Exxon Valdez Oil Spill
Restoration Project

Photographic and Acoustic Monitoring of Killer Whales in Prince William Sound and Kenai Fjords, Alaska

Restoration Project 00012
Annual Report

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 not been addressed in this annual report

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Photographic and Acoustic Monitoring of Killer Whales

STUDY HISTORY: The current project was initiated under Restoration Project 95012 (Comprehensive Killer Whale Investigations). This is the sixth annual report for this study. Prior to the current year's work, killer whales were monitored in Prince William Sound, Alaska with funding from the *Exxon Valdez* Oil spill Trustee Council in 1989, 1990, and 1991 (Dahlheim, M.E. and C.O. Matkin, 1993) and in 1993 (Dahlheim 1994). The North Gulf Oceanic Society (NGOS) independently maintained a monitoring program in 1994. A peer reviewed 1995 annual report was submitted in April 1996 and annual reports without review comments addressed were submitted in March 1997, 1998, 1999 and 2000. An assessment of the status of killer whales from 1984 to 1992 in Prince William Sound was published (Matkin et al. 1994). Feeding habit studies, geographic information system, and genetic studies were initiated in 1995 (95012a) and continued in 1996 (96012a) and 1997 (97012a). Journal articles describing killer whale movement and distribution (Matkin et al. 1997), resident pod genealogies and status of AB pod (Matkin et al 1999a) and feeding habits (Saulitis et al 2000) were published.

ABSTRACT: Monitoring of killer whales (*Orcinus orca*) was continued in 2000 using photo-identification and acoustic methods. There was one calf recruited and no new mortalities in AB pod. AB pod now numbers 25 whales but has not recovered to the prespill number of 36. Population modeling indicates that although the mortality rate in AB pod has remained higher than expected during recent years, the primary reason for the lack of recovery of the pod is the loss of reproductive potential due to the death of reproductive females at the time of the spill.

In the AT1 transient group, the nine individuals missing since 1990 and the two individuals missing since 1992 are presumed dead. There has been no recruitment in this genetically distinct population since 1984 and no recovery from losses following the spill. There was additional mortality in 2000 when an adult male, AT1, stranded and died near Cordova. Lack of recovery may be a result of several factors including high levels of contaminants (PCBs and DDTs), sharp, region-wide decline in numbers of harbor seals, their primary prey, and the genetic/social isolation of the group.

Improved techniques have been developed for acoustic monitoring of whales in winter months and allowed tracking of AB and AJ pods during part of this period. Field recordings made in 2000 have augmented our acoustic catalogue and increased our ability to identify pods by calls.

KEY WORDS: acoustics, biopsy, contaminants, *Exxon Valdez*, Geographic Information System, genetics, killer whales, photo-identification, *Orcinus orca* , Prince William Sound, resident, transient.

PROJECT DATA: Identification data consists of frame-by-frame identifications of individual whales for all exposed films. These identifications are available on computer disk upon request approved by the *Exxon Valdez* Oil Spill Trustee Council from Craig

Matkin, North Gulf Oceanic Society (NGOS), 60920 Mary Allen Ave., Homer, Alaska (907) 235-6590. All field observations, killer whale encounter data, vessel logs and tracklines are stored in a GIS system (Arc/Info) housed at the U.S. Fish and Wildlife Service, Marine Mammals Management, 1011 Tudor Rd, Anchorage, Alaska. Contact Doug Burn (800) 362-5148. This data is now available for inspection and use with permission of the NGOS or U.S.F.W.S.

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EXECUTIVE SUMMARY

Killer whales were monitored in Prince William Sound, Alaska with funding from the *Exxon Valdez* Oil Spill (EVOS) Trustee Council in 1989, 1990, and 1991 (damage assessment) and in 1993 (restoration monitoring). Monitoring was continued in 1995-1999 as part of the EVOS Trustee Council restoration program. The North Gulf Oceanic Society (NGOS) independently maintained a monitoring program in all other years since 1984 (Matkin et al. 1994). This report summarizes results of the monitoring of killer whales in Prince William Sound in 2000 using photo-identification and acoustic techniques. The goal of the photo-monitoring has been to obtain identification photographs of all whales in all major resident pods and the AT1 transient group on an annual basis. Photo-identification techniques (after Bigg et al. 1990) were used to identify individual whales. The current photographic database includes tens of thousands of frames of film collected from 1984-2000 and is used to provide individual identifications for each encounter with whales. Vital rates for AB pod and all other frequently sighted resident pods have been calculated annually based on the photographic data.

The total number of whales in the seven well-known resident pods other than AB pod has increased from 81 to 110 whales from 1988 through 2000, while AB pod has declined from 36 whales to 25 whales in that same time period. The resident pods other than AB pod have all increased or remained stable since 1984. From 1995 to 2000, AB pod has had a net increase of three individuals, due to recruitment of seven calves and four mortalities. Seven members of the pod (AB 25 subpod) still appear to travel with AJ pod a majority of the time, although they maintain their AB pod vocal dialect. Although recruitment rates for AB pod now exceed those of other pods and there are nine reproductive females in the pod, recovery has been hindered by unexpected mortalities. The primary reason for lack of recovery, however, has been the loss of females at the time of the spill, resulting in a loss of potential reproduction.

Encounter data for the AT1 transient group (a genetically unique population) was used to update sighting histories for this group in 2000. Despite substantial field effort, the number of AT1 whales sighted each year has declined following 1989 and remains consistently half or less of what it was prior to the spill. We are confident that 12 of the original 22 whales in the AT1 group have died since the spill. The rate of encounter with

members of this group also has declined significantly since 1989. Only four of the original 22 whales attributed to the AT1 group were photographed in 2000. One of these whales, a mature male (AT1) stranded and died near Cordova in June. Listing of the AT1 group under the ESA or MMPA remains a strong consideration.

Acoustic monitoring relies on a catalogue of distinct pulsed calls for each resident pod, the AT1 group, and the Gulf of Alaska transients collected from 1984 to 2000. Distinct pod/population repertoires allow identification from recordings collected by remote hydrophones. During winter 1999-2000, a remote hydrophone was operated in Resurrection Bay using a microwave transmission system powered by wind and solar electrical systems and monitored in Seward. Recordings determined that AB and AJ pod used this region as an important component of their winter range.

Killer whale behavioral and location data has been collected since 1984 in a standard format. Vessel tracks and maps of whale movements have been logged into a GIS database. Data entry into this database has been completed for all NGOS killer whale records from 1984 to 2000, including a total of 1,891 boat-days of search effort and 855 encounters with whales. In 2000, the GIS database was archived at both Marine Mammal Management, U.S.F.W.S. Anchorage, Alaska at Alaska Pacific University, Biology Department (Dr. David Scheel), Anchorage, Alaska.

Biopsy tissues from free ranging whales were collected on an opportunistic basis from transient whales and from a new resident pod in 2000 using a biopsy dart system developed by Barrett-Lennard et al. (1996). MtDNA analysis was conducted on these and the 1999 samples. Contaminant analysis was conducted on blubber samples collected concurrently and again indicates very high levels of PCBs and DDTs in the transient whales, particularly those of the Gulf of Alaska population.

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, and there was no recruitment into AB pod. The rate of mortality observed in this pod after the oil spill (19% in 1989 and 21% in 1990) exceeds by a factor of 10 the 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 the 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. The pod has been observed less often, while prior to the spill, AB pod was the most frequently encountered resident pod in Prince William Sound (Matkin et al. 1994). Although AB pod had a net gain of two whales from a low of 22 whales in 1995, in 1999, it still contained only 24 whales. There were 36 whales in AB pod in fall 1988 prior to the spill.

No individual resident whale missing during repeated encounters with its 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. Subgroups of resident pods may travel separately 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 stranded 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 over only several years cannot necessarily be considered dead.

Eleven of the 22 whales from the transient AT1 group have not been observed or photo-documented for at least 8 years despite extensive field effort. While mortalities in transient groups cannot be confirmed with the same certainty as for residents, AT1 transients have not been observed in adjacent regions, and in light of sighting records prior to the spill, it is most likely they are dead. Most of these whales (9 of 11) disappeared the year of or the year following the spill Sound (see Overall Conclusions).

The AB pod and AT1 group appear to have been injured due to the effects of the *Exxon Valdez* oil spill and neither has demonstrated a recovery. Numbers of whales in other well-documented resident pods have increased following the spill. Annual photographic monitoring has been the most effective tool in determination of the recovery status of AB pod and the AT1 group and the status of the entire Prince William Sound killer whale population (Matkin et al. 1994). This project continues using photo-identification to monitor changes in resident killer whale pods (including AB pod) and the AT1 transient group in Prince William Sound/Kenai Fjords.

Previous projects examined predation parameters using historical killer whale sighting and behavioral data in a geographic information system (GIS) framework. 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. The decline of harbor seals may also be a factor in the non-recovery of the AT1 group of transient killer whales. At least 300 harbor seals were killed at the time of the spill and the harbor seal population does not show signs of recovery from a decline that began before the spill. Of the two types of killer whales in Prince William Sound, only one, the transient, has been observed preying on marine mammals. Observation of predation and collection of prey remains has indicated harbor seals and Dall's porpoise are the primary food items of AT1 transient killer whales, at least from April to October. These results have been incorporated into models of harbor seal population dynamics (project 064, seal trophics). Resident killer whales appear to select coho salmon from mixed schools during the July to September period (Saulitis et al. 2000) and have been observed preying on chinook salmon in the May to June period.

A geographic information system (GIS) database was designed and the data from 1984 to 1999 entered into a computer from hand-written data sheets. Sighting records provide considerable behavioral information (travel rates, duration of feeding bouts, etc.). Location of encounters and basic behavioral information (resting, feeding, traveling, etc.) are available for each sighting. It has been a goal of the GIS project to provide a systematic and easily accessible storage system for geographically referenced data generated by this ongoing project since 1984. The system can be used to address questions of interest to restoration management, and to examine the distribution of whale groups over time in Prince William Sound. Data analysis has provided detailed demographics and spatial distributions of resident and transient killer whales (Scheel et al. 2001)

Killer whales are found regularly in Alaskan waters, but only a few locations allow acoustic tracking of animals for purposes of group identification and community assessment. Ambient and anthropogenic noise in some areas precludes use of remote hydrophones and may also interfere with the whales' ability to communicate or hunt and may cause avoidance of those areas. Some parts of Prince William Sound and Kenai Fjords, Alaska are relatively acoustically pristine and allow tracking of killer whales by calls. Since the mid-1980s, during systematic field studies of killer whales of this area, we have opportunistically recorded killer whale vocalizations while identifying individuals photographically. As a result, a relatively large number of acoustic recordings exist in addition to photo-identification pictures of killer whales. Acoustic analysis supports separation of populations described by genetic analysis and demonstrates resident pod specific dialects and acoustic clans, which make possible identification and enumeration of whale pods and groups from calls collected via remote hydrophone stations.

Past projects have examined the separation of marine mammal-eating transient and fish-eating resident killer whales using behavioral data and genetic analysis. Genetic samples were obtained from 103 identifiable whales. Samples were collected using lightweight biopsy darts (Barrett-Lennard et al. 1996). The genetic analysis used both mitochondrial DNA (mtDNA) and nuclear DNA microsatellites to separate populations and examine breeding systems. MtDNA evolves quickly, is only passed through the maternal line, and provides a faithful record of female lineages over long periods. MtDNA is considered an appropriate marker for distinguishing well-established populations. Microsatellite analysis has also provided further delineation of populations and examined male mediated breeding patterns.

Contaminant analysis has been completed on blubber tissue collected simultaneously with the genetic samples. The National Marine Fisheries Service Environmental Contaminant Laboratory in Seattle, Washington conducted the analysis using a rapid high-performance liquid chromatography/photodiode array (HPLC/PDA) method. This method has proven accurate in the analysis of very small blubber tissue samples. Patterns in contaminant accumulation suggest the importance of reproductive status and genealogy in determining contaminant levels. Contaminant levels in transient killer whales were 15 to 20 times higher than in resident whales. They are comparable or exceed levels in other marine mammal populations believed to have been negatively impacted by contaminants.

OBJECTIVES

1. To monitor changes in AB pod, the AT1 transient group and the other major resident pods in Prince William Sound.

2. To identify individual whales photographed on a frame-by-frame basis and complete entry of identification data for 2000 into a photographic database.

3. To complete input of observational data for 2000 into the specially designed GIS system and transfer system to U.S. Fish and Wildlife Service, Marine Mammal Management, Anchorage, Alaska.

4. To initiate population dynamics analysis/modeling using 17 years of data on known individuals from well documented resident pods and prepare for publication.

5. To submit for publication a paper on the AT1 group, their acoustics and behavior and to submit a paper examining killer whale predation on Steller sea lions using data collected in this project.

6. To continue analysis of acoustic data collected from 1984-2000 and determine pod specific killer whale dialects and vocal similarities between putative clans.

7. To analyze data from remote hydrophone recordings made in winter 1999/2000 in Resurrection Bay.

8. To continue monitoring killer whales via remote hydrophone system in Resurrection Bay during the fall/winter 2000/2001

FIELD METHODOLOGY

Fieldwork for the 2000 photo-identification study was conducted from the R.V. *Whale 2*, a 7.9m, live-aboard vessel powered by a 165 hp diesel engine with inboard/outboard drive and the R.V. *Natoa,* a 10.3 m inboard diesel powered vessel, capable of 18 knots and sleeping 4 researchers. The vessels operated in both the Kenai Fjords and Prince William Sound region. The twin diesel powered 42' *Mariah* was used for five days, primarily in conjunction with the Youth Area Watch program in mid May.

