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Assessing the Effect of the EXXON Valdez Oil Spill on Bald Eagles

Bird Study #4

Annual Progress Report - 1991

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EXECUTIVE SUMMARY

The area affected by the EXXON Valdez oil spill (EVOS) provides year-round habitat for a bald eagle population greater in size than the population of bald eagles inhabiting the Lower 48 contiguous states. Oil contamination of the intertidal habitats used extensively by breeding, wintering and migrating bald eagles have resulted in impacts to these birds.

Population surveys were conducted during each year of the study in Prince William Sound (PWS), and on the Kenai Peninsula in 1989 and 1990. Indices of adult bald eagles derived from population surveys, adjusted for visibility bias and the proportion of immatures in the population, indicate a population of about 4000 bald eagles in PWS, and 8000-10,000 in coastal environments of the north gulf coast of Alaska (Appendix pop@risk). The bald eagle population in Prince William Sound appears static among all years (Appendix poptable and bar graph hardcopy), but the lack of baseline data for other areas precludes an assessment of population trends in those areas. There was no indication that eagles were "attracted" to oiled areas in 1989 (Appendix attract).

A total of 134 bald eagles were radio-tagged and monitored to determine survival, and document movements and exposure to oiled areas. Pooled annual survival rates were 0.71 for first-year eagles, 0.86 for second-year eagles, and 0.86 for adults, as calculated using the Kaplan-Meier procedure (Appendix survival.ms and hardcopy of death time chart). There were no significant differences in survival rates between years or between eagles "exposed" and "not exposed" to oiled areas, and therefore little convincing evidence that indicates survival was affected by the EVOS. However, eagles were marked 4-5 months after the EVOS in 1989, and therefore were not monitored during the period when most oil-related mortality occurred.

Causes of death for radio-tagged eagles remain uncertain, but preliminary diagnoses included emaciation, trauma, and drowning. Toxicological tests on some tissue samples are pending. We characterized recovery locations of all radio-tagged eagles that died, and estimated whether the eagle would have been found by bird rescue or cleanup crews (Appendix deadbird.wk1). Seventy-four percent of those eagles ended up in the woods or in other places where they would likely not have been found. Using this proportion, and correction factors for estimated natural mortality and percent shoreline searched, we extrapolated the total number of dead eagles recovered by crews (151) to an estimate of total mortality due to the oil spill (Appendix totmort.89). This estimate was 553 bald eagles.

Bald eagle nesting surveys were conducted in 1989 and 1990 in PWS, Copper River Basin and Delta, Kenai Peninsula, Alaska Peninsula, and Kodiak Archipelago (Appendix compare.nst). Differences in survey methodology preclude accurate comparisons among study areas and to some extent, between years. The most significant finding was the low nest success and productivity in PWS in 1989. Approximately 69 % of occupied nests failed in 1989, whereas 43 % failed in 1990. A conservative estimate of lost production in 1989 was 133 chicks (Appendix lostprod). Reproductive surveys were not conducted in 1991, so it is not known if 1990 reproductive rates are normal, or were depressed due to continuing effects of the EVOS. Nest success and productivity on the Alaska Peninsula were also lower in 1989 than 1990, but differences between years for other coastal areas were less apparent. The Copper River Basin had similar productivity to coastal areas in 1989, but much lower productivity in 1990.

An analysis of reproductive success related to shoreline oiling was conducted using the linear extent and degree of oiling within a 483 meter radius of the nest site. The principal findings were that occupancy in oiled areas was lower than in unoiled areas in 1989. These rates did not improve in 1990. Nesting success was significantly impaired in 1989 with few successful nests and reduced production in those nests that were successful. The frequency of 2-chick nests was unusually high in 1990. Nest failure rates were significantly higher in 1989 at nests near heavy oiling and significantly lower in 1990 at nests along oiled beaches. Nest fates in 1989 and, to a lesser extent in 1990, were related to the linear extent and intensity of oiling in the vicinity of the nest (PWSNEST.DOC).

Addled eggs, prey remains, blood, and feathers were collected in 1989 and 1990 and analyzed for evidence of hydrocarbon exposure. Exposure was indicated in some samples of eggshells, egg contents, eggshell fragments, prey remains, and blood serum (Appendix contsum.wk1). Two of 3 eggshell samples collected in 1989 on the Alaska Peninsula and Kodiak area were exposed to hydrocarbons. Exposure was documented in both 1989 and 1990 in PWS. Concentrations of uric acid in blood serum from adult eagles in oiled areas were higher than those from unoiled areas in 1989, and eagles with high uric acid values experienced higher mortality (Appendix highuric). Blood samples were not collected from eagles in 1990, but were collected in 1991 to assess long term effects; analyses are pending. Surprisingly, eggs collected in 1990 from Eastern PWS indicated exposure to petrogenic hydrocarbons, which suggests either 1) persistence of hydrocarbons from EVOS, 2) the effects of EVOS were more widespread than previously believed, or 3) background levels of hydrocarbons from other sources were sufficient to indicate exposure.

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ESTIMATES OF THE BALD EAGLE POPULATION POTENTIALLY AT RISK BY THE EXXON VALDEZ OIL SPILL

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Abstract: We estimated the number of bald eagles potentially at risk in the area affected by the EXXON Valdez oil spill in 1989. Estimates were based on population survey data, corrected for visibility and the proportion of immatures. The population in Prince William Sound (PWS) was estimated at about 4000, and the population for the entire spill area (including PWS, Kenai Peninsula, Kodiak archipelago, and Alaska Peninsula) was estimated at about 8000 eagles. Most of the potential biases suggest the estimates may be conservative. However, these estimates have wide bounds, and we made several assumptions that are difficult to validate. Therefore, the estimates should be used with caution.

An estimate of the bald eagle population at risk in the area affected by the Exxon Valdex Oil Spill (EVOS) on 24 March, 1989 is needed to better understand the overall impact of the spill on the eagle population. These estimates may help to estimate the direct mortality of eagles resulting from the EVOS. The following is a discussion of the methods we used, the assumptions and potential biases involved with each method of estimation, and an assessment of the reliability of the estimates.

HOW THE ESTIMATES WERE DEVELOPED

Our approach to estimating the population at risk begins with an estimate of the number of adults per survey area, and adjusts that figure for visibility bias and the proportion of immatures in the population. Estimates of the population at risk in areas outside PWS were difficult to obtain because of the lack of population surveys and applicable visibility bias estimates for those areas.

Population Surveys

Estimates of the population at risk are based on estimates of the number of adults counted during population surveys (Hodges et al. 1984) conducted in late April and early May. During these stratified random plot population surveys, only white-headed (adult) eagles are counted, and the number of adult and immature eagles seen flying is recorded. The number of adult eagles we see on spring population surveys represents an index, rather than an estimate, to the population size. The ratio of adult to immature eagles seen flying gives an estimate of the proportion of immatures in the population.

Estimate of the Percent of Immatures in the Population

A correction for the proportion of immatures in the population, after correcting for visibility, enables a rough estimation of total population size. The ratio of flying immatures to flying adults in Prince William Sound, pooled for population surveys in 1982, 1989, 1990, and 1991, was 105/344, or 30.5% immatures in the population. Confidence limits (Fowler and Cohen, undated) on this estimate were 25.6% to 35.4%. Other estimates of the proportion of immatures are consistent with this figure. Hodges et al. (1984) estimated that 27% of the eagles in coastal British Columbia were immatures. The proportion of immatures observed during April and May reproductive surveys in PWS in 1990 was 25% (USFWS, unpubl. data).

Visibility Bias Estimates

The detectablity of bald eagles during aerial surveys may be influenced by bird activity, time of day, weather, snow cover, topography, observer experience, type and speed of aircraft, age and sex of birds, season, and habitat. Recognizing that not all adults are seen during population surveys, estimates of the number of adults must be corrected for visibility bias. We developed our own estimate of visibility bias because of the lack of existing estimates for bald eagles, especially in habitat similar to that found in PWS. Hancock (1964) estimated that he undercounted adult bald eagles by 10-15%.

The correction for visibility is based on radio telemetry experiments we conducted in 1990 to estimate the proportion of tagged eagles that would be seen during a typical population survey. Subjective criteria (Yes, No, or Maybe) were used to estimate whether an eagle would have been seen on a population survey. See Appendix A for notes on methodology and terminology used in visibility experiments.

Because our population surveys were conducted at a time when many eagles are incubating and therefore less visible, we believed it was prudent to calculate a visibility bias for non-nesting eagles only (i.e., we threw out any observations from our experiments where the bird was incubating). An estimate of incubating adults that would not have been counted during the population survey was calculated seperately. We determined that 77% (95% CL = 69% to 84%) of non-nesting adults would have been seen on a typical population survey (Appendix D), and that approximately 100 nesting eagles would have been missed on population surveys in PWS (Appendix C). The calculations for this may seem somewhat complicated and probably confusing to most readers, but they are presented in Appendix C for reference. Confidence limits on the visibility bias estimate were calculated according to Fowler and Cohen (undated).

We made the assumption that weather during the visibility experiments was similar to what was encountered during the 1989 population survey. Notes on weather were not taken during the 1989 survey, so this assumption cannot be evaluated for 1989. We compared the proportion of weather conditions observed during the 1990 population survey to the proportion of conditions (Class 1, 2, or 3 [Appendix A]) under which visibility experiments were conducted. The proportions were similar (34%, 25%, and 41% for visibility experiments, and 45%, 21%, and 34% during population survey, for classes 1, 2, and 3, respectively). We believe this is a fair assumption, but lack data from 1989 to verify that.

A visibility bias estimate determined from the blindfolding experiments.

We also took another approach to estimate visibility bias. We refer to this as the "blindfolding" experiments (Appendix B). However, the sample size is small for this method. Eleven of 17 (65%) radiotagged eagles were seen. We included observations in this estimate only if there was no snow in trees (conditions similar to population surveys). However, this estimate is probably biased because: 1) visibility is poorer in a Cessna with antenna mounted on the wing than in the modified DeHavilland beaver aircraft used during population surveys; 2) this method measures the ability of only one observer to see an eagle, whereas during population surveys the pilot also surves as an observer; and 3) observers were less experienced at population survey techniques when these experiments were conducted. The effect of these biases would be to underestimate the proportion that would be seen during a population survey. Considering these potential biases, the estimate of 65% seen is fairly consistent with the 77% determined using methods outlined in Appendix A.

ESTIMATES OF THE POPULATION AT RISK BY AREA

Prince William Sound

The 1989 population survey yielded an index of 2089 ± 308 adults. After adjustment for visibility and proportion of immatures in the population, we estimated there were about 4000 (95% CI = 2871 to 5495) bald eagles in PWS in late spring, 1989 (Table 1).

Kenai Peninsula and Cook Inlet

Estimates are based on the 1989 population index (USFWS population surveys) for the Kenai Peninsula (Cape Puget to Kachemak Bay, but not including Kachemak Bay), which was 354 +/- 62 (95% CI) adult eagles. The estimated population for this area was about 700 (95% CI = 474 to 956) (Table 1).

Kodiak Archipelago

Our estimates are based on a 1983 population survey (USFWS, unpubl. data) of the entire Kodiak archipelago, which estimated 1082 +/-249 adult eagles. After adjustments for visibility and percent immatures, we estimate a population of about 2100 (95% CI = 1386 to 3089) (Table 1). Zwiefelhofer (1989) estimated that the total population in the Kodiak Archipelago was in the range of 1300 to 1500 birds, but does not indicate method of estimation.

Alaska Peninsula

The Alaska Peninsula, from Cape Douglas to Unimak Island, was surveyed by Jack Hodges in 1983 (USFWS, unpubl. data). A stratified random sample of plots yielded an index of 657 +/- 148 adult eagles. Because of differences in habitat between PWS and Alaska Peninsula, we believed that an adjustment for nesting adults missed was not necessary for the Alaska Peninsula. The population index adjusted for percent immatures and visibility bias was about 1200 (95% CI = 784 to 1704) (Table 1).

Total population at risk in all areas combined

Combined estimates for PWS, Kenai, Kodiak, and Alaska Peninsula total about 8000 (95% CL = 5516 to 11245) adults plus immatures (Table 1).

TABLE 1. ESTIMATES OF BALD EAGLE POPULATIONS "AT RISK" IN THE EVOS AREA

Area		Index to # Adults	Visibility Bias Adjustment	Nesting Adult Adjustment	Total Adults	Adjustment for # of Immatures	Estimated Population
	Actual Est.	2089	0.77	100	2824	0.70	4063
PWS	Lower C.L.	1781	0.84	100	2223	0.77	2872
	Upper C.L.	2397	0.69	100	3550	0.65	5495
	Actual Est.	354	0.77	19	481	0.70	692
Kenai	Lower C.L.	292	0.84	19	367	0.77	474
Penin.	Upper C.L.	416	0.69	19	618	0.65	956
	Actual Est.	1082	0.77	80	1491	0.70	2145
Kodiak	Lower C.L.	833	0.84	80	1073	0.77	1386
	Upper C.L.	1331	0.69	80	1996	0.65	3089
	Actual Est.	657	0.77	0	857	0.70	1233
Alaska	Lower C.L.	509	0.84	0	607	0.77	784
Penin.	Upper C.L.	765	0.69	0	1101	0.65	1704
	Actual Est.						8133
All	Lower C.L.						5516
Areas	Upper C.L.						11245

An estimate of population size derived from an estimate of the number of occupied nests Prince William Sound

An alternate method of calculating the population of eagles in Prince William Sound is to use the number of territorial pairs as determined from nesting surveys. The 1989 nest surveys were incomplete, so data from the 1990 surveys were used. Assuming the population had declined from the oil spill, using 1990 data would result in a conservative estimate of the number of eagles at risk.

In 1990, 653 occupied nesting territories were located. We estimatedd that we located only 75% of the nests in the survey area and that we surveyed 80% of bald eagle nesting habitat in PWS. Using 75% and 80%, we calculated that there were 1088 nesting territories (653/ 0.75/ 0.80 = 1088). Assuming 2 birds per territory, there were 2177 territorial adults. Seventy-eight percent of the adult eagles we radiotagged were territorial, as determined by telemetry studies. This estimate is biased because we trapped eagles that were likely territorial (i.e., we avoided trapping near areas where nonterritorial eagles congregate, such as salmon spawning streams and attempted to trap only eagles that were in full adult plummage). However, 78 % could be used to calculate a minimum population size. Accordingly, there were 2791 (2177 / 0.78) adult eagles in PWS. Correcting for 30.5 % (± 4.9%) immatures, we calculated a lower estimate of 3605 and upper estimate of 4320 adults plus immatures in PWS. We think a more realistic estimate of the percent territorial is 60 % (this is a subjective judgement made by TB, JB, and PS). Using 60 %, we calculate 3628 adults (2177 / 0.60). Adjusting for immatures (3628 / (0.695 ± 0.048)), we estimate an upper limit of 5616 and lower limit of 4876 adults plus immatures in PWS. These figures approach the upper confidence limit for estimates calculated using the population survey index adjusted for visibility bias.

