

DEVELOPMENT OF SURVEY METHODOLOGY FOR LONG TERM MONITORING OF HARBOR SEALS IN WRANGELL-ST. ELIAS NATIONAL PARK AND PRESERVE, ALASKA, 1995

Karin Kozie, and Bill Route, Resource Management Specialists, Wrangell-St. Elias National Park and Preserve, PO Box 29, Glennallen, AK. 99588

Mark Schroeder, Resource Management Specialist, Alaska Regional Office, Anchorage, AK

DATE: January 30, 1996

INTRODUCTION

Harbor seals (*Phoca vitulina richardsi*) inhabit coastal waters in Alaska from southeast Alaska to the Aleutian Islands and the Bering Sea (Hoover 1988). Although they were previously considered abundant, surveys during the 1980's indicated declines as great as 86% have occurred from southcentral to western Alaska (Pitcher 1986, 1989, 1990). While the rate of decline appears to have slowed, the numbers of seals in these areas are substantially lower than they were in the early 1970's (Hoover-Miller 1992). Census data for southcentral and southeast Alaska indicate statistically significant declines have occurred in the Prince William Sound and Ketchikan trend areas. Numbers have declined but not significantly in the Sitka trend area (Loughlin 1992, 1994).

Limited data is available on the status of harbor seals in Wrangell-St Elias National Park and Preserve (WRST), specifically Icy and Disenchantment Bays. National Marine Fisheries Service (NMFS) documented 907 seals in Icy Bay and 747 seals in Disenchantment Bay in mid-September 1993 (Loughlin 1994). However, these data may under estimate the population. A ten-fold reduction in seal populations occurred in Glacier Bay between mid-August and mid-September due to movements of seals outside the bay (Mathews and Kelly 1996). Similar movements may have occurred in Icy and Disenchantment Bays. Additionally, while minimum population estimates are important for baseline information, these surveys were not designed to detect statistically significant changes in population numbers over time.

It has become increasingly important to collect baseline and population trend data for harbor seals in Icy and Disenchantment Bays due to the following factors. Offshore oil drilling may occur west of Icy Bay and south of Yakutat Bay (Minerals Management 1990). Marine mammals are at risk from potential oil spills and pollution if oil is developed in adjacent offshore areas. Logging is occurring along the east and west sides of Icy Bay. Increases in logging-related boat traffic may affect wildlife. Increases in tourism in Icy and Disenchantment Bays by

cruise ships and kayakers trying to observe calving glaciers may also disturb seals. In Disenchantment Bay, cruise ship visitation has increased from 5-15 ships per year in 1989 to 179 ships in 1995. Exact visitation in Icy Bay is unknown but rangers observed cruise ships on 2 of 6 patrols between 1992-1995. Kayakers quadrupled in numbers in Icy Bay from 1989-1993 and have now began doubling every year. It is estimated that about 40-50 parties of kayakers visited Icy Bay during 1995, with the highest visitation occurring between the end of June and the end of July (R Mossman, Natl Park Serv, Yakutat, pers. commun.). Seals are very sensitive to vessel activity and human disturbance (Allen et al. 1984, Calambokidis et al. 1983). Commercial fishing occurs throughout Yakutat Bay and may affect seal populations. Because harbor seals are distributed within coastal waters, they are commonly caught incidental to commercial and subsistence net fishing operations (Hoover 1988). The degree of take is unknown but could be significant in some salmon and herring gill net and purse seine fisheries. An unknown number are also shot by commercial fisherman when they disrupt their nets.

The purpose of this study was to develop long term monitoring methods for harbor seal pup and population surveys in Icy and Disenchantment Bays. We tested several survey methods in 1994 based on recommendations made by statisticians Kern and McDonald (1994) and what we found was feasible in the field (Kozie and Route 1995). In 1995, we further refined our survey methods. The results of 1995 surveys and recommendations for future surveys are presented.

OBJECTIVES

- 1) Determine harbor seal pup proportions in Icy and Disenchantment Bays
- 2) Determine a minimum population estimate for harbor seals in Icy and Disenchantment Bays
- 3) Develop survey methodology for monitoring long term trends in pup proportions and population levels of harbor seals in Icy and Disenchantment Bays

STUDY AREA

Icy Bay is located about 100 km west and Disenchantment Bay 40 km north of Yakutat (Fig 1). Seal haul out habitat within the bays consists of glacial ice which varies in abundance and distribution throughout the summer breeding season. Several land haul outs are also present in Disenchantment Bay within Russell and Nunatak Fiords.

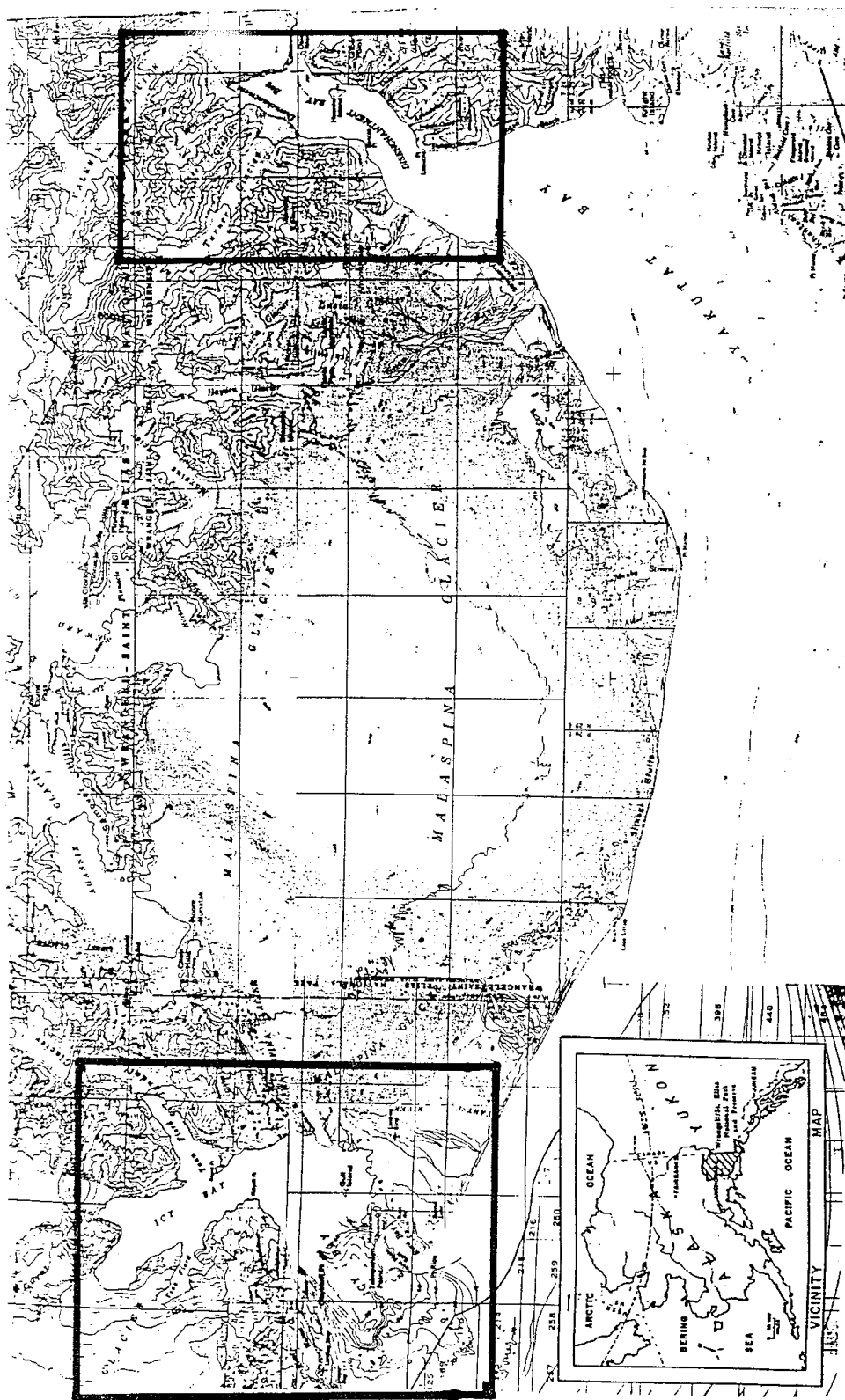


Figure 1. Location of study areas, Icy and Disenchantment Bays, Alaska.