N.G.O.S. biologists on the R.V.*Whale 1* (a 7.8 m light motor-sail vessel with 50hp outboard) also photographed killer whales and kept vessel logs and encounters sheets during surveys directed at humpback whale photo-identification. The daily vessel logs and killer whale encounter sheets for this vessel were included in the GIS database and used in our analysis

Researchers attempted to maximize the number of contacts with each killer whale pod based on current and historical sighting information to insure sufficient photographs of each individual within the pod. Consequently, searches were centered in areas that had produced the most encounters with killer whales in the past, unless sighting information indicated changes in whale distribution. Whales were found visually, or by listening for killer whale calls with a directional hydrophone, or by responding to VHF radio calls from other vessel operators. Regular requests for recent killer whale sightings were made on hailing Channel 16 VHF. In Kenai Fjords, Channel 77 was also monitored. 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. Photographs for individual identification were taken of the port side of each whale showing details of the dorsal fin and saddle patch. Photographs were taken at no less than 1/1000 sec using Fuji Neopan 1600 high-speed black and white film. A Nikon N70 auto focus camera with internal motor drive and a 300 mm f4.5 auto focus 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. Similar logs were kept for all previous study years and have been placed in a GIS format and used to estimate effort (Matkin et al. 1999b). On these logs, the elapsed time and distance traveled were recorded. 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 (Matkin et al. 1996). 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' track line during the encounter was drawn 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. Encounters with whales averaged from 2-5 hours, providing considerable behavioral information (travel rates, duration of feeding bouts, etc.).

Directed observations of feeding behavior and identification and collection of killer whale prey were made when possible during the 2000 fieldwork. 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 recorded. 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 lob tailing by humpback whales and fleeing behavior by small cetaceans, pinnepeds, or mustelids. When predation on fish was observed, scales from the site of fish kills were collected and later identified by species. Scales were individually mounted and identifications were made by the fish scale and aging laboratory at the Pacific Biological Station, Nanaimo, B.C. Canada. 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.

Biopsy samples were collected on an opportunistic basis in 2000 using a pneumatic rifle and custom-designed biopsy darts (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 and aluminum 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 was fired from a range of 16-20m. The dart struck the animal in the upper back, excised a small tissue sample, bounced clear of the whale, and floated with sample contained until retrieved with long handled net.

From the biopsy samples, the epidermis, which is heavily pigmented, was separated aseptically from the other layers with a scalpel soon after retrieval. The dermal sample, the source of DNA, was stored at about 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 with double distilled water (Amos and Hoelzel 1991). The dermis and hypodermis were made up primarily of collagen and lipid, respectively, and were frozen at -20C in autoclaved, solvent-washed vials for contaminant analysis. Contaminant analysis was conducted by the National Marine Fisheries Service, Environmental Contaminant Laboratory in Seattle, Washington using a rapid high-performance liquid chromatography/photodiode array (HPLC/PDA) method. This method has proven accurate in the analysis of very small blubber tissue samples.

Acoustic recordings were made using an Offshore Acoustics omnidirectional hydrophone in combination with Sony Walkman professional tape recorder. The hydrophone had a flat frequency response to signals ranging from 100Hz to 25 kHz. The tape recorder showed a flat response to signals up to 15kHz.

POPULATION STATUS

Introduction

Population monitoring of killer whales in Prince William Sound and adjacent waters has occurred annually since 1984. The existence of pre-spill data made it possible to determine that resident AB pod and the AT1 transient group declined following the *Exxon Valdez* oil spill and are not recovering. This project continues using photo-identification to monitor changes in resident killer whale pods and groups including AB pod and the AT1 transient group in Prince William Sound/Kenai.

Methods

Photographic Analysis

All photographic negatives collected during the fieldwork were examined under a Wild M5 stereomicroscope at 9.6 powers. 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) and has been continued in the latest catalogue of southern Alaska killer whales (Matkin et al 1999c). 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 and labeled 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. From this photographic database, the actual number of whales identified and pods of whales present for each encounter was determined and included with each encounter entered in the GIS database.

Calculation of Vital Rates

Most new calves were already present at the beginning of the field season 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. (Bigg et al. 1990, Matkin et al. 1999a).

If a whale from a resident pod is not photographed swimming alongside other members of its matrilineal group during repeated encounters over the course of the summer field season it is considered missing. If it is again missing during the repeated encounters in the following field season it is considered dead (Bigg et al. 1990, Matkin et al. 1994, Matkin et al. 1999a,b).

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 a given year
NP = number of whales present in a pod at end of the 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

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 an 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 that time. At sexual maturity, fin height will exceed width by at least 1.4 times (Olesiuk et. al. 1990). The fin continues to grow until physical maturity (about 21 years of age).

Sighting data for individual transient killer whales was recorded. The cumulative number of different AT1 individuals was plotted against effort (days in the field) for the 2000 season and compared with similar data averaged for 1984-89 and 1990-1995. AT1 whales that had not been resighted for 6 or more years were considered dead.

Results

The 27 ' diesel inboard/outboard powered bow picker *Whale 2* completed 13 days of surveys in 2000 before being replaced by the 34' diesel powered *F.V. Natoa* which completed a total of 33 survey days. The 26' high-speed motor sailer *Whale 1* completed 26 survey days in Prince William Sound, with the primary objective of humpback whale photoidentification. The 42' diesel powered high-speed charter vessel *Mariah* completed another 5 dedicated survey days and the 36' *Emanuel* made a one day survey in December. Researchers were on the water a total of 83 days and traveled a distance of 7409km in 492 hours searching for and traveling with whales. Effort was divided between the Kenai Fjords and Prince William Sound areas (Figure 1)

Table 1. Effort by vessels in 2000.

Vessel	#Days	Distance(km)	Time (hr)
Natoa	39	3621	231
Whale 1	25	2288	182
Whale 2	13	859	41
Misty	5	587	34
Emanuel	1	54	4
Total	**83**	**7409**	**492**

Killer whales were encountered on 44 occasions in 2000 (Table 2). Researchers spent approximately 142 hours traveling 855 km with killer whales.

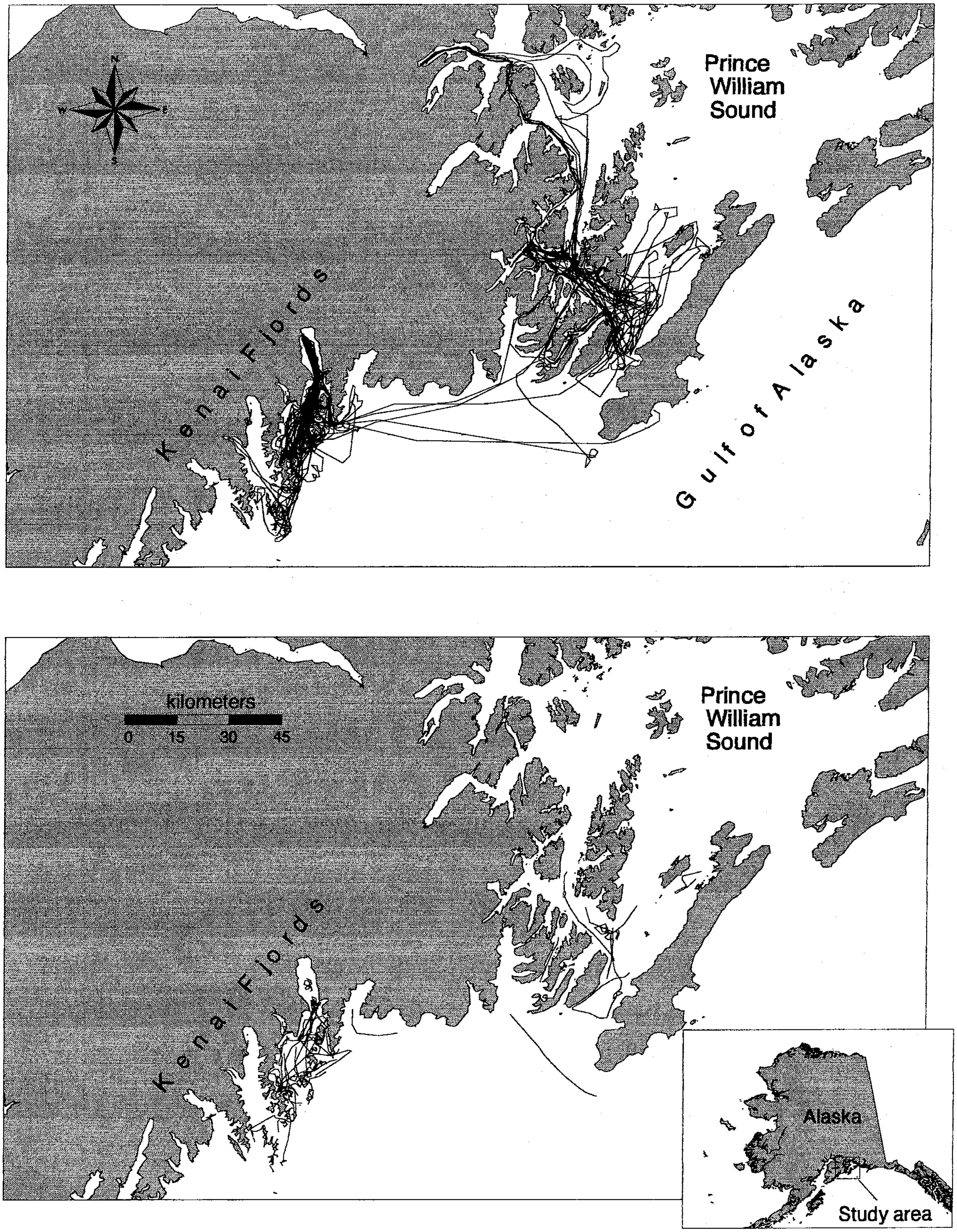


Figure 1. Vessel tracklines (above) and whale encounter tracklines (below) for Prince WilliamSound/Kenai Fjords 2000.

Table 2. Encounters with killer whales by vessel in 2000

Vessel	# encounters	Distance (km)	Time (hr)
Natoa	23	547	95
Whale 1	5	62	5
Whale 2	11	202	35
Misty	4	35	6
Emanuel	1	9	1
Total	**44**	**855**	**142**

In 2000 there were thirty-seven encounters with resident killer whales. There were only two encounters with members of the AT1 transient group, and five encounters with known or probable Gulf of Alaska transients (Table 3).

Overall we had fewer encounters (44) in 2000 than in 1997 (50), 1998 (48) and 1999 (50); however, this reflects a comparable reduction in search effort. We had complete photographic encounters with all the major resident pods used in population analysis (except for the southeastern Alaska centered pods, AG and AF22).

Encounter rates were lower in Prince William Sound than in Kenai Fjords again in 2000; however, the encounter rate in Prince William Sound was over three times higher in 2000 than in 1999. In 2000 in Kenai Fjords, there were 32 killer whale encounters during 47 vessel days for an average of 0.68 encounters/day compared to an average of 0.71, 0.63, and 0.79 encounters per day in 1999, 1998 and 1997 respectively. In Prince William Sound in 2000, there were twelve killer whale encounters in 36 vessel days or 0.33 encounters per day compared to 0.09, 0.29, and 0.14 encounters per day in 1999, 1998 and 1997, respectively. The encounter rate for all areas of 0.53 encounters per day was comparable to 0.51 and 0.49 encounters per day for 1999 and 1998, respectively; however, in 2000 we had more encounters with the larger resident pods such as AJ and AN10. In 2000 we had only 3 encounters with three or more resident pods ("superpods") from late July to September (Table 3). This is similar to 1999, but far fewer superpod encounters than in many previous years (ie. 9 superpod encounters in 1997). It is during these superpod encounters that less frequently observed pods (e.g. AG, AF22, AF05, etc.) are often photographed. Encounters with transient whales were rare (0.09 encounters/day) and scattered throughout the season. This rate was comparable to the 0.10 and 0.07 encounters per day with transients in 1999 and 1998, respectively.

Table 3. Summary of 2000 encounters with killer whales in Prince William Sound (PWS) and Kenai Fjords (KF)

DAY/MO/YR	BEGIN LOCATION	END LOCATION	PODS	REGION	#WHALES
16Mar00	Caines Head	1.5miWSW Fox Is	AJ	KF	36
17Mar00	0.5mi W Thumb Pt	1.5mi S. Thumb Pt	AJ,AB25	KF	44
18Mar00	4mi SSE of Seward	2 mi SE Seward	AJ	KF	36
23Mar00	3mi SW Thumb Pt	1 mi NW Mary's Bay	AJ,AB25	KF	44
16May00#1	3mi W Mary's Bay	2 mi E. Barwell I.	AD16	KF	6
16May00#2	2miNE Cheval I.	N end Rugged I.	AD5	KF	12
17May00	Cecil's Place/Chiswells	Lone Rock/Chiswells	AX	KF	24
18May00	Cheval Narrows	Pony Cove	New Trans.	KF	4
20May00#1	S. end Cheval	No Name I.	AD5	KF	12
20May00#2	N. End of No Name I.	Cape Aialik	unnamed AX	KF	5
24May00	1mi.SE Bear Glacier	1 mi E Tonsina	AK	KF	6
25May00	Marys Bay	2mi W Barwell I.	AD5,AX	KF	37
1June00#1	N end Cheval I.	.75 mi E Porcupine	AK,AD16	KF	11
1June00#2	Pilot Rock	off Bulldog Cove	AD5	KF	12
2 June00	1mi NE Caines Hd.	.25 milesW Sunny Co.	AK	KF	6
27June00	Channel Is, Montag St.	same	AT1,AT14	PWS	2
28June00	Lower KIP	Montague Str.	AE	PWS	18
10July00	Cape Resurrection	same	AT100	KF	1
16July00	Send Rugged Is	Callisto	AK	KF	5
19July00	N end Cheval I.	0.5miSW Mary's Bay	AK	KF	5
20July00	Holgate Arm	Holgate Glacier	AT13,AT17	KF	2
25July00	Wside Rugged I.	Cape Resurrection	AK,AD5	KF	9
26July00	1.5mi S Rugged I.	E. side Cheval I.	AD16&5,AK1,AN10,AI	KF	42
27July00	0.5mi WPilot Rock	2mi E Calistio	AN10,AI	KF	27
5Aug00	59 38/ 148 18	60 01/148 21	AF,AN10,AA	PWS	56
6Aug00	1miNE Pt Grace	1mi E mid Latouche I.	AN10,AE	PWS	38
8Aug00	1miWMummy I. KIP	2miSE Pt. Grace	AN10,AE,AD16AK	PWS	49
11Aug00#1	Needle	Needle	AT109	PWS	1
11Aug00#2	1miNPt Bazil	1mi E mid Latouche I.	AE	PWS	18
13Aug00	Lower KIP	same	?(residents)	PWS	20
14Aug00	1.5mi S Pt Helen	2mi. S Pt Grace	AB,AJ	PWS	61
17Aug00	No Name I.	1mi W Chat I.	AJ,AB25	KF	44
22Aug00	1mi.W. Mary's Bay	N end Cheval I.	AJ,AB25	KF	44
23Aug00	N.end Chiswell I.	Same	AT109	KF	1
25 Aug00	1mi. N. Calisto	1mi. NE Chevall I.	AJ	KF	36
26Aug00	2mi SE Bulldog Cove	2mi S Rugged Is	AJ,AK	KF	41
31Aug00#1	S end Chat Is.	N. End Harbor I.	AD5	KF	6
31Aug00#2	N. end Pony Cove	Chiswell I. (at rookery)	AT50	KF	3
1Sept00	1mi.S Eldorado Narr.	1mi. E. Cape Resurrection	AD5	KF	4
11Sep00	1mi E. Pt Grace	2mi E. Pt Grace	AJ	PWS	36
14Sep00	mid Prince of Wales Pas	0.5mi W Squirrel Bay	AD5	PWS	4
19Sep00	7mi E. Cape Res.	1mi S. Day Harbor	AN10,AB11	KF	21
20Sep00	1mi N Shelter Bay	2mi E Hogan Bay	AB,AJ	PWS	61
24Dec00	1mi S. Caines Hd.	1mi W of Nend Rugged I	AJ	KF	36

