 1993/94 and were confirmed in 1995. Two calves were recruited to AB pod; one (AB48) in 1992/93 and one (AB49) in 1993/94. AB 48, was one of the mortalities in 1993/94. Births and deaths from 1984 to1995 in the six well-documented resident pods are listed in Table 2. Annual mortality and recruitment rates were calculated by pod and listed in Table 3.

A summary of pooled mortality rates for AB pod and other pods before and after the spill is given in Table 4. Mortality rates for AB pod were much higher (6.1 %) for the period before spill than for other pods (1.9%) and nearly doubled (11.7%) again for the period following spill while the rate for other pods dipped slightly (1.4%). The years 84/85 and 85/86 made the major contribution to AB pod pre-spill mortality and the years 88/89, 89/90 and 93/94 were the major contributors to post spill mortality.

The pooled recruitment rate for AB pod was higher before and lower after the spill than for other pods and AB pod recruitment dropped to zero for two years following the spill. However, the overall recruitment rates from 1984 to 1995 (4.5% for AB pod and 4.6% for other pods) were comparable. Graphic representation of annual mortality and recruitment rates by year for AB pod and the six other well-documented resident pods (AI,AK,AE,AJ,AN10) is presented in Figure 3 and Figure 4. Killer whales appear to have a very high rate of mortality, near 50%, in the first months after birth (Olesiuk et *al.* 1990) and births generally occur in the winter months. These he recruitment rates represent survival to approximately 0.5 years, birth rates could not be determined.

The five mortalities that occurred within AB pod between 1992 to 1994 included an adult male (AB2), a reproductive female (AB16) and three juveniles (AB38, AB 41, AB48, Table 5). Mortalities in other resident pods included two apparent old, non-reproductive females (AJ 5, AN5), an older male (AJ 11) and one juvenile (AE 13).

Initial examination of pod structure indicated seven subgroups in AB pod containing 22 whales (Figure 5) and six subgroups in another major resident pod,AJ pod, that contained 35 whales in 1995 (Figure 6). One AB pod subgroup (seven whales in 1988) has only a single surviving member, AB3. Seven of the mortalities within this subgroup occurred at the time of the spill or thereafter. Another AB pod subgroup (five whales in 1988) now has only 3 surviving members (AB22, AB45, AB49) despite recent recruitment of two calves (AB45, AB49). Another AB pod subgroup (10 whales in 1988) is now reduced to six whales and was only photographed traveling with AJ pod in 1994 and 1995. It was last photographed with AB pod in 1993. There were no mortalities within three of the AB pod subgroups at the time of spill.

AJ pod (Figure 6) has demonstrated vital rates more representative of the other frequently encountered resident pods, It has had an an above average recruitment rate since

1984 (Table 3). Unlike AB pod, mortalities in AJ pod were apparently older whales and do not include reproductive females and juveniles (Table 5).

Transient Whales

A total of 10 of the original 22 AT group whales was photographed in 1995. This was the largest number of individuals identified in this group since 11 were photographed in 1992. AT whales identified in 1995 included two, AT13 and AT17, that had not been photographed since 1992 and three, AT2,AT4 and AT6, that had not been photographed since 1993. There were no new calves identified in 1995 and there has been no recruitment observed in this group since 1984.

The sighting rate of AT whales declined after 1989 (Figure 8). This coincides with the absence of at least 9 members of the group since that year. On average for all years Encounters with members of the AT group have occurred on average (1984-95) only once in ten field days. In some years (1991 and 1994) this figure fell to less than one encounter in 20 days. For all years each encounter was typically with only a few members of the group. Despite an above average rate of encounter in 1993, only seven different individuals where photographed.

The number of different AT individuals sighted each year decreased sharply after 1989. Since 1989 the number of individuals identified has been 12 or less despite a field effort that exceeded 200 vessel days in 1990 and 1991 (Figure 9).

Both before and after 1989 there was an initial high rate of discovery of non-photographed AT individuals in the first 60 days of each field season followed by a sharp reduction of new whale discoveries despite repeated encounters with AT whales (Figure9; years with less than 60 days of field effort were not charted). AT whales were most frequently encountered in the early season (April-June) In some years such as 1995 new whale discoveries were made near the end of the field season. Three AT whales that were photographed in 1995 were seen only in April and/or October.

The sighting data for the AT group used in logistic regression (Figure 7). Logistic regression analysis using model (1) with year and occurrence before and including 1989 or after 1989 as explanatory variables, and with year treated as a continuous variable, indicated significant decline in the probability of sighting individual AT whales from 1984 to 1995. The year variable made a significant contribution while the variable of year occurring before or after the spill did not (Table 6).

Model (2) assumed that the explanatory variables of year and occurrence of the year before and including or after 1989 were interrelated. Levels of significance were highest for this model (Table 7) indicating the interaction of year and occurrence of the year before and including or after 1989 was a better predictor of the observed pattern of sighting AT whales than was year alone. For model (2) the probabilities of not seeing a given whale were predicted for each year and compared with the actual probabilities (Table 8). When year was treated as a categorical variable, model (3), there was a significant effect of both year and occurrence before and including or after 1989 on the overall significance of the decline (Table 9). The results of logistic regression analysis indicated the probability of sighting specific individual AT whales decreased significantly since 1984 and that the decreased probability of sighting AT individuals accelerated after 1989.

Another 25+ transient whales were encountered in small groups on a very irregular basis from 1984-1995. These whales were not seen in association with the AT group nor with resident pods. Sighting trends for these whales were not examined and no attempt was made to assess changes within these groups.

Description of GIS database

NGOS data for 1984-1994 were transferred from NGOS to the Science Center in Spring 1995. Data for 1995 arrived at the Science Center following completion of the season's field work. NMFS data for 1993 were requested via letter dated 22 November 1995 from the Prince William Sound Science Center (D. Scheel) to National Marine Mammal Laboratory (H. Braham and M. Dahlheim). Response via phone (29 November 1995) and letter (5 December 1995) was received from M. Dahlheim. She sent a copy of a 1993 report detailing some analysis of these data (Dahlheim et. *al.* 1993). Data from NMML for GIS input has not yet been obtained and if available it may not contain systematic behavioral data.

The GIS database is physically housed at the Prince William Sound Science Center. Security is maintained through restricted access permissions and user passwords. Spatial and tabular data are stored in Arc/Info (version 6.1.1) on a Sun network running OpenWindows.

An exact total count of the killer whale encounters awaits completion of the database, but we estimate there are about 560 encounters encompassing 1700-3500 hours of whale observation during 9000-18000 hours of field effort from 1984 through 1994 (11 years). For example, in 1984, 180 field-boat days resulted in 1700 hours and 7600 miles of search effort including 64 sightings and 320 hours of whale observation. Data from the current season (1995) was entered into the database and summarized in this report.

For each year, the database consists of two GIS data layers. One layer contains the Log data; one contains the Encounter data. Eight different relate tables store the information associated with each day's observations (Figure 10). For both Log and Encounter layers, meta- and primary- level data were associated with a vector object portraying the trackline and direction. These data reside in the arc attribute table (AAT). Whenever there was a one-to-many relationship between a trackline and a data type (e.g. weather may have been recorded several different times during the day from a single vessel), that data type was stored in a related table linked to the AAT via a record ID number. Each Log was assigned a Log-ID that was written on the data sheet and entered into the data base. Log IDs were of the form yr-xxx (e.g. the first Log for 1994 was numbered 94-001). Each Encounter received a letter designation following the Log-ID (e.g. subsequent encounters on the first day receive the IDs 94-001a, 94-001b).

Weather and marine mammal sightings data were related to the appropriate log record and vessel path via the Log ID. Encounter records and whale paths were related to their Log records in the same manner. For data with a many-to-one relationship to the whale track lines, four tables were created linked to the Encounter AAT via the Encounter ID number. For a complete listing of the data types contained in each database table, see Figure 10.

Data are available for the years 1984 to 1995 inclusive. Under this project in FY95, all records for the years 1984-85, 1989, and 1992-1995 were entered into the database (Table 10). Entry of data from the remaining years is scheduled for February-March 1996.

Search effort was greatest in 1989. Effort was also high in 1995, 1992, and 1984. Search success (encounters per mile searched) was highest in 1985 and lowest in 1994 and 1989. Search effort was focused in the south west portion of Prince William Sound (Knight Island Passage and Montague Straight) in all years, although some years include effort in other areas as well.

Creating a database for the behavior-related aspects of the killer whale research focused attention on the design of the data sheets being used to collect the data. As a result, several changes were proposed to the data sheets (Appendix 5 & 6). These changes were implemented in the field in 1995. These changes serve to make data collection more precise and unambiguous and to assist in tracking samples from one database to the next (e.g. noting in this database the identifying information for any biopsy samples collected).

Killer Whale Predation

A total of 27 kills and 34 incidents of harassment of marine mammals by killer whales were observed from 1988 through 1995 (Table 11). All observations were made

Discussion

Elevated mortality rates for AB pod occurred in 1984/85 and 1985/86 and were attributed to fishery interactions (Matkin et *al.* 1986, Matkin et *al.* 1987). The very high mortality rate in 1988/89 and 1989/90 followed the *Exxon Valdez* oil spill (Matkin et *al.* 1994, Dahlheim and Matkin 1994). The mortality rate for AB pod rose sharply again in 1993/94. The majority these mortalities in were juveniles and reproductive females while recent mortalities in other pods appeared to be primarily older whales (Table 5). This pattern is consistent with the composition of mortalities in AB pod and other pods in the years 1989-1990 (Matkin et *al.* 1994). Very low mortality rates were reported for reproductive females and juveniles for resident pods in British Columbia and Washington (Olesiuk et *al.* 1990). These rates are similar to the resident pods other than AB pod in Prince William Sound (Matkin et al 1994).

Peaks in recruitment rate coincide between AB pod and other pods for some years (Figure 3, note: 1987/88, 1991/92 and the recent decline). To some extent these recruitment rates may reflect annual conditions that influenced early survival. The longterm recruitment rates for AB pod and for other pods are similar, the decline in AB pod since 1988 is not attributed to lack of recruitment but to very high mortality rates.

In British Columbian killer whale studies close relatives demonstrated the highest index of association (Bigg et *al.* 1990). Whales in the subgroups we have identified appear to be close relatives, primarily mothers and their offspring but may include some extended family, possibly sisters and their offspring and grandmothers. The identity of the fathers of the calves is unknown, but fathers are not thought to travel with their offspring.

The recent mortalities within AB pod can be visualized in the context of their subgroups (Figure 5). The juveniles AB38 and AB41 were both orphaned following the spill and lost many other apparent close relatives. The reproductive female AB16 had lost most of her subgroup. The death of reproductive females is extremely unusual (Matkin et. *al.* 1994). The male AB2 suffered a collapsed dorsal fin and appeared in poor condition following the spill. The calf AB48 possibly was less than one year at death and may have been a natural juvenile mortality.

It appears that resident pod social structure and the association of close relatives is extremely important in maintaining pod structure and viability. Bigg et *al.* (1990) found that within pods of resident killer whales the relative strength of bonds among individuals appear to be correlated with degree of relatedness. Deaths of key individuals in subgroups may reduce the viability of remaining relatives as appears to be the case for orphaned juveniles in AB pod. The calf AB45 orphaned by the death of AB16 has lost not only its mother but most of its close relatives. AB3, whose fin declined following spill, is the only surviving member of his once large subgroup. In 1995 he was often traveling behind the rest of the pod.

Some AB subgroups have not shown abnormal losses since the spill. These subgroups may not have had extensive contact with oil. Subgroups of pods do not always travel in tight formation. For example, the AB10 subgroup (a mother and her three adult sons) frequently travels some distance from the rest of AB pod.

There is no precedent for a resident pod subgroup joining another pod on an extended basis (Matkin et *al.* 1984, Bigg et *al.* 1990). When many closely related individuals within a pod die, the bonds that hold the pod together may weaken. It is conceivable that this would result in splitting of the pod and may explain while one AB pod subgroup has traveled with AJ pod for two consecutive years.

Because the ages and sex is not known for all whales within AB pod or any of the other pods, an accurate modeling of population dynamics is not possible at this time. Although there are six remaining reproductive females in AB pod, some of these may be entering post-reproductive age. Because of the large number of juveniles lost since the spill, there may not be enough maturing females to replace them.

between April 1 and October 30. All incidents involved transient whales, no resident whales were observed taking marine mammals. For the majority of observations the predators were members of the AT group, although some incidents involved other transient whales.

The proportion of kills by prey species are represented in Figure 11. Dall's porpoise and harbor seal predation by killer whales made up 74% of the observations. Inclusion of harassment incidents to create a diagram of potential prey (Figure 12) reduced the Dall's and harbor porpoise components and introduced other potential prey. These included Steller sea lion, sea otter, river otter, humpback whales. There was one incidence of an AT whale harassing or possibly preying on salmon not included in the chart.

Recording predation events sometimes required identification of subtle evidence. Pursuit and capture of marine mammal prey sometimes occurred entirely below the surface. For some mammal kills, oil slicks and very small bits of blubber or flesh were the only physical evidence of the kill. Gulls often gathered at kill sites. Mammal kills were typically followed by milling behavior by the killer whales when, presumably, prey was shared.

During June through September resident killer whales appeared to feeding in the mixed schools of salmon that enter Prince William Sound. In June and early July field effort was sporadic and surface feeding on fish was not frequently observed. From late July through September fish kills often occurred near the surface and scales from prey could be retrieved. Pursuit and kill of a fish was usually accomplished by individual whales although cow-calf pairs or pairs of juveniles were observed in tandem pursuit. A fish kill was often preceded by a chase below and at the surface. Whales sometimes made tight, twisting turns near the surface prior to making the kill.