METHODS

PUP PROPORTIONS

Pup proportions were determined using methods developed by E Mathews (1995) and modified by Kozie and Route (1995). Surveys were flown between 0920 and 0958 hours in a Cessna 185 piloted by M Sharp (Nat'l Park Serv, Yakutat). R Mossman surveyed Icy Bay on June 7 and M Kralovec (Nat'l Park Serv, Glacier Bay) surveyed Disenchantment Bay on June 11, 1995. Seal distribution was determined during a high altitude (3000 ft) pre-survey flight. The distribution of seals, a rough estimate of the percent of the population in each aggregation (for Icy Bay), the location of transects, and the film roll and frame numbers were recorded on a base map (Figs 2 and 3).

Each aggregation that contained more than 100 seals was sampled for pup proportions. A series of non-overlapping slide photographs were taken through an open window of the plane at 1000 ft above sea level (ASL), using a Nikon 8008S camera with a 80-200mm zoom lens, motor drive and data back.

Pup proportions were determined by viewing the slides through a dissecting microscope for ice haul outs (and by projecting slides onto a white background for land haulouts) and classifying seals as adults, pups, or unknown (Mathews 1992). Unknown age seals were excluded from calculations. A mean pup proportion and standard deviation were then calculated by averaging the percent pups from each group of seals. Differences in pup proportions between Icy and Disenchantment Bays was tested using the Z statistic (Zar 1974:296-298).

POPULATION ESTIMATE

General ice distribution was determined from a high altitude (2000-2500 ft) pre-survey flight. Ice shifted during the survey so some adjustments were made on maps. Ice was stratified into high, medium and low density areas on a base map each day (Figs 4-8). The plane then dropped to 1500 ft so the observer could map the general distribution of seals. Seals were stratified into high and low density areas on the same map as the ice density. Latitude and longitude were obtained for several points along the perimeter of the seal aggregations and at the start and end of each transect when physical landmarks were not available.

Survey times varied between about 1100-1500 hours. Survey dates were scheduled for days when low tide occurred between 1000-1400 hours whenever possible so the greatest number of seals would be hauled out.

1) **Transects**

Icy Bay was surveyed on August 16, 18, and 21 and Disenchantment

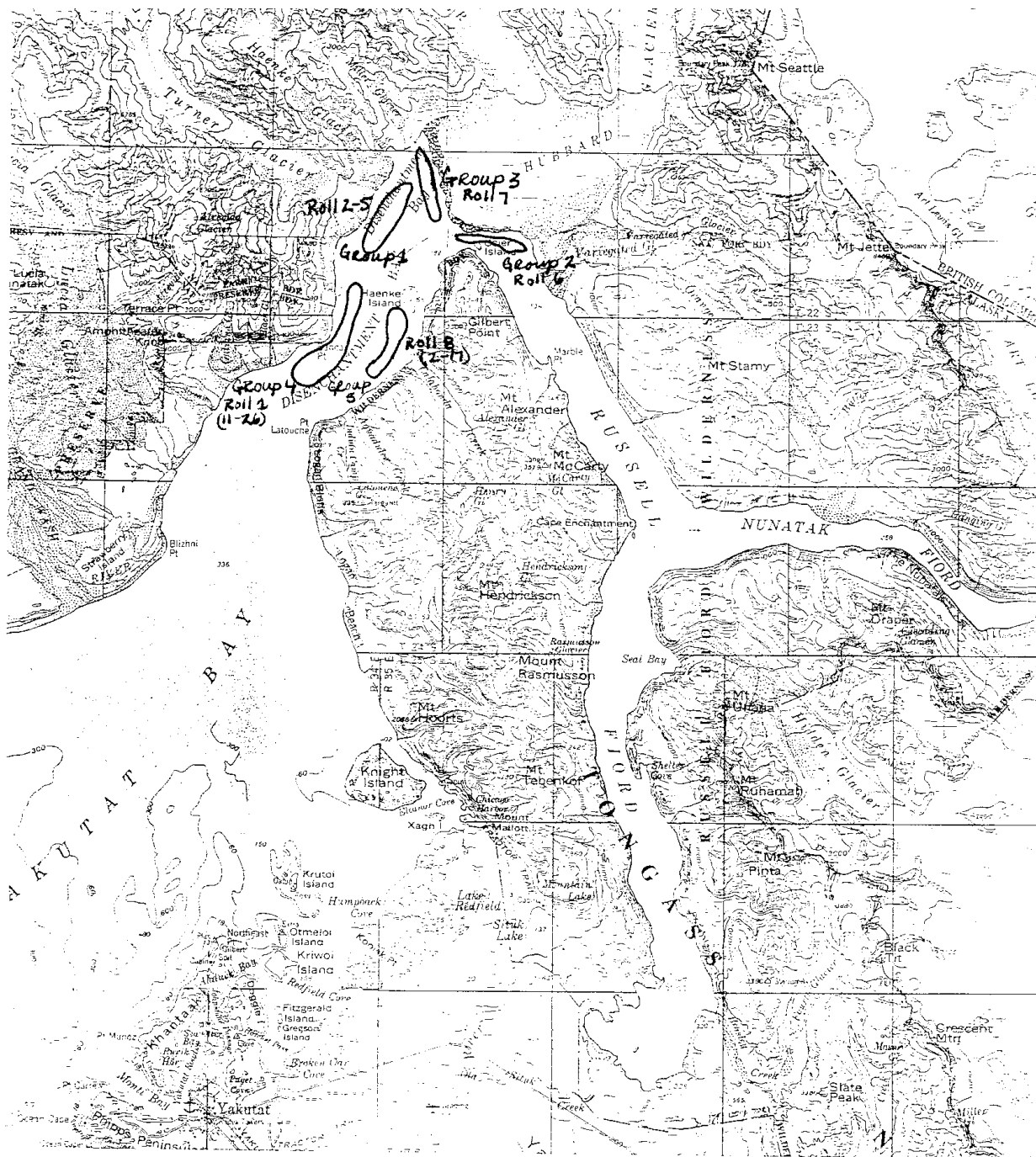


Figure 3. Location of seal aggregations and corresponding film rolls for pup proportion surveys in Disenchantment Bay on June 11, 1995.

Bay was surveyed on August 15 and 17, 1995. M Schroeder was the observer on all flights. M Sharp piloted the first 3 surveys and S Stevenson (Gulf Air, Yakutat) piloted the last 2 surveys using a Cessna 185. Seals were surveyed using transects spaced 1/4 to 1/2 mile apart in high and low density seal areas, respectively. The observer counted out to 1/8 mile. It was difficult to count seals beyond this distance in high density areas. Flight altitude was maintained at 1200 ft ASL.

When surveying dense seal aggregations (>100 individuals), a transparency with lines marked 1/4 mile apart was randomly placed over the aggregation and marked on the base maps (Figs 4-8). Direction of survey lines was based on safety considerations and the most efficient coverage of the aggregation. Only the portion of the survey lines going through the aggregation was flown. The observer counted from the same side of the plane for each aggregation. Numbers of seals were recorded into a hand held tape recorder as they were encountered along each transect and were transcribed later onto data sheets. High winds prevented complete coverage of several high density seal aggregations.

The remainder of the Bays (that were covered with ice) were flown according to recommendations by Kern and McDonald (1994) with the changes identified in Kozie and Route (1995). Briefly, when surveying seals dispersed throughout the Bays (usually areas of moderate and low ice density), a laminated map with survey lines spaced 1/2 mile apart was used to survey the main part of the bay. Every other survey line was flown, with the first line (1 or 2), being randomly chosen. In Icy Bay, these transect lines were pre-drawn directly on the base map. In Disenchantment Bay, we did not draw the 1/2 mile transects on the laminated base map since we were unsure what the safest flight direction might be on any particular day. A transparency with transects 1/2 mile apart was placed over the main part of Disenchantment Bay. It was taped onto the base map and photocopied when the observer returned to the office (Figs 4-8). Only areas with ice were surveyed. All fiords were circled for complete coverage at 1200 ft ASL.