We assumed that we found about 75% of all occupied nesting territories during reproductive surveys, whereas only about 60% (17 of 29) of the nests of tagged birds would have been found during our reproductive surveys. However, we believe our tagged birds nested in atypical areas (i.e. >300M from the shoreline or low in small trees). Therefore, we used an estimate of 75% for our calculations. However, there is little data to substantiate our 75% estimate. Grier et al (1981) estimated that they could find 94% of eagle nests with 2 searches, but nests were likely more visible in the habitat they searched (nests in tall, mature aspen trees) than in the coniferous forests of PWS.

Kodiak

We also calculated a population estimate for the Kodiak Archipelago using nesting data from 1990. Nest surveys in 1990 located 416 occupied nests in 1990. Nest surveys have been conducted in the Kodiak Archipelago for approximately 20 years, so we assumed all occupied territories were located (this assumption that 100% of all occupied territories were located in the Kodiak survey area results in a conservative estimate of the population). Therefore, we estimated that there were 832 territorial adults. Adjusting for non-territorial eagles we calculated an adult population of 1067-1387 (832/ 0.60 for upper estimate; 832/ 0.78 for lower estimate). Correcting for immatures we calculate 1378-2147 eagles in the Kodiak Archipelago. This estimate is within the confidence limits calculated using the population survey and visibility bias estimates.

DISCUSSION

Our visibility experiments estimate the proportion of birds that could be seen during a population survey, but not necessarily what would be seen. We know that even with 2 observers, some eagles are missed. This is probably minimal, but the effect would be to overestimate the proportion seen, which would result in a conservative estimate of total population size. We also assume that our estimate of visibility bias is applicable to areas outside of PWS because no bias estimates are available for other areas.

Our estimates of occupied nesting territories for PWS and Kodiak are conservative because we undoubtedly did not identify all occupied territories, but estimates derived from the number of occupied nests are similar to those obtained using the population index adjusted for visibility bias.

We do not evaluate the possibility that significant mortality of eagles occurred before the time population surveys were conducted. Little information is available to assess this. However, 18 of the 32 bald eagles logged in at the Valdez morgue were collected during April and May, and 9 of the 29 eagles logged at the Seward collection station were also collected then, which suggests some mortality occurred before we conducted population surveys in those areas. Therefore, the estimate of total population at risk should be considered conservative because of the likelihood that some mortality occurred between the time the oil spill occurred (March 15) and population surveys were conducted (late April and early May).

These figures are only a rough approximation of the total population at risk, and the estimates should be used with caution. Confidence intervals for population indices, upon which these estimates are based, are wide (14 % to 30 %). We have made some assumptions that cannot be validated, we used 1983 population survey data for the Kodiak Archipelago and the Alaska Peninsula, and applied correction factors for visibility and the proportion of immatures calculated for PWS that may not be valid for these areas or the Kenai Peninsula. Considering the potential biases involved with these estimates, we strongly believe that the estimates of population are conservative, and that the actual size of populations is near the upper bounds of our estimates. However, the population surveys included some areas that were not directly affected by the oil spill, therefore all of the population may not have been "at risk" by the EVOS.

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Appendix A. Notes on procedures used to determine visibility bias for bald eagles in Prince William Sound, Alaska.

SURVEY FORM TERMINOLOGY

WHY YOU ARE DOING THIS

The purpose of this part of the survey is to determine 1: Movements of territorial eagles during the nesting season; and 2: Determine if weather or time of day affects the sightability of bald eagles. We expect that on rainy or heavy overcast days, eagles are more likely to be seen on a population survey than on sunny days because fewer birds are soaring and lighting is more condusive to sighting eagles.

START/END: Time when you are surveying area on map, not total time of survey.

WEATHER CLASSES:

CLASS 1: Ceiling less than 2000 feet, fog, or rain.
CLASS 2: Ceiling greater than 2000 feet, but not clear. Also patchy fog but clear skies. This class is meant to be an intermediate between class 1 and 3.
CLASS 3: Clear skies, broken or high thin ceilings.

RECORD VISIBILITY DURING THE TELEMETRY FLIGHT

Was the eagle seen on the survey. Multiple passes are suggested before recording "N". If there are numerous birds in the area record as "?". Also use "?" if you suspect the eagle is nesting but not visible and that you are seeing the mate perched near the nest. If the eagle is seen by observer or pilot, record "Y".

LATITUDE/LONGITUDE

Coordinates from aircraft loran system. Try to fly directly over the bird when the coordinates are plugged in.

ESTIMATE VISIBILITY ON A POPULATION SURVEY

Would they eagle be seen on a population survey, in your best judgement? This is subjective but use the following criteria:

"Y": Use when the eagle is in an obvious or fairly obvious location. This will include high visibility nests and any perches which would be visible from a flight altitude of 300'.

"?": Use for birds which are tough to see or in unusual locations, but are visible. This will include birds on low-visibility nests, sitting among rocks on a beach or on offshore reefs, at high but visible perches, in perches obscured by tree limbs, or at unusually high perches. Also use this when you are unable to determine if the radioed eagle is on a questionable visibility nest or is perched in an obvious location nearby.

"N": Use this only when you are sure the eagle would not be seen during a population survey. This is for birds which are perched too high or too far offshore/inland to be seen readily, were not seen by you or the pilot after multiple passes (and you were confident in the telemetry), or birds in nests that would not be seen in a population survey.

Appendix B. Notes on Visibility Bias Experiments -- Blindfolding Method.

The purpose of this exercise is to estimate a visibility bias for adult bald eagles under different environmental conditions, particularly snow cover. We are using a sample of radio-tagged birds, therefore we can ascertain the existence of a bird at a particular location by locating it by aerial telemetry. Two observers are needed. The telemetry observer sits in the back seat and locates the bird by telemetry while the second observer in the front seat, same side of plane, remains blindfolded while the bird is spotted. Without any clues as the whereabouts of the marked bird, the plane circles around 1/2 to 1 1/2 miles, and flies along the stretch of shoreline where the bird is perched, simulating conditions of a typical population survey. The front observer points to any adult eagle he sees and the telemetry observer verifies if he has seen the tagged bird once they have passed by it. The percent snow cover in trees and on the ground is recorded. Percent snow cover on ground ranges from 0 to 100%, although cover in trees is about maximum at 80%.

Because some birds habitually perch in the same trees, the observer may recognize an individual's usual perch after repeated observations of the same bird, and be more likely to see the bird. These observations are not included if there is any chance that the observer was biased by his previous knowledge of the birds favorite perch. The decision to omit such data rests with the best judgement of the observer. The effect can be minimized by using different observers on different flights.

If a radiotagged eagle cannot be seen after several passes, but is positively known to be at a certain location based on signal strength, the eagle is considered "not seen" (i.e., it was an existing eagle that would not have been seen during a normal survey).

In all observations, a 5 element Yagi antenna is mounted on the wing strut of the airplane. Undoubtedly, this reduces visibility to some (unknown) extent. Therefore, any visibility bias we come up with should be considered a maximum bias, since more birds will be missed with an obstructed view than with an unobstructed view.

Appendix C. Calculations to determine the number of nesting Bald Eagles missed during population surveys in Prince William Sound.

Methods

Nest fate summaries for 1989 and 1990 were combined so nests were aligned (i.e. 95 23 34 data for 1989 and 90 in same row in Lotus). The data was then sorted into island survey units. From this file, the total number of successful and failed active nests in 1990 was calculated for the same area that was surveyed in the 1989 population survey. This total for 1990 was 345 nests. Assuming we found only 78% of the active nests, it was calculated that there were 442 nests in this population survey area (345/.78). Using the April data from the 1989 nest file (derived from the population survey data), 117 nests were recorded in this same area. Using nesting chronology data from 1990, and a median data of 23 April for the 1989 survey, we calculated that 168 (442 x 38%) nests should have been active during the population survey. Of the 168, 70% (117) were found during the nesting survey. For all of Prince William Sound (PWS), we calculated that there were 875 active nests (546 known / 0.78 found / 0.80 of area surveyed). Estimating that 38% of these 875 were active during the population survey, there would have been 332 nesting eagles. Estimating that 70% of the eagles on nests would have been found, 100 eagles would have been missed. Therefore, we add 100 eagles to the visibility-adjusted index for adult eagles.

This estimate is probably low. Some of the assumptions we made were probably invalid. For example, on 5 of the 13 island units, more eagles were seen nesting than were calculated using the 38% figure. During late April and early May, the proportion of eagles nesting increases rapidly. If the estimate for chronology or median survey date is off even a few days, it may mean an error of 5+% (i.e. 43% may have been active instead of 38%).

APPENDIX D. BALD EAGLE VISIBILITY BIAS EXPERIMENTS CONDUCTED 1990 AND 1991, PRINCE WILLIAM SOUND, ALASKA.

	Would Eagle be Seen?			
Date	Yes	No	?	Total
01-May	11	0	0	11
07-May	5	0	3	8
09-May	5	1	1	7
11-May	8	6	1	15
14-May	13	1	3	17
16-May	6	2	4	12
21-May	8	6	1	15
24-May	8	7	0	15
29-May	14	2	0	16
31-May	6	4	3	13
20-May	12	0	1	13
21-May	6	2	0	8
Totals	102	31	17	150
Percent	68.00	20.67	11.33	
% Yes/No	76.69	23.31		
S.E.	3.68			
CI+/-	7.21			
Upper CL	83.90			
Lower CL	69.48			

Notes: Final visibility estimate is based on the number that would have been seen (yes) divided by the number of sightings that were not questionable

Table 1. Population Indices for Adult Bald Eagles in Prince William Sound, Alaska.

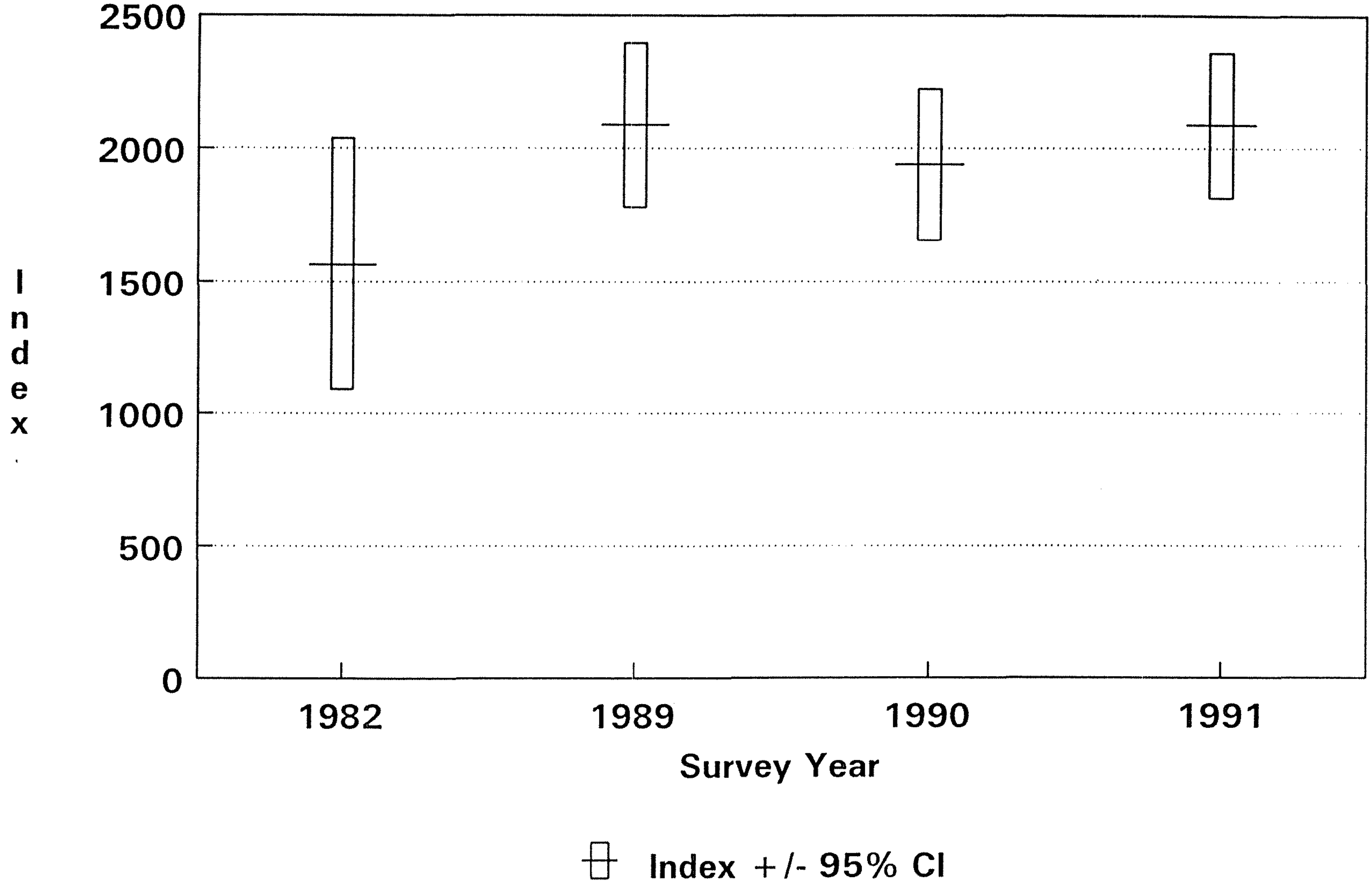
	Population Estimate Based on Island Census and Stratified Mainland Plots	Population Estimate Based on Similar Stratified Plots Sampled in 1982, 89, 90 and 91
1982	NA	1565 ± 473
1989	2089 ± 308	1981 ± 834
1990	1941 ± 283	1924 ± 504
1991	2088 ± 273	2166 ± 906

Table 2. Differences in indices for adult bald eagle population indices, Prince William Sound, Alaska.

	DIFFERENCE	95% CI	P=
*1989-90	- 148	196	0.130
*1989-91	- 1	279	0.996
*1990-91	147	257	0.212
1982-89	416	499	0.094
1982-90	359	347	0.042
1982-91	601	799	0.094
1989-90	- 57	620	0.840
1989-91	185	1203	0.678
1990-91	242	611	0.332

* Based on Island Census and Stratified Mainland Plots

Figure 1. Adult Bald Eagle Population Indices, Prince William Sound



AN ANALYSIS OF THE "ATTRACTION FACTOR" FOR BALD EAGLES IN PRINCE WILLIAM SOUND.