Five killer whales were found stranded in or near Prince William Sound in the three years following the spill (Table 12). None of these whales had fish parts in the stomachs. Three of the stranded whales contained marine mammal parts. All three of these contained harbor seal parts, two contained Steller sea lion parts, one contained Dall's porpoise parts, and one contained harbor porpoise parts.

A majority returning salmon enter through southwestern Sound. Most of the scale samples from fish kills were collected in the Montague Strait and Lower Knight Island Passage area. A total of 46 scale samples were retrieved and identified from 1991-1995 (Figure 13). Coho salmon scales were identified in 41 of the 46 scale samples obtained Other species of salmon, notably pink salmon, were far more abundant in the observed schools and in the catch of fishermen .

Biopsy sample collection and analysis

In 1994 and 1995 a total of 48 full size samples and seven micro-size biopsy samples were collected from free ranging whales for genetic analysis. Six full size samples were from AT group whales, five full size and one micro sample from other transients, and 37 full and six micro samples from resident killer whales. In most cases, the tips of darts that obtained samples were completely filled with tissue. These samples weighed approximately 0.5 gm and consisted of a core containing three primary cell layers: epidermis, dermis and hypodermis. Micro samples indicated improper retention of tissue by the dart. They were tiny bits of skin, sufficient for limited DNA analysis, but far less than a full sample.

PCR products were obtained from all full sized samples using custom primers. Two ul of each PCR product was run on a 1.5 % agarose gel and visualized by ethidium bromide staining under UV light. Both reactions consistently produced a single product estimated by comparison with standard concentrations of molecular weight marker DNA to contain 3 ug of DNA.

Transient type whales have been distinguished from resident whales by lack of association, differences in diet (this manuscript) and by preliminary genetic analysis. In the mid 1980s, the AT transient group consisted of 22 transient whales that seldom associated as a single group, but as small sub-groupings of varying composition (Leatherwood et *al.* 1984, Leatherwood et *al.* 1990, Matkin et *al.* 1994). Relationships within this group still are not clear, the social system is clearly different from that of residents. Travel associations are variable over time.

Although the reduction in rate of sighting of AT whales coincides with the absence of many individuals since 1989, it also appears that the remaining AT whales are spending less time in the Sound than in previous years. The larger number of AT individuals observed in 1995 than in the previous two seasons was probably due to increased field time in the spring (April) and fall (late September/ October). Three of the eleven AT whales photographed were only seen during these months. The fall winter and spring may be important periods for transient whales in the Sound and extending field seasons into those periods may increase the number of observations of transient individuals.

The logistic regression models and probabilities of resighting AT group whales developed in our analysis indicate significant changes occurred following 1989. These results should be viewed in conjunction with the sighting and effort data in Figure 9. The nine AT whales missing since 1989 may be dead or they may have emigrated to other areas. In either case the analysis suggests a change in the system that supports these whales, The change apparently began before the oil spill but was accelerated after spill. This pattern is similar to that described for the harbor seal population in Prince William Sound (K. Frost, pers. comm.). Harbor seals appear to be an important prey item for AT group killer whales.

Although harbor seals were indicated as an important prey item during the April to October period (30% of observed kills), the Dall's porpoise was a more frequently observed prey (44% of observed kills). Because incidents of harbor seal predation often leave scant evidence, we suspect harbor seals comprise a large component of the unidentified mammal kills (19% of observed kills). Harbor seal kills often occur underwater and leave only an oil slick and bits of blubber and hair as evidence.

We have no systematic observations of transient killer whale predation from late October through March. Numbers of Steller sea lions increase in the Sound in winter months and other trained observers have reported predation on sea lions by killer whales at that time (Karl Becker, Rich Corcoran, personal communication). Sea lion predation may increase during the winter months. Barrett-Lennard et *al.* (1995) estimated that Steller sea lions made up 25% of the diet of transient killer whales in Alaska

Examination of stomach contents from the five stomachs available supports the direct field observations which indicate specific killer whales eat either marine mammals or fishes, but not both (Table 13). Stomach contents also indicate the importance of harbor seals as prey of marine mammal eating killer whales. Although the stomach sample size is small it suggests a greater proportion of Steller sea lion in the diet than field observations indicate. Perhaps this is due to an increase in the proportion of Steller sea lions in the diet in winter when field observations are lacking. The strandings apparently occurred in winter or early spring although whales were not necropsied until spring or summer.

Opportunistic observations over the years by the authors have suggested larger numbers of harbor porpoise and fewer numbers of Dall's porpoise occur in the Sound in late winter and early spring than in the summer months. Little observation of killer whale predation has occurred in winter and early spring; increased killer whale predation on harbor porpoise and decreased predation on Dall' porpoise may take place at these times.

During the July through September period coho salmon (*Oncorhynchus kisutch*)comprised 89% of the observed of killer whale predation on salmon indicating the apparent selectivity of feeding resident killer whales. Unfortunately samples from the early summer season when silver salmon would be rare were not available. The winter feeding habits of fish eating killer whales are unknown. Some bias against collection of pink salmon (*Oncorhynchus gorbuscha*) scales may exist since the scales from these fish are much smaller and may be less easily observed in the water. However, it is striking that no pink salmon scales were recovered nor were the distinctly smaller pink salmon ever observed being attacked or in the mouths of killer whales in Prince William Sound. Pink salmon comprised about 16% of scale samples collected at sites of killer whale predation in British Columbia (J. Ford, pers. comm). In British Columbia killer whales appeared to selectively prey on chinook salmon (62% of scale samples).

Mitochondrial DNA is employed extensively as a molecular marker in population biology because (1) it evolves quickly relative to the nuclear genome,(2) it is inherited maternally and is ideal for tracing maternal genealogies, and (3) it is free from recombination, making it possible to discriminate between common ancestry and convergence (Harrison 1989). In British Columbia, the existence of fixed, albeit small mtDNA differences (Stevens et al 1989, Hoelzel 1991, Barrett-Lennard , unpubl. data) are very strong evidence that females do not move between the two populations of resident and transient killer whales. The current analysis will determine whether Prince William Sound resident and transient killer whales are also mutually closed stocks as far as female emigration is concerned, and will also provide evidence as to whether either population is genetically linked to southern populations. If the analysis reveals fixed differences in mtDNA genotypes diagnostic of each type of whale, as is the case in British Columbia, then this information will be useful in the future for classifying rarely-photographed groups of killer whales that frequent other parts of the Gulf of Alaska (Dalheim 1994).

Despite the fact that the mtDNA analysis is likely to shed important light on the structure and discreteness of the two populations, it cannot entirely eliminate the possibility of nuclear gene flow between them. Nuclear gene flow would occur if animal from the two populations mate on occasion, even if females do not emigrate and transfer mtDNA. Such a situation could arise if only males move between the two populations. The photo-identification databases for both Prince William Sound and British Columbia provide no evidence of male emigration, suggesting it is at the least uncommon. A second way it could happen is if matings occur between temporary associations of residents and transients that involve no permanent immigration. Again, the photo-identification databases provide no evidence of resident/transient associations. However, such matings in the absence of emigration may well occur between resident pods (Barrett-Lennard, unpubl. data), and it is not out of the question that they occur between residents and transients.

Restriction fragment length polymorphism analysis is currently being performed on the PCR products, using 6 base-pair recognition site restriction enzymes that were informative in discriminating mitochondrial differences between British Columbian killer whale populations (Stevens et al. 1989, Hoelzel 1991). In addition to the RFLP analysis, 360 base pair regions of the D-loop of selected individuals from each population will be sequenced using automated sequencing facilities at the University of British Columbia. This work is well underway at present, and we anticipate completing it within FY 1996.

Conclusions

AB pod is not recovering from the deaths of 14 individuals following the spill. There were five additional mortalities in 1994. These mortalities were primarily juveniles, but included one reproductive female. In addition, a subgroup of six AB pod whales was traveling with AJ pod in 1994 and 1995 and has not been sighted with AB pod since 1993. All other well-documented resident pods are stable or increasing. Recent changes within AB pod are thought to be linked to changes in social structure due to earlier deaths within the pod.

We suspect that 9 whales in the AT group died after 1989. There has been no recruitment within the group since 1984. The encounter rates with AT group whales and theprobability of sighting individual AT whales has declined, especially since the spill. The factors contributing to the decline of this group and its reduced role in the Prince William Sound ecosystem is unknown, but these changes accelerated after 1989 with the death or emigration of 9 individuals. Long-term changes could be related to changes in abundance or quality of prey.

The GIS system data base for killer whales has been designed and described. Over 60% of the available historical data was placed in the system. Simple mapping and tabulation routines were developed for initial data access. Field data sheets were redesigned to provide more detailed spatial resolution of behavioral events. Killer whale behaviors were more clearly defined.

The examination of seasonal components of the diet of resident and transient killer whales demonstrated a clear distinction between the two killer whale types. At least during the spring, summer and fall, residents consume fish while transients prey on marine mammals. Resident killer whales appear to be highly selective when preying on salmon, selecting for coho salmon during the July to September period. Dall's porpoise and harbor seal are important components of transient whale diet during April to October period. Steller sea lions and harbor porpoise may become more important in the winter months. Temporal and spatial aspects of killer whale foraging and predation will be investigated following completion of GIS data input.

Sufficient numbers of resident and transient killer whales have been sampled successfully to initiate mtDNA analysis. DNA has been successfully extracted and analysis is in progress. To examine the issue of population discreteness in more detail, we propose to conduct a parallel analysis to the present mtDNA analysis beginning in FY 1997, using nuclear microsatellite DNA instead of mitochondrial DNA. Microsatellites are simple tandem repeat loci that tend to be highly polymorphic and that are short enough to amplify readily using PCR. They are appropriate markers for investigating a wide variety of population properties, including mating systems, kinship patterns, inbreeding levels, effective population size, and population divisions (Queller et al. 1993). Unlike DNA fingerprints (which are based on larger minisatellite loci), microsatellite genotypes can be scored unambiguously, and samples need not be run simultaneously to be compared. As well as providing information regarding the discreteness of resident and transient populations that would compliment and extend the mtDNA analysis, microsatellite analysis of Prince William Sound killer whales would answer questions such as the following: (1) Is the spill impacted AB-pod closely related to other resident pods in Prince William Sound? (2) What is the effective size of the breeding populations of resident and transient killer whales in Prince William Sound, and (3) how inbred are they? (4) Is the commonly seen AT pod of transient whales that has lost many of its members since spill genetically isolated from other transients?

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Tables

Table 1. Summary of 1995 Vessel Operations

Vessel	Dates of operation
Lucky Star	April10-18; May30- June7; June22-28; July26; Sept 11-17; Oct 15-21 plus 5 partial days between July15 and Aug31 supplying fuel/supplies to the *Whale2* (not considered survey days)
Whale 2	July2- Sept 5; October 7; Nov 3
Whale 1	June21- July28; Aug 1-Aug 5
Auklet	July 30-31

Table 2

	Recruitment in Prince William Sound Resident Pods				{whale number(mothers number)}	
POD	AB	AI	AK	AE	AJ	AN10
YEAR						
84/85			8(6)	13(11)		
85/86	36(23),37(6)		9(2)			
86/87	38(31),39(25)					38(10)
87/88	40(14), 41(8)			15(10)	26(22),27(20)	40(35)
	42(32),43(17)				28(24)	
	44(22)					
88/89				16(2),17(5)	29(8)	41(8)
89/90			10(2)	18(11)	30(3)	
90/91	45(16)		11(6)			45(35)
91/92	46(25),47(32)				31(24),32(22)	46(10),47(11)
					33(13)	
92/93	48(26)		12(7)	19(11)	34(3),35(8)	
					36(4)	
93/94	49(22)		13(2)		37(18),38(20)	48(8)
94/95				20(2)		49(11)
	Mortalities in Prince William Sound Resident Pods				{by whale number}	
POD	AB	AI	AK	AE	AJ	AN10
84/85	9,15,34-			8-		
85/86	1,7,12-		5-	4-	23-	
86/87	28-					6-
87/88	6-			7-		
88/89	13,18,21,23			12-		2-
	30,31,37-					
89/90	8,19,20,36					
	42,44-					
90/91	29-					
91/92						
92/93					5-	5-
93/94	2,16,38,41			13-	11-	
	48-					
94/95			4*		6*	
	*to be confirmed in 1996					

Table 3

	Mortality rates in Prince William Sound Resident Pods						
	AB	AI	AK	AE	AJ	AN10	All other than AB
84/85	8.6	0	0	7.7	0	0	1.6
85/86	9.4	0	12.5	7.7	4	0	4.7
86/87	3.2	0	0	0	0	8.3	1.6
87/88	3.18	0	0	8.3	0	0	1.6
88/89	19.4	0	0	8.3	0	7.7	3
89/90	20.7	0	0	0	0	0	0
90/91	4.31	0	0	0	0	0	0
91/92	0	0	0	0	3.4	0	0
92/93	0	0	0	0	0	6.3	2.5
93/94	19.2	0	0	6.7	0	0	2.4
94/95	0	0	8.3	0	2.8	0	2.4
	Recruitment rates in Prince William Sound Resident Pods						
	AB	AI	AK	AE	AJ	AN10	All other than AB
84/85	0	0	14.3	7.7	0	0	3.2
85/86	6.3	0	12.5	0	0	0	1.6
86/87	6.4	0	0	0	0	8.3	1.6
87/88	15.6	0	0	8.3	12.5	8.3	8.1
88/89	0	0	0	15.4	3.7	7.7	4.5
89/90	0	0	12.5	7.7	3.4	0	4.4
90/91	4.3	0	11.1	0	0	7.7	2.8
91/92	8.7	0	0	0	10.3	14.3	6.8
92/93	4	0	10	7.1	9.4	0	6.8
93/94	3.8	0	9.1	0	5.9	6.7	4.9
94/95	0	0	0	7.1	0	6.3	2.4
# in pod84/95	[35/22]	[6/6]	[7/11]	[13/15]	[25/35]	[12/17]	[63/83]

Table 4. Pre and post spill and overall recruitment and mortality rates for AB pod and other resident killer whale pods.