Surveys (and analysis) of land haul outs in Disenchantment Bay followed the same methodology (aerial photography) described for pup proportion surveys. Fiords were circled separately for total counts. These numbers were totaled and added to the final estimate. Analysis of seal numbers on ice haul outs in the main part of the bays consisted of summarizing 1) The number of seals and area per transect. (To calculate the area of the transect, only the portion of the transect that went through the high density seal aggregation or, for transects through low density seal areas, the portion of the transect that was covered with ice, was measured out to 1/8 mile using a dot matrix grid.) 2) The area of high density seal aggregations in each bay, 3) The total area of ice cover (excluding the high density seal aggregations and fiords) in each bay. The total area of ice cover was used to calculate the low density seal population

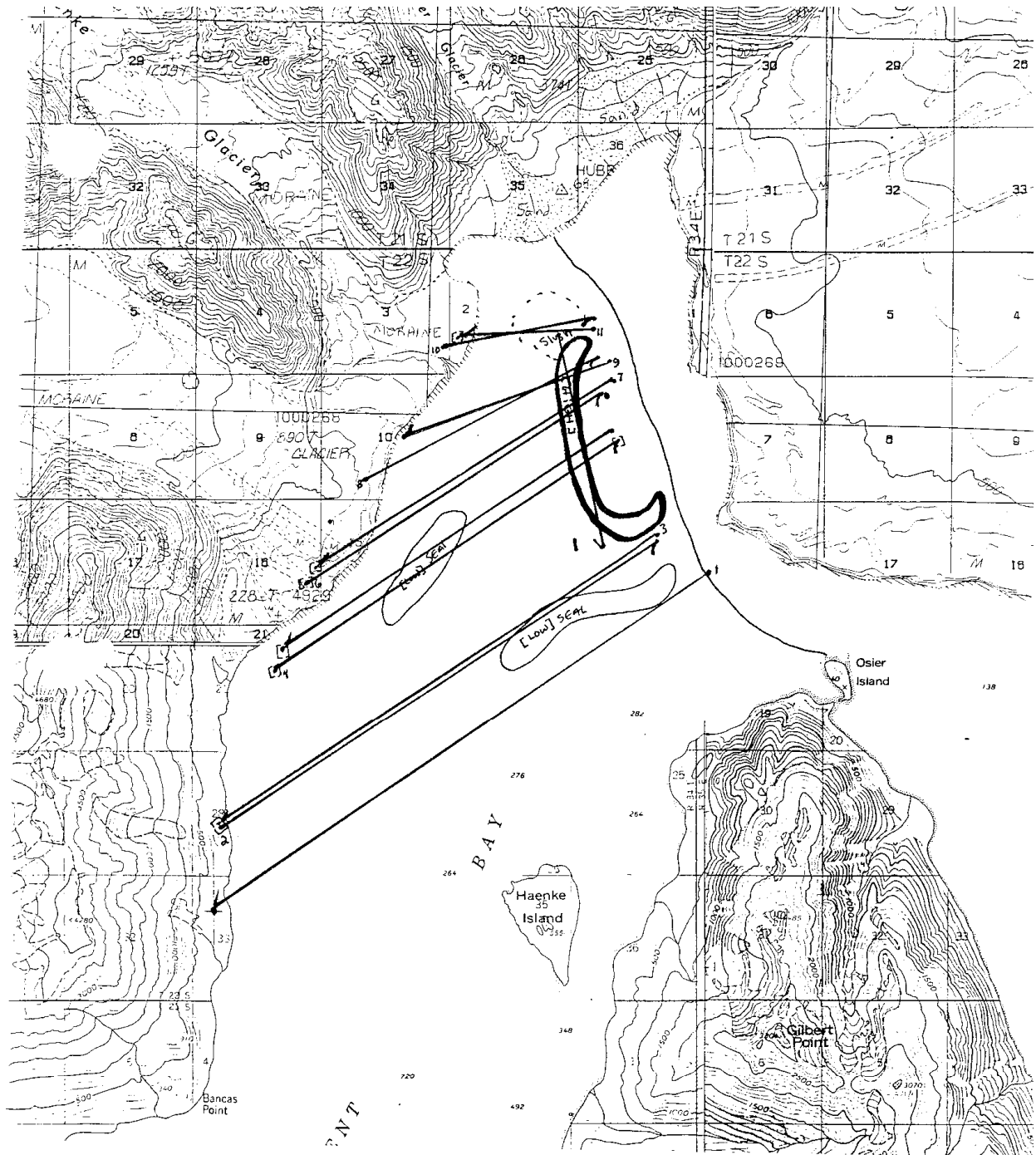


Figure 4. Location of seal aggregations and flight lines for harbor seal population surveys in Disenchantment Bay on August 15, 1995.

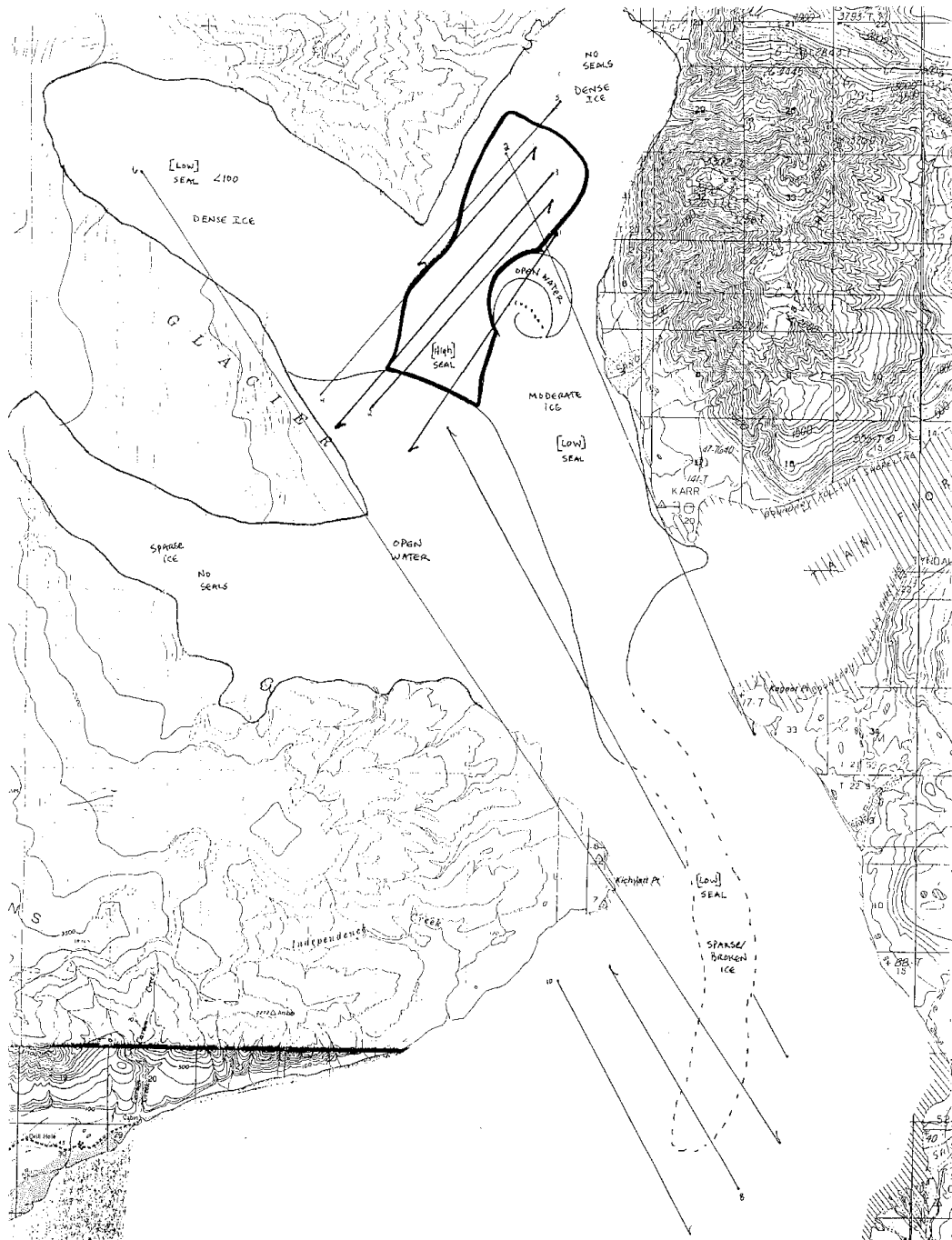


Figure 5. Location of seal aggregations, and flight lines for harbor seal population surveys in Icy Bay on August 16, 1995.