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Background

It has been suggested that bald eagles might have been attracted to oiled areas by the abundance of oiled prey in 1989, shortly after the Exxon Valdez oil spill, and that a greater-than-normal number of eagles could have been exposed to oil or oiled prey.

Population surveys were conducted in late April to early May in 1989, 1990, and 1991, during which all eagles seen were counted. These observations were entered into a GIS database which allowed a determination of the number of eagles present in oiled areas compared to unoiled areas in each year. Tom Jennings, USFWS GIS coordinator for oil spill studies, completed an analysis of the data which included a summary of the number of eagles that were observed within 500 m of shoreline with any oil.

Conclusions

There was no indication that eagles were attracted to oiled areas (Table 1). Numbers of adult and immature eagles in oiled areas were less in 1989 than in 1990 or 1991. The proportion of eagles in oiled areas versus unoiled areas was also less in 1989. A possible explanation for the fewer eagles in oiled areas could be that eagles avoided areas where disturbance from cleanup activities was high. Another possible explanation is that some mortality had occurred within oiled areas and reduced the population by the time surveys were conducted.

Table 1. Numbers of bald eagles on oiled and unoiled shorelines within the survey area* in Prince William Sound, Alaska.

	Number of Birds				Percentage of birds on oiled shoreline	
	Oiled shoreline		Unoiled shoreline			
Year	Adults	Immatures	Adults	Immatures	Adults	Immatures
1989	292	16	1196	82	19.6	16.3
1990	364	32	1103	75	24.8	29.9
1991	371	27	1209	72	23.5	27.3

SURVIVAL OF BALD EAGLES FROM PRINCE WILLIAM SOUND, ALASKA

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Abstract: Annual survival rates were calculated for 134 adult, first year, and second year bald eagles (*Haliaeetus leucocephalus*) radio-tagged in Prince William Sound (PWS) during 1989 and 1990 and monitored for 2 survival years. Annual survival rates were 0.71 for first year eagles, 0.86 for second year eagles, and 0.86 for adults, as calculated using the Kaplan-Meier procedure. Mortality was highest from March to May. We found no indication that survival of bald eagles tagged 4-5 months after the EXXON Valdez oil spill in PWS was directly affected by the spill.

Key Words: Alaska, bald eagle, Exxon Valdez, *Haliaeetus leucocephalus*, mortality, oil spill, Prince William Sound, radio-telemetry, survival.

Prince William Sound provides year-round and seasonal habitat for about 5000 bald eagles. Bald eagles are closely associated with shoreline habitats, and most nests occur within 100 m of the beach. Approximately 1200 km of shoreline in the North Gulf coast of Alaska were contaminated with oil after the oil tanker EXXON Valdez ran aground on 24 March, 1989 and spilled about 11 million gallons of crude oil into PWS. Concern over the welfare of eagles exposed to areas affected by the EXXON Valdez oil spill prompted a comprehensive study to document effects on eagles. Survival of bald eagles from PWS was one aspect of the study.

Information on survival rates for bald eagles is lacking (Buehler et al. 1991, Gerrard et. al 1978, McCollough (1986), Sherrod et al. 1976), but is needed to determine population dynamics. Grier (1980) and Young (1968), using estimated or hypothetical survival and productivity data, illustrated the importance of survival rates in assessing bald eagle population dynamics, and stressed the need for actual field data on survival, as well as other population variables. Banding data for most raptors are inadequate to estimate survival because of small sample sizes, low rates of return and lack of adult banding, but survival rates calculated from radio-telemetry can provide more direct and accurate estimates of survival.

We present information on the survival of bald eagles radio-tagged in PWS, and compare survival distributions of eagles exposed to oil to those from unoiled areas of PWS.

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STUDY AREA

Prince William Sound encompasses about 39,000 km^2 including 4800 km of shoreline (Fig. 1). A temperate rainforest encircles much of the convoluted coastline and islands of PWS. Summer temperatures range between 7 and 25° C, and winter temperatures seldom drop below -20° C. Annual rainfall exceeds 500 cm in some areas of PWS. Prince William Sound supports rich salmon and herring fisheries, and salmon populations are augmented by extensive hatchery operations. The nearby Copper River Delta (CRD) and vicinity also supports large salmon runs and tremendous numbers of waterfowl, shorebirds, gulls, and marine mammals.

METHODS

Fledgling bald eagles were marked at their nests when about 8 weeks old. Fledglings were selected for marking based on their age, nest location in relation to shoreline oiling, and the accessibility and climbability of nest trees. Tree climbers lowered chicks to the ground in nylon bags where they were weighed, measured, and tagged with radio transmitters. Chicks were returned to the nest after tagging.

Adult bald eagles were captured in marine areas using floating, noosed fish (Cain and Hodges 1989). Eagles were secured and transported to either boat or office where they were weighed, measured, and marked with transmitters. All eagles were released where captured.

Radio transmitters were a backpack design (Communication Specialists Inc. (CSI), Orange, CA., or Advanced Telemetry Systems (ATS), Inc, Isanti, MN) which weighed approximately 65 g (CSI type) or 90 g (ATS type). Transmitters were attached to the birds using tubular teflon ribbon, which was sewn together with dental floss where the 4 ends of the harness cross on the birds upper breast. Harnesses were left slack on fledglings to allow for additional growth. Transmitters had a life expectancy of about 3 years, and were equipped with mortality sensors that doubled the pulse rate after 5-7 hours without motion.

Aerial tracking flights were conducted using a Cessna 180 or 185 to relocate birds. Flights were conducted weekly until March 1991, and monthly thereafter. Standard telemetry techniques were used (Gilmer et al. 1981). A 5-element yagi antenna was mounted on each wing strut and angled downward at about 30° from a horizontal plane, perpendicular to the direction of flight. Reception distance of signals varied from 5-80 km, depending on altitude, local topography, and the strength of individual transmitters. A typical survey of PWS took about 6 hours of flying to complete.

Dead eagles were retrieved as soon as possible to substantiate cause of death and record physical characteristics of the recovery location.

Annual survival rates were estimated using a modification of the Kaplan-Meier procedure, and hypotheses about differences in survival functions between treatment groups were tested using the log-rank test described in Pollock et al. (1989). We chose these procedures because they allow for staggered entry of individuals, allow censoring of individuals, and do not assume constant survivorship. We estimated survival rates during 2 survival years: 1 September 1989 to 2 September 1990, and 3 September 1990 to 1 September 1991. The interval length was one week. Missing eagles were censored from the risk set the week after they were last known alive in the survival year. This included birds that emigrated from the study area, and birds with lost, weak, or failed transmitters. Although juveniles were tagged at about 8 weeks of age, they were not considered at risk until fledging, therefore survival of first year eagles is actually postfledging survival. We used 1 September as the approximate fledging date for this sample of eagles. Adults were considered at risk the week after tagging in the first survival year. Non-censored eagles surviving to the end of the first survival year were considered at risk the first week of the second survival year. Approximately equal numbers of chicks and adults were tagged in unoiled and oiled areas of PWS.

Comparisons were made to examine differences in survival that might have been attributable to oil exposure resulting from the Exxon Valdez oil spill. Eagles were classified into "oiled" or "unoiled" categories using several sets of criteria. The first set was based solely on the oiling at the tagging location of individual eagles. Oiling data were based on data provided by Alaska Department of Conservation which depicted shoreline oiling cumulative through August 1989. If any shoreline was oiled within a 483 m radius (a value determined by radio-telemetry that represents a core use area for nesting eagles) of the capture site (i.e., the nest site for juveniles and territorial adults or capture site for nonterritorial adults), the eagle was classified into the "oiled" category. The second classification scheme accounted for the eagles' movements and potential exposure to oiled areas after tagging, based on relocations by radio-telemetry. We used objective criteria, and subjective judgement based upon our knowledge of areas used by eagles, to classify eagles into oiled or unoiled categories. If more than 50% of the relocations were in oiled areas (broadly defined as west PWS), the eagles were considered exposed to oil. All territorial adults that were classified as oiled based on capture site were classified as oiled based on relocations, too. The third classification scheme was a simple grouping of eagles, by tagging site, into west PWS (i.e., most directly oiled) or east PWS (i.e., not directly oiled). Other comparisons of survival distributions were made 1) for territorial adults tagged in oiled areas versus unoiled areas, 2) between years for the same age classes, 3) among age classes, 4) between sexes (for adults), and 5) between territorial and nonterritorial adults.

Assumptions

The assumptions required for the Kaplan-Meier procedure were: 1) birds of a particular age and sex class were sampled randomly, 2) survival times were independent for the different eagles, 3) survival of eagles was not influenced by capturing or radio-tagging, 4) the censoring mechanism was random, and 5) newly tagged animals had the same survival function as previously tagged animals.

We are reasonably certain that we sampled eagles randomly within the study areas (oiled vs unoiled areas). Our objective was to capture territorial adults so we avoided trapping in areas of high food concentrations (e.g., salmon streams) where nonterritorial or transient adults are more likely to be encountered. We do not believe these potential departures from assumption 1 biased survival estimates. We have no evidence to suggest that survival times were not independent for different eagles, therefore we believe assumption 2 was valid. We do not believe that survival of eagles was influenced by radio-tagging, banding, or handling (assumption 3), and none of the dead eagles recovered exhibited adverse physical effects of transmitter and harness attachment. We cannot rule out the possibility of non-random censoring (assumption 4), but believe the likelihood of violation was minimal, if any occurred at all. We attributed most censoring to emigration from the study area. Because we surveyed outside the core study area less frequently, we were less likely to detect deaths of eagles that emigrated. One could hypothesize that emigrating eagles were exposed to more hazards than resident eagles. Alternatively, one could also hypothesize that emigrating eagles were more likely than resident eagles to exploit temporally abundant food sources during critical periods (late winter, early spring). We have no reason to believe that survival distributions of emigrating eagles was different from those of resident eagles. We did not "update" records for censored birds that returned to the study area after the survival year, because only surviving birds could be accounted for and survival estimates would be biased high. Assumption 5 required that newly tagged animals had the same survival function as previously tagged animals. For juvenile eagles, survival was estimated from a common approximate fledging date (1 September) and all were tagged at the time monitoring began. Most adult eagles were marked in September. Therefore, the assumption was met for first-year eagles and a violation of the assumption for adults would potentially have only a minimal effect on survival estimates because of the short time interval among tagging dates. Furthermore, we observed no mortality of adults in September of either year.

RESULTS

A total of 134 bald eagles (66 adults and 68 fledglings) were radiotagged in PWS from July to October in 1989 and 1990. Twenty-nine eagles (11 adults, 2 second year, 16 first year) died in the 2 survival years. Most mortality occurred from March to May (Fig. 1). Analyses indicate causes of death as emaciation, trauma, and drowning. Two of the 3 dead adults are suspected to have died as a result of aggressive encounters with other eagles (one in October, one in June).

Estimated annual survival rates, pooled for the 2 survival years, were 0.71 for first year eagles and 0.86 for adults (Table 1). Survival for second year eagles during the 1990-91 survival year was 0.86. Survival rates of first year eagles was less than for adult bald eagles ($X^2 = 4.319$, $P = 0.038$), but survival of second year eagles was not significantly different ($X^2 = 0.013$, $P = 0.909$) from either adults or first year eagles. Survival was not significantly different between years (for any age group), between sexes, or between territorial and nonterritorial adults.

Survival relative to oil exposure

There was no evidence of physical oiling on any of the dead radio-tagged eagles, but toxicological tests on some tissue samples are still pending and might reveal other, less obvious, effects of oil contamination.

Comparisons of survival between oiled and unoiled groups, based on oiling at the capture site, or between east PWS and west PWS, revealed no significant differences for any age group during either year. Survival between groups based on oiling exposure determined by telemetry relocations were significantly different in only one instance: survival of first year eagles "exposed to oil" ($n = 3$) was significantly different ($X^2 = 6.43$, $P = 0.011$) from first year eagles "not exposed to oil" ($n = 27$). Sample sizes for oiled categories were small because few juveniles stayed within oiled areas; most dispersed from natal areas soon after fledging to other areas within PWS or to the southeast of PWS (i.e., CRD) (Bowman and Bernatowicz, 1990).

DISCUSSION

It was difficult to accurately classify eagles to oiled or unoiled groups. We therefore used several approaches to estimate exposure to oil. Using only the tagging or capture site as criteria, we could not take into account the potential exposure to oiled areas after the bird was tagged. Likewise, by using radio-telemetry relocations to estimate exposure to oiled areas after tagging, we were unable to consider the exposure before tagging. Although our criteria for classifying eagles into treatment groups are difficult to validate, we believe the criteria were reasonable conservative estimates of exposure.

The only comparison between treatment groups that showed significance (first year birds "exposed to oil" versus "not exposed") may be misleading because of the small sample size of the "oiled" group. Necropsies of the 2 carcasses from birds that died in oiled areas revealed no damage indicative of hydrocarbon contamination, but histological examinations are pending.

Perhaps the most appropriate comparisons of survival between birds from oiled and unoiled areas is for territorial adults only. These birds were marked, and remained, in either oiled or nonoiled areas throughout the year. Although one could speculate that eagles moved from territories during the oil spill when carcasses were plentiful in oiled areas, our radio-telemetry studies show that territorial adults rarely venture from their territories during spring. This was observed despite locally abundant food sources (e.g., herring and eulachon runs) that should have been as attractive to eagles as the abundance of carcasses after the spill. However, there was no significant difference in survival for territorial adults during the 1989-90 survival year or for pooled data from both survival years.

Our data suggest that there was no adverse effect of oiling on survival of postfledging juvenile or adult bald eagles during 1989 and 1990. However, our eagles were tagged 4-5 months after the spill, and therefore were not monitored during the period when most oil-related mortality occurred. Approximately 151 bald eagles were found dead during cleanup operations from April to August, 1989.

Survival estimates for bald eagles are available only for a few local populations, and methods of survival determination differ among studies and may not be directly comparable. Buehler et al (1991) observed 100% survival of radio-tagged first-year eagles in Chesapeake Bay, and survival between 0.83 and 0.92 for adults. Survival rates for PWS bald eagles were remarkably similar to those for Maine eagles (0.73 for first-year eagles, 0.84 for second-year eagles, and 0.91 for older eagles) (McCollough 1986), as determined by resighting of marked birds. However, survival of Maine eagles may be abnormally high because of a winterfeeding program which enhanced survival, and because that population is likely in a recovery phase where there is little competition for food, nest sites, or favorable winter habitat (M. McCollough, pers. commun.).