Pre spill (**1984-88**)		Post spill(**1989-95**)		Overall(**1984-95**)	
		Recruitment Rates			
AB	Others*	AB	Others	AB	Others
6.9	2.8	2.7	4.6	4.5	4.6
		Mortality Rates			
AB	Others*	AB	Others	AB	Others
6.1	1.9	11.7	1.4	8.6	1.8

Table 5. Mortalities in Prince William Sound resident pods (1992-1994)

Pod	Whale	Died	Sex	Age class	Description
AB	2	93/94	M	Adult	Fin folded at time of spill
	16	93/94	F	Reproductive	Leaves juvenile (AB45, 4 yr)
	38	93/94	-	Juvenile(7yr)	Orphaned calf of AB31(died'89)
	41	93/94	-	Juvenile(6yr)	Orphaned calf of AB8 (died'90)
	48	93/94	-	Juvenile(<1yr)	Calf of AB26 (born 92/93)
AJ	5	92/93	F	Old	Non-reproductive
	11	93/94	M	Old	Photographed as adult in "77
AN	5	92/93	F	Old	Non-reproductive(mother AN1?)
AE	13	93/94	-	Juvenile(9yr)	

Table 6. Maximum-Likelihood Analysis-Of-Variance Model (1)

Source	DF	Chi-Square	Prob.
Intercept	1	9.68	0.0019
Pre or Post 1989	1	0.53	0.4673
Year	1	9.11	0.0025
Likelihood Ratio	8	10.96	0.2041

Table7. Maximum-Likelihood Analysis-Of-Variance Model (2)

Source	Df	Chi-Square	Prob
Intercept	1	25.08	0.0000
Year x Pre or Post 1989	1	36.59	0.0000
Likelihood Ratio	9	20.50	0.0151

Table 8. Predicted (Model 2) and actual probability of not seeing a given AT whale by year

Year	Predicted Probability	Actual Probability
1984	0.146	0.05
1985	0.147	0.09
1986	0.146	0.05
1988	0.143	0.36
1989	0.142	0.18
1990	0.542	0.38
1991	0.544	0.48
1992	0.547	0.48
1993	0.550	0.67
1994	0.552	0.76
1995	0.555	0.52

Table 9. Maximum-Likelihood Analysis-Of-Variance Model (3)

Source	Df	Chi-Square	Prob
Intercept	1	25.86	0.0000
Prepost	1	15.89	0.0001
Year	9*	18.14	0.0335
Likelihood Ratio	0	.	.

'*' Contain one or more redundant or restricted parameters

Table 10 - Data entered into the Killer Whale GIS database in FY95.

Year	Logs	Encounters	Miles Searched	Miles w/ whales	Dates	Enc./mi x1000
1995	125	65	11018	1549	4/10-11/3	5.9
1994	84	30	5791	815	7/5-9/10	5.2
1993	84	41	5554	688	5/24-9/14	7.4
1992	137	71	10619	1932	6/1-9/6	6.7
1991						
1990						
1989	206	89	16183	1799	3/31-9/15	5.5
1988						
1987						
1986						
1985	60	46	4403	1045	6/15-9/15	10.4
1984	128	69	11199	2147	4/10-9/26	6.2
Total	824	411	64767	9975		6.3

Table11. Summary of Kills and Harassments of Marine Mammals

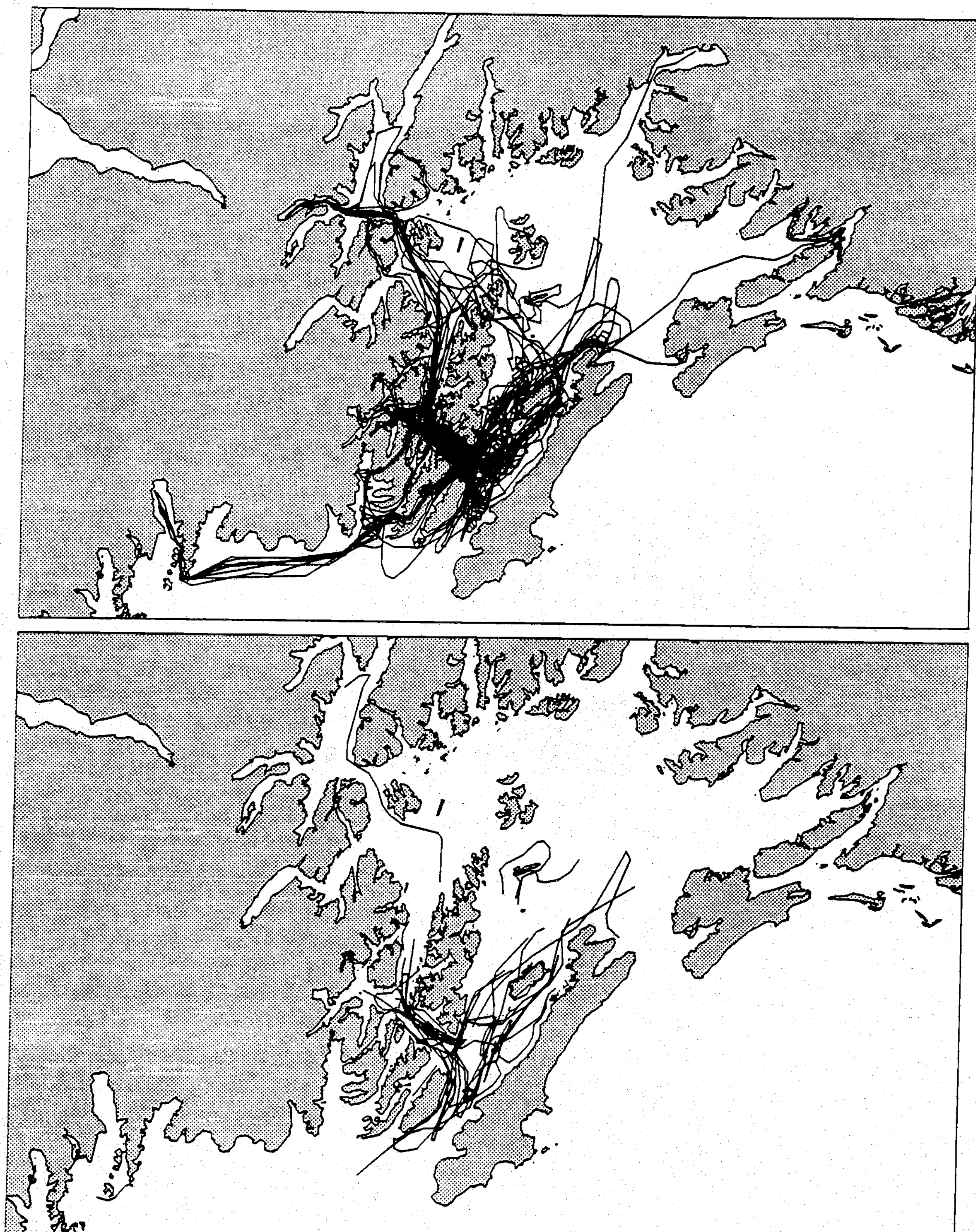
SPECIES	KILLS	HARASSMENT
Harbor seal	8	13
Dall's porpoise	12	3
Harbor porpoise	2	0
UnID mammal	5	5
Steller sea lion	0	6
Sea otter	0	2
River otter	0	1
Humpback whale	0	3

Table 12. Stomach contents from killer whales stranded in Prince William Sound and adjacent waters

1990	Culross Is., PWS	bones, whiskers and hair from adult and juvenile harbor seal, 18 teeth (13 confirmed harbor seal, 5 probable harbor seal), Dall's porpoise parts	L. Barrett-Lennard and K. Heise
1990 17 April	Beartrap Bay, PWS	empty	K. Wynne
1991 8 March	Cape St. Elias, AK*	sub-adult sea lion including skull, harbor seal, harbor porpoise	K. Wynne
1992	Montague Is. PWS	15 Steller sea lion tags, 480 sea lion whiskers, harbor seal claws, 20 harbor seal whiskers, bullet, halibut hook, 29 small and 27 large sea lion claws, 1 squid beak	E. Saulitis
1991	Montague Is. PWS	2 circle hooks with gangion and stainless steel snap, small pieces of plastic	L Barrett-Lennard and K. Heise

* approx. 130 km SE of PWS

Figure1. The study area with vessel and whale tracks, 1995



DLS, PWSSC 1996

All 1995 data is shown. Upper box: Vessel tracks; lower box: Whale tracks.

Figure 2. Total number of whales in AB pod and in other resident pods by year, 1984-1994.

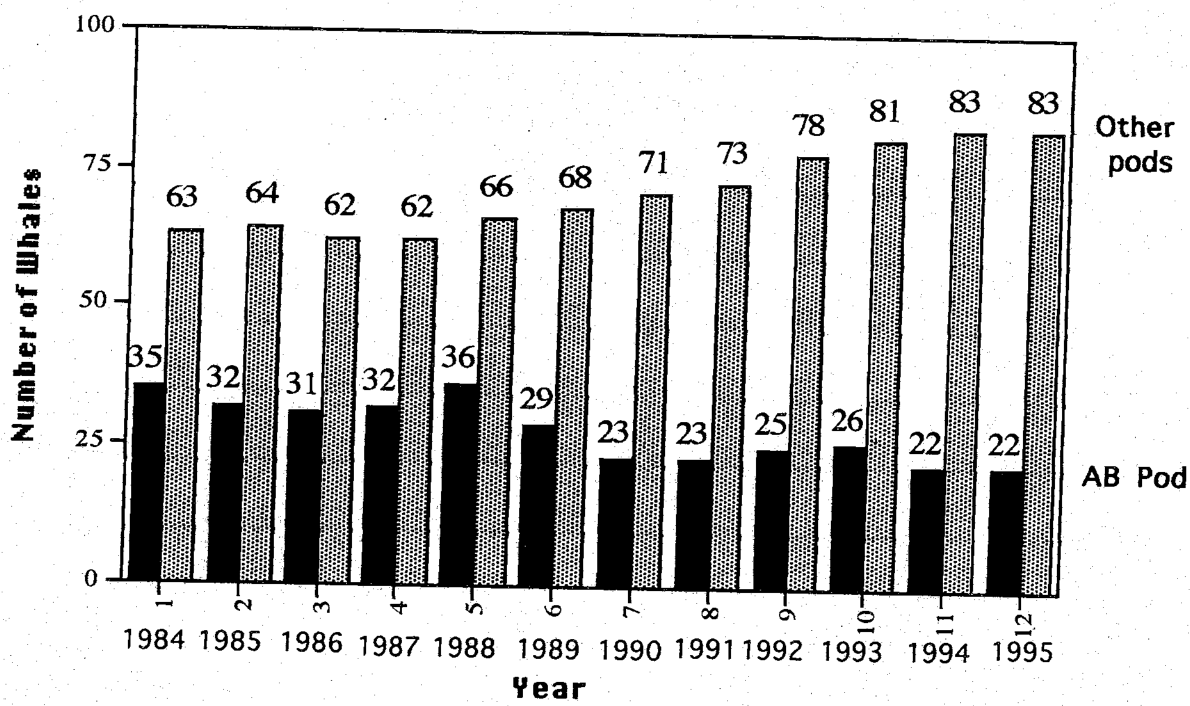


Figure 3

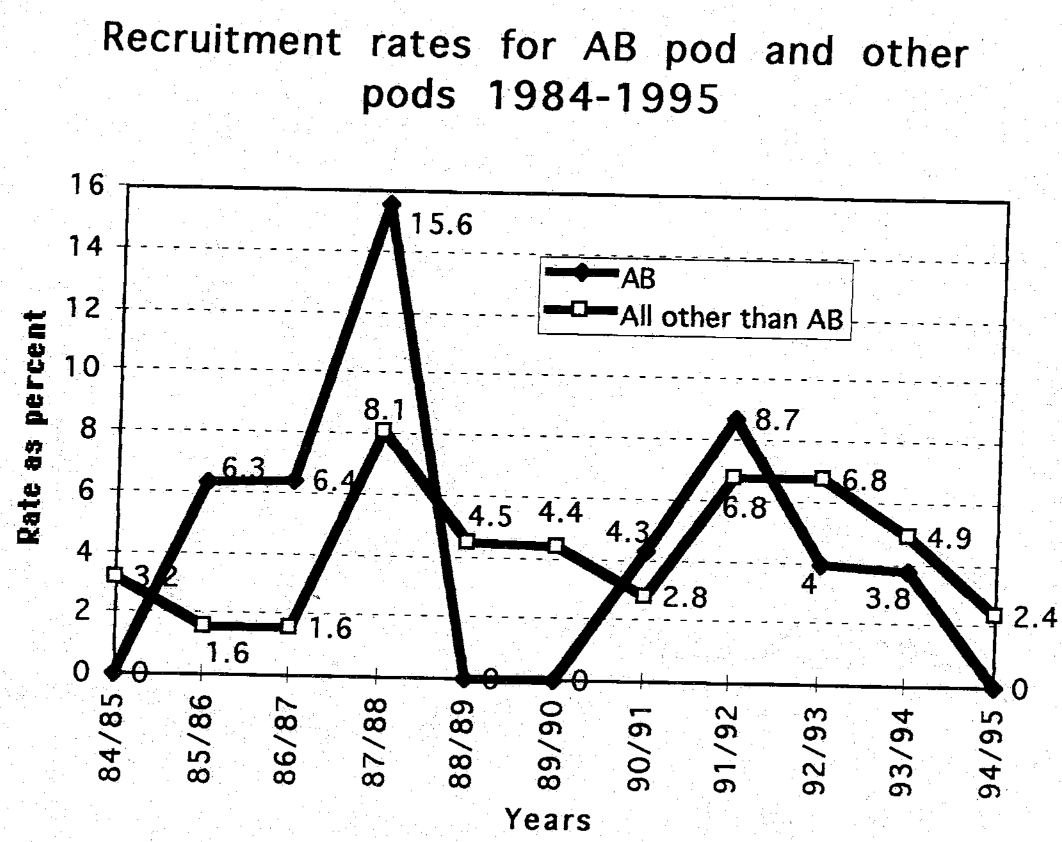

Recruitment rates for AB pod and other pods 1984-1995
Rate as percent
Years
AB
All other than AB
16
14
12
10
8
6
4
2
0
84/85
85/86
86/87
87/88
88/89
89/90
90/91
91/92
92/93
93/94
94/95
15.6
8.1
6.3
6.4
3.2
1.6
1.6
4.5
4.4
4.3
2.8
8.7
6.8
6.8
4
3.8
4.9
2.4
0
0
0
0