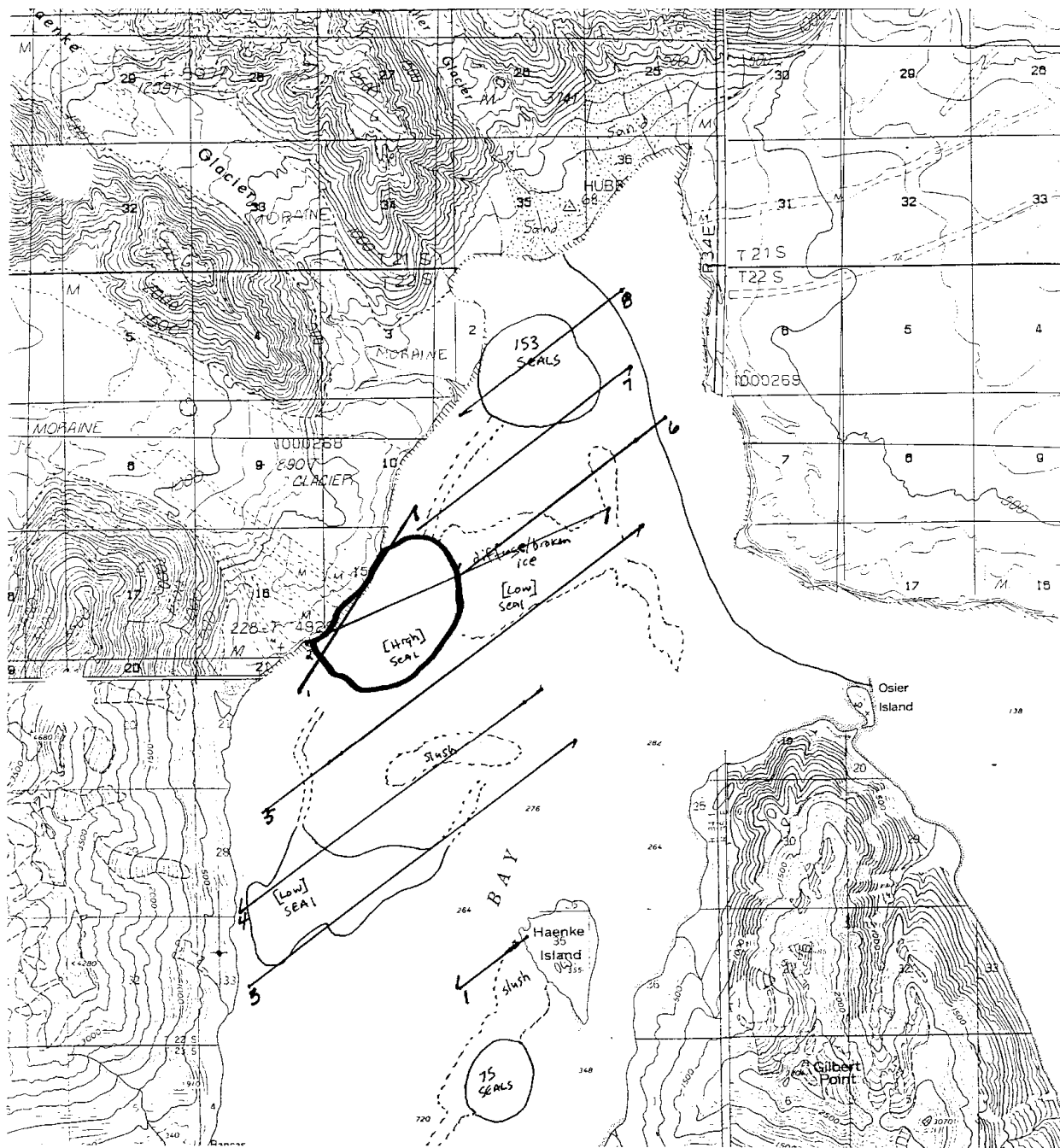


Figure 6. Location of seal aggregations and flight lines for harbor seal population surveys in Disenchantment Bay on August 17, 1995.

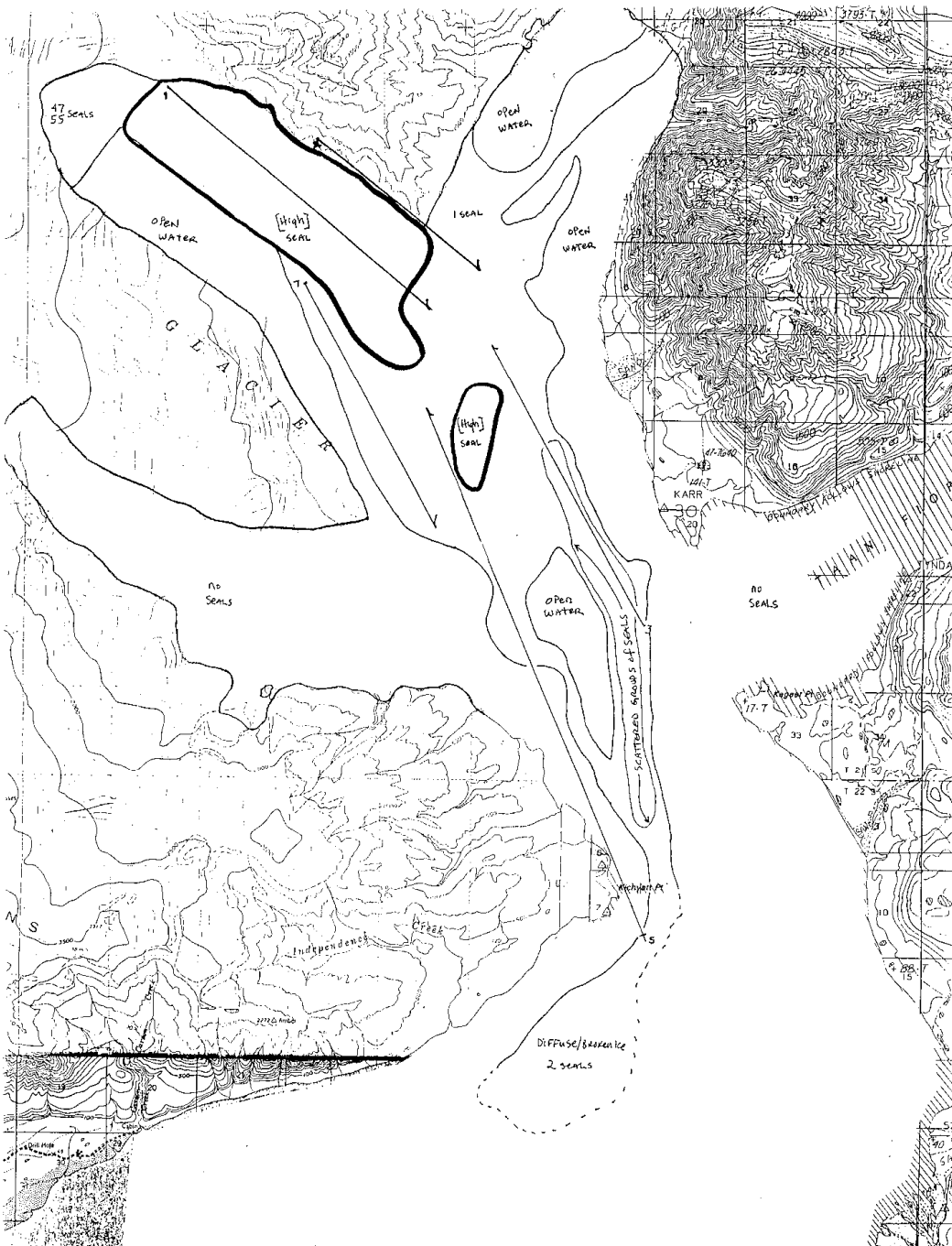


Figure 7. Location of seal aggregations and flight lines for harbor seal population surveys in Icy Bay on August 18, 1995.