Young (1968) and Grier (1980) illustrated the importance of reproduction and survival estimates in modeling bald eagle populations, but showed that survival is more critical to the existence of the population. Our inability to detect significant differences in survival related to oiling suggest that our estimated survival rates are suitable for use in modeling population dynamics of bald eagles in PWS, Alaska. To satisfactorily model population dynamics of bald eagles in PWS, information is needed on age specific survival rates for 3 and 4 year old eagles, age at first breeding, and the percentage of adults that successfully raise young. Continued tagging and monitoring of bald eagles should address these needs and provide age-specific survival estimates with improved confidence. Further studies on productivity of bald eagles in PWS will provide the information necessary to model population dynamics, and should clarify "natural" versus "oil-affected" reproductive rates.

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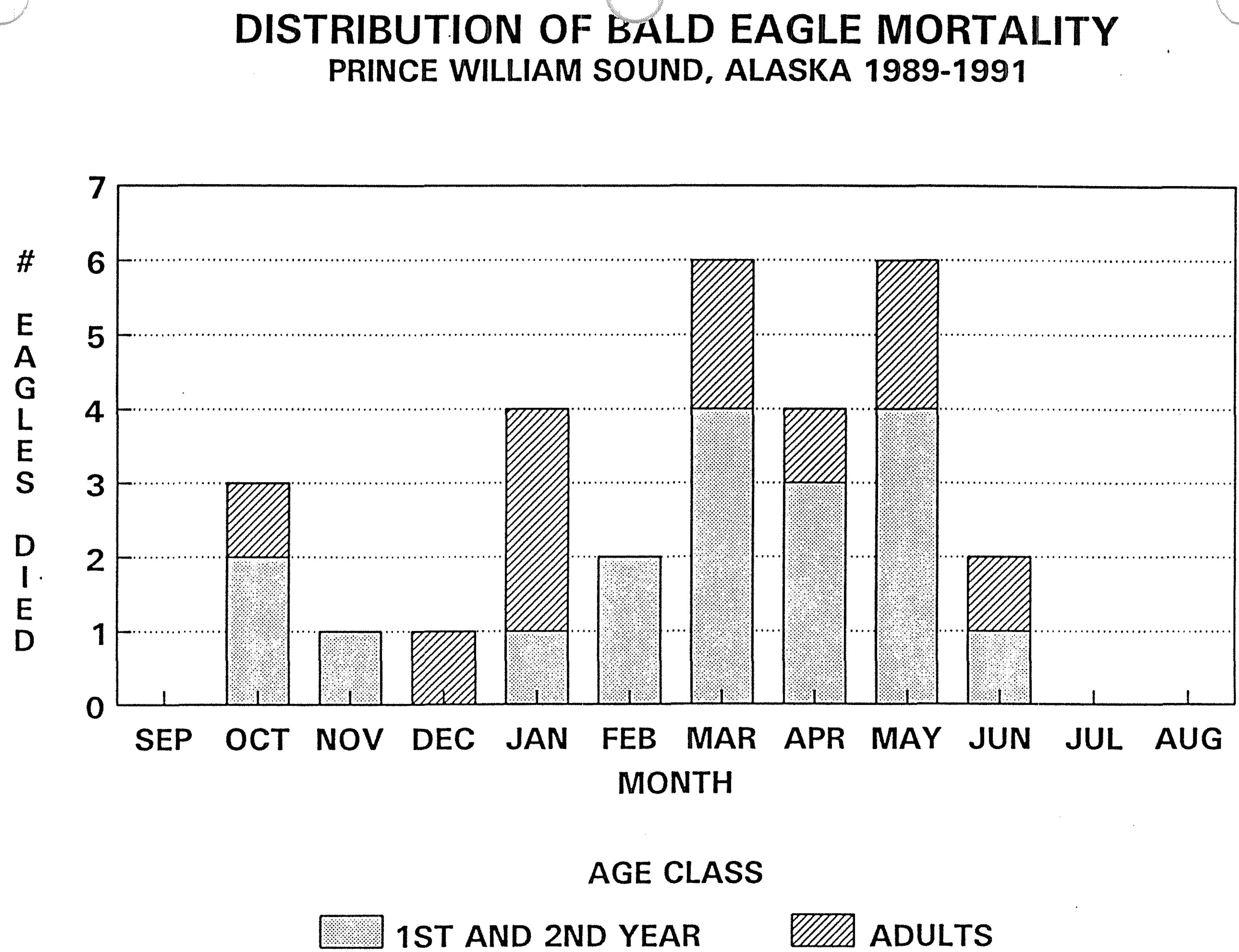
Table 1. Estimated annual[1] survival rates for bald eagles in Prince William Sound, Alaska.

	SURVIVAL YEAR							
	1989-1990		1990-1991		POOLED			
	SURVIVAL RATE	95% CI (±)	SURVIVAL RATE	95% CI (±)	SURVIVAL RATE	95% CI (±)		
FIRST YEAR BIRDS								
ALL	0.78	0.19	0.62	0.21	0.71	0.14		
OILING AT TAGGING SITE	0.83	0.22	0.47	0.33				
NO OILING AT TAGGING SITE	0.73	0.30	0.74		0.32			
OILING, DETERMINED BY TELEMETRY	0.33	0.53	1.00[2]	0.00				
NO OIL, DETERMINED BY TELEMETRY		0.83	0.18	0.62		0.21		
FROM WEST PWS	0.79	0.24	0.52		0.32			
FROM EAST PWS	0.76	0.30	0.70		0.27			
SECOND YEAR BIRDS	NA	NA	0.86		0.19			
ADULTS								
ALL	0.90	0.72	0.82		0.14		0.86	0.08
OILING AT TAGGING SITE	0.92	0.17	0.77		0.26			
NO OILING AT TAGGING SITE	0.88	0.16	0.84		0.16			
OILING, DETERMINED BY TELEMETRY	0.92	0.17	0.80	0.22				
NO OILING, DETERMINED BY TELEMETRY	0.88	0.16	0.83		0.18			
FROM WEST PWS	0.94	0.14	0.84		0.17			
FROM EAST PWS	0.85	0.19	0.77		0.23			
MALES					0.80	0.14		
FEMALES					0.92	0.10		
ALL TERRITORIALS					0.90	0.08		
ALL NONTERRITORIALS					0.93	0.14		
TERRITORIALS MARKED IN OILED AREAS, 1989	1.00	0.00						
TERRITORIALS MARKED IN UNOILED AREAS, 1989	0.87	0.18						

[1] Survival rates calculated from 1 September 1989 to 2 September 1990 and 3 September 1990 to 1 September 1991 using Kaplan-Meier procedure (Pollock et al. 1989).

[2] Survival was 1.0 up to mid-April, when the last of the 5 birds in the subset was censored. Thereafter, survival was unknown.


DISTRIBUTION OF BALD EAGLE MORTALITY
PRINCE WILLIAM SOUND, ALASKA 1989-1991
EAGLES DIED
0
1
2
3
4
5
6
7
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
MONTH
AGE CLASS
1ST AND 2ND YEAR
ADULTS

SUMMARY OF RADIO-TAGGED BALD EAGLES RECOVERED DEAD
[includes eagles recovered up to November 1, 1991]

Band # [629-]	Radio Freq.	Age at Death	Date Recovered	Est. Date of Death	Recovery Location	m to high tide line	m into woods	m elevation	Would be found by cleanup crews?	Comments	Prelim Diagnosis by NWHL
11201	6.554	FY	3-20-90	3-90	ICY BAY	800	0	15	N	IN DUMP, INLAND	Emaciation
11202	6.528	FY	3-20-90	3-90	PEAK IS.	20	15	10	N		Emaciation
11217	7.314	AD	1-25-90	1-90	ESHAMY LAGOON	50	45	8	N		Emaciation, fractured mandible
11224	6.874	AD	10-31-89	10-89	DEEP BAY	0	0	0	Y	DROWNED BY OTHER EAGLE	Drowning
11228	6.174	FY	10-22-89	10-89	GRAVINA PT	40	15	5	N		Emaciation
11243	7.411	AD	7-03-90	6-90	SIMPSON BAY	150	145	15	N	KILLED BY OTHER ANIMAL	Inter/Intra spp. aggression
11370	6.412	FY	2-12-90	1-90	ESHAMY L.	5	7	8	N	IN FRESHWATER LAKE	Fracture of clavicle
11371	6.190	FY	4-27-90	4-90	WOODED IS.	30	10	10	N		(carcass not collected)
11378	6.275	FY	10-21-89	10-89	LONE IS.	80	75	20	N		Emaciation, frac. sternum
11393	6.555	AD	10-31-90	8-90	BLUE FJORD	5	3	3	?	REHAB BIRD; IN ROCKY CREVICE	(carcass not collected)
34313	7.588	L	8-30-90	8-90	NAKED IS.	2	1	10	N	NOT YET FLEDGED	Emaciation
34316	7.688	L	9-02-90	8-90	CHENAGA IS.	50	45	30	N	NOT YET FLEDGED	(carcass not collected)
34320	8.138	FY	9-02-90	9-90	SHEEP BAY	0	0	0	Y		Trauma, fractured sternum
34339	8.383	FY	11-19-90	11-90	NR.COPPER R.	NA	200	200	N	INLAND, SUSPICIOUS	Trauma, fractured wing
11396	6.529	AD	12-18-90	11-90	PEAK IS.	6	6	10	N	REHAB BIRD, BLIND 1 EYE, IN CAVE	Trauma, fractured humerus
11234	6.755	AD	12-28-90	12-90	NELSON BAY	5	5	3	N	CAUGHT IN LEGHOLD	Trapping, emaciation
34363	7.589	AD	1-24-91	1-91	CHANNEL IS.	10	5	3	N		generalized hyperemia
34356	8.538	AD	2-13-91	1-91	BLOCK IS.	1	0	0.5	?	IN CREVICE AT BASE OF LEDGE	(carcass not collected)
34310	8.209	FY	3-91	3-91	CRAIG, AK	NA	NA	NA	N	NEAR DUMP; SUSPICIOUS	(carcass not available)
34309	8.114	FY	3-19-91	2-91	CHICHAGOF I.	NA	NA	NA	N		not yet submitted
34340	8.412	FY	5-13-91	2-91	MIDDLETON I.	450	10	30	N	ON RIDGE, CENTER OF IS.	not yet submitted
34372	8.838	AD	5-20-91	3-91	PORT GRAVINA	200	190	130	N		emaciation
34345	8.172	AD	5-20-91	5-91	STOREY IS.	0	0	0	Y		not collected
11219	7.090	AD	5-21-91	4-91	DISK IS.	50	50	20	N		(carcass not collected)
11377	6.498	SY	6-07-91	3-91	ELEANOR IS.	0	0	0	Y	FOUND BY VECO CREW	(carcass not collected)
34329	7.790	FY	6-07-91	6-91	MONTAGUE IS.	4	0	1	?	CARCASS IN TALL GRASS	Emaciation, renal gout
34312	7.563	FY	6-19-91	5-91	MONTAGUE IS.	75	0	3	N		(carcass not collected)
34328	7.514	FY	6-19-91	5-91	WOODED IS.	15	10	7	N		(carcass not collected)
34326	7.861	FY	6-19-91	4-91	MONTAGUE IS.	70	0	7	N		(carcass not collected)
11389	8.298	AD	6-20-91	5-91	SQUIRE IS.	30	30	20	N		(carcass not collected)
11374	6.315	SY	6-20-91	5-91	FALLS BAY	0	0	0	Y	FOUND BY FISHERMAN	(carcass not available)
34342	8.463	FY	6-20-91	4-91	STOREY IS.	0	0	0	Y		(carcass not collected)
34363	9.705	AD	6-12-91	4-91	CORDOVA DUMP	NA	NA	NA	N	BURIED IN LANDFILL	(carcass not found)
34334	6.413	FY	7-25-91	5-91	DANGER IS.	30	25	5	N		(carcass not collected)
			mean for all birds recovered =			62.23	25.49	16.39			

Age Codes:
FY = FIRST YEAR OF LIFE
SY = SECOND YEAR OF LIFE
TY = THIRD YEAR OF LIFE
AD = ADULT
L = LOCAL

fn:deadbird
date: 11-19-91

Draft of November 25, 1991

AN ESTIMATE OF TOTAL MORTALITY OF BALD EAGLES CAUSED BY THE EXXON VALDEZ OIL SPILL

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The oil tanker Exxon Valdez ran aground on Bligh Reef on 24 March, 1989, spilling more than 11 million gallons of North Slope crude oil into the waters of Prince William Sound (PWS). Oil moved southwest and contaminated much of southwestern PWS, Kenai Peninsula, Kodiak Archipelago, and the Alaska Peninsula. Bald eagles (*Haliaeetus leucocephalus*) are closely associated with shoreline environments. Most nests are within 100 m of the shoreline and eagles forage extensively in the intertidal and shoreline areas. PWS supports an estimated 4000 bald eagles, whereas the population for the entire spill area is about 8000 (USFWS, unpubl. survey data). Eagles found dead by bird rescue crews and cleanup crews were delivered to bird collection centers in Valdez, Seward, Homer, and Kodiak. It is generally believed that the number of eagles recovered during these activities represents only a fraction of the total mortality.

The purpose of this report is to estimate the total mortality of bald eagles in PWS, and within other areas affected by the Exxon Valdez oil spill (EVOS). Our estimate of total mortality is based upon: (1) the number of bald eagles found dead and logged in to the "morgues" during the spring and summer of 1989, (2) the locations of radiotagged eagles found dead in the spill area, and the likelihood of their being found by cleanup crews, and (3) an estimate of natural mortality during the spring and summer of 1989.

METHODS

Since July, 1989, 162 bald eagles (71 fledglings and 82 adults, plus 9 rehabilitated eagles) have been radiotagged in Prince William Sound to monitor survival and document movements and exposure to oiled areas. Transmitters were equipped with mortality sensors that allowed us to easily identify and locate a dead eagle. For each dead eagle recovered, we recorded the distance to the high tide line, elevation, and distance into the woods. We also made a subjective judgement (yes, no, or maybe) as to whether the carcass would have been found by a cleanup or bird rescue crew searching the shoreline. Anecdotal information, and interviews with persons who participated in search and rescue efforts, indicated that crews usually searched only up to the boundary of the woods. Therefore, we expect that eagles found in the woods would not have been found during shoreline cleanup operations.

An estimate of natural mortality was made using survival rates estimated from the radio-telemetry survival study during the period when shorelines were searched (April 1 to 31 August), and an estimate of the total population at risk at the time of the spill.