Total Encounters: 44 Kenai Fjords: 32encounters /36 vessel days PWS: 12 encounters/ 47 vessel days

Resident pods

In 2000 AD05 and AD16 pods were thoroughly photographed. This coupled with reinterpretation of historic data allowed the addition of these two pods to the group of well-known resident pods (other than AB pod) for which we have maintained recruitment and mortality data since 1985. The total number of whales in these 7 well-known resident pods increased from 81 to 110 whales from 1988 through 2000, while AB pod declined from 36 whales to 25 whales in that same time period (Figure 2). All well known resident pods have increased or are at the same numbers as in 1984 except AB pod (Figure 3). Three resident pods that apparently center their range in southeastern Alaska also increased in number during this period. They totaled 47 whales in 1988 and 75 whales in 1998 (Figure 2). All three of these pods have not been completely photographed since 1998.

From 1995 to 1998, AB pod showed a net increase of three individuals, due to recruitment of five calves and two mortalities. In 1999 AB pod decreased to 24 whales due to two mortalities and the recruitment of one calf. In 2000 we confirmed the previous years mortalities, recorded no new mortalities and observed one new calf, AB 56. The mother of the new calf, AB22, was a juvenile at the beginning of the study and produced her first viable calf in 1988. The total number of whales in AB pod is now 25.

Fig. 2. The number of killer whales in AB pod, in seven other Prince William Sound pods, and in three Sout Alaska pods.
1984-2000

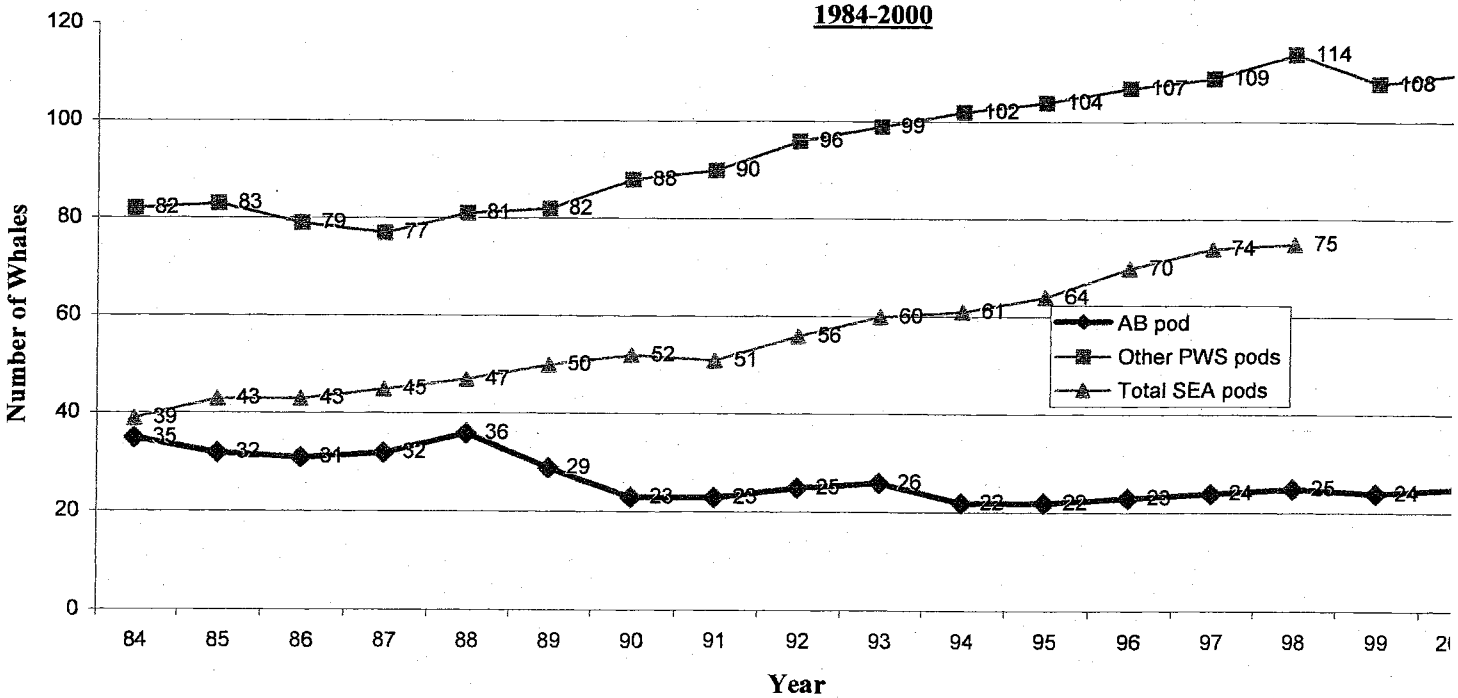
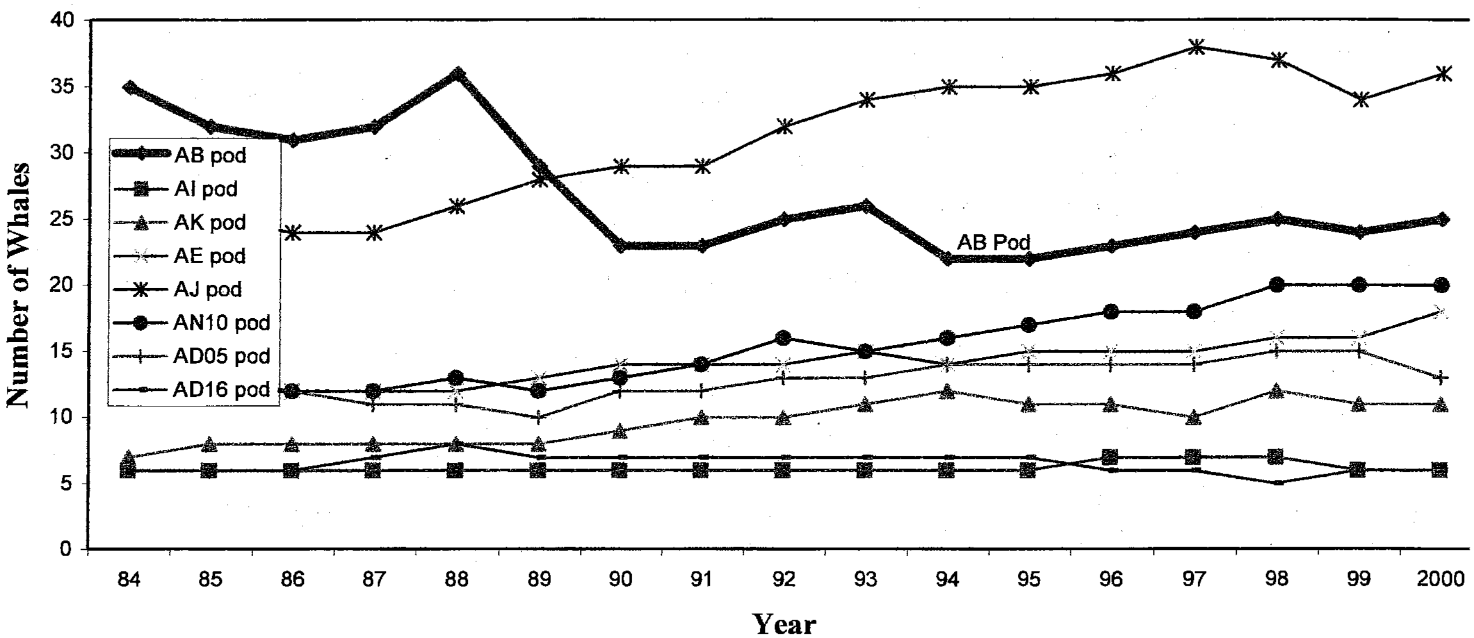


Figure 3. Number of whales in AB pod and in seven other major resident pods 1984-2000



Members of AB pod were encountered on seven occasions in 2000. The entire pod was encountered and photographed only once, on August 14 in Prince William Sound. The first encounter with the pod was 17 March 2000, and they were last photographed on 20 September. In four of the seven AB pod encounters, only the AB25 subpod was photographed and they were traveling with AJ pod in all of these encounters. The AB25 subpod was not encountered without AJ pod present in 2000. One AB pod encounter included only the mature male, AB11, mixed in with AN10 pod. It is not unusual for mature males to temporarily travel with other pods. AB pod was not present during most of the summer field season, and the entire pod was never observed in the Kenai Fjords region. From fieldwork, sighting reports, and data from the remote hydrophone, it also appeared that AB pod was seldom in the Kenai Fjords region in fall and early winter 2000/2001 although they returned in late winter (late February-March).

In 2000 our first encounter with AJ pod was on March 16, and last encounter on December 27. In the ten encounters with AJ pod in 2000, the AB25 subpod was present in six, while the remainder of AB pod was absent in all but one. The numerous encounters with AJ pod clarified recent births and deaths in that large pod which now numbers 36 whales. This is currently the largest well-documented resident pod. In six of the ten encounters, only a part of the pod was present and included the AJ20, AJ24, AJ22, and AJ14 matrilines, and the male AJ25.

A total of 6 calves were recruited into the well-known resident pods other than AB pod in 2000 (Table 4). These were AJ 44, calf of AJ13; AJ45 calf of AJ3; AK16 calf of AK2; AE22 calf of AE10; AE23 calf of AE11; and AD33, calf of AD20. The five

Table 4 Recruitment and mortalities in Prince William Sound resident pods.

	Recruitment in Prince William Sound/Kenai Fjords Resident Pods [whale#(mothers#)]									Southeast Alaska Resident Pods		
POD	AB	AI	AK	AE	AJ	AN10	AD05	AD16		AF05	AF22	AG
YEAR 85			8(6)	13(11)							24(6)21(8)	18(8)19(11)
86	36(23),37(6)		9(2)									
87	38(31),39(25)					38(10)				31(20)29(15)		
88	40(14), 41(8) 42(32)			15(10)	26(22)27(20)	40(35)		20(16)		33(11)	28(4)	16(11)
89	43(17), 44(22)			16(2)17(5)	28(24)29(8)		26(11)			36(5)	27(7)26(8)	17(5)
90			10(2)	18(11)	30(3)	41(8)	21(5)24(7)			35(20)	30(10)	20(4)21(10)
91	45(16)		11(6)			45(35)				38(11)		
92	46(25),47(32)				31(24)32(22)33(13	46(10)47(11	22(7)			34(15)	44(6)40(22)	22(5)23(15)
93	48(26)		12(7)	19(11)	34(3)35(8)36(4)					37(5)51(20)55(11)42(13	48(4)	24(11)
94	49(22)		13(2)		37(18),38(20)	48(8)	23(8)				39(16)	25(8)
95				20(2)		49(11)	25(5)	28(16)		43(11)41(25)		26(6)
96	50(26),51(25)	7(4)			39(13)	50(35)51(12	27(11)			54(20)49(23)	45(6)46(10)47(8	27(15)28(5)
97	52(33), 53(27)				40(3)41(4)	54(10)		29(18)		50(11)		29(14)30(11)31(10)
98	54(17)	8(3)	14(7)15(9)	21(5)		55(8)56(11)	30(7)			52(12)		
99	55(39)				42(24)43(22)		31(8)	32(16)		53(13)	NA	NA
2000	56(22)		16(2)	22(10) 23(11	44(13)45(3)			33(20)		NA	NA	NA
	Mortalities in Prince William Sound/Kenai Fjords Resident Pods [by whale number]									Southeast Alaska Resident Pods		
POD	AB	AI	AK	AE	AJ	AN10	AD05	AD16		AF05	AF22	AG
YEAR 85	9,15,34			8-								
86	1,7,12		5-	4-	23-		9-	17-				
87	28-					6-	1-	15-				
88	6-			7-								1-
89	13,18,21,23,30,31,37			12-		2-	3,10				2-	
90	8,19,20,36,42,44										1-	9-
91	29-										3,7	
92												
93					5-	5-						7,~~16~~
94	2,16,38,41,48			13-	11-					55-		
95			4-				23-					
96	4-					1-	26-			43-		
97	3-		11-			49-						
98		8-			6-							
99	5,52	1-	3-		9,12,16,17,18		12-	18,29				
*2000			8-				7,30	14-				
	*to be confirmed in2001											
(#84/#00)	[35/25]	[6/6]	[7/11]	[13/18]	[25/36]	[12/20]	[13,13]	(6,6)		[12,28)	(12,21)	[15/27]

Table 5. Mortality and recruitment rates in Prince William Sound/Kenai Fjords resident pods.