Figure 4

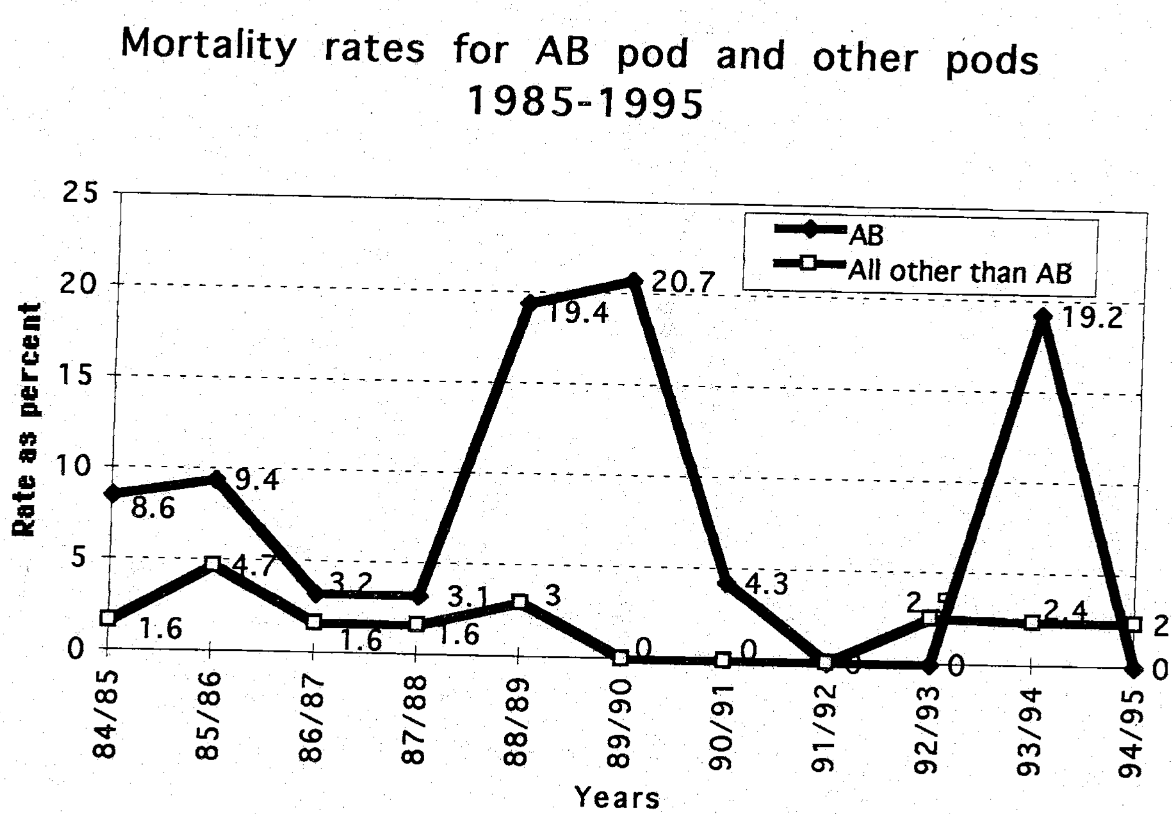
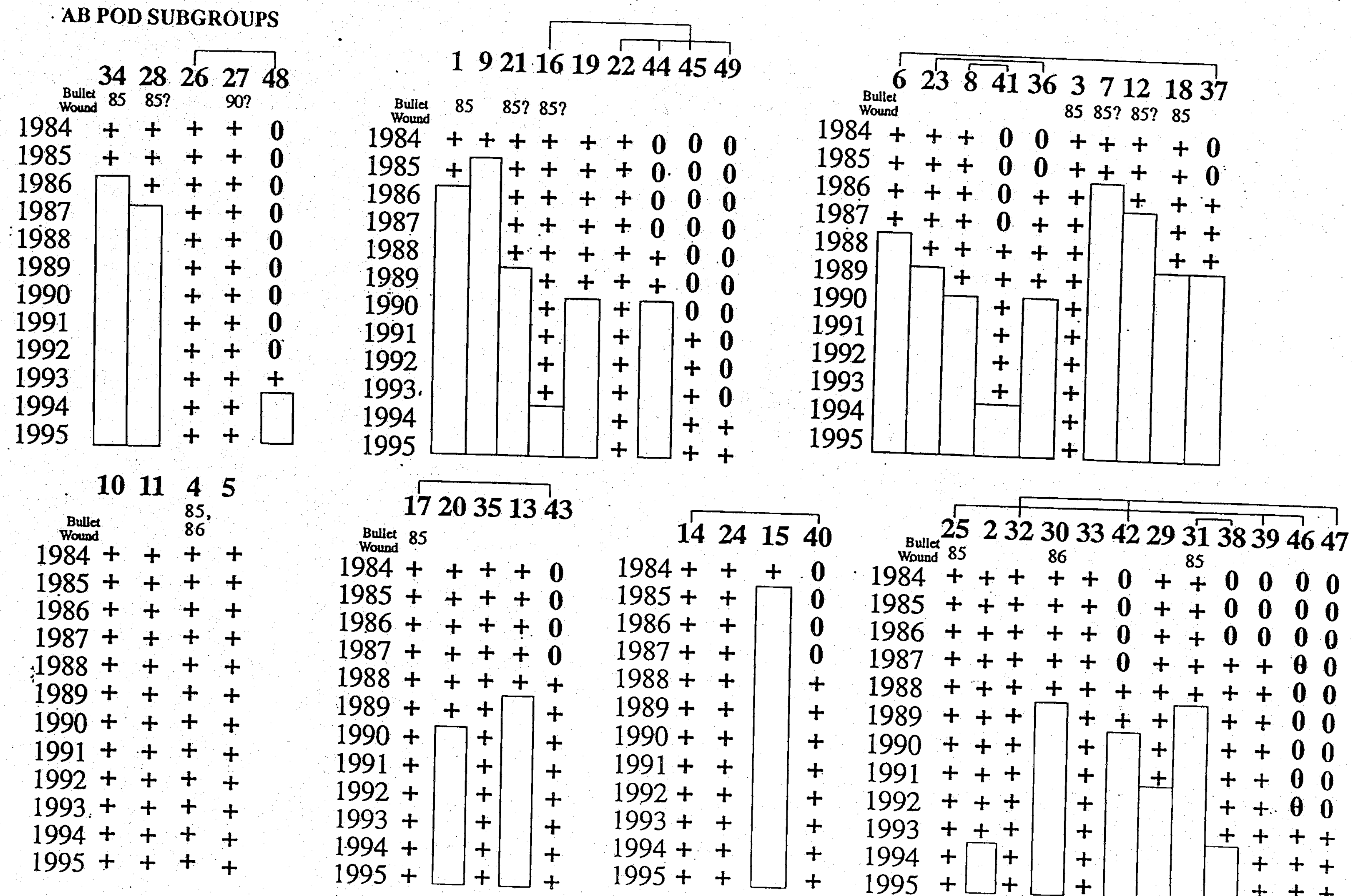

Mortality rates for AB pod and other pods
1985-1995
AB
All other than AB
Rate as percent
Years
25
20
15
10
5
0
84/85
85/86
86/87
87/88
88/89
89/90
90/91
91/92
92/93
93/94
94/95
8.6
9.4
3.2
3.1
19.4
20.7
4.3
0
0
19.2
0
1.6
4.7
1.6
1.6
3
0
0
2.5
2.4
2

Figure 5



+ = whale present 0 = whale not yet born empty rectangles= whale dead
cows and calves connected by lines (cows = lower number)

Figure 6.

AJ POD SUBGROUPS

	20	21	27	38
1984	+	+	0	0
1985			0	0
1986	+	+	0	0
1987			0	0
1988	+	+	+	0
1989	+	+	+	0
1990	+	+	+	0
1991	+	+	+	0
1992	+	+	+	0
1993	+	+	+	0
1994	+	+	+	+
1995	+	+	+	+

	18	17	9	19	37
1984	+	+	+	+	0
1985					0
1986	+	+	+	+	0
1987					0
1988	+	+		+	0
1989	+	+	+	+	0
1990	+	+	+	+	0
1991	+	+	+	+	0
1992		+			0
1993	+	+			0
1994	+	+	+	+	+
1995	+	+	+	+	+

	8	2	3	30	34	4	36	10	29	35
1984	+	+	+	0	0	+	0	+	0	0
1985				0	0		0		0	0
1986	+	+	+	0	0	+	0	+	0	0
1987	+	+	+	0	0		0	+	0	0
1988	+	+	+	0	0	+	0	+	0	0
1989	+	+	+	0	0	+	0	+	0	0
1990	+	+	+	+	0	+	0	+	+	0
1991	+	+	+	+	0	+	0	+	+	0
1992	+	+	+	+	0	+	0	+	+	0
1993	+	+	+	+	+		0	+	+	+
1994	+	+	+	+	+	+	+	+	+	+
1995	+	+	+	+	+	+	+	+	+	+

	11	14	16	12	13	15	33
1984	+	+	+	+	+	+	0
1985							0
1986	+	+	+	+	+	+	0
1987	+	+	+	+	+	+	0
1988	+	+	+	+	+	+	0
1989	+	+	+	+	+	+	0
1990	+	+	+	+	+	+	0
1991	+	+	+	+	+	+	0
1992	+	+	+	+	+	+	+
1993	+	+	+	+	+	+	+
1994	□	+	+	+	+	+	+
1995	□	+	+	+	+	+	+

	23	24	25	28	31	22	26	32
1984	+	+	+	0	0	+	0	0
1985				0	0		0	0
1986	□	+	+	0	0	+	0	0
1987	□			0	0		0	0
1988	□	+	+	+	0	+	+	0
1989	□	+	+	+	0	+	+	0
1990	□	+	+	+	0	+	+	0
1991	□	+	+	+	0	+	+	0
1992	□	+	+	+	+	+	+	+
1993	□	+	+	+	+	+	+	+
1994	□	+	+	+	+	+	+	+
1995	□	+	+	+	+	+	+	+

	5	1	6	7
1984	+	+	+	+
1985				
1986	+	+	+	
1987				+
1988	+	+	+	+
1989	+	+	+	+
1990	+	+	+	+
1991	+	+		+
1992	+	+		+
1993	□	+	+	+
1994	□	+	+	+
1995	□	+		+

+ = whale present 0 = whale not yet born empty rectangles= whale dead
cows and calves connected by lines (cows = lower number)

Figure 7.

AT 1 Group: Individual Sighting Histories

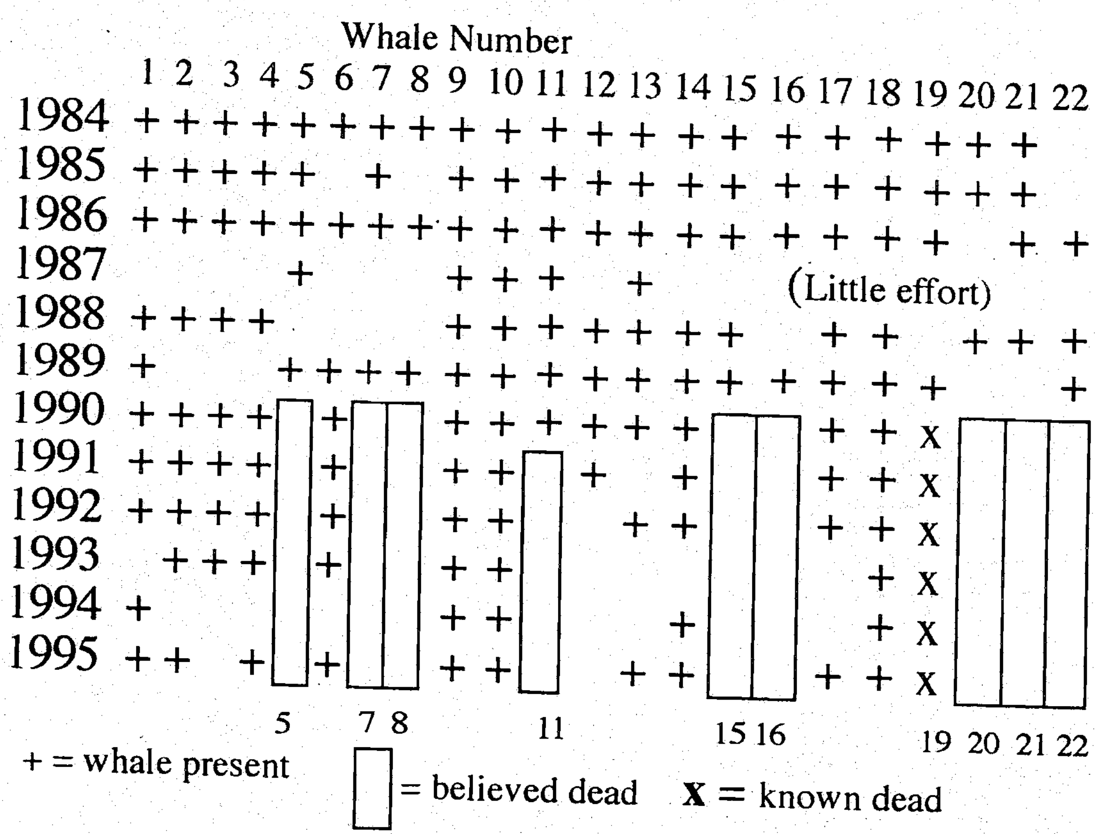


Figure 8.