Assumptions:

1. All carcasses were found and delivered to collection sites.
2. Survival rates determined for PWS eagles are the same for eagles from other areas in the spill area.
3. Emigration and immigration of eagles were equal.
4. Natural mortality continued throughout the summer and search effort was consistent for that entire time period.
5. Dying radio-tagged eagles behaved the same as eagles that died from the effects of oil.

RESULTS

Collection of carcasses from oiled beaches

Approximately 151 bald eagles were collected during shoreline cleanup operations in the entire spill area, of which 32 came from PWS.

Location of carcasses of radio-tagged eagles

Thirty-four eagle carcasses have been recovered as of November 1, 1991. Sixty-six percent of the dead radio-tagged eagles were found in the woods. We estimated that at most 26% (6 yes, 3 maybe, 25 no) would have been found by cleanup or bird rescue crews.

An estimate of natural mortality and eagles available for discovery

Survival rates from the period 1 April to 31 August were 0.63, 0.83, and 0.91 for first-year, second-year, and third-year and older eagles. These survival rates were applied to the estimated number of eagles in each age class (Table 1) to determine the number of eagles expected to die "naturally" within PWS and in the EVOS area. About 500 eagles could be expected to die during that time period in PWS, and an additional 500 in the rest of the EVOS area. However, consider that 74% of dead eagles end up in areas where they would not be found, so we would expect that only 26%, or 262 (0.26 * 1009) of those dead eagles which died "naturally" ended up on beaches. These are estimates for the entire area, which includes all shoreline, oiled or not. Certainly, not all of the eagles could have been found because not all shoreline, especially non-oiled areas, was searched by bird rescue or cleanup crews. Of 5975 miles of total shoreline in the EVOS area, 804 miles (13.5%) were oiled (Alaska DNR, unpubl. report), and 564 miles of shoreline (i.e., 9.4% of all shoreline in EVOS area) were treated in some way. Assuming that more shoreline was searched than was actually treated (e.g., by bird rescue crews, etc.), the percentage of shoreline where carcasses could have been found probably lies between these 2 figures of 13.5% and 9.4%. Let's use 11%. Using this percentage, only about 14 (11% of 131) eagles would have been "available" for discovery by cleanup crews in PWS, assuming eagles were distributed evenly in the spill area within PWS. Using the same procedures, we estimate that only about 28 (11% of 262) eagles would have been "available" for discovery within the entire EVOS area.

Estimate of total mortality

The estimated total mortality within the EVOS area is 581 (= 151 eagles found by cleanup crews) / 0.26 (percentage that would be found). This is an estimate of the number of eagles that died within the EVOS area. Subtract from this the estimated natural mortality available for discovery (28), and you get 553 (total mortality due to oil spill).

DISCUSSION

The assumptions we made imply a very conservative approach to estimating mortality due to the EVOS. It is highly unlikely that all dead eagles were found or recorded at collection centers. We have no data to evaluate the assumption that oiled eagles behaved like "normal" radiotagged eagles, and we would probably experience considerable public scrutiny if we were to try to test that experimentally. Furthermore, most of the radiotagged eagles died during winter, under environmental conditions different from those encountered during the oil spill and subsequent cleanup.

The estimated total eagle population at risk for PWS, Kenai Peninsula, Kodiak archipelago, and Alaska Peninsula in 1989 was about 8000 (USFWS, unpubl. survey data). Confidence limits on population estimates vary from 14% to about 30%, therefore, it is unlikely that we would be able to detect a change in population size of the magnitude estimated resulting from the spill.

TABLE 1. AN ESTIMATED AGE-CLASS DISTRIBUTION AND ESTIMATED NATURAL MORTALITY OF BALD EAGLES IN PRINCE WILLIAM SOUND AND THE WESTERN GULF OF ALASKA

AGE CLASS	ESTIMATED ANNUAL SURVIVAL RATE	SURVIVAL RATE 1 APRIL 31 AUGUST	% IN AGE CLASS	# OF EAGLES IN AGE CLASS PWS	EVOS AREA	ESTIMATED NATURAL MORTALITY, 1 APRIL TO 31 AUGUST PWS	EVOS AREA
FIRST YEAR	0.71	0.63	10.7	429	858	159	317
SECOND YEAR	0.86	0.83	7.6	304	608	52	103
THIRD YEAR	0.86	0.91	6.6	262	523	24	47
FOURTH YEAR	0.86	0.91	5.6	225	449	20	40
SUBTOTAL: (30.5% IMMATURES IN POPULATION) =				1220	2440		
FIFTH YEAR +	0.86	0.91	69.5	2780	5560	250	500
			TOTAL =	4000	8000	504	1009

NOTES:
1. PERCENT IMMATURES IN POPULATION ESTIMATED FROM POPULATION SURVEYS
2. SURVIVAL RATES CALCULATED USING KAPLAN-MEIER PROCEDURE.
3. POPULATION FIGURES ARE ADJUSTED FOR VISIBILITY BIAS
4. ESTIMATED NATURAL MORTALITY = (# IN AGE CLASS) * (1 - SURVIVAL RATE)

fn: totmort.89
date: 11-18-91

BALD EAGLE PRODUCTIVITY IN SOUTHCENTRAL ALASKA, 1989 AND 1990.

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Abstract: Bald Eagle nesting surveys were conducted in 1989 and 1990 in Prince William Sound, Copper River Basin and Delta, Kenai Peninsula, Alaska Peninsula, and Kodiak Archipelago. Differences in survey methodology precluded accurate comparisons among study areas and to some extent, between years. Nest success and productivity in Prince William Sound and on the Alaska Peninsula were lower in 1989 than 1990, but differences between years for other coastal areas were less apparent. The Copper River Basin had similar productivity to coastal areas in 1989, but much lower productivity in 1990.

After the EXXON Valdez oil spill (EVOS) in March, 1989, studies were initiated to assess the damage to bald eagles in the area affected by the spill. Several agencies were involved in efforts to monitor bald eagle productivity, with U.S. Fish and Wildlife Service (USFWS) taking the lead role. One objective of this portion of the damage assessment study was to collect and analyze bald eagle nesting data from several areas within the EVOS area, and control areas, in a standardized manner that would allow comparison among areas and between years, and provide estimates of productivity with minimal bias. This was not always possible, especially in 1989. During the hectic period after the spill, personnel and logistical constraints precluded standardization of survey timing and technique. Standardization of surveys was improved in 1990.

Proper and consistent timing of surveys is critical to obtain accurate and comparable data for raptor reproductive studies. Nesting chronology is apparently consistent between years (Fig. 1) and failures (Fig. 2) and fledging (Fig. 3) occur rapidly during certain periods of the nesting season. In Prince William Sound (PWS), we determined that optimal timing of activity surveys was 9-16 May, and mid to late July for productivity surveys (Fig. 2). In circumstances where activity surveys were flown later than optimal, we estimate the number of active nests which may have failed before the surveys were conducted, based on nesting chronology data from PWS in 1990. These rough estimates are given to help the reader evaluate how improper survey timing may have biased results. However, little is known about how synchronous failures are between areas and years. In PWS, 1990, most failures of active nests occurred about the time of hatching (Fig. 11), whereas data from Alaska Peninsula (Dewhurst 1989) indicate more failures occur post-hatching than in PWS. Furthermore, because failures occur during such a short period of time in PWS, any variations in nesting or failure chronology may bias our estimates.

Terminology and criteria used to evaluate reproductive success for raptors is often confusing and different interpretations of data among researchers often result (Postupalsky 1974). Results presented in this report may differ from results presented in some of the cited reports. This is largely due to differences in interpretation of data. For example, some researchers considered nests successful even if no activity survey was conducted. We believe this overestimates success rates because failed nests would not be recognized as such and would be incorrectly recorded as empty. In this study, we have attempted to 1) standardize interpretation of data among years by using consistent definitions among all survey areas, and 2) provide several measures of productivity. We used definitions proposed by Postupalsky (1974). Because terminology can often be confusing, especially to persons unfamiliar with raptor behavior, we recommend referring to Table 1 for these definitions.

This report presents and compares data on productivity among several areas of southcentral Alaska. We discuss factors that influence the quality of the data (e.g., timing of surveys, completeness of observations, sample size) to help the reader evaluate the reliability and accuracy of the information. It is not within the scope of this report to assess actual damages of the EVOS to bald eagles. An assessment of reproductive success versus oiling will be addressed in a separate report.

STUDY AREA

The major areas in this assessment of bald eagle productivity included Prince William Sound, Copper River Basin (CRB), Kenai Peninsula, Kodiak Archipelago, and Alaska Peninsula (Fig. 4). For purposes of analysis, the Copper River Basin was further delineated into Copper River Basin and Copper River Delta (CRD).

METHODS

Bald Eagle nest locations were plotted on USGS 1:63360 topographic maps, which were used as field maps during surveys. Each nest was assigned a unique number consisting of QMQ (quarter-million quad) code, ITM (inch-to-the-mile) code, and nest number for that particular map (i.e., nest number 31 on map Seward B1 was referred to as 95, 21, 31). All nests within each map were numbered consecutively and newly found nests were assigned the next number for that particular map.

Whenever possible, at least 2 surveys were conducted to assess bald eagle productivity. An early survey (i.e., activity survey) was conducted during the incubation period (mid-May to early

June), and a late survey (i.e., productivity survey) was conducted after eggs had hatched but before young had fledged (late July to early August). Helicopters were used for most surveys, although small fixed-wing aircraft were used in some instances. We used terminology adapted from Postupalsky (1974) for activity and productivity assessments (Table 1).

Two terms used frequently, occupied and active, are often confused and require further definition. An occupied nest is any nest with a territorial pair, whether they actively nested or not. Active nest are only nests in which pairs actively nested as determined by an adult in incubating posture, eggs, or young.

We calculated the following measures of reproductive performance for both active and occupied nests: percent successful, percent failed, total number of young produced, young per successful, and young per active/occupied nest (See Table 1 for definition of these parameters). Young per occupied nest is the standard definition of productivity. This definition recognizes that failure to lay eggs may be a response to environmental conditions which are less conducive to breeding, and should be considered another type of nest failure (Postupalsky, 1974). The intensity with which observers look for occupied nests, weather conditions, and survey timing may all influence the number of non-breeding territories found. In some survey areas, non-breeding territories were not recorded or the data is vague. Therefore we include other less acceptable measures such as young per active and successful nest. Total young produced is one of the best measures of an areas productivity when survey intensity and observer experience are consistent.

Information on nesting was often collected in a manner that precluded a standardized calculation of nest fate (e.g., no activity survey was conducted, or was conducted too late), but sufficient information was recorded to calculate certain measures of production. For example, a nest surveyed only in August and found to contain 2 chicks would be used in calculations of productivity, but would not be used to calculate nest success.

RESULTS AND DISCUSSION

Prince William Sound

All data were collected by USFWS. Surveys covered approximately 80% of PWS (Fig. 5). Initial nest occupancy data in 1989 were collected opportunistically (i.e., as a secondary objective) during bald eagle population surveys, 18 April to 5 May, using fixed-wing aircraft. Data were collected on all islands in PWS and segments of the mainland shoreline on this survey. Occupancy status was not recorded for many nests during population surveys in April, so we used the presence of 2 adults near a documented nest site as evidence of occupancy. A second activity survey in

1989 was conducted 20-27 May using a helicopter and concentrated on oiled areas in western PWS. Although this survey was only slightly later than the optimal dates (9-16 May), a substantial number of early failures, due to oil related mortality and disturbance, may have been missed. Productivity surveys were flown on various dates from mid-July through 8 August before few chicks had fledged. Because of the emphasis on collecting data in oiled areas, the majority (87%) of nests with complete survey data were in western PWS.

Data on nesting success and productivity in PWS in 1990 is excellent. Survey areas included nesting habitat within oil-impacted areas and in areas distant (eastern PWS) from the spill area. All surveys were done by helicopter with two observers and a pilot. All nests were surveyed for activity twice (10-19 April and 13-19 May) and all occupied nests were surveyed for productivity from 21-25 July. Follow up surveys were flown on 12- 14 August. All chicks seen during the productivity surveys were aged to determine nesting chronology. In addition, an "intensive" survey (Fig. 5) was conducted every 10 day period from early April through mid-August to precisely define the timing of incubation and failure (Fig. 2).

Nest success was 31% for occupied nests and 35% for active nests, with 0.66 young per occupied nest in 1989. In 1990, nest success was 57% for occupied nests, 68% for active nests, with 0.86 young per occupied nest (Table 2). The estimate of success for occupied nests in 1990 is not directly comparable to 1989 or other areas. Activity surveys in 1990 were conducted more intensively (multiple surveys for each nest) and the observers were counting adult eagles in addition to locating nests. Therefore, occupied nests with non-breeding pairs were more likely to be seen in 1990.

Caution should be used in comparing data for PWS between years. Data for PWS in 1989 were obtained primarily in western PWS, whereas 1990 data represent all of PWS. However, it is obvious that nesting success and productivity were significantly lower in 1989 than in 1990. Furthermore, nest success and productivity for a subset (n=192) of nests monitored in both 1989 and 1990 also indicates lower success in 1989 (1989: 31% and 34% successful for occupied and active nests, 0.39 young per successful; 1990: 63% and 72% successful for occupied and active nests, and 1.02 young per occupied). Given the potential biases in the 1989 data, the difference seems more pronounced.

<u>Copper River Basin and Copper River Delta</u>

Bald eagle nests were surveyed in the Copper River Basin (CRB) from Tanada Lake and the Gulkana River drainage to the Million Dollar Bridge (MDB) in 1989 and additionally in the lower Copper River and Copper River Delta (CRD) in 1990 (Fig. 6). Results of surveys for the CRB and CRD are discussed separately because of the differences in habitat between the areas.

Copper River Basin:

Surveys were conducted by personnel of USFWS, Bureau of Land Management (BLM), and National Park Service (NPS) from Wrangell Saint-Elias National Park. In 1989, activity surveys were flown from 23-27 May over the entire CRB and productivity surveys were conducted from 30 June to 7 July on the Copper River and 25-26 July in the Gulkana Drainage. Activity surveys in 1990 were flown 12-16 May and productivity surveys were conducted 26 July - 18 August. Nest observations on the Copper River from Tanada Lakes to Chitina were largely incomplete in 1989. Only 65 occupied nests were covered by both activity and productivity surveys in the entire CRB. In 1990, 163 occupied nests had complete data. All chicks (n=67) observed on the Copper River downstream from the Tiekel River and on the CRD were aged to determine nesting chronology. Nesting chronology on the lower Copper River was similar to PWS (Fig. 7), the Tanana River (Ritchie, 1981), and southwest Yukon (Blood and Anweiler, 1990). Data were collected for non-breeding (i.e. occupied, but not active) pairs both years, but not consistently over the entire area.