	Recruitment rates in PWS/KF Resident Pods										Southeast Alaska Resident Pods			
	AB	**AI**	**AK**	**AE**	**AJ**	**AN10**	**AD05**	**AD16**	**non-AB total**		**AF05**	**AF22**	**AG**	**Total SEA**
85	**0**	0	14.3	7.7	0	0	0	0	2.4		0	16.7	13.3	7.7
86	**6.3**	0	12.5	0	0	0	0	0	1.2		0	0	0	0
87	**6.4**	0	0	0	0	8.3	0	0	1.3		16.7	0	0	4.7
88	**15.6**	0	0	8.3	8.3	8.3	0	25	6.5		7.1	7.1	5.9	6.7
89	**0**	0	0	15.4	7.7	0	9.1	0	6.2		6.7	13.3	5.9	8.5
90	**0**	0	12.5	7.7	3.6	8.3	20	0	7.3		6.3	6.3	11.1	8
91	**4.3**	0	11.1	0	0	7.7	0	0	2.3		5.9	0	0	1.9
92	**8.7**	0	0	0	10.3	14.3	8.3	0	6.7		5.6	14.3	10.5	9.8
93	**4**	0	10	7.1	9.4	0	0	0	5.2		21.1	6.3	4.8	10.7
94	**3.8**	0	9.1	0	5.9	6.7	7.7	0	5.1		0	5.9	5	3.3
95	**0**	0	0	7.1	0	6.3	7.1	20	3.9		9.1	0	4.8	4.9
96	**9.1**	16.7	0	0	2.9	11.8	7.1	0	4.8		8.7	16.7	9.1	10.9
97	**8.6**	0	0	0	5.4	5.5	0	16.7	3.7		4	0	12.5	5.7
98	**4.2**	14.3	20	6.7	0	11.1	7.1	0	6.4		3.8	0	0	1.4
99	**4**	0	0	0	5.4	0	6.7	14.3	3.5		3.7	0*	0*	1.3
2000	**4.2**	0	0	12.5	5.9	0	0	16.7	5.6		0*	0*	0*	0*
	Mortality rates in PWS/KF Resident Pods										**Southeast Alaska Resident Pods**			
	AB	**AI**	**AK**	**AE**	**AJ**	**AN10**	**AD05**	**AD16**	**Other than AB**		**AF05**	**AF22**	**AG**	**Total SEA**
85	**8.6**	0	0	7.7	0	0	0	0	1.2		0	0	0	0
86	**9.4**	0	12.5	7.7	4	0	8.8	16.7	6		0	0	0	0
87	**3.2**	0	0	0	0	8.3	8.3	20	3.8		0	0	0	0
88	**3.18**	0	0	8.3	0	0	0	0	1.3		0	0	5.9	2.2
89	**19.4**	0	0	8.3	0	7.7	18.2	0	4.9		0	6.7	0	2.1
90	**20.7**	0	0	0	0	0	0	0	0		0	6.3	5.6	4
91	**4.31**	0	0	0	0	0	0	0	0		0	11.8	0	3.8
92	**0**	0	0	0	0	0	0	0	0		0	0	0	0
93	**0**	0	0	0	3.1	6.3	0	0	2.1		0	0	9.5	3.6
94	**19.2**	0	0	6.7	2.9	0	0	0	2		4.3	0	0	1.7
95	**0**	0	8.3	0	0	0	7.1	0	2		0	0	0	0
96	**4.5**	0	0	0	0	5.9	7.1	0	1.9		4.3	0	0	1.6
97	**4.3**	0	9	0	0	5.5	0	0	1.9		0	0	0	0
98	**0**	14.3	0	0	2.6	0	0	0	1.8		0	0	0	0
99	**8**	14.3	8.3	0	13.5	0	6.7	28.6	8.8		0	0*	0*	0*
2000	**0**	0	9.1	0	0	0	13.3	16.7	3.7		0*	0*	0*	0*
# in pod84/98	**[35/25]**	[6/6]	[7/11	[13/18	[25/36	[12/20	(13,13)	(6,6)	**[82,110]**		(12,28)	(12,21)	[15/27]	**[39,76**
	*entire pod not photographed													

mortalities in AJ pod determined in 1999 were confirmed in 2000. In AK pod, AK8 disappeared in June 2000 and is apparently dead. This male recently became sexually mature and is an unlikely mortality. His death will be confirmed in 2001. There were two mortalities in AD05 pod, AD7, a reproductive female at least 35 years of age, and her most recent calf, AD30, born in 1998. The death of a reproductive female is an unusual event (Matkin et al. 1994). Finally, AD14, an older post- reproductive female in AD16 pod, died. She was at least 52 years of age and possibly older. Births and deaths are listed by pod for 1984-2000 in Table 4 and annual mortality and recruitment rates are listed in Table 5.

We encountered members of 12 different resident pods in 2000 (Table 6) and photographed a total of 196 resident killer whales. Pods that were completely photographed in 2000 included AB, AD16, AD05, AE, AJ, AI, AK, and AN10. Also, three of the four matrilines that compose AX pod (see 1999 catalogue, Matkin et al 1999) were photographed in addition to 5 other individuals classified as "AX" whales in our 1992 catalogue (Heise et al 1992) but no longer considered part of AX pod. AF05 pod was also encountered and photographed, as was a new resident pod, designated AA pod. This new pod contained 8 individuals.

Table 6. Resident pods: number of whales and number of encounters in 2000.

Pod	#Whales	#Encounters
AB	25	7
AJ	36	10
AN10	20	6
AI	6	6
AE	18	4
AK	11	9
AD16	6	4
AD5	12	9
AX*	22	3
AX?	5	1
AA **	8	1
AF05	27	1
TOTAL	**196**	

* pod not completely photographed
** new pod

Transient whales

Only 4 of the original 22 whales from the genetically unique AT1 group were photographed during 2 encounters in 2000. This is the smallest number of encounters we have had with AT1 whales in a season since the study began. One of the whales, AT1, photographed June 27 in the southwestern Sound, died on a beach about 12km east of Cordova in Hartney Bay on July 11 (see below). The other AT1 group whales photographed in 2000 were AT13, AT14, and AT17. These whales had been last photographed in 1998. The other surviving AT1 group whales, AT2, AT3, AT4, AT6, AT9, AT10 and AT18 were all photographed in 1999 but were not encountered in 2000.

Eleven whales in the AT1 group have been missing for nine years or more and are considered dead. With the additional mortality of AT1 this year the group numbers only ten individuals as of late 2000 (Table 7, Figure 4). Since 1989, the number of AT1 individuals identified annually has been 12 or less despite a field effort that exceeded 200 vessel days in 1990 and totaled 120 days in 1997, 98 days in 1998 and in 1999 and 83 days in 2000. There were no new calves identified in the AT1 group in 2000 and there has been no recruitment observed in this group since 1984.

The average number of different AT1 individuals sighted per field day of effort for 1990-1997 was considerably lower than for 1984-1989. In 2000 the individuals sighted per effort was well below the average for both these periods. This pattern has been consistent over the past several years.

Both before and after 1989, all of the AT1 whales photographed in a particular year were generally seen in the first 20 to 60 days of the field season. In 2000, there were no sightings of unphotographed individuals after the first 40 days of the field season (Figure 5).

Seven non-AT1 transients made appearances in the study area. The transient whales AT50 and AT52 were photographed on August 31, and AC22, AC25, AC26, and AC27 were photographed on May 18. The transient AT109 was seen on three occasions during the July/August period, each time near sea lion haulouts or rookeries.

<u>Stranding of AT1</u>

On 12 July 2000 the transient whale, AT1 ("Eyak"), stranded and died near the bridge at Hartney Bay on the road system near Cordova, Alaska. Identification made from photographs was confirmed by genetic testing (AT1 had been previously biopsied) The animal had been sighted in the two previous days in Orca Inlet and may have temporarily stranded the day prior to the fatal stranding (Steve Rainey, pers comm.) This whale was an adult male that developed an adult dorsal fin at the beginning of our study in 1984; hence, we estimated his age at death as 32 years. His length was 24 feet overall and weight estimated at 10,000 pounds. The stocky conformation was consistent with that attributed to transient killer whales in past strandings. The cause of death was not determined. Examination of digestive tract contents yielded three harbor seal tags. Two (563-459-7214) were from a harbor seal pup double tagged at Port Chalmers/PWS spring 2000, which, at tagging, weighed 25.9lbs. The remaining tag was from a harbor seal adult female (lactating) tagged at Applegate Rock/PWS in spring 2000. Its weight at tagging was 48.9 kg. In addition, a large, partially digested male harbor seal (bacculum extracted) was found in the stomach with claws still attached to the flippers and a partial skull. There were dozens of harbor seal claws of various sizes in the aft digestive tract and a ball of hair mixed with harbor seal claws. All parts appeared to be harbor seal (although hair has been submitted for genetic

Table 7. Sighting histories for all AT1 transient whales for years with effort greater than 40 days.

YEAR	*AT01*	**AT02**	**AT03**	**AT04**	*AT05*	**AT06**	*AT07*	*AT08*	**AT09**	**AT10**	*AT11*	*AT12*	**AT13**	**AT14**	*AT15*	*AT16*	**AT17**	**AT18**	*AT19*	*AT20*	*AT21*	*AT22*
84	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
85	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
86	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X
88	X	X	X	X				X	X	X	X	X	X	X	X		X	X		X	X	X
89	X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	-	-	X
90	X	X	X	X	-	X	-	-	X	X	X	X	X	X	-	-	X	X	O	-	-	-
91	X	X	X	X	-	X	-	-	X	X	-	X		X	-	-		X	O	-	-	-
92	X	X	X	X	-	X	-	-	X	X	-	-	X	X	-	-	X	X	O	-	-	-
93		X	X	X	-	X	-	-	X	X	-	-			-	-	X	X	O	-	-	-
94	X				-		-	-	X	X	-	-		X	-	-		X	O	-	-	-
95	X	X	X	X	-	X	-	-	X	X	-	-	X	X	-	-	X	X	O	-	-	-
96	X	X	X	X	-	X	-	-	X	X	-	-		X	-	-		X	O	-	-	-
97	X	X	X	X	-		-	-			-	-	X		-	-	X		O	-	-	-
98	X				-	X	-	-	X	X	-	-	X	X	-	-	X	X	O	-	-	-
99		X	X	X	-	X	-	-	X	X	-	-			-	-		X	O	-	-	-
2000	O				-		-	-			-	-	X	X	-	-	X		O	-	-	-