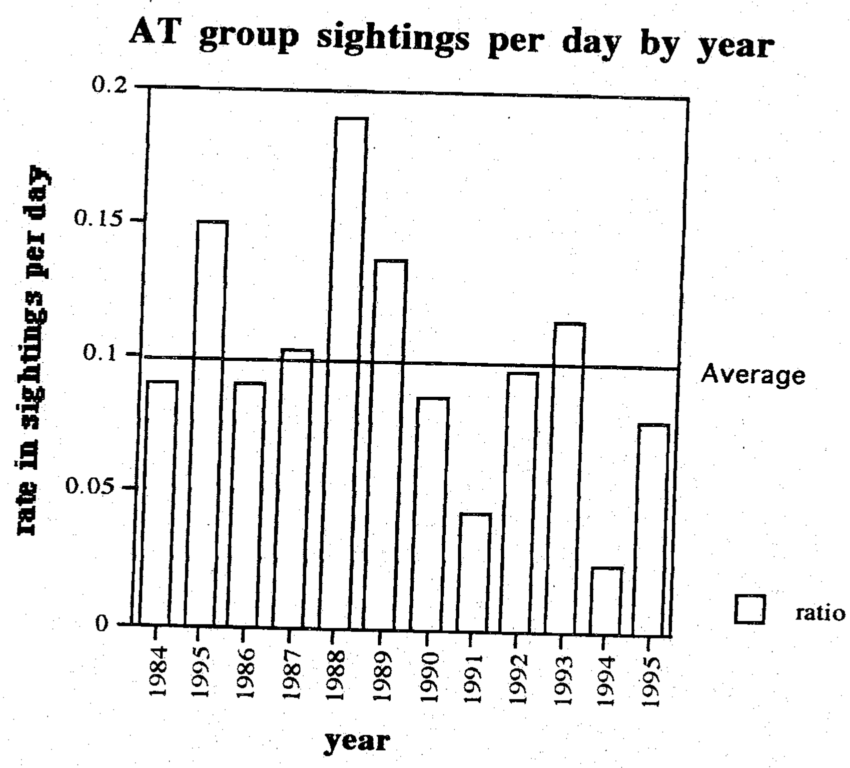
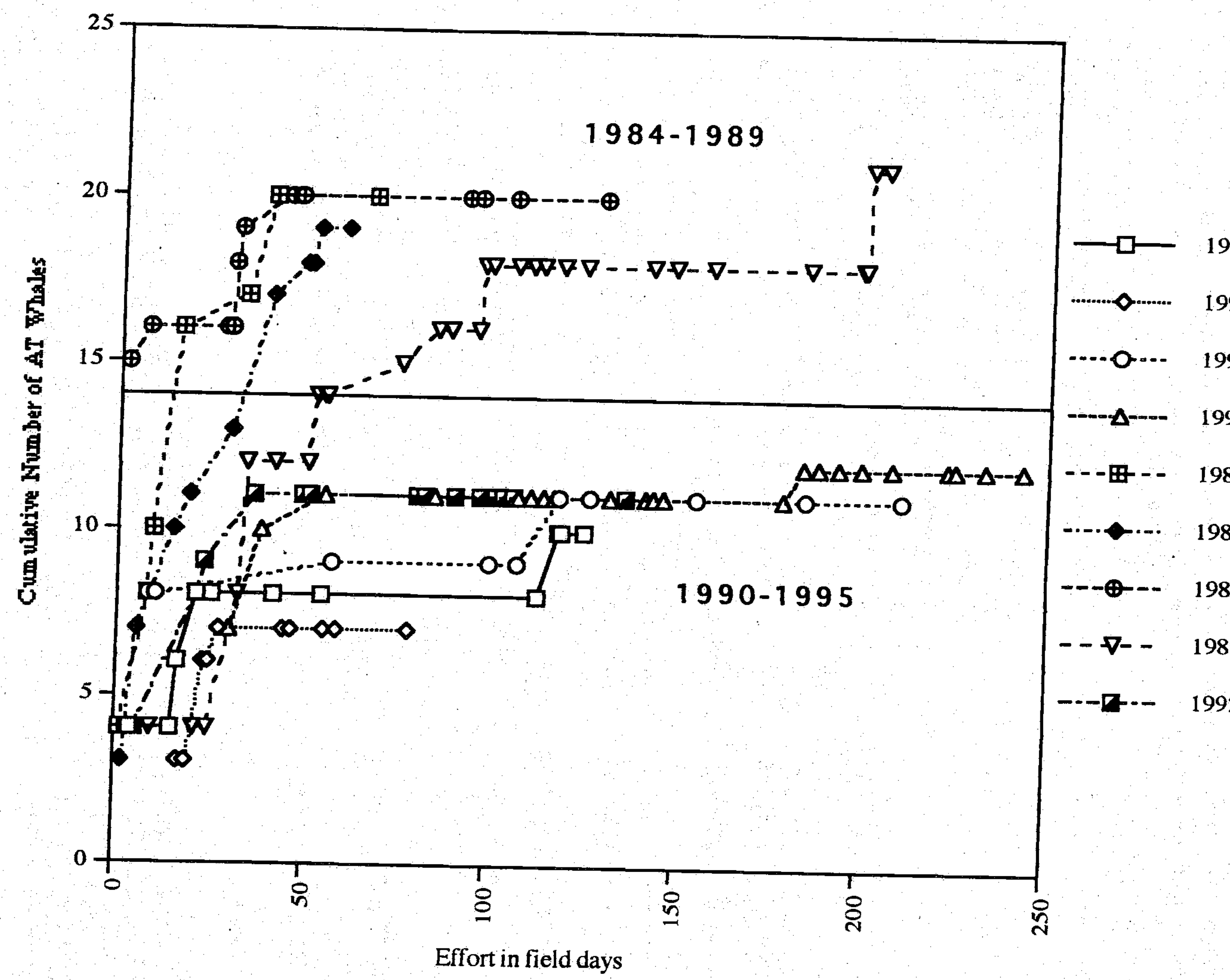

AT group sightings per day by year
0.2
0.15
0.1
0.05
0
rate in sightings per day
Average
ratio
1984
1995
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
year

Figure 9. The number of AT whales identified by year for selected years from 1984-1995



GIS layer 2: Encounters

Associated vector object:

(Whale path)

Encounter attributes

Enc-ID	EB-time	Log-ID	Pods	Tot-whl	Tot-pho
94-001a	12.83	94-001	AB	15	13
94-002a	8.1	94-002	AT1,AC	29	10
94-002b	13.0	94-002	AE	2	2

Film attributes

Film-rec	Enc-ID	Film-date	Film-roll	Film-ini
1	94-001a	8-Jul-94	1	PWS-ES
2	94-001b	8-Jul-94	2	PWS-SS
3	94-002a	9-Jul-94	1	PWS-NS

Tape attributes

Rec-rec	Enc-ID	Rec-tape	Rec-beg	Rec-end
1	94-002a	9-Jul-94	0	225
2	94-002b	9-Jul-94	225	end
3	94-002b	9-Jul-94	0	end

Biopsy attributes

Biop-rec	Enc-ID	Biop-pod	Biop-ID
1	94-002b	AE	12
2	94-002b	AE	09

Activity attributes

Obs-rec	Enc-ID	Act-time	Act-behv	Act-grp
1	94-001a	12.83	trav	AE10,14,15/AE5,17,6/9/
2	94-001a	14.5	rest	AE3,2,16
3	94-002a	8.1	breach	AB4,5,11,10,2,33,39

Sighting attributes

LS-rec	Enc-ID	Log-ID	Lwhl-spp	Lwhl-no	Lwhl-behv
1		94-001	HBWH	1	Breach
2		94-001	HBWH	1	
3	1	94-001			
4		94-002	DAPO	2	Trav

Associated vector object:

(Vessel path)

Log attributes

Log-ID	Date	Vessel	Personel	LS-time
94-001	8-Jul-94	Whale 2	ES, JL	4.5
94-002	9-Jul-94	Whale 2	ES,JL	3.0
94-003	9-Jul-94	Whale 3	CM,HO	5.5

Weather attributes

Wea-rec	Log-ID	Wea-time	Wea-sea	Wea-wind
1	94-001	9.5	B1V1	
2	94-001	15.0	B3V2	SW15
3	94-002	8.0		Calm

GIS layer 1: Vessel logs

Figure 10 Tabular data structure for vessel logs and whale encouter sheets showing linkage to geo-referenced vector objects (some attributes not shown; data is fictional)

/pictures/evosstuf/killerwh/ltkwdbas.pre

Figure 11.

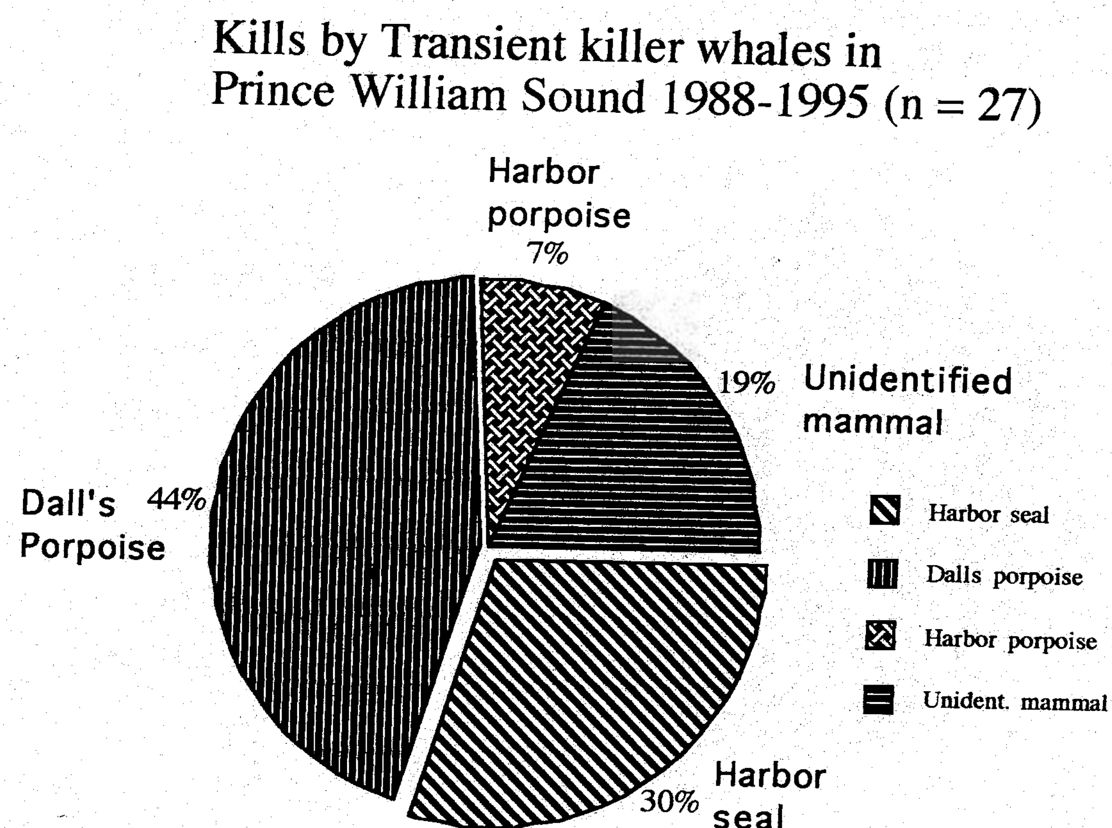
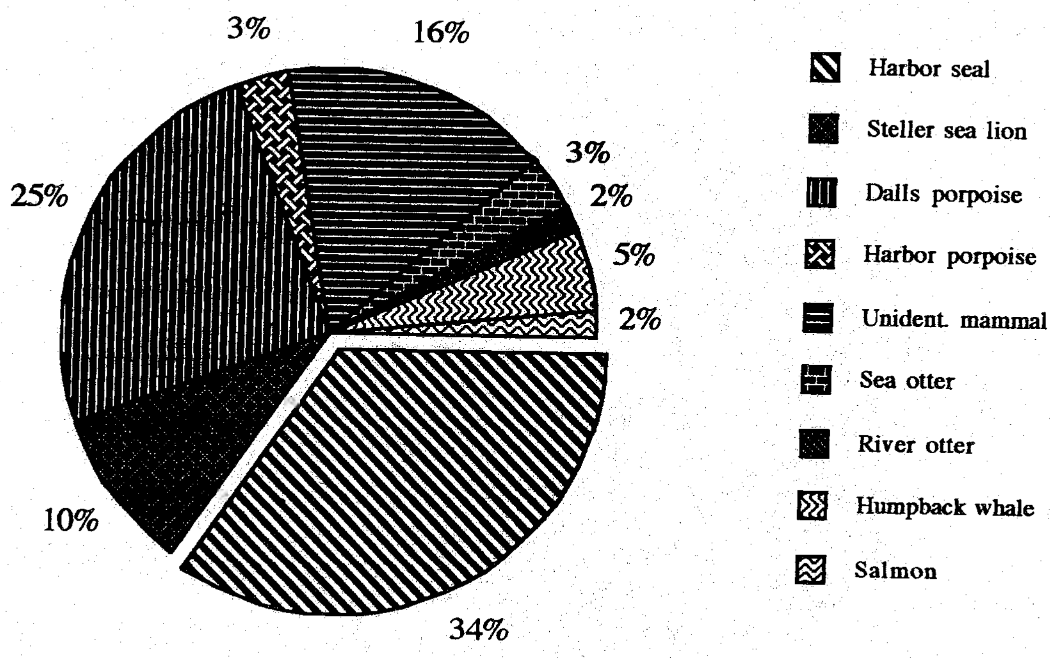

Kills by Transient killer whales in
Prince William Sound 1988-1995 (n = 27)
Harbor
porpoise
7%
19%
Unidentified
mammal
Dall's
Porpoise
44%
Harbor
seal
30%
Harbor seal
Dalls porpoise
Harbor porpoise
Unident. mammal

Figure 12.