Success for occupied nests in the CRB was 51% and 40% for 1989 and 1990, respectively. Productivity (young per occupied nest) was 1.18 in 1989 and 0.64 in 1990. In 1989, 106 occupied nests produced 125 young whereas 163 occupied nests produced only 105 young in the same survey area in 1990 even though surveys were more intense. Nest success and productivity may be overestimated in 1989 because an estimated 17% - 35% of failures may have occurred before activity surveys were completed.

Productivity surveys on the Copper River in 1989 were completed before the young were fully feathered and after some young may have fledged in 1990. Blood and Anweiler (1990) found that young had fledged from 87% (n=8) of nests by 19 August, and Ritchie (1981) observed fledged young on 7 August. Fledged young were seen by the second week of August on the Copper River below Chitina and in PWS. However, young on the Gulkana Drainage do not start fledging until late August and mortality of chicks after hatching is low (B. Steidl, Oregon State Univ., pers. comm.). Mortality of chicks after 4 weeks of age was less than 10% in PWS (USFWS, unpubl.). Although the discrepancies in the timing of productivity surveys may have caused success rates to be overestimated 1989 and underestimated in 1990, we feel this bias was not significant.

Nest success was much lower both years than for other similar inland areas (71-90% in southwest Yukon [Blood and Anweiler 1990], 54-80% on the Tanana River [Ritchie 1981]), or coastal areas in southcentral Alaska (Table 2). Young per occupied nest was lower than most inland or coastal areas in 1990. The greater number of occupied nests in 1990 for the same survey area can probably be attributed to increased surveyor experience and more intensive surveys. Overall productivity in the Copper River Basin was higher in 1989 as more chicks were produced from fewer nests.

Copper River Delta

Surveys were conducted in 1990 from the Million Dollar Bridge downstream to the Copper River Delta west of Storey Slough by USFWS. The timing of surveys was good (activity survey: 12-16 May; initial productivity survey on 26 July with follow-up survey on 15 August), and observations are complete for most nests in this area. Data were collected on non-breeding pairs.

Nest success was 60% for occupied nests in 1990 and 64% for active nests, with 0.97 young per occupied nest. Sixty-five young were fledged on the CRD. These data are similar to other areas in southcentral Alaska (Table 2) and inland areas ([Blood and Anwieler, 1990], [Ritchie, 1981]), but success rates are greater than the CRB.

Kenai Peninsula

Nest surveys were conducted by personnel from Kenai Fjords National Park and the USFWS on the Kenai Peninsula from Day Harbor to English Bay in 1989, and from Day Harbor to Elizabeth Island in 1990 (Fig. 8). Data for 1989 were collected primarily by personnel from Kenai Fjords National Park, and are summarized by Hoover-Miller (1990).

Bald eagle nesting and productivity for the Kenai Peninsula in 1989 is poorly documented, and most data were obtained using methods that precluded an accurate assessment of productivity. No activity surveys were flown (or dates were not recorded) and many notes on nest status were vague. Some information on nest status was recorded by Bird Rescue crews, but these data were not used unless there was a detailed account of activity. Consequently, no calculation of nest success or productivity can be made for 1989. Active nests produced 52 young. Successful nest produced an average of 1.27 young per nest.

In 1990, activity surveys were conducted 19-23 May (74% of observations) and 6-7 June (26% of observations). Productivity surveys were flown 4-5 August. There was some conflicting information on nest status between field maps and summary reports; these nests were not used in our analysis. Nest success was 51% for occupied nests and 58% for active nests. Productivity was 0.92 young per occupied nest with 58 young produced. Young per successful nest averaged 1.45. Nest success is probably slightly overestimated as 17% and 45% of failure for active nests may have occurred before the 23 May and 7 June surveys, respectively.

The total number of young produced was greater in 1990, however, surveys in 1989 were less intensive. Therefore, we can assume that young produced in 1989 is a minimal estimate and that there was no difference in productivity between 1989 and 1990. No comparisons of nest success can be made.

Kodiak Archipelago

Data were obtained from Denny Zwiefelhofer, Wildlife Biologist, Kodiak NWR (Zwiefelhofer 1989, 1990). Surveys were conducted by biologists and technicians from Kodiak NWR. Activity surveys on the Kodiak Island coastline from Cape Grant to Spruce Cape were flown in a Piper Supercub from 10-12 May 1989, and 7-11 May 1990. The Afognak, Shuyak, and remaining archipelago coastline was surveyed for activity in a Bell Jet Ranger helicopter from 1-7 June in 1989 and from 14 May to 3 June in 1990. The May and June surveys accounted for 64% and 36%, respectively, of the nests surveyed for activity in 1989. In 1990, the majority (86%) of nests were surveyed for activity before 16 May and 99% were surveyed before 25 May. Nests with non-breeding pairs were recorded as "active" nests in 1989. In 1990, "occupied" nests were distinguished from active nests. The survey area (Fig. 9) and intensity of surveys was identical both years.

The 1989 productivity surveys on Kodiak Island were conducted in a Piper supercub from 29 July to 5 August in 1989 and 1990. All other productivity surveys in the archipelago were flown 21-22 July in 1989 and 24-25 July in 1990. A Bell Jet Ranger helicopter was used on all productivity surveys on islands outside of Kodiak Island.

In 1989, 333 occupied nests produced 399 young (Table 2). Productivity was 1.20 per occupied nest and 1.66 young were produced per successful nest. The success rate for occupied nests was 72% in 1989, but data were insufficient to calculate success rates for active nests. In 1990, 412 occupied (401 active) nests produced 431 young. Productivity in 1990 was 1.05 young per occupied nest, 1.07 young per active nest , and 1.63 young per successful nest. The success rate for active and occupied nests in 1990 was 66% and 64% respectively.

The real success and productivity rate for active nests in 1989 was probably lower than the reported 72% success and 1.20 young per occupied nest, because 1-7 June activity surveys probably missed some early failures (35% of failures by 31 May and 52% by 10 June). Nesting chronology in the Kodiak archipelago is similar to PWS (D. Zwiefelhoffer, pers. comm.). Most nests in 1990 (86%) were surveyed for activity before many failures had taken place. Productivity surveys in both 1989 and 1990 were well timed. The 1990 success rate (64%) is identical to the historic average for the Kodiak refuge (Zwiefelhofer, 1989). Productivity of 1.05 young per occupied nest and 1.66 young per successful nest are greater than the historic averages for the refuge of 0.99 young per occupied nest and 1.54 young per successful nest. Although estimates of nest success and productivity (young per occupied nest) was higher in 1989 than 1990, there were more occupied nests and young produced in 1990. The larger number of occupied nests and total young produced in 1990 may have been due to a significant number of non-breeding pairs and failures being missed by the late nesting surveys in 1989, or increased surveyor experience and new nests being found. There was probably no significant difference in productivity between 1989 and 1990.

Alaska Peninsula

Data were obtained from Donna Dewhurst, Wildlife Biologist, Alaska Peninsula/Becharof NWR (Dewhurst 1989, 1990). Surveys were conducted by USFWS personnel from the Alaska Peninsula/Becharof National Wildlife Refuge. The 1989 survey area covered approximately 350 miles of coastline from Cape Kubugaki to Cape Kunmik (Fig. 10). Activity surveys in 1989 were flown from 10 May to 3 June, but most of the nests (89%) were surveyed during 1-3 June. Productivity surveys were flown on 24 July and 25 July. Additional surveys were conducted on 19-20 June and 4-5 July. Nests with non-breeding pairs were not noted on the activity surveys.

The 1990 survey area covered 825 miles of coastline from Cape Kubugaki to American Bay, however only the section from Cape Kubugaki to Cape Kumlik (375 miles)(Fig. 10) was surveyed for both activity and productivity. The 1990 activity surveys were conducted from 9-11 May for the section from Cape Kubugaki to Cape Kumlik, and from 23-31 May for the remainder of the coast. Productivity surveys were flown from 26-28 July with an additional survey 19-21 June. Non-breeding pairs were noted during the activity surveys in 1990. The 1989 productivity survey was flown in a Cessna 206, all other surveys in 1989 and 1990 were flown in a Bell 206 helicopter.

In 1989 some successful nests may have been called failed due to fixed-winged productivity surveys. Most bald eagle nests on the Alaska Peninsula are ground nests, which are more difficult to see than stick nests. Ground nests often become grown over with grass when not maintained, making it difficult to locate empty or failed nests, especially if the location was not accurately mapped. Furthermore, ground searches are sometimes needed to confirm "failed" nests because chicks may hide in the grass next to the nest. This was not possible during the 1989 productivity survey as a helicopter was needed for access to the majority of nests. In 1990 empty and failed nests were more easily identified as surveys were conducted by the same experienced observer in a helicopter.

In 1989, 69 active nests produced 62 young (Table 2). Young per active and successful nest were 0.90 and 1.59 respectively. The success rate for active nests was 55% in 1989. This compares to 107 active (114 occupied) nests producing 104 young in 1990. Productivity in 1990 was 0.91 young per occupied nest. Active and successful nests produced 0.97, and 1.6 young per nest respectively. The success rate in 1990 was 59% and 56% for active and occupied nests, respectively. We could not calculate success rates for occupied nests in 1989.

The real success rate for active nests in 1989 may have been lower than the reported 55% because 35% of failures of active nests may have occurred by 1-3 June. However, hatching success data from Dewhurst (1989, 1990); suggest the rate of failures is probably slower on the Alaska Peninsula. Although the inability to ground truth failed nests in 1989 may have overestimated the number of failures and offset biases caused by late activity surveys, the number of occupied nests and total young produced was higher in 1990. Although the large increase in occupied nests and young produced was partly due to a larger survey area in 1990, the section from Cape Kubugaki to Cape Kunmik (1989 survey area) produced 81 young from 79 occupied nests in 1990. This increase in productivity supports the theory that late activity surveys missed early failures and that the real success and productivity rates were higher in 1990.

CONCLUSIONS

Differences in survey timing and methodology made comparisons between areas and years difficult. This is especially true when activity surveys were conducted after some failures had likely taken place. The most significant finding was the low nest success and productivity in PWS in 1989 and in the Copper River Basin in 1990. Production in the Kodiak Archipelago and on the Kenai Peninsula apparently did not change substantially between 1989 and 1990, but probably improved on the Alaska Peninsula. There are no consistently remarkable differences in bald eagle productivity among coastal areas in southcentral Alaska.

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Table 1. Definitions of terms used in calculations of nest success and productivity.

Occupied Nest: Two adults actively defending, near, or at the nest. Includes any nesting(active) and non-nesting territorial pairs. One adult near an empty, un-maintained nest is not sufficient evidence for an occupied nest.

Active Nest: Any nest with eggs, chicks, or adults in incubation posture. The presence of a pair or lone bird near the nest does not count as Active.

Total Young Produced: Number of young produced to an advanced stage of development. Includes all nests found in the productivity survey.

Young per Occupied Nest: Number of young produced per occupied nest. Includes all occupied territories located.

Young per Active Nest: Number of young per active nest. Includes only nests in which eggs were laid.

Young per Successful Nest: Number of young per successful nest.

Percent Successful: Percent of occupied or active nests with complete data that successfully raised young to an advanced stage of development.

TABLE 2. BALD EAGLE NEST SUCCESS AND PRODUCTIVITY FOR SOUTHCENTRAL ALASKA, 1989 AND 1990

SURVEY AREA	YEAR	OCCUPIED NESTS FOUND	OCCUPIED NESTS WITH COMPLETE DATA	TOTAL YOUNG PRODUCED	YOUNG PER OCCUPIED NEST	YOUNG PER ACTIVE NEST	YOUNG PER SUCCESSFUL NEST	PERCENT SUCCESSFUL (OCCUPIED NESTS)	PERCENT SUCCESSFUL (ACTIVE NESTS)
PWS	1989	301	212	198	0.66	0.71	1.31	31	35
PWS	1990	650	622	558	0.86	1.03	1.50	57	68
KODIAK	1989	333	333	399	1.20	NA	1.66	72	NA
KODIAK	1990	412	412	431	1.05	1.07	1.63	64	66
AK PEN.	1989	69	62	62	NA	1.00	1.59	NA	55
AK PEN.	1990	114	108	104	0.91	0.96	1.60	56	59
CRB	1989	69	37	81	1.17	NA	1.59	51	NA
CRB	1990	163	153	105	0.64	0.65	1.48	40	40
CRD	1989	NO DATA COLLECTED							
CRD	1990	67	63	65	0.97	1.03	1.58	60	64
KENAI	1989	45	0	52	NA	1.16	1.27	NA	NA
KENAI	1990	63	45	58	0.92	1.00	1.45	51	58

Data in this table are not directly comparable. Differences in survey timing, techniques and extent of survey area may have biased results. Comparisons between years for the same area, and between areas, should be made with caution and with a full understanding of the biases involved.

CRB- Copper River Basin
CRD- Copper River Delta

Figure 5. Bald Eagle survey areas in Prince William Sound, Alaska, 1989 and 1990.

Extensive Survey
Area, 1989 and 1990

Intensive Survey
Area, 1990 only

Figure 10. Bald Eagle survey areas on the Alaska Peninsula, 1989 and 1990.

Figure 3. Nesting Chronology for Bald Eagles in Prince William Sound, Alaska, 1990.

Figure 9. Bald Eagle survey areas in the Kodiak Archipelago, 1989 and 1990.

Figure 8. Bald Eagle survey areas on the Kenai Peninsula, 1989 and 1990.

Figure 1. Bald Eagle egg-laying chronology in Prince William Sound, 1989 and 1990.

Figure 2. Timing of nesting and failures for bald eagles in Prince William Sound, 1990.

Figure 4. Bald Eagle survey areas in southcentral Alaska, 1989 and 1990.

Figure 6. Geographic divisions for bald eagle surveys, Copper River Drainage.

Figure 7. Bald Eagle egg-laying chronology in Prince William Sound and Copper River Basin, 1990.

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AN ESTIMATE OF LOST PRODUCTION OF BALD EAGLES IN PRINCE WILLIAM SOUND AND OTHER AREAS WITHIN THE EXXON VALDEZ OIL SPILL AREA, 1989

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To estimate loss in bald eagle production in Prince William Sound (PWS) in 1989, we compared productivity (i.e., total number of young produced) for a sample of nests in oiled areas that were surveyed in both 1989 and 1990. We also estimated the proportion of nests in PWS that were within oiled areas (i.e., within 0.5 km of any oil), and extrapolated the production to the total area within PWS that was oiled using both 1989 and 1990 values for production. The difference in total production between years was the "loss in production".