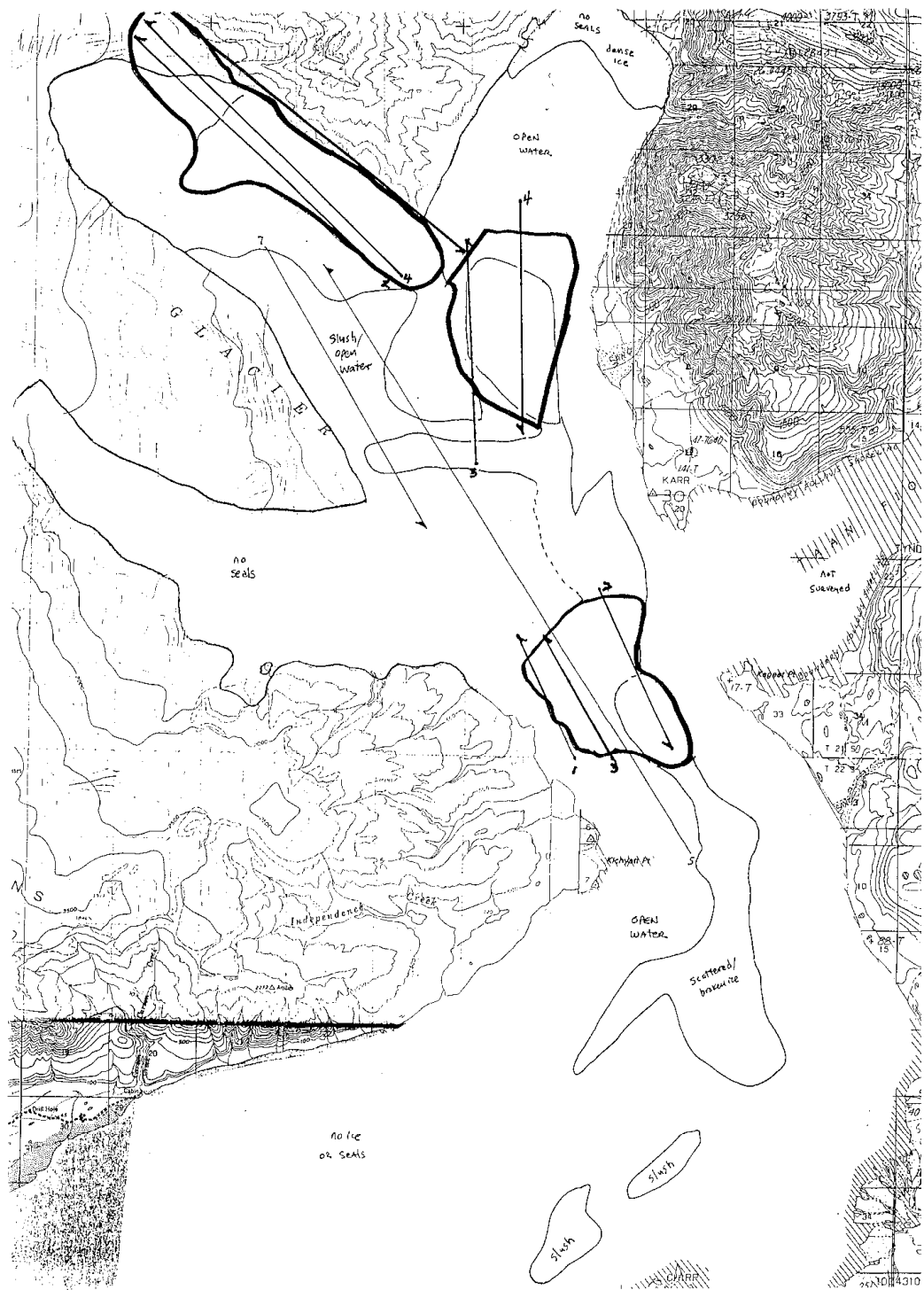


Figure 8. Location of seal aggregations and flight lines for harbor seal population surveys in Icy Bay on August 21, 1995.

estimate. Summary statistics (Kern 1996) were calculated for population estimates for each survey. J Kern developed a fortran program (run from DOS) to calculate all summary statistics. Data for seal density, transect area, seals per transect, and total area per strata (e.g. high or low density) is entered into the program. The population estimate and variance is calculated.

Mean seals per day was used to combine independent surveys and is described in Kern (1996). He also describes two variance calculations for within or between surveys. The larger of the two variances should be used (Kern 1996). We report the between survey variability in this report.

2) Aerial Photography

Aerial photography was also used to obtain a population estimate and consisted of at least 30 non-overlapping slides of each seal aggregation. Prior to the survey, the observer took slides of a marked area using the same flight altitude (1000 ft ASL) and camera focal length (200 mm) that was used in the actual survey. Slides of telephone poles, spaced 72 ft and 45 ft apart, were used to interpret the area of the slides (172 ft X 113 ft = 0.0326 ft X 0.0214 ft = 0.00697 sq miles). The average number of seals per slide (e.g. per known area) was then extrapolated to the total area of the aggregation to obtain a population estimate.

RESULTS AND DISCUSSION

Objective 1: Determine pup proportions in harbor seal population in Icy and Disenchantment Bays.

There was no significant difference ($Z=1.495$, $P>.01$) in the proportion of harbor seal pups in Icy and Disenchantment Bays during 1995 (Table 1). While these data are believed to be representative of pup proportions in each of the bays, more effort should be made to fly pupping (and population) surveys between 1000 and 1400 hours when the greatest number of seals are hauled out.

Table 1. The proportions of harbor seal pups in Icy and Disenchantment Bays, 1993-1995.

AREA	YEAR	ROLLS OF FILM	# OF ADULTS	# OF PUPS	TOTAL SEALS PHOTOGRAPHED	MEAN % PUPS	SD
Icy	1993	8	916	269	1185	25	7.1
Icy	1994	6	231	81	231	34	4.9

AREA	YEAR	GROUPS	# OF ADULTS	# OF PUPS	TOTAL SEALS PHOTOGRAPHED	MEAN % PUPS	SD
Icy	1995	4	198	114	312	37	3.3
Disenchantment	1995	3	108	45	153	26	5.7

Objective 2: Determine a minimum population estimate for harbor seals in Icy and Disenchantment Bays

Transects

The mean seal population estimate for Icy Bay is 3297 (se = 603) and for Disenchantment Bay is 542 (se = 173) (Table 2). Data analysis from individual sample days are presented in Appendix 1.

Table 2. Seal population estimates, standard error (SE), and 95% confidence limits from aerial transects flown in Icy and Disenchantment Bays in 1995.

LOCATION	DATE	POPULATION ESTIMATE	SE	LOWER LIMIT	UPPER LIMIT
Icy Bay	5/16/95	2093 ^a	832	1261	2925
Icy Bay	5/18/95	3938 ^b	2585	1353	6523
Icy Bay	5/21/95	3861	1257	2604	5118
Mean Population Estimate		3297		2694	3900
Disenchantment Bay	5/15/95	330 ^c	30	300	360
Disenchantment Bay	5/17/95	753 ^d	42	711	795
Mean Population Estimate		542		369	715

^a 80 seals from Guyot Fiord were added to transect estimates.

^b 52 seals from Guyot Fiord were added to transect estimates.

^c 117 seals from fiords and land haul-outs were added to transect estimates.

^d 370 seals from fiords, land haul-outs and groups small enough to count total seals were added to transect estimates.

Variances in this data were high which will result in trend data being difficult to interpret. Variances within individual sample days can be reduced by 1) flying all of the transect lines through the high density seal aggregations (with the exception of weather and safety considerations), and 2) orient the direction of the transects perpendicular to group orientation to increase the number of transects flown through each aggregation (Figure 9). This will decrease the variance on our population estimates and improve our ability to detect increases or decreases in population trends. J Kern advised that increasing the number of days sampled in each bay will also decrease variance.