X whale present

- whale missing, believed dead

0 whale known dead

Figure 4. Number of Whales in the AT1 Transient Group 1984-2000

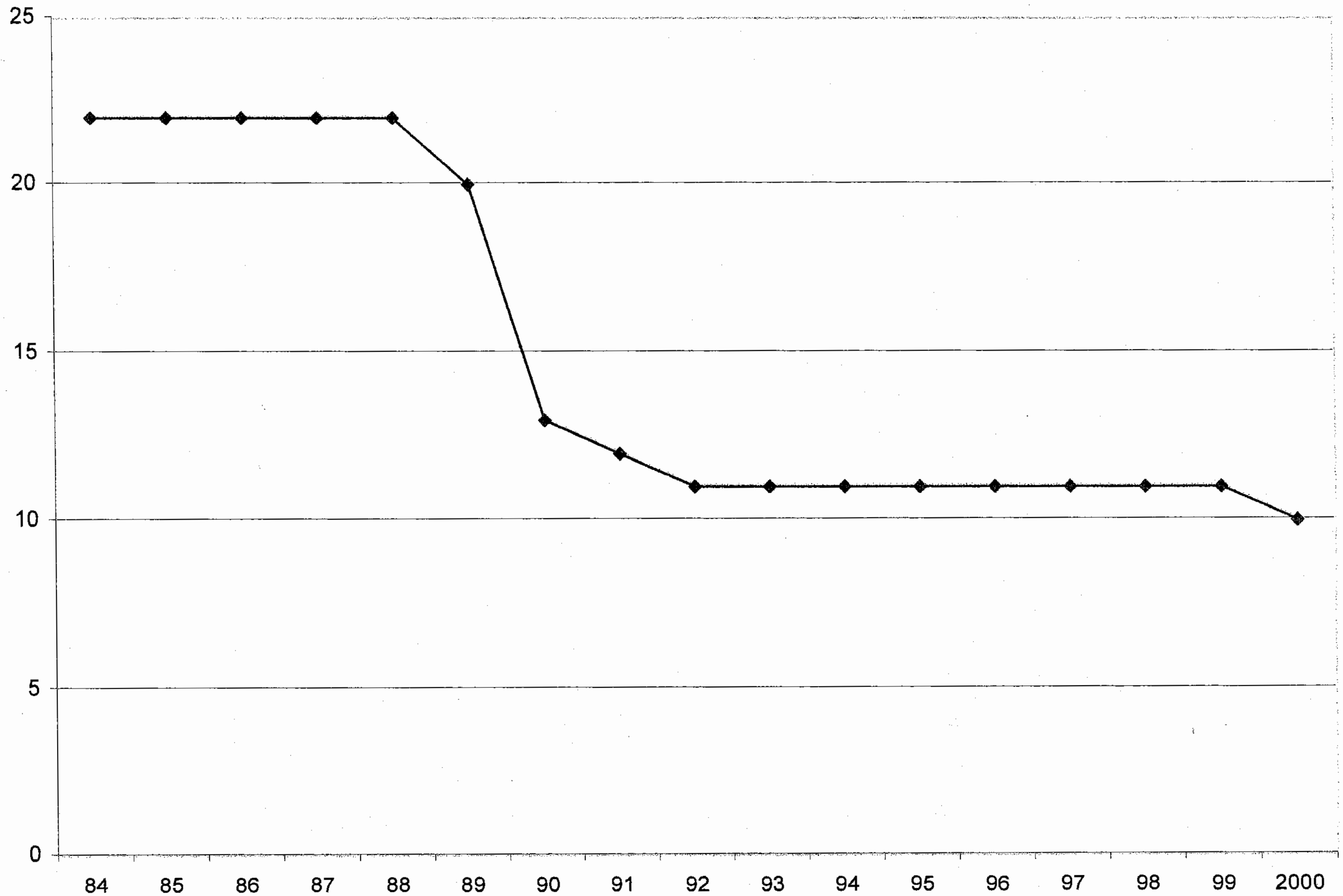
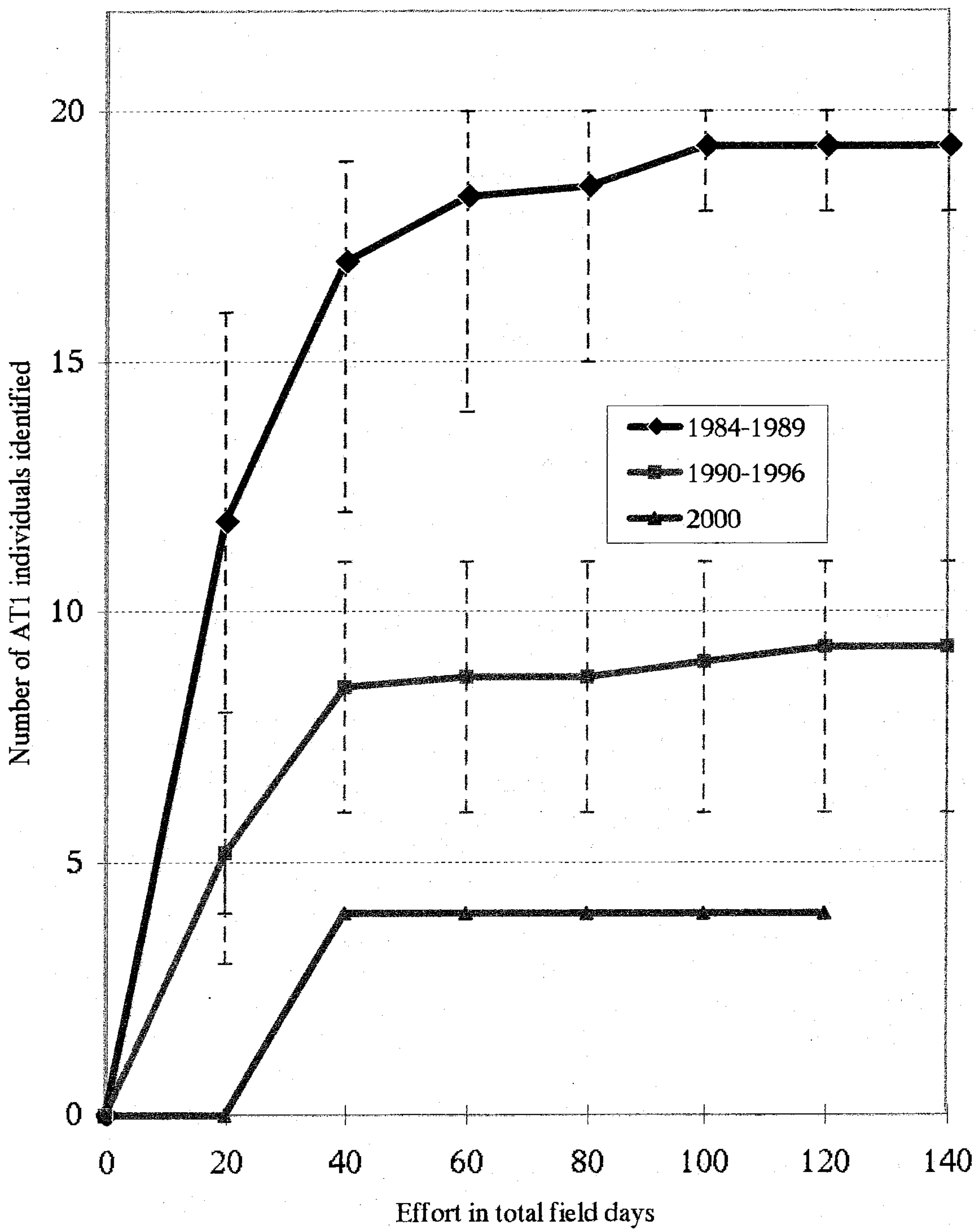


Figure 5. Average number of AT1 transient group whales identified for years with effort greater than 60 field days
(error bars = range)



testing). This confirms field observation that indicated this whale was a harbor seal specialist. The AT1 group has been observed to eat primarily harbor seals and Dall's porpoises.

The whale is being skeletonized to be part of an exhibit planned by the Eyak Tribal Council and the Prince William Sound Science Center for display in Cordova.

Discussion

There was a net gain of one individual in AB pod in 2000, and no new mortalities. Although there is still no clear trend toward recovery of this pod to pre-spill numbers, we are hopeful that this signals a return to reduced mortality rates necessary for the pod's eventual recovery.

Population analysis suggests that in resident killer whales, there is a relatively steady rate of calf production over time and that mortality rates determine the net gain or loss within the population or pod. Although calf production may vary from year to year due to environmental factors, over an extended period the calf recruitment rate in our region as well as in British Columbia has been quite consistent. The pregnancy rate may be substantially higher than the recruitment rate (Olesiuk et al 1990, Population Modeling, this report) with calves not surviving in years where the mother is not in good enough condition to support the newborn nutritionally. Pregnancy has a relatively small energetic cost compared to the energetic cost of rearing a calf that may nurse for several years. The long calf recruitment intervals for some females (up to 10 years) may reflect the inability of females to support new calves energetically in many years. In this case, females may have become pregnant, but the calves died at birth or prior to our initiation of fieldwork

Unexpected mortalities cannot be easily offset by increased calf recruitment (see following section, Population Modeling). From observations in Alaska and British Columbia, we suspect that recruitment rates of around five percent are near the maximum rate for resident killer whales. Populations in both British Columbia (northern resident population) and our area have shown net increases over the past 15 years and may still be recovering from some past perturbation that increased the mortality rate. In the past, shooting of killer whales may have been a regular occurrence as evidenced in British Columbia by the numerous bullet wounds observed in whales taken into captivity in the 1970s. Also, there was bullet wounding and unexpected mortalities in AB pod during interactions with commercial longline fisheries in the mid 1980s, which may have affected our population model (see section Population Modeling). Although we do not suspect that this is a current problem or the cause of the unexpected mortalities in AB pod at the time of the spill, this may be an historic factor that reduced the now increasing resident killer whale populations. Additionally, salmon populations were very much reduced from historic numbers prior to the late 1970s. It is not unlikely that carrying capacity for resident killer whale has increased in the past 25 years due to recovering salmon populations. Despite population wide increases of resident killer whales, AB pod has not recovered from losses at the time of the spill, for reasons that have become more explicit in our model (see Population Modeling)

As was the case in 1999, AB pod appeared to be using the Resurrection Bay/Kenai Fjords on a regular basis in late winter and early spring 2000. However, they were absent during the summer and early fall months. They were present in southwestern

Prince William Sound in late summer, however. Killer whales were irregularly sighted in the Kenai Fjords region by researchers and tour boats in September and October 2000, as was the case in 1999. This contrasts with the large groupings seen in the area in previous years (Matkin et al 1998).

The rate of encounter with killer whales in Prince William Sound was higher than it had been in most years. AB pod was seen in Sound only in late summer/fall and not in Kenai Fjords. This may signal a return to patterns of distribution for resident killer whales that we have not seen since the early 1990s.

Repeated encounters with AD05 and AD16 pod has allowed us to bring these groups into the list of well-known resident pods for which we closely track mortality and recruitment rates. This increase in sample size increases our confidence that the patterns in recruitment and mortality that we see in these pods reflect that of the entire resident population that uses the northern Gulf of Alaska region.

Again in 2000, resident killer whales were observed frequently in May and early June by tour boat operators and during our field operations in Kenai Fjords. Pods that repeatedly used the area at this time included AD05, AD16, AK, and occasionally AX. In May, the whales appeared to be feeding on king salmon. Many of the pods we expected to see in Kenai Fjords in late summer and fall (eg. AB, AI, AJ, AN10, AX) again made only brief appearances in 2000, unlike 1996-98 when they spent extended periods in the region. This may have been in part due to another poor return of coho salmon to Resurrection Bay. The residents are known to feed on coho salmon *(Oncorhyncus kisutch)* in late summer and fall (Saulitis et al. 2000). We did not observe the repeated large social aggregations (superpods) that were observed in Prince William Sound in the late 1980s and Kenai Fjords in the mid 1990s.

There was another mortality (the male AT1) in the AT1 transient group, reducing the number of whales in the group to 10, compared to a total of 22 prior to the 1989 spill. Again, there has been no observed recruitment into the AT1 group in 2000 and has not been since 1984. It is uncertain if any of the AT1 whales are capable of recruiting a calf since there has been no recruitment in 16 years. The suspected female AT3, born in 1984, may be the only potential for reproduction in the group. In addition, the high contaminant levels in this group could interfere with reproduction

The surviving members of the AT1 group are seen less frequently than in pre-oil spill years, and we suspect they now are forced to range more widely in search of prey because of the severe reduction in harbor seal numbers in the region. They may also be forced to forage further offshore for porpoises, reducing our ability to locate them. Although we no longer observe and photograph all of the remaining 11 whales in a given year, we have not received photographs of these whales from adjacent areas and suspect that they do not range far from the Prince William Sound/Kenai Fjords region. This group has been determined genetically distinct by mtDNA and nuclear microsatellite DNA analysis and is acoustically distinct from all other pods and groups sampled (Saulitis et al., in review).

POPULATION MODELING

Introduction

After 17 years of monitoring individual life histories (Matkin et al 1999b), establishing genealogies (Matkin et al 1999a) and using comparative data from British Columbia (Olesiuk et al 1990), we have initiated the construction of a population model for the resident killer whale population in the Prince William Sound/Kenai Fjords region. There are limitations to the modeling approach due to the relatively short duration of the study in relation to killer whale life span. We have observed these whales for only 17 years or approximately one generation. Female calves that were born at the beginning of the study are now beginning to produce calves. Nonetheless, the initial modeling exercise and comparison to a model developed with longer term data from British Columbia has established population attributes and indicated data needed for further analysis. With field data collected in 2001 and a reanalysis of old photographic data, we hope to refine and extend the modeling effort and submit a manuscript in 2002.

Methods

Killer whales used in this analysis were aged using the following criteria:

1) Animals born during study were aged on basis of year first observed or on their size if they were not seen in the year of birth. In addition, three females born several years prior to study were aged on the basis of size when first seen. These are referred to as known-aged animals, although the latter might actually be known to within +/- 1 or 2 years.

2) Males that were juveniles when first seen but too large to estimate based on size were aged by subtracting mean age of onset of sexual maturity (13.4 years) from the year the dorsal fin began to sprout.

3) Males that were sexually but not physically mature when first seen were aged by subtracting mean age of onset of physical maturity (18.8 years) from the year by which the dorsal fin was fully developed.

4) Males that were physically mature when first seen were aged on basis of the year they were first seen (these are considered minimum ages).

5) Animals that were approaching adult size when first seen but died before maturing were aged based on their size when first seen (these are considered crude ages).

6) Females that were juvenile-size when first seen were aged by subtracting mean age of first recruitment (14.8 years) from year they gave birth to their first viable calf.

7) Females that were adult-size when first seen were also aged by subtracting mean age of first birth (14.8 years) from year of birth of oldest known calf. Since these females may have given birth but lost older progeny prior to the start of the study, a correction was applied to account for this calf loss. For example, if the female had lost her first calf, she would have been one calving interval older; if she had lost her first two calves, she would have been two calving intervals older, etc. Based on calving rates and survival rates of calves, a probabilistic correction factor was calculated as outlined in Section 3.1.2 of Olesiuk et al. 1990. The corrections increased as a function of the age of the oldest known offspring when first seen, and ranged from 0.7 when the oldest known offspring was first seen at age 0, to 1.4 when first seen at age 10, to 2.8 when first seen at age 20, to 5.4 when first seen at age 30. (Note: for 6 females, the oldest offspring were minimum-aged males, so their ages and the correction factors are also minimums).

We used life history parameters based on northern resident model in British Columbia, which is considered the best data (and represents a population increasing at its intrinsic rate. The most important parameters are for the females, since they drive the model. The age estimates are contingent upon three main parameters: 1) age at birth of first viable calf; 2) calving intervals; and 3) juvenile survival rates (the latter two are required for the correction factors). In our cursory comparison, these parameters seem to be similar for Alaskan pods, and thus not likely to have major effect on age estimates.

Once ages had been estimated, we examined whether the Alaskan pods conformed with the B.C. model (i.e. were indicative of population increasing at its intrinsic rate). The expected number of births each year was estimated as:

$$\text{Births} = Nf(x) \bullet FEC(x)$$

Where Nf(x) represents the number of females of age x and FEC(x) the age-specific fecundity rate as given in equation 26 of Olesiuk et al. 1990 (but updated to include data to the late 1990s). The expected number of juvenile, female and male deaths each year was estimated as:

$$\text{Juvenile Deaths} = N(x) \bullet MR(x)$$

$$\text{Adult Female Deaths} = Nf(x) \bullet MRf(x)$$

$$\text{Adult Male Deaths} = Nm(x) \bullet MRm(x)$$

Where N(x), Nf(x) and Nm(x) represent the number of juveniles of either sex, adult females and adult males aged x in that year, MR(x) is the age-specific mortality rates of juveniles aged less than 15 of both sex as per Table 9 in Olesiuk et al (1990) but updated to included data to the late 1990s, and MRf(x) and MRm(x) represent the age-specific mortality rates of females and males aged 15 or greater as per Table s 11 and 12 respectively in Olesiuk et al (1990) again updated for data to the late 1990s.

We then compared the observed and expected number of deaths, and to dampen year-to-year fluctuations due to stochastic events (births and deaths are integers, where predicted values are real numbers), we also calculated 3-year running means of the ratio of observed to expected values.

Since there were far more deaths in AB-pod than expected in 1989-90 following EVOS, we examined the effects of these losses. During 1989-90, there were 14 deaths in this pod, when only 1.14 would have been expected. The 14 deaths included two juvenile females, six juveniles of unknown sex, four reproductive-age females, three of which had recently matured. In order to estimate the lost production from these animals, we projected their production in the decade following their disappearance:

$$N_{t+1} = \mathbf{M} \bullet N_t$$

Where **Nt** is a vector giving the number of animals by age and **M** the Leslie projection matrix giving the age-specific fecundity and survival rates (see Section 4.1 in Olesiuk et al 1990 for details).