Kills and Harassments by Transient killer whales in Prince William Sound, 1987-1995 (n=61)



Appendix 1. Daily log used by vessels

DAILY RESEARCH LOG

DATE__________ PLATFORM__________

BEGIN LOCATION__________ END LOCATION__________

BEGIN TIME__________ END TIME__________

SEARCH TIME__________ TIME WITH WHALES__________(Hrs)

TOTAL MILES SURVEYED (trackline) __________

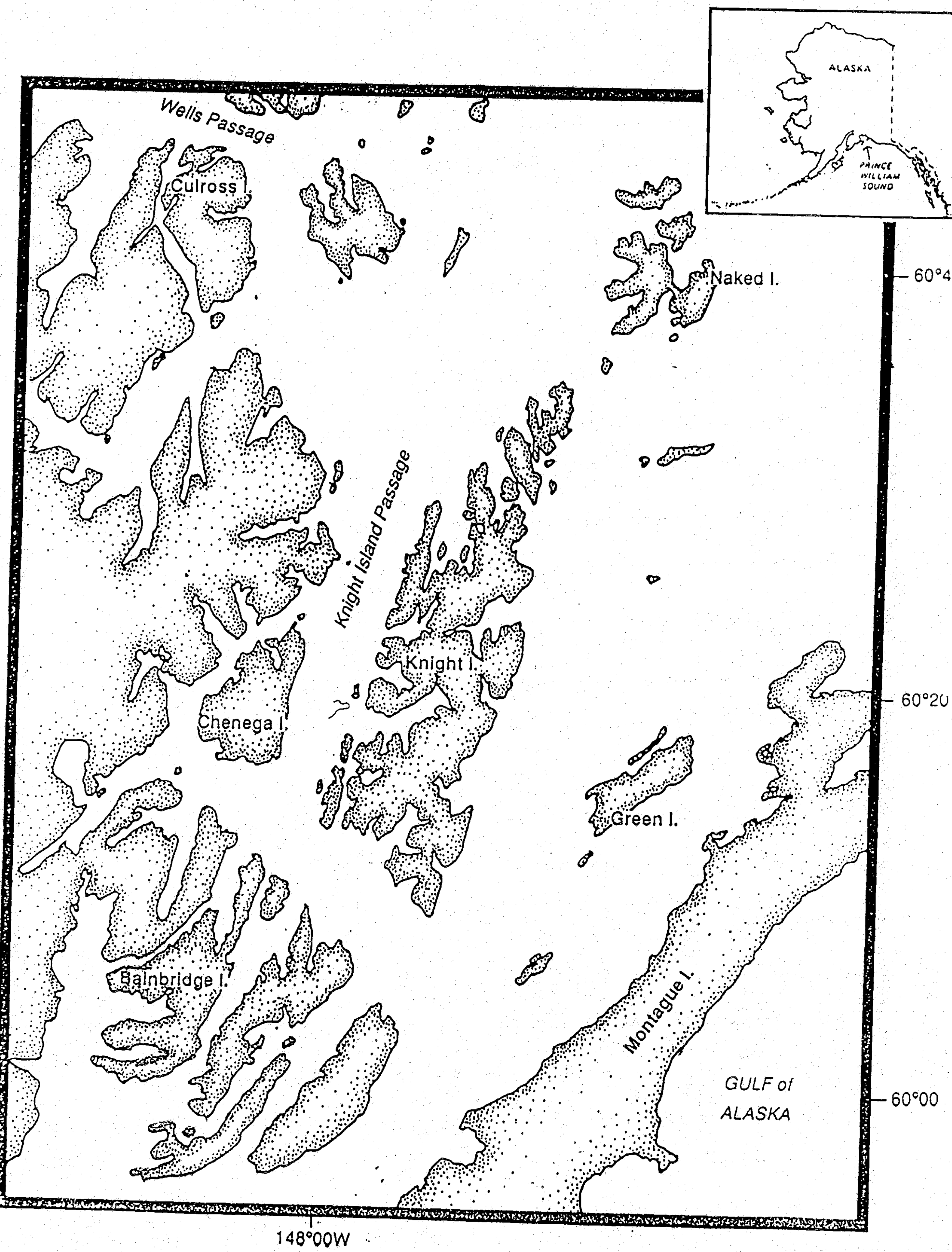
PERSONEL__________

WEATHER & SEA STATE /TIME __________

WHALE
SIGHTINGS/TIME__________

ACTIVITIES/COMMENTS __________

VESSEL TRACK ON REVERSE-------


ALASKA
PRINCE WILLIAM SOUND
Wells Passage
Culross I.
Naked I.
60°40N
Knight Island Passage
Knight I.
60°20
Chenega I.
Green I.
Bainbridge I.
Montague I.
GULF of ALASKA
60°00
148°00W

Appendix 2: Modified killer whale encounter data collection sheet

Date/Enc # NGOS Killer Whale

Survey

Platform

Observers Time (Beg/End)

Location (Beg/End)

Pods Naut. miles traveled w/whales

Total # whales ad ad /im juv/calf

Recognized individuals

#Whales photographed

Film (Date/Enc#/Roll#/Initials)

Recordings (Tape#/Side Beg/End)

Prey samples (Type/Sample #/Location/Whale I.D.)

Tissue samples (Sample #/Whales darted)

Oil present Yes/No (Type)

Harrassment of whales by researchers Yes/No (#harrassed)

Observations:

Time Behavior Location

Observations Time/Rec#

Killer Whale Killer Whale Survey Continued Page
of_____

Time Behavior Location

Observations Tape/Rec#

Behavioral categories for killer whales:

Travel (Tr)
Feed/Forage/Fish (Ffish)
Feed/Mammal (Fmam)
Mill
Social (Soc)
Rest
Forage/Offshore/Transient (Ofor)
Forage/Nearshore/Transient (Nfor)
Rub

Associated behaviors that may appear on kw data sheets or daily logs:

Breach (Br)
Tail slap (Tail)
Pec slap (Pec)

Appendix 3: Data Dictionary

Data dictionary, Long-term killer whale database (NGOS & PWSSC/OSRI)

Item	Source	Level	Stored Width	Display Width	Type	Dec.	Description	Units
	NB: File name LOG94.AAT. One log per vessel per day, each log has a vessel path attatched to it.							
Log-ID	Log	meta	6	6	Char	-	Year-page number of log (numbered consecutively)	
Date	Log	primary	8	8	Date	-	Day, month, year of vessel log (repeated on Encounter)	Date
Platform	Log	meta	12	12	Char	-	Name of vessel (repeated on Encounter)	-
Personnel	Log	meta	16	16	Char	-	Initials of personnel on vessel	-
LB-Loc	Log	primary	50	15	Char	-	Place name where vessel began the day	-
LE-Loc	Log	primary	50	15	Char	-	Place name where vessel ended the day	-
LB-time	Log	primary	6	6	Num	2	Begining time of log	dec hours
LE-time	Log	primary	6	6	Num	2	End time of log	dec hours
LS-time	Log	primary	6	6	Num	2	Duration spent searching	dec hours
LW-time	Log	derived	6	6	Num	2	Duration spent with whales	dec hours
LS-length	Log	derived	5	5	Num	1	Length of trackline surveyed, as recorded on the Log	dec miles
Log-comm	Log	primary	200	15	Char	-	Running commentary on events	-
	NB: File name LOG94.WEATH. Up to three weather records may be recorded per log							
Log-ID	Log	meta	6	6	Char	-	Year-page number of log (e.g. 94-001, 94-002...)	
Wea-time	Log	primary	6	6	Num	2	Time of weather/sea state observation	dec hours
Wea-cov	Log	primary	4	4	Int	0	Cloud cover as percent	-
Wea-wind	Log	primary	7	7	Char	-	Wind as: SW15, NE40 etc (direction and velocity in knots)	-
Wea-vis	Log	primary	3	3	Int	-	2 char code for visibility (see list)	
Wea-sea	Log	primary	3	3	Int	-	2 char code for sea state (Beaufort)	Unk
Wea-prec	Log	primary	7	7	Char	-	Precipitation - none, fog, ltrain, modrain,hvrain, snow	
Wea-comm	Log	primary	75	75	Char	-	Location of weather observation, commentary on weather	
	NB: File name LOG94.SIGHT. Multiple whale sightings may be recorded per log.							
Log-ID	Log	meta	6	6	Char	-	Year-page number of log (e.g. 94-001, 94-002...)	
Enc-ID	Log	meta	7	7	Char	-	Encounter number in database (94-001a, 94-002a, 94-002b, ...)	-
LWhl-time	Log	primary	6	6	Num	2	Time of whale observation	dec hours
LWhl-spp	Log	primary	4	4	Char	-	2-3 char code for species observed (not all porpoise sightings noted)	-
LWhl-loc	Log	primary	50	15	Char	-	Place name where sighting occured	-
LWhl-no	Log	primary	3	3	Int	-	Number of whales recorded in the sighting in the Log (porpoise and HW n	animals
LWhl-behv	Log	primary	7	7	Char	-	See list	-
LWhl-comm	Log	primary	75	75	Char	-	Commentary on whale observation w/pods present if KWs	
	NB: File name ENC9.AAT. May be multiple encounter sheets per log; each sheet has a vessel path attatched to it.							
Log-ID	Log	meta	6	6	Char	-	Year-page number of log (e.g. 94-001, 94-002...)	-
Enc-ID	Log	meta	7	7	Char	-	Encounter number in database (94-001a, 94-002a, 94-002b, ...)	
Enc-date	enc	primary	8	8	Date	-	Day, month, year of animal encounter (repeated on Log)	Date
Enc-platform	enc	meta	12	12	Char	-	Name of the vessel (repeated on Log)	-
Observers	enc	meta	16	16	Char	-	Initials of observers making encounter record	-
EB-time	enc	primary	6	6	Num	2	Begining time of encounter	dec hours
EE-time	enc	primary	6	6	Num	2	End time of encounter	dec hours
EB-Loc	enc	primary	50	15	Char	-	Place name where encounter began	-
EE-Loc	enc	primary	50	15	Char	-	Place name where encounter ended	-
Pods	enc	derived	16	8	Char	-	2-3 char codes for pods represented at encounter	-
Mi-trav	enc	derived	5	5	Num	1	Nautical miles traveled with pod, as recorded on form	dec miles
Tot-whl	enc	primary	3	3	Int	-	Total number of whales counted in the encounter (field estimate).	whales

Data dictionary, Long-term killer whale database (NGOS & PWSSC/OSRI)