The accuracy of the data collected can also be improved by incorporating the following factors into surveys. 1) The area of the high density seal aggregations is critical to obtaining an accurate population estimate. Computer linked GPS points should be obtained just prior to the survey of an aggregation to improve the accuracy of the estimates. The importance of using a GPS computer link may determine which planes can be used in the

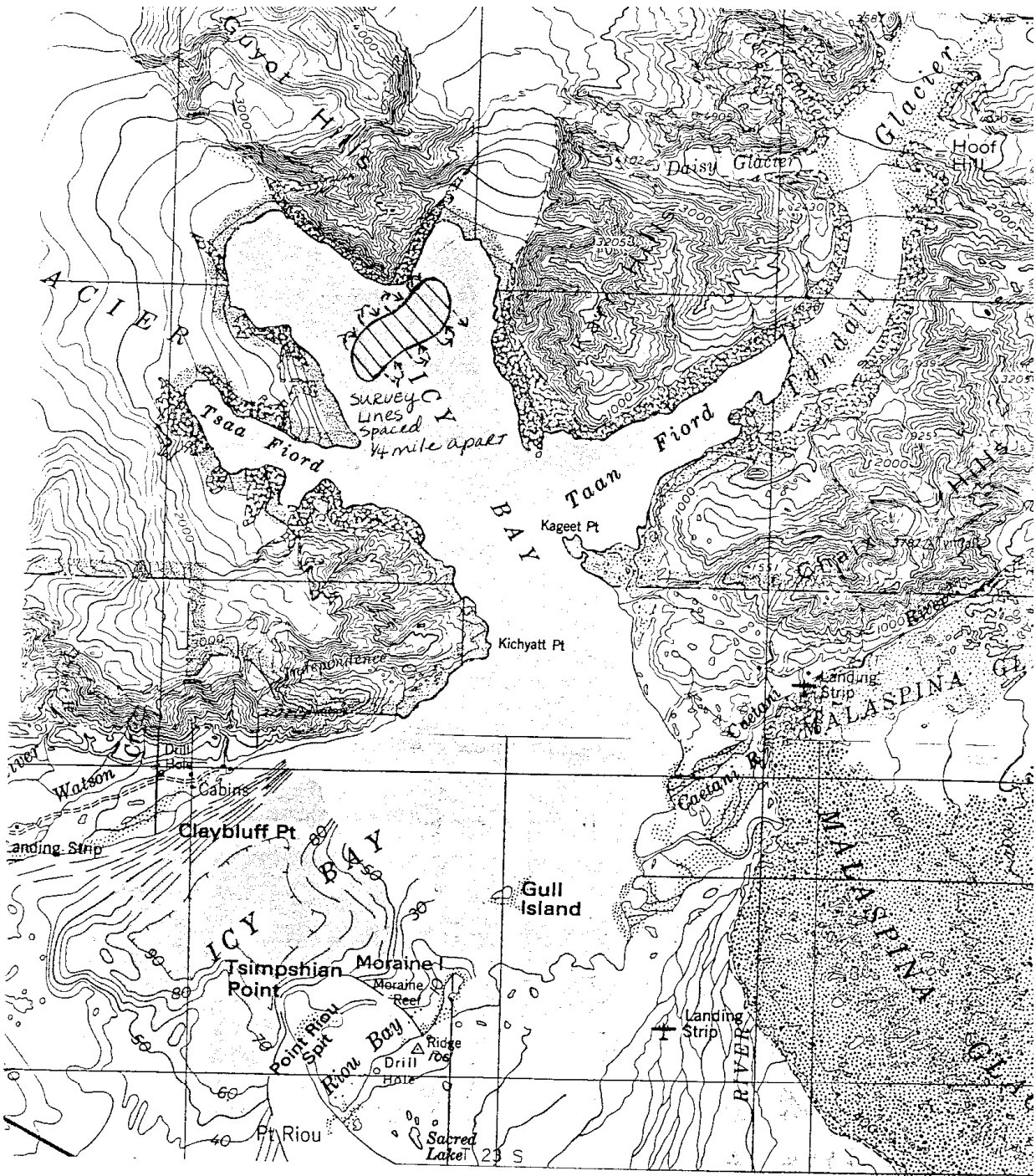


Figure 9. Example of survey lines placed perpendicular to group orientation to increase sample size of transects through high density seal aggregations.

survey. The Park plane contains a computer linked GPS. Fishing and Flying (Cordova, AK) also owns a plane with computer linked GPS capabilities. They do not own a portable computer, however. It may be necessary to use Fishing and Flying's piper supercub depending which plane contains the hook up. Charter planes should also have an intercom system (if at all possible) so the pilot and observer can talk to one another. 2) GPS locations should be similarly obtained at the beginning and end of each transect (e.g. where the seal aggregation begins and ends along each transect). GPS data from transects can be used to accurately determine the length and location of transects and may also be important to future data analysis (J Kern, pers commun). 3) The glaciers have receded substantially since the last topographic maps were drawn. Maps of both bays are being updated by the GIS division in Anchorage from recent aerial photography (1993) and should be available by summer 1997. This will assist in more accurately drawing ice configuration throughout the bays. 4) Observers should become familiar with camera use prior to the survey to improve the quality of photographs taken.

Aerial Photography

The mean seal population estimate based on aerial photography for Icy Bay is 4118 and for Disenchantment Bay is 467. The Disenchantment Bay estimate is from August 17 only since the August 15 data could not be calculated (see table foot notes). These estimates are from high density seal aggregations and land haul-outs only and do not include additional seals counted separately in fiords, small groups, or low density areas. The estimate for Disenchantment Bay is an underestimate since a minimum of 597 seals were counted in non-overlapping slides of the high density seal aggregation on August 15 plus an additional 78 seals were observed on South Island (e.g. minimum total 675).

Table 3. Harbor seal population estimates from slides taken in Icy and Disenchantment Bays during 1995.

AREA	DATE	ASL (FT)	# SLIDES	TOT. SEALS IN SLIDES	MEAN SEALS	SD	POP. EST.
Icy	8/16/95	1000	29	160	5.5	5.1	2525
Icy	8/18/95	1000	33	110	3.3	3.0	2403
Icy	8/21/95	1000	29	171	5.9	6.4	7427
Disenchantment	8/15/96	1300	33	597	17.1	18.0	--- ^a
Disenchantment	8/17/96	1000	32	86	2.7	3.7	467 ^b

^a No known distance photography was taken from 1300 ft ASL. Consequently, the area of the slide could not be calculated and no estimate was obtained for this date. This figure could be calculated in the future if slides with marked distances are taken from 1300 ft ASL. This estimate, when eventually calculated, should add 78 seals hauled out on South Island.

^b This estimate contains 142 seals on land haul-outs. The highest count from 2 slides of each land haul-out at South Island and head of the Nunatak fiord was

used.

RECOMMENDATIONS FOR FUTURE SURVEYS

Objective 3: Develop survey methodology for monitoring long term trends in pup proportions and population levels of harbor seals in Icy Bay