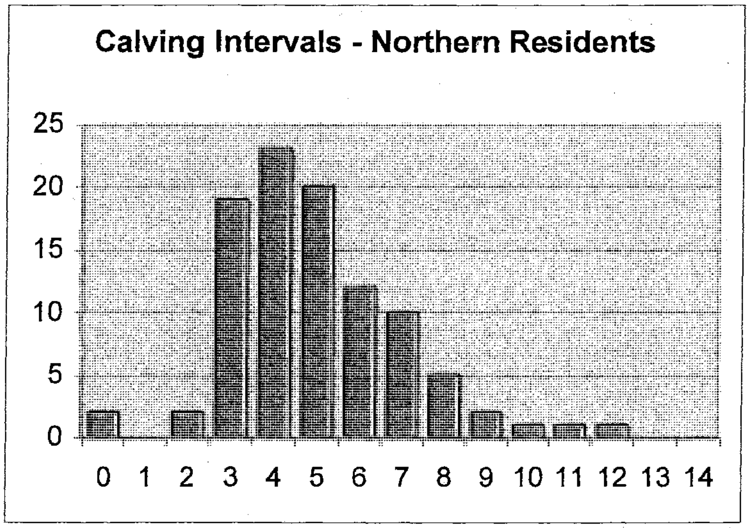
For the six juveniles of unknown sex, we assumed half were female (each was counted as 0.5 females in the vector). In each year, we summed the estimated number of animals that would have been born to the animals that disappeared and would have survived, and added them to the observed size of AB-pod.

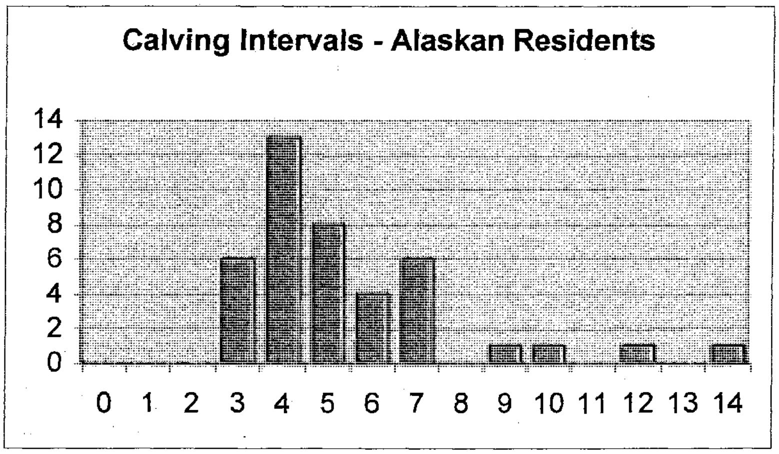
Results

Data were insufficient to accurately determine age of first reproduction for the Alaska resident killer whale population. At this time we have observed only three known-aged females give birth to their first viable calves during the study. Since these were the first maturing females, their age at first reproduction (12 years) was likely low-biased compared to the average. If we include AB33, AD18 and AN12, which were first seen at age three, two, and three years and gave birth at estimated ages of 16, 15 and 15 respectively, the age of first viable reproduction appeared similar to that determined for northern resident killer whales in British Columbia, 14.75 years. This figure was used in other calculations in this preliminary model.

The calving interval was determined for known reproductive females in the Alaskan population. The calving intervals for British Columbia residents and Prince William Sound/Kenai Fjords residents are compared in Figure 6.

Figure 6. Calving intervals for B.C. northern residents (Olesiuk 1990) and for Alaskan resident killer whales (1984-2000)





Calving intervals in the northern B.C. residents and PWS/Kenai Fjords residents were very similar, (mean 5.17 and 5.39, respectively). The rate was nearly the same whether AB-pod was included or excluded; the AB pod mean of 5.33 was similar to the rate of other Alaskan pods of 5.40.

We examined survival rates for various sex and age classes. The rates for juveniles were very similar for our population and the northern B.C. residents. Except for AB-pod, the overall survival of viable calves to age 15.0 (approximate age of onset of maturity) was 0.79 for all Alaskan pods, which was similar to 0.77 in northern B.C. residents. Juvenile survival dropped to 0.66 when AB-pod was included since survival of this age class within AB pod was only 0.33 due to deaths at the time of the oil spill. In the overall population, the adult female survival rates over the 25-year reproductive lifespan were 0.69. This is substantially lower than the British Columbia rate 0.85.

Primarily this is due to the sharp increase in mortality of females in their late 30's in the Alaskan population.

We modeled the expected number of births and deaths (broken down by juveniles, adult females and adult males) for the study period (1984-2000) had the Alaskan pods conformed to the northern B.C. resident model (Table 8). The resident pods in our study are producing calves at about the expected rate, or slightly higher. There were 70 births compared to 65.3 expected in pods other than AB-pod, and 21 births versus 15.9 expected in AB-pod. The higher than expected production of calves in AB-pod continued after EVOS; during 1990-2000 there were 12 births versus 9.0 expected. The number of deaths in all pods except AB-pod was slightly higher than expected (39 versus 31.5 expected). The actual number of deaths was very close to expected for juvenile and adult males (12 versus 13.28 and 11 versus 11.67, respectively), but there were 16 adult female deaths which was far higher than the 6.6 expected for the Alaskan population.

Table 8. Actual and predicted births and deaths in AB pod and other Alaskan pods based on the model developed for British Columbia northern resident killer whales.*

	All pods except AB pod		**AB pod**	
	Predicted	*Actual*	*Predicted*	*Actual*
Births	65	70	16	21
Deaths (total)	31	39	8	31
Juvenile deaths	13	12	4	15
Male deaths	12	11	3	6
Female deaths	7	16	2	10

*Olesiuk et al. 1990.

Comparison of the actual and expected number of deaths in AB-pod indicates mortality was much higher than expected for all sex and age classes over the course of the study (1984-2000). There were 31 deaths when only 8.1 were expected. The discrepancy between actual and expected was most pronounced for females and most of those deaths occurred following the *Exxon Valdez* oil spill.

The population trend for pods excluding AB-pod shows an exponential increase over the study period at a finite rate of 2.4%, which is similar to the 2.9% in B.C. northern residents (Figure 7). However, a large number of deaths (7) in 1986 reduced the finite rate of increase in the Alaskan population. The rate after 1986 of 2.9% is consistent with B.C northern residents (Figure 8).

Figure 7. Population trend for all pods other than AB pod for 1994-2000.

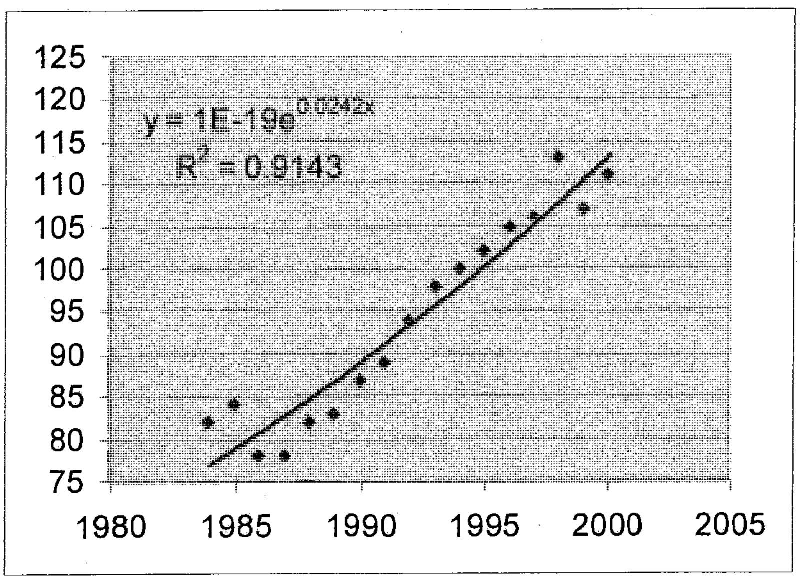
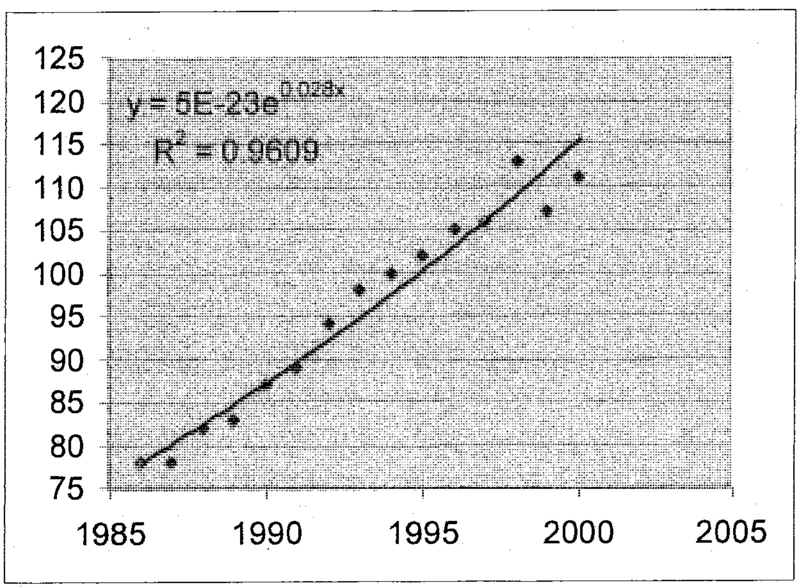


Figure 8. Population trend for all pods other than AB pod for 1997-2000.



Finally, we examined AB-pod, which declined following the 1989-90 EVOS and has shown little sign of recovery. As indicated in Matkin et al. 2000, calving rates did not decline within the pod following 1990 despite the mortalities associated with the *Exxon Valdez* oil spill. Although the mortalities since 1990 have remained greater than expected (9 actual deaths, 5 expected, the lack of recovery is almost exclusively due to the loss of many young females which, had it not been for the EVOS, would presumably still be present and producing calves. The actual and projected size of AB-pod had the females that disappeared in 1989-90 continued to produce and die at the expected rates based on the B.C. model are given in Table 9. This indicates that without the loss of females, the pod would have fully recovered by now.

Table 9. Number of whales in AB pod 1994-2000; actual and projected if no females had been lost at the time of the oil spill.

Year	1994	1995	1996	1997	1998	1999	2000
Actual	22	22	23	24	25	24	25
Projected	28.4	29.7	31.7	33.7	35.7	35.7	37.9

Discussion

Our population modeling efforts initiated in 2000 were constricted by two factors:

1) *Lack of recent encounters with AG, AF05, and AF22*. Although AG, AF05, and AF22 pods seem to center their range in southeastern Alaska, they are clearly connected acoustically and genetically with the Prince William Sound/Kenai Fjords residents. We have accurate data for these pods reaching back to 1984 except for the previous two years and, with more data, we could include them in this model.
2) *Lack of enough years of data to establish accurate average age of first reproduction for females*. Because females generally do not mature (produce their first viable calf) until 12 years of age or older, we now observe calving only for early maturing females born during the study.

The similarity of the preliminary age at first birth and the calving intervals for northern B.C. residents and the resident killer whales in our study indicates that calves are being produced at similar rates in both populations. Since these parameters as well as juvenile survival were quite similar between the populations, we confirmed that is was reasonable same techniques and parameters to estimate ages of Alaskan whales (as described in the Methods).

Our population model diverged from the B.C. northern resident model markedly in the lower survival rates in Alaska female killer whales (excluding AB pod). This may partly be due to underestimation of the ages of some females because aging was based on physically mature male offspring. The genealogies of some of these whales may need reexamination. The mortalities in 1986 may have also contributed to a higher overall mortality rate. However, in Alaska, more adult females than adult males died (16 versus 11) which is the opposite of what occurs in the northern residents where females are more longer-lived than males. Even so, the sex ratio of adult males to females in Alaskan pods is skewed toward females (range 1.8 to 1.2; average 1.36), but less so than predicted by the B.C. model (1.63). This will be examined in greater detail after reexamination of genealogies and ages of some of the older females.

Preliminary models indicate all pods except AB-pod essentially conform with the B.C. northern resident model, although adult female mortality appears to be higher. Since this occurs toward the end of the reproductive lifespan, it doesn't have much impact on the productivity of the population.

ACOUSTICS

Introduction

In our previous annual report (Matkin et al. 2000) we presented the results of our analysis of pod specific call repertoires of seven resident pods, AB, AD (now AD5 and AD16), AE, AI, AJ, AK, AN (now AN10 and AN20). We demonstrated that the two acoustic clans that exist in the Prince William Sound/Kenai Fjord community, AB-clan (AB, AI, AJ, AN10, and AN20 pods) and AD-clan (AD05, AD16, AE, and AK pods) do not share calls. In a more detailed analysis of this pattern (Yurk et al., in review), we showed that these clusters are distinct vocal clans. Among vocal clans, acoustic non-similarity among pods of different clans matches their genetic distinction based on mitochondrial DNA (Barrett-Lennard 2000). In this report we will present the results of an analysis of inter-observer reliability in recognizing killer whale call-types. This analysis is on-going and shows the accuracy of the qualitative structural analysis method used to classify killer whale call types.

In the current report, we also detail the results of an analysis of recordings made in Resurrection Bay in March 2000. This hydrophone was moved to its present location at Thumb Point, Resurrection Bay when noise from swells acting on gravel beaches adjacent to its original location of Fox Island made winter recording impossible. The current location has proven acoustically superior and logistically simpler to maintain. It tracks animals that use inner Resurrection Bay.

Methods

Analytical techniques used to analyze calls follow Matkin et al. (1998) and are similar to those developed by Ford (1984) for resident killer whales in British Columbia. These techniques have also been applied successfully to vocalizations of resident-type killer whales in Norway (Strager 1995), and to vocalizations of an isolated transient group of killer whales called AT1 in Prince William Sound, Alaska (Saulitis et al., in review). We combined a qualitative structural analysis of call types with a quantitative call-type frequency analysis (Matkin et al. 1999) to assess pod identity in remote hydrophone recordings. The results of calculations of call type usage differences among closely related pods is presented in Table 10.