Item	Source	Level	Stored Width	Display Width	Type	Dec.	Description	Units
adM	enc	primary	3	3	Int	-	Total number of adult males counted in the encounter (field estimate)	whales
adF-I	enc	primary	3	3	Int	-	Total number of adult females or immatures counted (field estimate)	whales
juv-calf	enc	primary	3	3	Int	-	Total number of juv/immatures counted in the encounter (field estimate)	whales
Recg-ind	enc	primary	200	16	Char	-	3-4 char names of individuals recognized (for individuals photographical *	-
Tot-pho	enc	primary	3	3	Int	-	Total number of whales photographed (field estimate). For transient whale	whales
Tot-har	enc	primary	3	3	Int	-	Total number of whales harassed by researchers	whales
Oil	enc	primary	32	8	Char	-	None if no oil present, otherwise type of oil present	-
	NB: File name ENC94.FILM May be multiple rolls of film per encounter sheet							
Log-ID	Log	meta	6	6	Char	-	Year-page number of log (e.g. 94-001, 94-002...)	-
Enc-ID	enc	meta	7	7	Char	-	Encounter number in database (94-001a, 94-002a, 94-002b, ...)	
Film-date	enc	primary	8	8	Date	-	Day, month, year of film roll	Date
Film-roll	enc	primary	3	3	Int	-	Number of film rolls taken	-
Film-ini	enc	primary	8	8	Char	-	Initials of photographer	-
	NB: File name ENC94.REC May be multiple recording tapes per encounter sheet.							
Log-ID	log	meta	6	6	Char	-	Year-page number of log (e.g. 94-001, 94-002...)	
Enc-ID	enc	meta	7	7	Char	-	Encounter number in database (94-001a, 94-002a, 94-002b, ...)	
Rec-tape	enc	primary	3	3	Int	-	Tape number ID of recording	-
Rec-side	enc	primary	1	1	Char	-	Side on which tape was recorded (A or B)	-
Rec-beg	enc	primary	4	4	Int	-	Counter number where recording began	-
Rec-end	enc	primary	4	4	Int	-	Counter number where recording ended	-
	NB: File name ENC94.ACTIVE May be multiple activites per encounter sheet.							
Log-ID	log	meta	6	76	Char	-	Year-page number of log (e.g. 94-001, 94-002...)	
Enc-ID	enc	meta	7	7	Char	-	Year-page number-encounter	
AB-time	enc	primary	6	6	Num	2	Beginning time of activity	Time
AE-time	enc	primary	6	6	Num	2	Ending time of activity	
Activ-behv	enc	primary	14	14	Char	-	See list	-
Activ-vess	enc	primary	50	15	Char	-	Vessel traffic	* -
Activ-inter	enc	primary	50	15	Char	-	Interaction with whales by other boats	* -
Activ-grp	enc	primary	50	15	Char	-	Sub-groupings of whales listing individual IDs	* -
Activ-note	enc	primary	50	15	Char	-	Additional information on the activities	* -
	NB: File name ENC94.BIOP May be multiple pods biopsied per encounter sheet							
Log-ID	log	meta	6	76	Char	-	Year-page number of log (e.g. 94-001, 94-002...)	-
Enc-ID	enc	meta	7	7	Char	-	Year-page number-encounter	-
Biop-pod	enc	primary	32	8	Char	-	2-3 char codes for pod biopsied	-
Biop-ID	enc	primary	4	4	Num	-	1-2 numerical code for identity of whales biopsied	-

Appendix 4: Beaufort Scales

Beaufort Sea Surface Scale

Beaufort Number	Speed (knots)	Effects Observed at Sea
0	<1	Calm, sea like mirror
1	1-3	Light air; ripples with no foam crests
2	4-6	Light breeze; small wavelets; glassy, non-breaking crests
3	7-10	Gentle breeze; large wavelets crests begin to break; scattered whitecaps
4	11-16	Moderate breeze; small waves 0.5-1.25 m becoming longer; numerous whitecaps
5	17-21	Fresh breeze; moderate waves 1.25-2.5 m becoming longform; many whitecaps, some spray
6	22-27	Strong breeze; larger waves 2.5-4 m; whitecaps everywhere, spray
7	28-33	Near gale; sea heaps up; waves 4-6 m; white foam from breaking waves blown in streaks
8	34-40	Gale; waves 4-6 m of greater length; edges of crests break into spindrift; foam blown in well-marked streaks

Beaufort numbers 9-12 not applicable to this database.

Beaufort Visibility Scale

Number	Description	Effects Observed
1	Excellent	Clear or high overcast with no glare; horizon visible; effective sighting distance (efd) = >3 miles
2	Very Good	Clear or some cloud cover; some glare or surface ripple; efd = 2-3 miles
3	Good	Some fog, haze, or low clouds; some chop, surf, or glare; efd = 1-2 miles
4	Fair	Fog, full overcast, light rain, or haze with glare; whitecaps; efd = 1/2-1 mile
5	Poor	Moderate rain or fog, large surf, bad glare, etc; efd = 1/4-1/2 mile
6	Unacceptable	Heavy rain, dense fog, near darkness, etc; efd < 1/4 mile

Appendix 5: Instructions for Entering Data into the Long-term Killer Whale Database

Getting Started (Unix-based network at the Science Center)

*Turn on the appropriate computer.
*Log in to "Whale" at the login prompt.
*If not in a windows environment already, , type "openwin".
*Otherwise, the windows will open up automatically.
*To get into the longterm killer whale directory,
*Type "cd ltkwdb/" at the % prompt.
*Type "arc" at the next % prompt.
*Type "&r swim" at the Arc: prompt.
*A menu will come up with several choices.
*With the mouse, using the right button, click on the Data input button. (When using the mouse, the right button is used to open a menu. The left button is used when there is only one choice.)
*Using the left mouse button, click on longterm killer whale.
*The year menu will come up on the screen.
*Click on the year for which data will be entered.
*If starting a new year, click on "Start a new year". Watch the x term window. When the computer is finished getting the new year shells ready, click on the "add/edit data" button.
*If continuing a year already begun, simply press the add/edit button.
*You are now ready to enter data.

Data Entry

*Keep in mind that the cursor needs to be in the window you are working on.
*For missing numerical data, enter "-99". For other missing data leave blank.
*After each item entered, a carriage return is necessary or the item will not be saved.

Entering the Daily Log Data

Enter the Sheet ID. This is assigned to each daily log sheet. The first day for each year is, for example, 95-001. Write this id on the top of each data sheet that is entered, along with the initials of the person entering the data. Once the sheet id is entered, press return. Enter the date on the log sheet as mm/dd/yy. Press return. Enter the vessel name. Return. Enter the location at which the day was begun. Return. Enter the end location for the day. Press return. Enter the time that observation were begun. To do this you must convert the time on the data sheet to decimal time, i.e., 0930 should be entered as 9.5. Do the same for the end time. Enter the search time. On older data sheet (pre-1990) there is no space for search time or time with whales. Enter missing and the computer will later calculate out search time. The same is true for the time with whales. Enter miles traveled. Enter the initials of the personnel. After this is entered the first time during a session, personnel and platform will automatically come up with the same data on the next log sheet. Enter activities and comments. Only relevant statements need to be entered. For example, if whales were heard on the hydrophone but not found, it can be entered. Abbreviate words whenever possible to conserve space. Comments on boat/engine problems, personal activities, or information that is repeated again elsewhere, such as whale encounters, should not be entered. The only pinniped sightings that should be entered are counts of Steller sea lions at haul-outs like the Needle or Cape Elrington, or counts of harbor seals at haul-outs or in Icy Bay. Press return.

Weather Data on Log Sheets

If there is weather data present on the log sheet, click on "weather data" with the left mouse button. Another menu will come up on the screen. Enter the time of the weather observation in the same way as on the log sheet, as decimal time. If the weather notes say "overcast" or "cloudy", enter 100 for cloud cover. If the notes say "clear skies" or "sunny" enter 0. For ambiguous cloud descriptions such as partly cloudy, or clearing, type -99. Only in late 1995 did we start noting %cloud cover. Enter the Beaufort number for "Sea". This will usually be written on the data sheet as, i.e., B1V2. In this example you would enter 1 for Sea and 2 for Visibility. In years prior to 1990 these items will generally be missing. For wind enter the direction and speed as, for example "NE15", for northeasterly winds of 15 knots. If no direction is given, just type in the wind speed, or if no speed is given just type in the abbreviation for the wind direction. If the wind was calm, type in "calm"; if the data sheet says light winds type in "lt"; if the data sheet says variable winds type in "var". Otherwise leave blank. Precipitation has a menu. To see the choices place the cursor on the line after precipitation and click the right mouse button. Select a choice. If you know the choices, you can also type in the first 2 or 3 letters of the appropriate choice and press return and the rest of the choice will be typed out automatically. For weather comments type in the location of the weather observation and any reference to cloud cover, such as "high ovc" for high overcast, "low ovc" for low overcast, and "ptly cldy" for partly cloudy. Type in "fog" if ground fog was present. Press return. When you are done filling in a weather observation, press "Add record". This saves the data for that weather observation. If there is another observation, enter the data after the previous weather has been saved. Watch the x term window and check to see that the correct data was entered. In general, it is wise to keep an eye on this window whenever something is being saved. Any error messages will be listed there. They should be carefully noted and brought to Dave Scheel's attention before continuing with data entry. If there are more weather observations, enter them, pressing "Add record" after each and remembering to press return after each item that is added. Enter no more than 3 weather records. If there are more than 3 on the log sheet, choose ones at the beginning, middle, and end of the day. When all weather records are entered, press "Done adding weather". Watch the x term window for error messages. You will be returned to the log sheet.

Whale Sightings on the Log Sheet

If there were any whale sightings, press "Whale sightings". Enter only whale sightings at this time, not porpoise sightings. Enter the beginning time of the observation, in decimal time. The species item is a menu. Place the cursor on the line following species and click the right mouse button. Choose the appropriate species. If you remember the choices, just enter the abbreviation for the species without clicking on the menu button. If there is a killer whale data sheet for the day you are entering, you will need to fill in the Encounter#. This is simply the same number as the log sheet with a letter after it, to indicate which sighting is being entered. For example, if there is only one killer whale sighting, the encounter id could be, i.e., 95-001a. If there is another killer whale data sheet, the next encounter id for that date would be 95-001b. If there is no killer whale data sheet, or if the sighting is of another species of whale, leave the encounter# blank. Next fill in the number of animals in the encounter, if known. If the number is missing, remember to type in -99, or the computer will replace the blank with a zero. "Behavior of whales" is a menu item. The choices, however, are rarely used. This item is most often left blank. Enter the beginning location of the sighting. Under whale sighting comment, type in the pods of killer whales present if known. Other comments related to other species may include behavior of the whales, i.e. lunge feeding, etc. Do not repeat comments that will be entered in the killer whale encounter menu. Press return. Click on "Add record". If there is not another sighting to enter, click on "Done adding sightings". Once again, check for error messages in the x-term window.

Drawing in the Vessel Track

*You are now ready to draw in the vessel track.
*In the log sheet menu, click on "Add record".
*You are now in arcedit mode and ready to use the mouse and cursor to draw in the vessel track.

Locate the beginning point of the vessel track on the map. Without clicking the mouse button, type in "2". This locates the "node" marking the beginning of the arc you are drawing. Move the cursor along, clicking the right mouse button whenever you need to change direction. Each of these clicked on points is called a vertex. If you make a mistake, and just need to delete part of the line you are drawing, type in the number "4". This will delete the last vertex you entered. If you want to delete the whole arc and start all over again, type in the number "5". These choices are also listed at the bottom of the x-term window when you are in arcedit mode. When you have reached the end point of the vessel track on the map, do not click the mouse button, but simply mark the end point by typing in the number "2", which marks the end node of the arc.

If you need to make the background map bigger, you can place the cursor at the right lower corner of the map box until you see the pointer turn into a circle. Click the left mouse button and "drag" the corner of the map to enlarge the desired map. You can also use the menu at the top left corner of the map to change the map scale. Click on the "Pan/Zoom" button with the right mouse button. If you want to enlarge a certain area, click on "Zoom In" with the left mouse button and then click on the center of the area which you would like to enlarge with the left mouse button. "Zoom Out" works the same way and will allow you to expand the area that you are looking at on the map. If you want to move to other areas on the map that are not visible on the screen, click on "Pan" with the left mouse button, then click on the map in the direction of the area you wish to have displayed. You can zoom in and out or pan while in the middle of drawing a vessel track. When you are finished drawing the vessel track and have ended your arc by typing "2", type in "9", which quits the map-drawing session. Move the cursor to the x-term window and at the prompt type "&ret". You will now be out of arcedit and returned to data-editing mode. If there is a killer whale encounter for the day just entered, click on "Enter Encounters for Log".

Entering Killer Whale Encounter Sheets

Assign an encounter id to the sheet. This is the same encounter number entered in the sighting menu on the log sheet, i.e., for an encounter from the same day as log 95-001, assign 95-001a to the first encounter for that day. Write this encounter id number and your initials on the killer whale data sheet.

Enter the initials of the observers present during the encounter. Type in the Begin and End times in decimal time. Type in the beginning and end locations of the whale encounter. Type in the miles traveled with whales. Remember to type in "-99" if this is missing on the data sheet. Enter the pods present in the encounter. No spaces are necessary after commas, i.e., AB,AI,AN...etc. The pods present should be verified by checking Graeme Ellis's photographic database. Enter the total number of whales estimated to be present in the encounter in "Total whale". If present, enter field estimates for number of adult males, female/immatures and calves. For non-resident whales (AT,AC,AU whales), enter the individuals recognized in the field from the data sheet. For AT,AC, or AU whales, enter the actual whales photographed in the "Recognized individuals" item, using Graeme Ellis's photographic data summaries for AT,AC, and AU whales. If the data sheets indicate that other whales were present but not photographed, enter these whales as well. For non-resident whales, enter the number of whales photographed from Graeme Ellis's data summary. For resident whales, enter -99 at this time. For "Oil", enter the type seen, i.e., "hv oil sheen" for heavy oil sheen, etc. Otherwise, type in "none". In 1990-1995, the information for oil present will be found on the killer whale data sheet, in a specific comment. Pre-1990, this information is to be found in the comments section of the data sheet. The same is true of harassment of whales by researchers. Press return after entering the number of whales harassed.

Film Details

If photographs were taken, click on "Film Details". Enter the date on the roll of killer whale film, the number of rolls taken, and the initials of the photographer. When more than one photographer, enter the rolls for each photographer separately. Click on "Add Record" after each film record entered. Click on "Done Adding Film" all film has been entered.

Recording Details

If recordings were made, click on "Recording Details". For each tape side recorded, enter a separate record. Enter the beginning tape counter number in "Beginning" and the end tape counter number in "End". If no number are present, leave these two items blank. If a whole side was recorded, type "0" for "Beginning" and "end" for "End". If a tape recording was made at the beginning of a side of a tape but the end number is not given, type "pause" for "End". After each tape side entered click on "Add Record". After finishing adding records, type "Done adding recordings".