Loss of production in Prince William Sound

Assumptions and Estimates

1. 1990 was a "normal" year for bald eagle production in PWS. This is a conservative approach because there may have been lingering effects of oiling even in 1990.

2. Bald eagle production was not affected outside the spill area. This is unlikely, and results in a very conservative estimate of lost production. Our estimate only addresses lost production within the immediate spill area of PWS.

3. We estimate that about 300 nests in PWS were oiled (i.e., had some oil within 0.5 km of the nest). This is based on the number of nests that we found during 1989 and 1990 nest surveys that had oil near them (n= 261) and an adjustment to 300 because we did not survey all the oiled nests in PWS. This is a conservative number, and therefore will result in a conservative estimate of lost production.

Calculations

From the above, we calculate that a sample of nests (n= 172) within the "spill area" produced 29 chicks in 1989 and 105 in 1990. We also estimated that there were about 300 nests in oiled areas in PWS. Therefore, our sample of nests represent 57 % (172/300) of the total nests oiled. An estimate of "lost production" is the difference in production for the sample nests, extrapolated to the total number of nests in oiled areas in PWS. This estimate is 133 chicks (105 chicks in 1990 - 29 chicks in 1989 = 76 chicks X 100/57 = 133 chicks).

Discussion

This is a conservative estimate of "lost production" in 1989. We restricted our estimate to nests in the immediate vicinity (i.e., within 0.5 km of any oil). This is probably unrealistic because eagles nesting farther than 0.5 km were potentially exposed to oil. Results of hydrocarbon analyses of eggs and prey remains collected at eagle nests indicated exposure even in East PWS (up to 45 km away), in both 1989 and 1990. This may be a conservative estimate also because 1989 was a bumper year for eagle production in most other areas of Alaska.

Changes in bald eagle production, 1989 to 1990, in other areas affected by the Exxon Valdez oil spill

A estimate of annual production comparable between years can be estimated for areas of Kodiak Archipelago and Alaska Peninsula which were surveyed in both 1989 and 1990. Production at Kodiak in 1989 was 399 chicks, compared to 431 for the same area in 1990. This represents a 7% lower productivity in 1989, which probably is not significant and may be attributed simply to increased number of nests found in the survey area. On the Alaska Peninsula, 62 chicks were produced in 1989 compared to 81 chicks for the same area in 1990 (i.e., 23 % fewer chicks in 1989). Data for the Kenai Peninsula did not allow a comparison of production.

Bald eagle nest success following the EXXON Valdez oil spill in Prince William Sound, Alaska, 1989-90.

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ABSTRACT: Bald eagle nesting in Prince William Sound, Alaska was monitored for two years following the EXXON Valdez oil spill on March 24, 1989. Each nest was surveyed at least twice from the air, once early in the breeding season to determine nest occupancy and again later in the nesting season to evaluate ultimate nest fate. Nest occupancy, nest success and the number of young produced were all negatively impacted in 1989. These adverse effects were correlated with the distribution and concentration of crude oil on the beaches in the study area. A decrease in crude oil toxicity or availability may have been responsible for the improvement in nesting success in 1990.

On March 24, 1989, the EXXON Valdez ran aground on Bligh Reef in northeastern Prince William Sound and spilled more than 260,000 barrels (11 million gallons) of Prudhoe Bay crude oil. The oil was pushed to the southwest by winds and currents for more than 750 kilometers, eventually reaching Kodiak Island and more than half way down the Alaska Peninsula (Piatt et al. 1990). This coast is essentially undeveloped and sparsely inhabited by humans, facing for the most part into the Gulf of Alaska on the northern Pacific Ocean. The once pristine habitats of the affected area are occupied by at least 5000 adult bald eagles (Haliaeetus leucocephalus) (USFWS unpubl. data), nearly double the 1500 pairs of bald eagles breeding in the rest of the United States combined (Johnsgard 1990).

Bald eagles along the coast of southern Alaska are strongly associated with intertidal habitats. Nest sites average 37 meters from the tide line (Hodges and Robards 1982) and essentially all of their food is obtained from the intertidal zone and the surface of adjacent waters (Imler and Kalmbach 1955). Areas used most heavily by bald eagles became extensively fouled as the drifting oil came ashore. Severe impacts to bald eagles nesting in the path of the spill were expected.

The potential threat to bald eagles and other coastal raptors from a major oil spill has been recognized for a long time (Schempf 1982, Todd et al. 1982). No literature exists on the impact of crude oil on nesting bald eagles, but there are numerous studies available for other species discussing mechanisms of contamination (Albers 1980), influence on incubation, embryo survival and fecundity (Albers 1978, Albers and Szaro 1978, Coon et al. 1979, Couillard and Leighton 1989a, 1989b, 1990, Hartung 1965, Hoffman 1978, 1979, King and Lefever

1979, Szaro 1979, Szaro and Albers 1977, Szaro et al. 1978a, 1980), post-hatching impacts (Flemming et al. 1982, Lee et al. 1985, Pattee and Franson 1982, Szaro et al. 1978b) and general impacts of petroleum on birds (Albers 1983, Leighton 1985, Piatt et al. 1990, Szaro 1977).

Aerial surveys were initiated in April, 1989, to locate active nests and monitor their success. These surveys were repeated in 1990. Data for both years were obtained on 304 nest sites in Prince William Sound.

The principal findings were that occupancy in oiled areas was lower than in unoiled areas in 1989. These rates did not improve in 1990. Nesting success was significantly impaired in 1989 with few successful nests and reduced production in those nests that were successful. The frequency of 2-chick nests was unusually high in 1990. Nest failure rates were significantly higher in 1989 at nests near heavy oiling and significantly lower in 1990 at nests along oiled beaches. Nest fates in 1989 and, to a lesser extent in 1990, were related to the linear extent and intensity of oiling in the vicinity of the nest.

METHODS

Initial nest occupancy data in 1989 were collected during a bald eagle population survey flown with fixed-wing aircraft from April 18 to May 5, following the methods presented in Hodges et al. (1984). This survey was flown primarily to count adults with nest occupancy data collected secondarily. The survey covered the shorelines of all islands in Prince William Sound and 24 random plots that were predominately along the mainland shores of Prince William Sound, but including coastlines along the Gulf of Alaska from Cape Spencer in the east to Cape Elizabeth in the west. The location and status of bald eagle nests observed during the population survey were recorded. These data were used to supplement later helicopter surveys.

In 1989, authorization to proceed with helicopter surveys was received in mid May and the surveys were initiated on May 20. If a nest was not seen before the end of May, it was not included in subsequent analyses of nest occupancy or success. There is an increasing likelihood of nest failure after this date causing incorrect classification of nests observed as empty that may have been active earlier in the breeding season. Surveys concentrated on the islands in the western part of Prince William Sound and westward along the Kenai Peninsula, the anticipated route of the moving oil slick, because of the immediate need for data on bald eagle nest locations and breeding status in relation to cleanup operations of oiled shorelines. Surveys were repeated throughout the summer until the final nest fate was determined. Due to the late start and crisis situation, data on some nests were fragmentary or otherwise unsuitable for analysis. These data were deleted from the data set.

The fixed-wing population survey was repeated in 1990 from April 27 to May 4, again noting the location and status of nests observed during the flight. Helicopter surveys of bald eagle nest occupancy were begun on April 10, and were repeated at least five times or until the final fate of the nest was determined. Precautions were taken to minimize the length and duration of disturbance during surveys (Fyfe and Olendorff 1976). No adverse consequences were noted due to the survey intensity (White and Sherrod 1973). Standard survey techniques and terminology were used during all surveys (Postupalsky 1974).

Bald eagle nest locations were plotted on USGS 1:63,360 topographic maps which were used as field maps during surveys. Each nest was assigned a unique number consisting of QMQ (quarter-million quad) code, ITM (inch-to-the-mile) code, and nest number for that particular map (e.g., nest number 31 on map Seward B1 was referred to as 95, 21, 31). All nests within each map were numbered consecutively and new nests were assigned the next number consecutively and new nests were assigned the next number for that particular map. Our total survey area encompassed approximately 80% of the total shoreline area of Prince William Sound, and included nearly all of the area directly affected by the oil spill.

A Bell 206 helicopter was used for all nest occupancy and productivity surveys. Shorelines were searched for previously observed nests and new nests by flying at an altitude of 50-500 feet at speeds of 40-70 mph. Two observers were present in the helicopter during surveys. The front observer served as navigator and recorded nest status and new locations on field maps. The back seat observer recorded data on field forms. Survey data were entered into computer files and cross-checked with data on field maps.

On the initial survey, nest status was determined as empty or as occupied/active with a pair of eagles attempting to breed, following the terminology of Postupalsky (1974). Final nest fate was listed as empty, failed for nests where breeding was attempted, but the nest was found empty on subsequent surveys or successful for those nests that produced young that were assumed to have fledged. The number and age of young at successful nests were recorded.

In order to assess the influence of oil contamination on breeding success, we developed a measure of the contamination within an area about the nest likely to be used by the breeding pair of eagles. A "core area" about the nest site was determined using radio telemetry. The "core area" was defined as a radius about the nest equal to the greatest distance between telemetry relocation points for perches within the nest area. Extreme outliers were eliminated from the data set. This distance determined for radio tagged adults was 483 meters. We feel this is a conservative estimate of the area actually used by breeding eagles, but representative of the area they would use most intensively. The length of shoreline within a radius of 483 meters of each nest was measured. This length was subdivided into oiling classes based on shoreline survey data from the Alaska Department of Environmental Conservation. Four classes were used for analysis, heavy, moderate, light or unoiled. These classes are defined in Table 1. Unsurveyed shorelines were considered to be unoiled.

Productivity parameters were analyzed based on the total number of nests surveyed and were compared between years and between oiling classes using the Chi-squared test. The groupings used for oiling included all "core areas" with heavy oiling versus those "core areas" with no oil, those with heavy and/or moderate oiling versus those with no oil and "core areas" with any oiling versus all others. These groupings gave a range of impacts from heavily oiled areas to those with only a limited effect from oil contamination. These groupings are not mutually exclusive; the any oil group includes all nests in the heavy and/or moderate group and the heavy and/or moderate group includes all nests in the heavy group. It would have been desireable to have exclusive categories, but the complex distribution of the various oiling classes within each "core area" made such a separation impossible. The relative frequency of nests with 0, 1, 2, or 3 young also were compared using Chi-squared, comparing between the oiling groupings. The average number of young produced between impacted areas and areas without oil were compared using a T-test.

Nest fates in 1989 and 1990 were compared using Chi-squared to determine if nest outcome in 1989 influenced the fate of the nest in the following year. Nest fates also were compared with the degree of oiling in the "core area" using Tukey's HSD multiple comparison test after applying Bartlett's test for homogeneity of group variances. The degree of oiling was estimated as weighted mean, giving beaches a weight of 1.0, 0.67, 0.33, and 0.0 for heavy, moderate, light, and no oil, respectively. These weights were multiplied times the length of shoreline in the "core area" for each class, summed, and divided by the total amount of shoreline in the "core area". The values of this "oiling index" ranged from 0.0 for unoiled "core areas" to 1.0 for care areas where beaches were entirely coated with heavy oil.

RESULTS

A total of 824 nests were observed in 1989 with status determined for 344 of them. In 1990, 1101 nests were observed with complete data for 1039 of them. Data were available for a subset of 304 nests in both 1989 and 1990 (Figure 1). This group of 304 nests was used for the following analyses.

Of the 304 nests, eagles attempted to breed at 189 sites in 1989 and at 184 sites in 1990. There was no significant difference in occupancy rates between years ($X^2 = 0.173$, df = 1, p = 0.678). However, nests occupied in 1989 were much more likely to be occupied in 1990 than nests not occupied in 1989 (Table 2). In 1989, occupancy rates at nests in "core areas" with any heavily oiled beaches were significantly lower than expected (Table 3), 54 percent of 76 heavily oiled nests were occupied compared to 70 percent of 152 nests in "core areas" without oil. Differences between nest occupancy in "core areas" with heavy and/or moderate concentrations of oil (53%) and for unoiled "core areas" (70%) were highly significant. The difference in occupancy rates between "core areas" with any oil (55%) and those without oil (70%) were highly significant. Although the occupancy rates for nests in "core areas" with oil were lower than expected in 1990, these differences were not statistically significant for any of the oiling regimes.

Eagles successfully raised at least one chick at 58 of the 304 nests in 1989. There were 116 successful nests in 1990. The difference between years was highly significant ($X^2 = 27.084$. df = 1, p = 0.000). The difference between nest success for nests on unoiled (24%) and heavily oiled (7%) beaches was highly significant in 1989 (Table 4). Differences in nest success between unoiled and heavily and/or moderately oiled (11%) beaches were also highly significant. Success at nests on beaches with any oil was still significantly poorer (15%) than along unoiled beaches. Nest success was independent of oiling intensity in 1990.

131 of 304 nests failed in 1989 while only 68 failed in 1990. This difference is highly significant ($X^2 = 29.649$, df = 1, p = 0.000). Nest failures at individual nest sites were independent between years. When considering all of the nests surveyed, differences in nest failure rates among the various oiling intensities in 1989 were not significant, but fewer nests than expected failed in "core areas " with any oil in 1990 (25 of 152, 16 percent) compared to those areas with no oil (43 of 152 failed, 28 percent; $X^2 = 6.138$, df = 1, p = 0.013). However, when failure rates are calculated base on occupied nests, nest failures were highly dependent on the presence of heavy oiling in the "core area" with <u>more</u> nest failures than expected in "core areas" with heavy oil (Table 5). This dependence decreased with decreasing oiling intensities. A similar trend was observed in 1990, but it shifted to the other end of the spectrum with significantly <u>fewer</u> nest failures than expected for when considering "core areas" with any oil.

Overall, nest fates in 1990 were highly dependent on the fate of the nest in 1989 (Table 6). This was primarily due to nest occupancy. Nests found empty in 1989 were likely to be empty in 1990, while nests that were occupied in 1989 were likely to be occupied the following year (Table 7). Nest success in 1990 was likely to follow nest success in 1989, but the relationship was not significant (Table 8).

Significant differences were observed among the mean "core area oiling index" for the three nest fates in 1989. Mean "oiling index" values for empty, failed and successful nests in 1989 were 0.258, 0.212, and 0.109, respectively. When these means were compared using Tukey's HSD multiple comparison test, highly significant differences were observed between the means for empty versus successful nests ($p = 0.005$), while significant differences were observed between the means for failed versus successful nests ($p = 0.017$). No significant difference was observed between empty and failed nests in 1989. Oiling index means were not significantly different among nest fates for 1990.