Table 10. Call type frequency indices for pods that share a considerable proportion of their repertoire.

	AB CLAN			AD CLAN	
Call type	***AB POD***	***AI POD***	***Call type***	***AE POD***	***AK POD***
AKS 11 i	.16	.03	**AKS 01 i**	n/a	.30
ii	.07	.01	**AKS 02 i**	.35	n/a
AKS 13	.1	.02	**ii**	.33	n/a
AKS 14	.14	.01	**iii**	.15	.01
AKS 17 i	.06	.39	**AKS 05**	.04	.04
ii	.01	.18	**AKS 09 i**	.01	.20
iii	.02	.08			

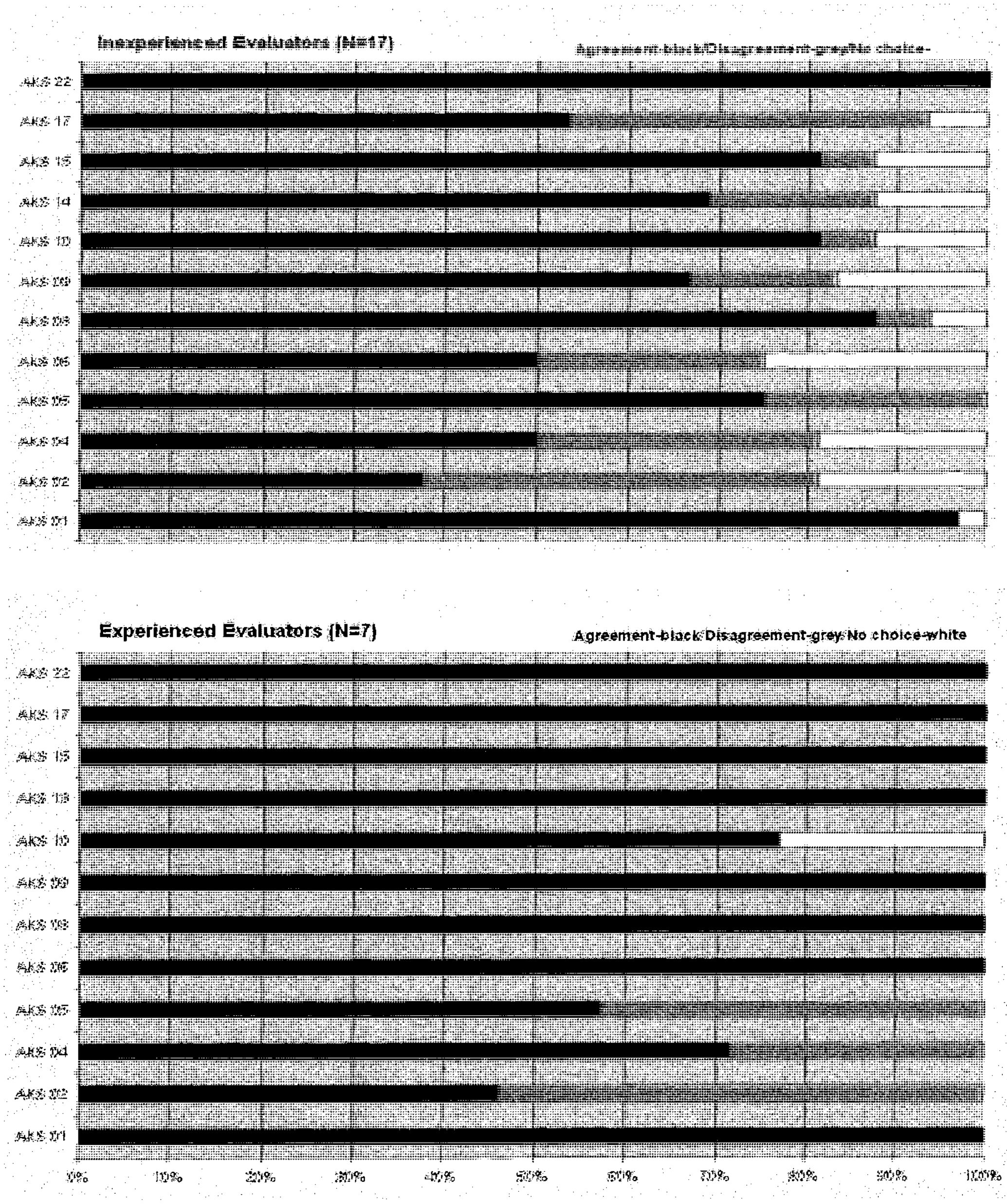
To test inter-observer reliability in call type recognition, we played samples of classified calls to two groups of human observers for re-classification. Group A consisted of 17 individuals unfamiliar with either killer whale or other cetacean vocalizations, and group B consisted of 8 individuals that had experience in classifying killer whale and/or other cetacean vocalizations. Each individual was asked to find the most similar call to a sample call among four similar sounding calls. Calls were presented in two test sequences consisting of 10 calls each. First, individuals from groups A and B both evaluated the same test sequence. In the second test sequence, group A individuals evaluated calls with equal degrees of similarity to the first sequence, while group B individuals were given call samples with higher degrees of similarity. In total, 12 call types were evaluated by both groups to identify possible effects of experience on call-type recognition. The test with higher similarity for group B was done with seven call variants. Different examples of the same call-types were used in more than one evaluation to minimize influences of variation in different recordings of calls. Results were arcsine square root transformed and mean differences between observer groups tested using a paired Student t-test.

Results

Inter-observer reliability in call-type classification

The results of classification of 12 call types that had similar sounding alternatives by inexperienced and experienced observers indicated high degree of agreement with our analytical results (based on measurement of sonograms). The evaluations showed that on average, 71% (geometric mean = 68%, sd = 20) of the inexperienced evaluators agreed with our call type classifications and 88% (geometric mean = 85%, sd = 20) of the experienced evaluators did so (Figure 9). The mean difference of 17% between the two groups was significant at $p=0.02$ (paired Student t-test; $t_{11}=-2.841$).

Figure 9. Results of the call type evaluations by 17 observers without previous experience and 7 observers with previous experience with cetacean vocalizations.



Discrepancies between the call type classifications we made and those of the experienced evaluators occurred for three call-types (AKS 16, 19, and 26), while agreement was near 100% for other call types. This analysis contributed to our conclusion that these call types should not necessarily be regarded as discrete forms.

In Table 11 we present an updated list of all identified call types from the seven pods AB, AD, AE, AI, AJ, AK, and AN.

Table 11. List of all identified call types of southern Alaskan residents and their variants in alphanumerical order. An X in the appropriate column indicates call types produced by an individual pod. Pods that share call types are grouped together.

Pod Names	**AB**	**AI**	**AJ**	**AN**	**AD**	**AE**	**AK**
# Matrilines	**11**	**1**	**8**	**13**	**6**	**5**	**2**
# Whales*	**25**	**7**	**38**	**51**	**24**	**16**	**11**
AKS 01 i					X		X
ii					X		X
iii					X		
AKS 02 i						X	
ii						X	
AKS 03					X	X	X
AKS 04 i					X	X	
ii					X	X	X
AKS 05					X	X	X
AKS 06						X	
AKS 07					X		
AKS 08					X		
AKS 09 i					X	X	X
ii					X		X
AKS 10 i	X			X			
ii	X	X	X	X			
AKS 11 i	X	X	X				
ii	X	X	X	X			
AKS 12	X						
AKS 13	X	X		X			
AKS 14	X	X		X			
AKS 15 i	X	X	X	X			
ii	X	X	X	X			
AKS 17 i	X	X		X			
ii	X	X					
iii	X	X		X			
iv				X			
v				X			
AKS 18	X	X	X	X			
AKS 20				X			
AKS 21	X	X		X			
AKS 22	X	X		X			
AKS 23			X				
AKS 24 i			X				
ii			X				
AKS 25	X	X	X				
AKS 27			X				
AKS 28			X				
AKS 29			X				
TOTAL	17	14	13	15	11	8	7
1998 Census							

Analysis of remote hydrophone recordings

The remote hydrophone at Thumb Point in Resurrection Bay was monitored on 100 days between October 5, 1999 and April 29, 2000 for a total of 516 hours and 15 minutes. Resident killer whales were heard on 17 days for a total of 36 hours and 12 minutes. During 10 different sessions on nine days in March 2000, 360 minutes of recordings were made from resident killer whales. The days and time of recordings and the recorded call-types with acoustically identified pods are presented in Table 12.

Table 12. Summary of March remote recordings from Thumb Point, Resurrection Bay.

Date	Whales heard (min)	Call Types (AKS)	Call-Type-Frequency Index	Pods present
March 14, 2000	50	10ii, 14, 23, 24i, 24ii, 25	for AKS 14: ~.14	AB, AJ
March 15, 2000	35	11i, 14, 18, 23	for AKS 14: ~.14	AB, AJ
March 16, 2000	215	11i, 14, 23	for AKS 14: ~.14	AB, AJ
March 17, 2000	220	23, 25	n/a	AJ (AB or AI)
March 18, 2000	10	16i	n/a	AF or AG
March 19, 2000	215	14, 15, 24ii, 25	for AKS 14: ~.14	AB, (AI), AJ
March 20, 2000	??	14, 15, 23, 24ii	for AKS 14: ~.14	AB, AJ
March 21, 2000	135	14, 25	for AKS 14: ~.14	AB, (AI or AJ)
March 22, 2000 (AM)	65	10, 14, 18	for AKS 14: ~.14	AB
March 22, 2000 (PM)	90	14, 23	for AKS 14: ~.14	AB, AJ

Detailed call classification analysis for the major resident pods within each acoustic clan allowed us to refine our ability to more accurately infer the presence of pods based on remote hydrophone recordings. For example, on March 14, 15, 16, 20 and during the second recording session on March 22, were able to determine that AB and AJ pods were both present. On March 19, AB and AJ pods were present again; however, there was some indication of the presence of AI pod because we recorded the AKS25 call type, one that is used by AJ, AB and AI pods. However, the specific acoustic structure of the AKS25 type calls recorded that day resembled more closely the AB-pod "version" of the call. Also, no AKS17 call types, the most frequently emitted call by AI pod, were recorded. Therefore, it's most likely that only AB and AJ pods were present.

On March 17, AJ pod was likely the only pod present. There were no AKS14 or AKS17 call types recorded which are commonly heard when AB pod is present. Furthermore, the acoustic structure of the recorded AKS25 type suggests that they were produced by AJ pod. Likewise, we determined that during the first session on March 22, AB pod was the only pod present, and, because of the acoustic structure of the AKS 25 types recorded on March 21, that AB pod was the only pod present during that recording.

On March 18, acoustic structures of calls allowed us to document the presence of either AF or AG pods, which normally center their ranges in southeastern Alaska, and which have never before been documented in our region during the non-summer months.

Discussion

Call-type recognition tests showed that our classifications of killer whale call types were reliable with regard to the ability of human observers to discriminate different types. The inter-observer reliability for call type classification has been very high in other studies as well (Bain 1986; Deecke et al. 1999).

Although the remote hydrophone system has had some developmental problems, it is proving a useful tool in winter monitoring of the resident killer whale population. It is clear that movements of acoustically identifiable whales through specific areas can be reliably mapped on a day-to-day basis using this system. In the future, a network of hydrophones could track wide-ranging movements as well as identify important areas of winter range for particular pods. Our results so far indicate that, especially in March, Resurrection Bay is an important part of the winter range of the oil spill damaged AB pod as well as for AJ pod, the largest of our well known resident pods.

TOURBOAT AND MARINE MAMMAL INTERACTIONS: WORKSHOP AND FIELD OBSERVATIONS

Introduction

The viewing of sea otters, Steller sea lions, killer whales, humpback whales, gray whales and occasionally fin whales has become an important component of Kenai Fjords National Park/ Resurrection Bay vessel tours that now attract in excess of 100,000 patrons annually. Sightings of whales in the area, particularly killer whales, have increased in recent years along with the increased public desire to view the whales. As commercial tour boat vessels maximize viewing opportunities, there is increasing pressure on all species of marine mammals, particularly killer whales and humpback whales. The National Park Service and others have become increasing concerned that whale harassment regulations are being violated. We are concerned that the effect of the *Exxon Valdez* oil spill on killer whales not be exacerbated by other anthropogenic factors.

For the past three seasons (1997-99) we worked informally and opportunistically with operators and owners of tour boats both on the water during our field research and on dockside after hours. Our goal has been to provide a more educational experience for clients and a less stressful experience for the whales. In addition, with the assistance of the tour boat companies, we published and distributed a book/catalogue of individual whales that included research results and whale viewing guidelines. Since in this region the whale watching industry is still in its formative stages, and the turnover rate of vessel operators and tour boat owners is low, there is an excellent opportunity to instate a formal training program for non-invasive whale viewing and visitor education.

Methods

1) Pre-season operators' workshop

Two evenings of interactive workshops were conducted on May 16 and May 17 2000. The workshops emphasized development of workable guidelines for marine mammal viewing designed by the operators with assistance from facilitators.

Initially, facilitators presented the latest findings from studies of whale behavior and of reaction of whales to vessels and fielded questions regarding these studies. Operators then broke out into groups, each looking at specific sub-topics, which were:

1. Vessel behavior around resident and transient killer whales
2. Vessel behavior around pinnepeds
3. Vessel behavior around baleen whales
4. Interpretation of marine mammal encounters for visitors
5. Timing of vessels around whales and communication among vessels
6. How to deal with problem operators

These workshops took an interactional approach; participants were encouraged by facilitators (who moved between groups) to share their experience and knowledge. There were approximately 5-6 participants in each group and they represented all the major tour operators as well as military operators.

2) Field operations training

Members of our staff accompanied operators on the water on several occasions to observe operations and assist with application of the guidelines developed in this workshop. This also gave workshop facilitators a chance to aid in developing the interpretive programs used on board the vessels.

3) Monitoring of whale and vessel interactions:

In the final phase of this project, we documented and described the interaction of tour and other vessels with whales. Data were collected from our research vessel (R.V. Natoa) in conjunction with other field activities described in this report and included date and time, whale species, location, type and name of vessel, the operators name if known, duration of interaction with the whales, estimated distance of the vessel from the whales, and manner of approach. These observations had the dual purpose of developing a comparable systematic database that would give an indication of the level of whale harassment currently occurring in the Kenai Fjords region and to reinforce the importance of guidelines and methods for low impact whale observation developed in the workshop and training sessions.