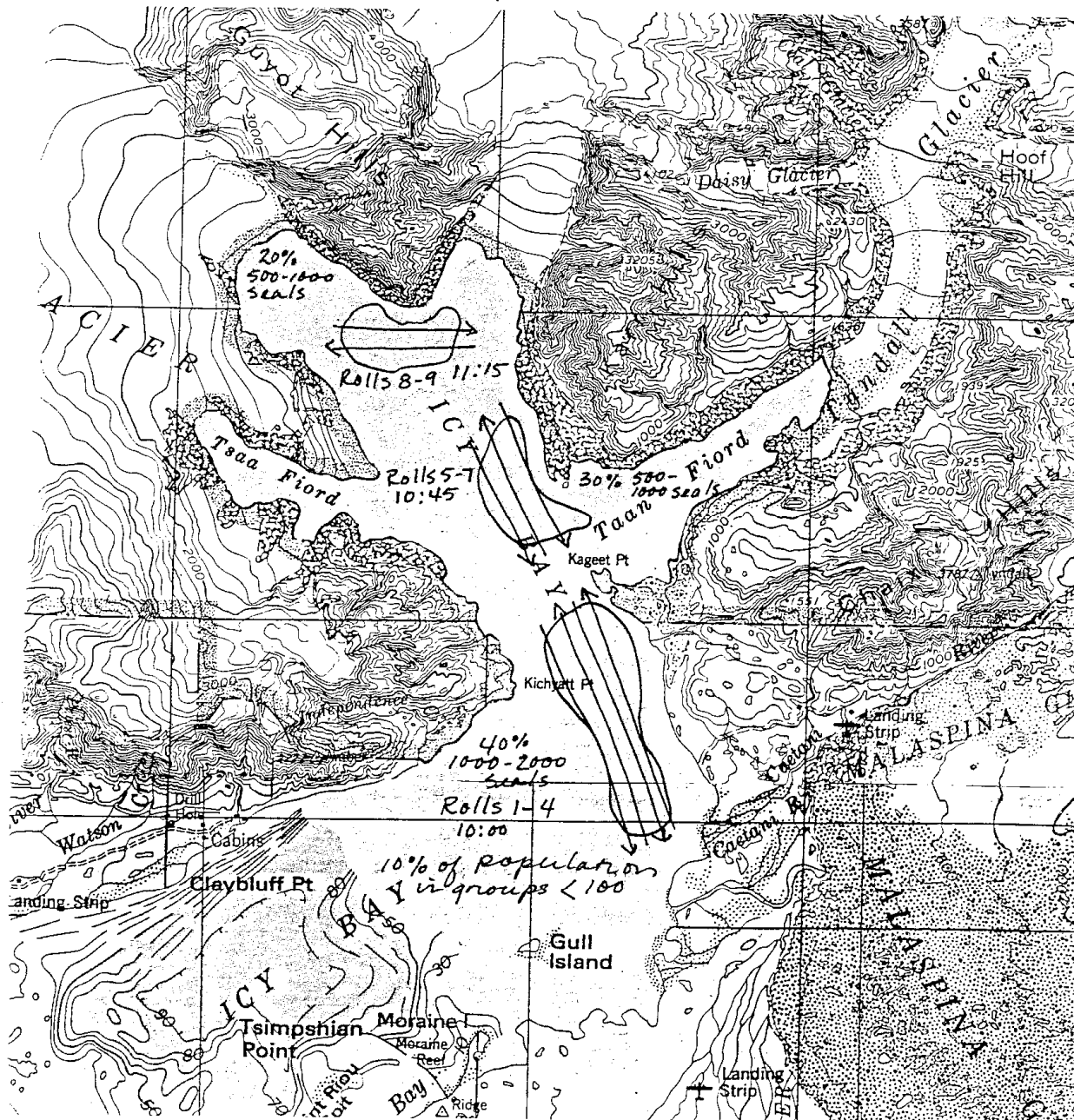
Pup Proportions

Surveys should be flown in mid-June or about 1 week on either side. They should be conducted mid-day (1000-1400 hours) when the greatest number of seals are hauled out (Calambokidis et al 1987). Seal distribution will be determined from a high altitude (2000-2500 ft) pre-survey flight. The distribution and a rough estimate of the percent of the population in each aggregation (in increments of 10) should be recorded on a base map (Fig 10). The aggregations may not necessarily total 100% if some seals are spread out in the bay. For example, if there are 3 seal aggregations, group 1 may comprise about 20%, group 2 about 40%, and group 3 about 30%, for a total of 90% in the 3 groups. The remaining 10% are singles or small groups less than 100 scattered throughout the bay.

Each aggregation that contains >100 seals should be sampled for pup proportions. Up to ten rolls (24 exposures per roll) of non-overlapping slide photographs (100 or 200 ASA Kodachrome film depending on light conditions) of seals hauled out on ice flows will be taken in proportion to the distribution of seals throughout the bay. Each increment of ten represents one roll of film so if 40% of the population is in one aggregation, the observer would take 4 rolls of film. Ideally, each roll will be flown along a corresponding transect. If the configuration of the aggregation limits the number of transects to less than the required rolls of film, the observer may need to decrease the increment of time between shots (e.g. every 10 seconds to every 3 seconds) so 2 rolls can be taken along one transect. Since film needs to be changed mid-transect in this situation, the pilot should note the latitude and longitude on the GPS and a compass bearing so the plane can return to that location and continue along the same transect. The observer may feel it is difficult to maintain non-overlapping photographs in some aggregations but as long as the observer and pilot make a reasonable effort to keep the transects as separate as possible, the probability of over-lapping slides, especially in large aggregations, is minimal, since the area of each slide is very small (e.g. there are usually only 1-3 seals per slide).

The location of transects, the roll number, the beginning time for photographing each aggregation, and a rough estimate of the number of seals in each aggregation using the following categories (e.g. 100-500, 500-1000, 1000-2000, 2000-4000, 4000+) should also be recorded on the base map (Fig 10). Each roll of

Figure 10. Example of data recording for pupping surveys in Icy Bay.
 1. Location of aggregations and percent of the total population in each aggregation (in increments of 10);
 2. Location of photographic transects; 3. Roll number(s) of film for each aggregation; 4. Beginning time for photographing each aggregation; and 5. Rough estimate of the number of seals per group (100-500, 500-1000, 1000-2000, 2000-4000, 4000+).



film and mailing envelope (which is returned with the slides) should be labeled with the date and the roll number.

Seals are photographed through an open window of the plane flying at 1000 ft above sea level (ASL), using a Nikon 8008S camera with an 80-200mm zoom lens, motor drive and data back. All photographs should be shot as close to vertical as possible so the entire slide is in focus and at the fastest speed (1/1000-1/250 second). If the camera is tilted, a portion of the slide becomes blurred. E Mathews has written directions for camera use during the survey. A copy is stored with the camera in Yakutat and an additional copy is in the harbor seal files in the WRST Resource Management Office in Copper Center.

In groups with sparse seal distribution, a photograph should be taken each time a seal is observed through the view finder. The observer should wait until the seal moves across the field of view before taking the photograph. For example, if the plane is traveling north, the observer will first view a seal at the north end of the view finder but should wait to take a photograph until the seal has reached the south end of the view finder. This helps decrease the potential bias of photographing adults with pups, which are easier to see than lone adults (E Mathews, pers commun).

In areas of dense seal distribution, the observer should space photographs every 3-10 seconds depending on the size of the aggregation. The number of seconds between frames should be maintained on each transect but may be changed between transects if it appears the interval is too short or long for the size of the aggregation. The observer should take the first photograph at the edge of the aggregation and then begin counting "one-one thousand, two-one thousand, etc...". When the desired interval is reached, the observer should locate the first seal along the north edge of the frame, wait to photograph it until it reaches the south edge of the frame, and then begin counting again (E Mathews, pers commun).

Pup proportions will be determined by viewing the slides through a dissecting microscope for ice haul outs (and by projecting slides onto a white background for land haulouts) and classifying seals as adults, pups, or unknown (Mathews 1995). Unknown age seals are excluded from calculations. A mean pup proportion is then calculated by averaging the percent pups from each aggregation and reporting the standard deviation between aggregations. Differences in pup proportions between Icy and Disenchantment Bays can be tested using the Z statistic (Zar 1974:296-298). Differences in proportions between aggregations within each bay should also be tested. If there is no significant difference between aggregations after 3 years of surveys, all groups within the bay can be treated as one aggregation and photographic sampling methods can be simplified (e.g. Use 5-7 rolls to sample all groups within the bay. Number of rolls would not need to be proportional to number and size of

the aggregations.)

Land haul outs in Disenchantment Bay (none exist in Icy Bay) should be surveyed by taking slide photographs (200-400 ASA film) of the entire haul out. In many cases, 1 or 2 photographs can cover the entire haul out. If several photographs are required, slides **should be overlapping**. Land haul outs should be approached by flying parallel to the shoreline instead of flying directly at the haul out site and a minimum altitude of 1200 ft ASL should be maintained. It may be necessary to increase altitude if seals flush from the haul out site. If more than 1 aerial pass must be made to photograph a haul out, the pilot should make a wide turn rather than a tight circle, to limit disturbance. Seals hauled out on land can be difficult to distinguish in slides. The observer should adjust the camera so there is a slight overexposure of 1/2-1 F stop (as much as possible without losing film speed)(E Mathews, pers commun). Survey dates for Disenchantment Bay should be scheduled for days when low tide occurs between 1000-1400 hours so the greatest number of seals will also be present on land haul outs.