The number of young in each nest in 1990 was independent of the number of young observed in 1989. The differences in the mean number of young per nest surveyed, per occupied nest and per successful nest between 1989 and 1990 were all highly significant with many fewer young produced in 1989 (Table 9). The frequency of nests producing 0, 1 or 2 young in 1989 was dependent on the degree of oiling. No 3-chick nests were observed in 1989. Heavily oiled "core areas" produced fewer 1 or 2 chick nests with the difference between these areas and unoiled "core areas" being highly significant ($X^2 = 10.414$, $df = 2$, $p = 0.005$). The difference between the mean number of young produced from nests in heavily oiled "core areas" (0.092, $N = 76$, $SD = 0.372$) and the mean number of young produced in unoiled "core areas" (0.289, $N = 152$, $SD = 0.559$) were highly significant ($t = 3.170$, $df = 208.4$, $p = 0.002$). Significant differences also were observed in the frequency of 1 or 2 chick nests after including moderately oiled nests ($X^2 = 7.581$, $df = 2$, $p = 0.023$) and in the mean number of young produced (0.144, $N = 111$, $SD = 0.444$; $t = 2.346$, $df = 259.2$, $p = 0.020$) when compared with unoiled "core areas". Although all oiled "core areas" produced only 29 young from 152 nests (0.19 yg/nest) and unoiled "core areas" produced 44 young from the same number of nests (0.29 yg/nest), differences in the frequency of 1 or 2 chick nests and the mean number of young produced were not found to be statistically significant. The frequency of 0, 1, 2, and 3 young nests in 1990 was not dependent on the degree of oiling. 22 percent of all nests in 1990 contained 2 chicks compared with 5 percent of the 1989 nests. In 1990, 15 percent of the nests contained one chick compared with 14 percent of the 1989 nests. Two nests in 1990 produced 3 chicks, both of which had failed in 1989 (Table 10).

DISCUSSION

Occupancy rates were lower in all oil impacted "core areas" in 1989 than in "core areas" not impacted by oil. Some unknown degree of oil related impacts had already happened by the time nest surveys were initiated on May 20, nearly two months after the spill occurred. Considering the mobility of Bald Eagles, it is not unreasonable to believe that some degree of impact may have occurred at nests in unoiled "core areas" as well. It is likely the lower occupancy rate was due either to the death of one or both of the breeding adults, abandonment of the nesting attempt or early death of the embryo and loss of the egg. There was no evidence for a change in occupancy rate in 1990. This lower occupancy rate, 62 percent in 1989 and 61 percent in 1990, is 10 to 30 percent lower than rates reported for other Bald Eagle populations in North America (Stalmaster 1987). The lack of any improvement in occupancy rate in 1990 suggests that the impacts of 1989 carried over into the following year. Nests that were empty in 1989 were likely to be empty in 1990. I believe this lowered rate is the result of the loss of established breeding adults from the population.

Nest success was lower in oiled "core areas" in 1989 and lowest in "core areas" with the heaviest oiling. Nest success in 1990 was independent of oiling intensity. The percentage of successful nests in 1989 was one half of the percentage for 1990, 19 percent compared to 38 percent. These rates are well below the 60 percent success rate observed for other North America populations (Stalmaster 1987), but the 1990 success rate may be near normal for the denser populations in Alaska.

The number of young produce in 1989 was severely reduce in oiled areas. This was due to the large number of nests that failed outright and to reduced productivity of nests that were successful.
Continuing effects were observed in 1990 with an unusual distribution of young in the nests. Under normal circumstances, 60 percent of successful nests will produce 1 young and 40 percent will produce 2 young. In 1990, these ratios were reversed for eagles nesting in Prince William Sound with 40 percent of the successful nests producing 1 eaglet and 60 percent of them producing 2.

Nest failures were widespread in 1989. For occupied nests on heavily oiled beaches, failures occurred more frequently than expected. Empty nests and oiled nests had similar degrees of oiling. Some of this lack of difference may be due to early nest failures that were missed before surveys were initiated in 1989, causing nests that actually failed to be classed as empty nests. Curiously, failure rates in 1990 were lower than expected in oiled areas, except for those "core areas" with the heaviest oiling.

We believe the close relationship between nest fate and the linear extent and intensity of oiling lends support to the hypothesis that the observed responses in the eagle population was due to the oil itself and only secondarily to the disturbance created by oil clean up activities.

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Table 1. Alaska Department of Environmental Conservation Beach Oiling Classifications for the Area Between Mean High and Mean Low Tide.

Class	Amount of Oil
Light	1 to 10 percent coverage/penetration or a band of oil 1 to 3 meters wide
Moderate	10 to 50 percent coverage/penetration or a band of oil 3 to 6 meters wide
Heavy	More than 50 percent coverage or a band greater than 6 meters wide

Table 2. Bald eagle nests occupied in Prince William Sound, Alaska, 1989-90.

		Occupied 1990		
		No	Yes	Total
Occupied 1989	No	62	53	115
	Yes	58	131	189
	Total	120	184	304

$X^2 = 16.142$, $df = 1$, $p = 0.0001$

Table 6. Bald Eagle nest fate dependence between years, 1989-90, in Prince William Sound, Alaska, following the EXXON Valdez oil spill.

		Fate 1990			
		Empty	Failed	Successful	Total
	Empty	62	20	33	115
Fate 1989	Failed	45	31	55	131
	Successful	13	17	28	58
	Total	120	68	116	304

$X^2 = 18.600$, $df = 4$, $p = 0.001$

Table 7. Bald Eagle nest occupancy dependence between years, 1989-90, in Prince William Sound, Alaska, following the EXXON Valdez oil spill.

		Occupied 1990		
		No	Yes	Total
Occupied 1989	No	62	53	115
	Yes	58	131	189
	Total	120	184	304

$X^2 = 16.142$, df = 1, p = 0.000

Table 8. Bald Eagle nest success dependence between years, 1989-90, in Prince William Sound, Alaska, following the EXXON Valdez oil spill.

		Successful 1990		
		No	Yes	Total
Successful 1989	No	158	88	246
	Yes	30	28	58
	Total	188	116	304

$X^2 = 3.109$, df = 1, p = 0.078

Table 9. Mean number of bald eagle chicks produced in Prince William Sound, Alaska, 1989-90.

	Mean	N	SD
All '89 nests	0.240	304	0.531
All '90 nests	0.618	304	0.852
$t = 6.795$, $p = 0.000$			
Occupied '89 nests	0.386	189	0.631
Occupied '90 nests	1.022	184	0.887
$t = 7.974$, $p = 0.000$			
Successful '89 nests	1.259	58	0.442
Successful '90 nests	1.621	116	0.522
$t = 4.505$, $p = 0.000$			

Table 10. Frequency distribution of the number of young produced in Bald Eagle nests in Prince William Sound, Alaska, 1989-90.

	Number of Young Produced			
	0	1	2	3
1989	246	43	15	0
1990	188	46	68	2

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Table 3. Bald Eagle Nest Occupancy Under Various Degrees of Oiling Intensity, Prince William Sound, Alaska.

		HEAVY		HEAVY/MODERATE		ANY OIL	
		NONE	YES	NONE	YES	NONE	YES
OCCUPIED 1989	NO	46	35	46	52	46	69
	YES	106	41	106	59	106	83
	TOTAL	152	76	152	111	152	152
	X^2	5.515		7.547		7.399	
	df	1		1		1	
	p	0.019		0.006		0.007	
OCCUPIED 1990	NO	54	35	54	48	54	66
	YES	98	41	98	63	98	86
	TOTAL	152	76	152	111	152	152
	X^2	2.359		1.609		1.983	
	df	1		1		1	
	p	0.125		0.205		0.159	

Table 4. Bald Eagle Nest Success Under Various Degrees of Oiling Intensity, Prince William Sound, Alaska.

		HEAVY		HEAVY/MODERATE		ANY OIL	
		NONE	YES	NONE	YES	NONE	YES
SUCCESSFUL 1989	NO	116	71	116	99	116	130
	YES	36	5	36	12	36	22
	TOTAL	152	76	152	111	152	152
	X^2	10.051		7.126		4.176	
	df	1		1		1	
	p	0.002		0.008		0.041	
SUCCESSFUL 1990	NO	97	48	97	67	97	91
	YES	55	28	55	44	55	61
	TOTAL	152	76	152	111	152	152
	X^2	0.010		0.326		0.502	
	df	1		1		1	
	p	0.922		0.568		0.479	

Table 5. Bald Eagle Nest Failures Based on the Number of Occupied Nests Under Various Degrees of Oiling Intensity, Prince William Sound, Alaska.

		HEAVY		HEAVY/MODERATE		ANY OIL	
		NONE	YES	NONE	YES	NONE	YES
FAILED 1989	NO	36	5	36	12	36	22
	YES	70	36	70	47	70	61
	TOTAL	106	41	106	59	106	83
	X^2	6.965		3.410		1.217	
	df	1		1		1	
	p	0.008		0.065		0.270	
FAILED 1990	NO	55	28	55	44	55	61
	YES	43	13	43	19	43	25
	TOTAL	98	41	98	63	98	86
	X^2	1.780		3.048		4.311	
	df	1		1		1	
	p	0.182		0.081		0.038	

A SUMMARY OF ANALYSES FOR SAMPLES COLLECTED AS PART OF EVOS DAMAGE ASSESSMENT STUDY, BALD EAGLES, BIRD STUDY #4

Notes: Hydrocarbon "exposure" decisions were made by Everett Robinson-Wilson, USFWS, Anchorage, Ak.

Metals "exposure" decisions were made by testing oiled vs unoiled groups with a t-test, a=0.05. (Oiling based on oiling at collection site.)

Blood Chemistry "exposure" criteria: Uric acid concentrations greater than 10ml/dl.

		1989									1990									
		WEST PWS			EAST PWS			OTHER*			WEST PWS			EAST PWS			OTHER**			
		EXPOSURE INDICATED									EXPOSURE INDICATED									
SAMPLE TYPE	TYPE OF ANALYSIS	YES	NO	UNK	YES	NO	UNK	YES	NO	UNK	YES	NO	UNK	YES	NO	UNK	YES	NO	UNK	TOTAL # SAMPLES
ADULT NEW FEATHER	METALS	0	5	0	0	5	0													10
ADULT OLD FEATHER	METALS	0	5	0	0	5	0													10
JUVENILE FEATHER	METALS	0	5	0	0	5	0													10
WHOLE BLOOD	HYDROCARBONS	0	0	12	0	0	10													22
WHOLE BLOOD	METALS	0	13	3	0	8	2													26
BLOOD SERUM	BLOOD CHEM	9	8	0	4	9	0													30
EGGSHELL	HYDROCARBONS	15	5	0	1	1	0	2	2	0	0	5	0	10	1	0	0	11	0	53
EGGSHELL FRAGMENTS	HYDROCARBONS	36	0	1	8	0	0	0	0	0	16	0	0	11	0	0	0	0	0	72
EGG CONTENTS	HYDROCARBONS	5	13	0	0	2	0	1	3	0	0	5	0	0	9	2	0	11	0	51
PREY REMAINS	HYDROCARBONS	32	13	1	6	6	1	0	0	0	8	7	1	2	12	0	0	0	0	89
TOTAL		97	67	17	19	41	13	3	5	0	24	17	1	23	22	2	0	22	0	373

* Two samples from Kodiak Is., one sample from Alaska Peninsula, and one sample from interior Alaska. One egg shell sample from Kodiak Is. and one from Alaska Peninsula exposed to hydrocarbons.

** Eleven samples from the Copper River Delta near Cordova, AK.

Fn: Contsum.wk1

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STATUS OF EAGLES SAMPLED FOR BLOOD IN 1989

Sample I.D.	Radio Frequency	Territorial Status	Uric Acid	Bili-rubin	BUN	Potassium	Status as of Nov. 91
11220	217.113	No	22.00	0.30	5.00	3.70	Alive
11248	217.984	Yes	19.50	0.50	5.00	3.40	Failed trans.
11212	216.694	Yes	19.00	0.40	5.00	3.30	Failed trans.
11249	217.814	No	18.00	0.50	12.00	3.30	Alive
11221	217.288	Yes	17.00	0.30	6.00	3.00	Alive
11237	216.514	Yes	12.10	0.20	3.00	3.10	Alive
11214	217.334	Yes	12.00	0.30	5.00	3.00	Failed trans.
11217	217.314	No?	11.70	0.40	4.00	3.10	Dead 1-90
11219	217.090	Yes	11.60	0.30	4.00	3.70	Dead 4-91
11243	217.411	Yes	11.50	0.20	4.00	3.40	Dead 7-90
11224	216.874	Yes	11.40	NA	4.00	3.20	Dead 10-89
11215	217.212	Yes	11.20	0.30	3.00	3.70	Alive
11244	217.638	Yes	10.70	0.30	5.00	3.10	Alive
11218	216.653	Yes	9.30	0.30	4.00	3.20	Alive
11210	217.010	Yes	7.60	0.30	3.00	3.20	Failed Trans.
11245	217.912	Yes	6.70	0.30	3.00	3.10	Failed Trans.
11240	217.035	Yes	6.20	0.20	3.00	3.50	Alive
11247	218.719	Unk	6.00	0.30	2.00	3.30	? (sat. trans.)
11235	216.715	Yes	5.60	0.30	2.00	3.20	Alive
11233	216.951	Yes	5.20	0.30	2.00	2.80	Alive
11213	217.189	Unk	4.30	0.30	2.00	2.90	Missing
11234	216.755	Yes	4.10	0.20	1.00	3.20	Dead 12-90
11239	217.263	Yes	4.00	0.20	1.00	2.80	Alive
11236	217.237	Yes	3.90	0.30	2.00	3.30	Missing
11242	217.437	Unk	3.70	0.30	2.00	2.80	Missing
11241	217.166	Yes	3.70	0.20	1.00	3.10	Failed Trans.
11250	218.013	Yes	3.20	0.20	2.00	3.10	Failed Trans.
11223	216.834	No	3.00	0.20	2.00	3.10	Alive
11222	216.994	Yes?	2.80	0.20	2.00	3.30	Missing
11216	217.390	No	2.40	0.20	1.00	3.40	Alive

SUMMARY OF FATES OF EAGLES IN RELATION TO URIC ACID VALUES

	EAGLES WITH HIGH URIC ACID (GT 10 ML/DL)	EAGLES WITH LOW URIC ACID (LT 10 ML/DL)
# DEAD	4	1
# ALIVE	5	6
# MISSING	1	5
# FAILED TRANSMITTERS	3	4
# NOT TRACKABLE		1