Behavior/Vessel Details

Enter the beginning and end time (in decimal time) of each behavior noted. If no times are noted, enter the behaviors that are described with "-99" for the times. The "Behavior" item is a menu. Place the cursor on the line after "Behavior" and press the right mouse button. Press on the appropriate behavior. Alternatively, the first few letters of the name of the behavior category can be typed in and after return is pressed, the computer will type out the rest.

Some Notes on the Behavioral Categories

*If travel and feeding are noted at the same time, the category entered should be "forage-resident".
*The only time "feed-salmon" should be entered is when actual evidence of feeding on salmon was noted, i.e., salmon in whales' mouths, scales seen or collected. In all other cases, behaviors described as "feeding" should be entered as "foraging".
*Evidence of predation is noted in the observations section of the data sheet, in the years since 1995, when a specific item was added to the data sheet for this information.
*Social behavior includes play, close physical contact among the whales, and sexual activity.
*For rest, not if individual or group in the comments.

*In some years, forg-offsh-tr (offshore foraging for transients) was noted as "slow travel/milling". Note any non-predatory interactions between the whales and potential prey.
*If a marine mammal was attacked or killed, enter "feed-mam" as a category. If an attack or kill was seen, note species of prey and evidence in the comments.
*For forg-nearsh-tr (nearshore foraging in transients) note if any marine mammals were near the whales even if no attack was observed. Note reactions of marine mammals to the whales.

More comments on Behavior/Vessel Details

If noted, type in the location of the behavioral activity. This can be general (i.e., KIP for Knight Island Passage, or S KIP for southern KIP) or specific (i.e., off Drier Bay). If sub-groupings of individuals are noted, (not common) type in the individuals in each subgroup without spaces after the commas and 2 diagonal slashes when a subgroups of a new pod are begun, i.e., AB5,6,16//AN1,2. Important comments should be typed in using abbreviations. The most important things to note are speeds of travel, dive times, evidence of predation, i.e., scales collected, salmon seen in whales' mouths, oil slick seen, blubber collected, species of prey, dispersal of whales, i.e., widely spread or tightly grouped, sexual activity, presence of other species in association with the whales, whales approaching the boat.

If other vessels were present, type in the name or description of the vessel and number of vessels in the "other vessels" item. Type in the interactions between other vessels and the whales and any reactions by the whales to the vessels.

After each activity, click on "Add Record". When finished adding activities, click on "Done Adding Activities".

Biopsy Data

Biopsy data was not collected prior to 1994. In 1994 information about biopsies collected is in the comments section or on separate biopsy data sheets. From 1995 on, there are is a specific item on the data sheet with biopsy information. Enter a biopsy record for each pod biopsied in the encounter. Type in the identity of each whale biopsied. Note that the pod designation need not be entered in the whale IDs, only the whale number, i.e., 19 for AD19. Click "Add Record" after data for each pod is entered. Click "Done Adding Biopsies" when finished.

Finishing up an Encounter Sheet

When all data has been entered from the encounter sheet, click "Add Record". Draw in the map in the same way as described for the log sheet. After drawing the whale path, type in "9" to exit, then move the cursor to the x-term window and type &ret. If there is another encounter sheet for the log you are working on, click on "Enter another Encounter".

If you want to enter the next log sheet, click on "Enter another Log Sheet". If you want to quit completely click on "Return to Year menu".

Leaving the Data Entry Routine

If there are no killer whale encounter sheets to enter, click on "Enter another log sheet". When you are entirely done entering data for a session, click on "Return to Year menu". When you have finished entering data for a year, click the "Backup database" button.

To Quit out of a session

*Click on "Quit Macro".
*Move the cursor down to the x-term window.
*At the Arc: prompt, type "Quit".
*At the % prompt in each open window type "exit".
*Using the right mouse button, click onto any blank space on the screen. A menu will come up. Click on "exit".
*Now you can turn off the monitor screen.

To edit data on log and encounter sheets

*Get to the long-term killer whale year menu as described previously.
*Click on the year you wish to make corrections for.
*Click on Add/Edit data
*When the log menu comes up, type in the log-id of the sheet you wish to edit.
*Click on "Select ID" (near the top of the menu).
*If editing an item on the log menu, correct the item, and then click on "Apply Edits". Do not click on "Add Record".
*If editing an item in a weather or whale sightings, click on the appropriate item. Click on "select record". Correct the item. Click "Apply Edits". Click "Done adding ...(weather or sightings). If you have only edited something in the weather or sightings table, do not click apply edits when you return to the log menu.
*If editing a killer whale encounter sheet, after typing in the log-id number and pressing "Select Record", click on "Enter Encounters for Log". On the Encounter menu, type in the complete encounter id and click on "Select id". Correct in the same way as described for the log sheet.

To edit a map

*In most cases, it is easier to re-do the map completely than to correct an existing map.
*Go to the desired log or encounter sheet in the same way as described above.

*Click on Select Record
*Click on "Arcedit Session"
*In the x-term window, at the prompt type "delete". The existing vessel or whale track should disappear.
*At the prompt type "&ret".
*Return to the log form.
*Click on "Add Record".
*Redraw the map in the usual way.
* When done editing, remember to click "Return to Year menu" to quit. Click "Backup database to make sure your changes are backed up.

Appendix 6: Proposed changes to killer whale data sheets and killer whale data collection

Additions to data sheets:

1. Add line for prey samples collected from predation events, to include type of sample collected (i.e., scales, blubber, tissue), sample numbers, location where sample collected, ID of whale or whales involved, if known.

2. Add line for whale tissue samples collected from biopsy darting, to include sample numbers and i.d.'s of whales darted.

3. Add the following columns to the"Observations" section of the data sheets:
   a. Behavioral Category - a one-word descriptor for the general behavior observed from a list of specifically defined categories.
   b. Location - The geographical location of the whales when the behavior was observed.
   c. Tape side, #, Recorder #: The location on cassette of recordings made of the whales' vocalizations during the time observation of a particular behavior was made (if recordings were made.).

Suggestions for improved data collection for ease of data entry into the GIS:

1. A new behavioral observation entry should be made on the data sheet at least each time there is an overall change in the behavior of the whales (from one category to another). If only part of the pod is being observed, this should be noted on the data sheet, with sub-group identity. Note should be made of the activity of the rest of the pod and if they are still within sight. The location of each time/behavior change should be noted, especially for feeding events. This is important because this data can be used to determine use patterns of specific geographical areas in the Sound for different behaviors of killer whales. Of specific interest is locations where feeding takes place.

2. If whales are being monitored acoustically, note should be made in the behavioral observations if the whales are vocal or silent, i.e., echolocation heard, calls heard. This is important in understanding behaviors that are ambiguous, such as resident killer whale foraging for fish. Echolocation is a strong indication that foraging is taking place.

3. Note should be made in the observation log of presence and location of any potential prey observed in the vicinity of the whales, even if the whales are not feeding, i.e., salmon jumping, harbor seals, sea lions, porpoises in area, porpoises 'harassing" or "playing" with killer whales. Include notes on behavior of prey, especially reaction to the presence of

the whales. This is important in that one of the goals of the NGOS/PWSSC project is to assess habitat use of killer whales and their distribution in relationship to their prey distribution.

4. Behavioral categories should be specifically defined so that activities described in the data sheets are consistent among observers.
5. Maps should be drawn as accurately as possible. Feeding events should be marked on the map. This is important in that the track-lines on the maps are drawn directly into the GIS and should match as accurately as possible the locations of the whales. The location of feeding events is an important component of this analysis.

6. Note should be made of any interactions between vessel traffic and whales.

Suggestions regarding specific behavioral categories (to be included in "Observations" column):

1. Type of evidence used to determine fish predation should be clearly noted (i.e., fish scales collected, whale observed with fish in mouth, scales seen in water, behavior of whales, etc.).

2. Careful searching in areas of transient whale milling behavior should be undertaken to look for evidence of predation on marine mammals, i.e., blood, oil slicks, tissue, hair floating in water. Harbor seal kills are generally made beneath the water, and can easily go undetected without careful searching. In order to address the issue of the importance of harbor seals in the diet of transient killer whales, it is important that measurements of predation rates be as accurate as possible.

3. If whales are traveling, note if fast or slow.

4. During social activity, note should be taken of sexual activity observed, including the IDs of social animals, if known. Note characteristics of social animals, i.e., all-male groups, juvenile/calves. If transients are observed engaged in social activity, look for signs of a kill.

5. During observations of transient killer whale attacks on marine mammals, note should be made if the attack was successful or not and the age class and size of the animal attacked, if known.

6. During resident whale observations, if acoustical monitoring is carried out, note if echolocation is present or not. Echolocation is an indicator of foraging activity.

SUMMARY OF KILLER WHALE ENCOUNTERS FOR 1995

DATE	TIME	PODS	#WHLS	KM TRAV	LOCATION
04/14/95	11.50	AT	4	40.4	1/2 mi SW Seal I
04/17/95	10.50	AI	6	20.1	1/2 mi NW Pt Bazil
04/17/95	11.08	AE	15	44.8	2 mi SE Pt Grace
05/30/95	12.25	AD	9	10.4	bet Barwell Is and Cape Res
05/31/95	13.50	AE	15	22.8	2 mi S Lucky Bay
06/01/95	8.25	AK	6	75.0	1/2 mi W Herring Bay
06/05/92	10.58	AT	3	38.1	bet Seal and L Smith I
05/06/95	7.75	AT	2	27.1	Hogan Bay
06/25/95	9.00	AT	5	56.8	1 mi SW Pt Chalmers
06/24/95	15.25	AT	2	58.7	bet Lucky Bay and P of W Psg
06/26/95	22.25	AT	5	3.0	Port Chalmers
07/03/95	13.92	AI	6	10.5	1 mi E Discovery Pt
07/05/95	11.00	AB	4	2.5	1 mi E Pt Grace
07/05/95	17.50	AK	11	31.4	1 mi NW Pt Helen
07/06/95	16.83	AE	15	6.0	bet Pt Helen and Evans Pt
07/08/95	20.00	AT	2	2.8	1/2 mi S Delenia Is
07/09/95	13.00	AK	6	20.0	N end P of Wales Psg
07/18/95	9.67	AE	15	54.4	bet Pt Helen and Grace
07/18/95	16.50	AK,AE	10	18.6	1/8 mi NE N end L Green
07/21/95	17.00	AE	15	13.1	bet Pleiades and Gage I
07/22/95	10.25	AE	15	50.7	1/2 mi N Evans Pt
07/22/95	12.75	AT,AE	4	10.2	1/2 mi N Chenega Pt
07/25/95	10.83	AE	15	32.5	1/2 mi SE S end L Green
07/27/95	13.00	AE	15	53.2	1/2 mi S Pleiades
07/30/95	10.33	AE,AI	21	34.6	bet Squire Pt and Pleiades
07/30/95	18.00	AK	10	9.9	1/2 mi S N end Elrington Is
07/30/95	20.00	AC	3	13.9	1 mi S Little Green
07/31/95	7.67	AC,AU	6	25.8	bet Pt Grace and Pt Bazil
08/01/95	15.50	AI,AB,AS,A?	50	29.0	1/8 mi SE Needle
08/04/95	7.67	AB	16	14.6	bet Squire I and Chenega Pt
08/06/95	17.75	AE	15	18.8	1 mi S N end Chenega
08/08/95	12.50	AC,AU	6	58.3	2.5 mi E Hogan Bay
08/09/95	14.75	AB	16	20.6	off Pt Helen
08/10/95	17.50	AB	5	11.3	2 mi N Evans Pt
08/11/95	8.75	AD	13	69.0	bet Macleod Hbr and Latouche
08/13/95	18.67	AB,AD	20	7.7	N end Dangerous Psg
08/15/95	15.00	AT60	2	33.8	bet L Green and Needle
08/16/95	9.75	AB,AN	35	32.9	bet Pt Grace and Helen
08/17/95	16.00	AT60	2	33.1	1/2 mi E Needle
08/18/95	17.58	AB	16	12.7	bet Little Bay and Evans Pt
08/20/95	14.00	AB,AE,AI	37	16.8	bet Needle and Sleepy Bay
08/21/95	11.18	AB,AN	17	43.4	off Pt Helen
08/22/95	10.42	AB,AN	17	32.6	1/2 mi SE Sleepy Bay
08/24/95	15.33	AT60	2	23.9	2.5 mi SW Needle
08/25/95	16.00	AB	16	34.8	off Gibbon Anch
08/26/95	20.00	AB	16	1.3	NW side Pleiades
08/27/95	12.50	AB,AE,AI,AN	39	18.8	bet Latouche Psg and Pt Helen
08/28/95	17.18	AE,AI	22	8.2	1 mi NE Pt Helen
09/02/95	10.33	AE	15	8.2	off Pt Helen
09/02/95	15.83	AB	16	1.9	bet Pt Helen and Evans Pt
09/03/95	15.33	AI	5	15.8	bet Pt Helen and Pt Grace
09/13/95	15.83	AT	3	32.9	Gibbon Anch
09/15/95	12.00	AB	16	53.7	bet Green I and Disc Pt
09/16/95	17.00	AT60	2	7.7	1.5 mi SE Needle
06/23/95	20.50	AT	3	3.4	Bainbridge Pt
07/27/95	11.50	AE	15	2.1	off Camp
07/31/95	22.50	AI	5	2.6	Port Bainbridge
08/01/95	13.50	AT	2	11.9	Jackpot Bay
08/04/95	13.50	AB,AN,AK	27	12.6	S of Needle
10/07/95	12.25	AT	2	5.2	2 mi N Observation Is
10/15/95	18.33	AT	3	3.4	Pigot Pt
07/19/95	8.50	AJ,AB,AE,AK,AI	65	85.6	1/4 mi E Hogan Bay
09/01/95	12.00	AB	16	40.5	bet Little and Shelter Bay