Results

A total of 30 participants attended the workshop; nearly all were tour boat captains. Most participants had at least several years experience running tour boats in the region. Small charter and pleasure boat operators had not been invited and did not attend. Workshop facilitators, Vladimir Burkanov, Craig Matkin, and Eva Saulitis made presentations on pinnipeds, baleen whales, resident killer whales and transient killer whales. Following the presentations, participants broke into six working groups, each considering a specific topic of concern.

After each group reported on their specific topic, the entire workshop group developed general marine mammal viewing guidelines and specific guidelines for pinnepeds and cetaceans. These guidelines were circulated to all tour boat companies for comment before being attached to this report. Workshop participants also decided to form a group called the Kenai Fjords Tour Vessel Operators Association, This group plans to meet annually in spring to learn of recent research findings, to reassess viewing guidelines, and to discuss problems.

Observations of Whale and Vessel Interactions

All observations of whale and vessel interactions were made from either the R.V. Whale 2, a 7m bow picker style vessel with a diesel inboard/outboard or the R.V. Natoa, a 10m diesel inboard powered vessel during the course of research activities described in the field methodology section of this report. A total of 177 observations of vessels interacting with whales were logged between 16 May and 18 September. Of these, 143 involved whales and commercial tour boats, and 36 involved whales and other vessel types, which included sport fish/pleasure boats, small charter boats, and kayaks. An interaction was considered to occur when a vessel took notice of whales and altered either course or speed to view the whales. Nine of the observations were with humpback whales and 168 were with killer whales. The research vessels logged a total of 2333 minutes of observation time including 2083 minutes of tour boat/whale interactions and 250 minutes of other vessel/whale interactions. The average encounter time for tour boats was 14.9 minutes (range 2-55) and for other vessels, 7.1 minutes (range 2-20). On a typical peak season day such as 25 July 2000 when killer whales were in Resurrection Bay, 33 different vessels observed the whales (25 tour boats and 8 sport/charter/kayaks). On that day, interactions occurred from 1045 and 1805 (7.6 hours), and a total of 5.4 vessel hours were spent viewing the animals.

Measurement of closeness of approach to whales was estimated as the closest distance that vessel actively moved toward the whales. Note was also made if whales continued to approach the vessel after it was stopped. On twelve occasions (12% of the observations) tour boats approached an estimated distance less than 100m, and on 17 occasions (47% of the observations), other vessels approached closer than an estimated 100m. For the two encounters with kayaks, one involved approach to within an estimated 15m and the other to within and estimated 6m.

Discussion

We believe that direct involvement of whale operators in establishing a code of conduct for their industry is a proactive approach to reducing harassment of whales in the Kenai Fjords region. Their close involvement cements their investment in the process and provides an initial forum where less concerned operators face the peer pressure from other operators. Although this type of workshop may not be necessary in the future in the Kenai Fjords region, it would be valuable to have an annual refresher meeting where the operators can again look at the behavioral code that they helped develop.

Although we feel the data does give a good general picture of the interaction of vessels with whales (particularly killer whales) in the Kenai Fjords region, the presence of the research vessel may have influenced the field observation data of the interaction between whales and tour boats. Additionally, because we did not have a fixed land-based observation post, distances were estimations, usually made based on the known lengths of the vessels under observation. Although we had as many as six vessels viewing the whales at one time, more often visits were made sequentially. Commercial tour vessels generally made an attempt not to box in the whales or pin them against shorelines, although in two observed cases, one of beach rubbing killer whales and another with humpback whale feeding tight to shore, this did occur.

The commercial tour boats were likely to take a slow approach that was initiated 300m or more from the whales, while charter and sport boats often rapidly approached whales and made quick course changes to get into viewing position. Sport and charter boats were also much more likely to approach closer than the estimated 100m guideline, although they remained with the whales on average half the time that was spent by the tour boats. The kayakers we observed were part of guided trips from Fox Island and did not heed any of the published NMFS guidelines, actively pursuing whales and approaching within 6 meters in one case.

Although there was a wide range of time that individual tour boats spent with whales, up to 55 minutes in one case, the average time of 14.9 minutes was within the National Marine Fisheries Service guidelines of less than 30 minutes and within the 20 minute maximum agreed to by operators during the spring workshop. Either due to training and/or experience, the tour boat operators were generally more aware and considerate of the whales than sport/charter operators, although there were some obvious violations of NMFS and workshop guidelines by both groups and particular tour boat operators. These individuals were approached and addressed, either by us on the water or at dockside or by other concerned tour boat operators, when possible.

During the spring workshop tour boat operators had agreed to make a single visit per trip to view a particular group of whales; however, this guideline was not always adhered to. Particularly in the later part of the season, a second viewing of whales was often made on the return trip to town if whales were within range.

Conclusions

Without additional data it is not possible to determine whether vessel activities are negatively impacting killer whales in the region. However, minimizing potential damaging effects of harassment is recommended. As a prescriptive measure, the NMFS guidelines presented as their "Marine Mammal Code of Conduct" should become regulation and serve as a clear baseline against which a vessel operator's behavior can be judged.

It would be valuable to hold annual spring refresher workshops for tour boat operators that stress the guidelines developed by the operators in the 2000 workshop as well as the NMFS guidelines. Tour company owners should make it mandatory for captains to attend such workshops. An educational program similar to this should be conducted for sport and charter boat operators, as it appears that their interest in whale viewing is increasing. Unfortunately, it will be more difficult to assemble such a group at a single time and place.

The opportunistic monitoring of vessel/whale interactions should be continued to determine any changes in activity or behavior of vessels viewing whales. This will also serve as a reminder to operators that NMFS is concerned about marine mammal/ vessel interactions.

It would be beneficial to have a NMFS enforcement officer make at least two trips per season into waters of the Kenai Fjords region in order to demonstrate the NMFS concern that a code of conduct is adhered to that prevents harassment of marine mammals.

GIS DATABASE

Vessel logs and killer whale encounter sheets were entered into the GIS database, held at both U.S. Fish and Wildlife Service, Marine Mammal Management in Anchorage, Alaska (contact Doug Burn) and at Alaska Pacific University, Anchorage, Alaska (contact Dr. David Scheel). No analysis other than data summaries and mapping were performed on the data in 2000. The annually updated GIS database will serve as an important long-term baseline in the event of future perturbations in the environment and against which changes in distribution can be assessed. The database is now opened for use by other agencies (i.e. USFWS and NMFS). A copy of the entire database was provided to Exxon Inc. in 1999 in response to their request filed under the Freedom of Information Act.

POPULATION GENETICS

Although we opportunistically sampled individuals important to our long-term genetics program in 1999 and 2000, there was no directed funded genetics program in either year. We did obtain seven samples from additional transient whales, two from AT1 transients, three from Gulf of Alaska transients, and two from Southeast Alaska/British Columbia transients. We also sampled AT1 after his death to confirm his identity and determine contaminant levels in the blubber. One additional sample was obtained from a resident whale (AJ41) to replace a damaged sample of the same whale taken previously, and two samples were obtained from males in the newly designated resident AA pod. A summary of haplotypes determined from these is provided in Table 13. (Note: This research was funded exclusively by the University of British Columbia). Also, sex was genetically determined for a number of individuals based on samples taken in previous year as listed in Table 14. A total of 106 skin samples have been obtained by biopsy dart from unique identifiable killer whales in the Prince William Sound/Kenai Fjords region since this program began in 1994.

Table 13. Haplotypes determined from mtDNA analysis in 1999-2000.

Sample no.	ID	Haplotype
AKW99-01*	T88	west coast transient
AKW99-02*	T102	"
AKW99-05	AT32	Gulf of Alaska transient
AKW99-06	AT30	"
AKW00-03	AT51	"
AKW00-01	AA1	AB clan resident
AKW00-02	AA2	"
AKW00-04	AT1	AT1 (done as a check on identity of the carcass)

*sample taken in Icy Strait, southeastern Alaska

Table 14. Sexes of selected whales biopsied 1998-2000.

Sample number	ID	Sex
AKW98-03	AD20	M
AKW98-04	AD14	F
AKW98-06	AK14	F
AKW98-07	AK15	F
AKW98-09	GAT	F
AKW98-10 (micro)	GAT	M
AKW98-12	AB39	F
AKW98-15	AJ39	F
AKW99-01	T88	F
AKW99-02	T102	M
AKW97-04	AK03	F
AKW99-07	AJ41	F

The three probable Gulf of Alaska transients, AT30, AT32 and AT50 all tested with the Gulf of Alaska haplotype confirming affiliation with that population. Both transients sampled in southeastern Alaska (Glacier Bay) were West Coast Transient haplotypes. The new resident pod, AA pod, exhibited the AB clan haplotype.

CONTAMINANTS

Although there has been no directed funding for contaminant sampling under this project since 1998, contaminant analysis was provided by the NMFS Environmental Contaminant Laboratory, Seattle, WA on the 10 samples collected in 1999/2000. The results are comparable to levels found in residents and transients in previous years (Table 15). However, there were extremely high levels in some of the transients compared to the average in previous samples of 237.7ppm total PCBs and 346.0ppm total DDTs (lipid wt). The transient male, AT50, whose fin has bent over, had the highest adjusted lipid weight contaminant levels yet measured of 651.4 ppm total PCBs and 1003.7 ppm total DDTs. The Prince William Sound transient male, AT1, who stranded and died, had very high levels as well, 370.0 ppm total PCBs and 424.1 ppm DDTs.

The two male resident killer whales sampled had very high levels compared to the average of 14.2ppm total PCBs and 14.4 ppm total DDTs found in previous resident samples (Matkin et al 1999). Adult male AA1 had total PCB and DDT levels of 65.5ppm and 69.3ppm, respectively, and adult male AA2 had total PCB and DDT levels of 29.8ppm and 36.7ppm. These whales were from a pod not previously photographed or sampled and suspected to center their range south and west of Kenai Fjords, possibly in the Kodiak region.

Table 15. Contaminant levels in the blubber of killer whales sampled 1999-2000 (ppm lipid weight).

Sample number	ID	Sex	%lipid	Total PCB	Total DDT
Transients					
AKW99-01	T88	F	28.0	355.0	526.8
AKW99-02	T102	M	9.1	185.7	334.6
AKW99-03	AT6	M	7.4	66.2	70.3
AKW99-04	AT3	F	26.0	267.3	359.6
AKW99-05	AT32	M	21.0	135.7	199.5
AKW99-06	AT30	M	2.7	322.9	455.2
AKW00-03	AT50	M	7.2	651.4	1003.7
AKW00-04	AT1*	M	15.0	370.0	424.1
Residents					
AKW00-01	AA1	M	3.1	65.5	69.3
AKW00-02	AA2	M	17.0	29.8	36.7

* Although AT1 was sampled in 1995, blubber from that sample was used in attempted lipid fatty acid analysis and was unavailable for contaminant work.. AT1 was stranded when the sample reported on here was taken.

Current samples again indicate that transient whales generally have much higher levels of contaminants that resident whales and the Gulf of Alaska transient population has even higher levels than the AT1 transient population. The much higher than average contaminant levels in the previously unknown male resident whales from AA pod suggests that the resident whales from other areas to the southwest may have higher contaminant levels than those from our area.

OVERALL CONCLUSIONS

1. AB pod numbered 25 whales in 2000, a net increase of three whales since a low of 22 members was recorded in 1995. There were no new mortalities in the pod in 2000, and one calf was recruited. It is not clear whether recovery is underway.
2. All major resident pods were thoroughly photographed in 2000, including AD05 and AD16 pods, which we now include in our population assessment. There were 82 whales in these pods in 1984 and 110 whales in 2000. All pods except AB pod have been increasing at a rate similar to that for the B.C. northern resident population.
3. Of the southeastern Alaska pods that visit Kenai Fjords/Prince William Sound, AF05 was photographed, however AF22, and AG were not.
4. Population modeling of resident whales indicated a higher mortality rate for adult females in the Alaskan population than in the B.C. northern resident population. The lack of recovery in AB pod can be attributed primarily to the loss of reproductive potential due to the deaths of reproductive females at the time of the oil spill. Overall female mortality also was higher in the entire Alaskan population.
5. The AT1 population lost another individual, the male AT1, in 2000 and produced no new calves. There are now 10 individuals in this group and no indication of potential recovery.
6. Encounters with the larger resident pods were less frequent than in some previous years and superpod aggregations were rare. Encounter rates were higher than in most recent years in Prince William Sound and may indicate a shift in distribution of some pods, including AB pod.
7. The remote hydrophone was moved to Thumb Point and again indicated that Resurrection Bay is an important late winter range for AB and AJ pods. AG pod also used the Bay in March 2000. Improvements in transmission technology have increased signal quality and reliability of the remote hydrophone. It is broadcast continuously on FM 91.1 in Seward.
8. Observations of vessel interactions with killer whales indicated that harassment does occur on a regular basis, particularly with sport vessels; however, the effect of these interactions on the movement and distribution of the whales is unknown.
9. Genetic analysis confirmed the population affiliation of several suspected Gulf of Alaska transients. Genetics also confirmed the identity of the stranded male transient, AT1, and classified a new resident pod (AA pod) as part of AB clan.

10. Contaminant analysis of blubber biopsies continued to show very high levels of contaminants in transient whales. One transient male (AT50) had 651ppm total CBs and 1003ppm total DDTs, the highest levels yet recorded in our study. Two males from the new resident pod, AA pod, also had levels much higher than found in other resident whales that have been sampled in our area.

As a result of the long-term investigations reported here, as well studies in adjacent regions, it is clear that even the largest killer whale populations identified to date in the Eastern North Pacific number only in the hundreds of individuals. These populations should be considered at all times "vulnerable" because of their low numbers, low reproductive rates, and susceptibility to anthropogenic as well as natural environmental perturbations. Because these small populations occupy a position atop the marine food chain and because of their potential to accumulate toxic contaminants, killer whales should be considered a sentinel species that warrant careful long-term monitoring.

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