Population Surveys

General recommendations for all population survey methods

Seal distribution is an important factor in determining survey methodology. Distribution was highly clumped during the 1994 surveys but was more variable in 1995. Sampling effort in high density seal areas should be based on seal distribution since ice density did not correlate well with seal numbers. However, ice distribution was important for calculating population estimates in moderate or low density seal areas where seals were more dispersed. Therefore, general ice distribution should be determined from a high altitude (2000-2500 ft) pre-survey flight. Ice can shift greatly from the beginning to the end of the survey so some adjustments may need to be made. The plane should then drop to 1500 ft so the observer can map the general distribution of seals. Seals should be stratified into high, medium, and low density areas on a map each day. If seals are tightly aggregated, high and low categories are sufficient. To obtain a more accurate map of high density seal areas, the pilot should track the outline of each seal aggregation just prior to the transect survey for that aggregation using GPS locations which are downloaded into a computer during the survey. These locations can later be plotted and the area measured using a digital planimeter. GPS locations should be similarly obtained at the beginning and end of each transect (e.g. where the seal aggregation begins and ends along each transect). GPS data from transects will be used to accurately determine the length and location of transects and may also be important to future data analysis. Kern and McDonald have developed a geostatistical program which may be applicable to this seal data and

incorporates GPS locations with count data for each transect.

Surveys should be flown from about August 10-25. They should be conducted mid-day (1000-1400 hours) when the greatest number of seals are hauled out on ice flows (Calambokidis et al 1987). When possible, survey dates should be scheduled for days when low tide occurs between 1000-1400 hours so the greatest number of seals will be hauled out. Surveys occurring over a short period of time (e.g. 3 days) may miss cohorts of the population which haul out at different times during the season (E Mathews, pers commun). There should be a minimum of 3 surveys per bay, with at least 2 days between surveys if possible. Additional surveys should be flown if funding and weather allow.

Specific recommendations for specific survey methods

1) **Transects**

Transects should be flown at 1200 ft ASL. All seals within 1/8 mile of the transect should be counted. To identify how far 1/8 mile is from the transect, wing struts should be marked prior to surveys by flying along a road marked 1/8 mile from an intersection at 1200 ft ASL. Some type of ruler taped to the strut will assist the observer to identify where 1/8 mile is. Consistency in observers, pilots, and planes should be maintained when possible. All fiords should be circled for complete coverage at 1200 ft ASL. The number of seals encountered along each transect can be recorded into a hand held tape recorder during the survey and later transferred to data sheets.

a) High Density Seal Aggregations

If seals are aggregated in one to several groups of >100 animals, survey lines, spaced 1/4 mile apart, should be flown at 1200 ft ASL through the aggregation(s). A transparency with lines marked 1/4 mile apart should be randomly placed over the aggregation and drawn onto the base map for that day. Direction of survey lines should be based on safety considerations. However, whenever possible, the plane should fly perpendicular to the group orientation resulting in the greatest number of survey lines per aggregation (Fig 9). Only the portion of the survey lines going through the aggregation are flown. The observer should consistently count from the same side of the plane for each aggregation and all survey lines should be flown.

b) Seals Dispersed Throughout the Remainder of the Bays

If seals are dispersed throughout all or parts of the bays (usually in areas of moderate and low ice density), surveys methods should follow recommendations in Kern and McDonald (1994) with the modifications identified in Kozie and Route (1995). A laminated map with survey lines spaced 1/4 mile apart will be used to survey the main part of the bays. Every other survey

line with the first line, 1 or 2, being randomly chosen, should be flown. If fuel becomes limited after surveys of high density seal areas, coverage can be decreased (e.g. every third or fourth survey line depending on the amount of survey time left) in the low density seal areas. In Icy Bay, these transect lines are pre-drawn directly on the base map. In Disenchantment Bay, we did not draw the 1/4 mile transects on the laminated base map since we were unsure what the safest flight direction might be on any particular day. A transparency with transects 1/4 mile apart will be placed over the main part of Disenchantment Bay, taped onto the base map, and photocopied when the observer returns to the office. GPS locations taken at the beginning and end of each transect may make this step unnecessary. Only areas with ice should be surveyed.

Land haul outs in Disenchantment Bay should be surveyed using the same methodology described for pup proportion surveys of land haul outs.

2) Aerial Photography

Aerial photography will also be used to obtain a population estimate and should consist of at least 30 non-overlapping slides of each seal aggregation. Prior to the survey, the observer should take slides of a marked area using the same flight altitude (1000 ft ASL for seals located on ice flows and 1200 ft ASL for land haul outs) and camera focal length (200 mm) that will be used in the actual survey. Pictures should be taken of 3 markers placed 50 ft apart or landmarks a known distance apart (<100ft). This will allow for later interpretation of the area of the slides. The average number of seals per slide (e.g. per known area) can then be extrapolated to the total area of the aggregation to obtain a population estimate. An additional aerial photograph of a marked area taken at 1300 ft ASL would allow for calculation of a population estimate from slides taken in Disenchantment Bay on 8/15/95.

ADDITIONAL RECOMMENDATIONS

The survey of seal populations throughout Alaska is a joint effort between many agencies and individuals. The resource staff at Wrangell-St Elias should continue to work with other agencies and statisticians Kern and McDonald to further improve monitoring methodology and share data. Copies of this report were sent to the following people:

Tom Loughlin
National Marine Mammal Lab
National Marine Fisheries Service
7600 Sandpoint Way
Seattle, WA 98115

Beth Mathews
Univ of Alaska-Southeast (LAS)
11120 Glacier Highway
Juneau, AK 99801

John Kern
Western Ecosystems Technology Inc
2003 Central Ave
Cheyenne, WY 82001

Kathy Frost
Alaska Dept Fish & Game
1300 College Rd
Fairbanks, AK 99701

Doran Walters
US Forest Service
Box 327
Yakutat, AK 99689

LITERATURE CITED

- Allen, S.G., D.G. Ainley, G.W. Page and C.A. Ribic. 1984. The effect of disturbance on harbor seal haulout patterns at Bolinas Lagoon, California. Fish Bull 28:493-500.
- Byrden MM. 1972. Growth and development of marine mammals. Pages 2-79n IN: RJ Harrison, ed. Functional anatomy of marine mammals. Vol 1. Academic Press, New York. 451pp.
- Calambokidis J, BL Taylor, SD Carter, GH Steiger, PK Dawson, LD Antrim. 1987. Distribution and haul-out behavior of harbor seals in Glacier Bay, Alaska. Can J Zool 65(6): 1391-1396.
- Calambokidis J, LE Healey, and GH Steiger. 1983. Behavior of harbor seals and their reactions to vessels in Glacier Bay, Alaska. Abstract IN: Proceedings of the Fifth Biennial Conference on the Biology of Marine Mammals. 27 Nov - 1 Dec. 1983. Boston, MA.
- Gasaway WC, SD DuBois, RD Boetjie, DJ Reed, and SJ Harbo. 1986. Estimating moose population parameters from aerial surveys. Biol Paper No. 22, Univ of Alaska, Fairbanks.
- Hoover AA. 1988. Harbor Seal (*Phoca vitulina*). IN: Lentfer JW, ed. Selected Marine mammals of Alaska: Species accounts with research and management recommendations. Marine Mammal Commission, Wash. D.C. pp.125-157.
- Hoover-Miller AA. 1992. The Harbor Seal in Alaska. IN: Lentfer JW, ed. Revised Marine mammals of Alaska: Species accounts with research and management recommendations. Marine Mammal Commission, Wash. D.C. 78 pp.
- Kern J. 1996. Aerial survey and analysis methods for estimation of harbor seal population density in Icy Bay. Western Ecosystems Tech Inc, Cheyenne, WY.
- Kern J, LL McDonald. 1994. Recommended survey procedures for harbor seals in Icy Bay, Alaska. Western Ecosystems Tech Inc, Cheyenne, WY.
- Kozie KD. 1993. Coastal wildlife survey - seabirds and marine mammals along the Malaspina Forelands 1992. Rep to Natl Park

Serv., Glennallen, AK

Kozie KD, WT Route. 1995. Development of survey methodology for long term monitoring of harbor seals in Wrangell-St Elias National Park and Preserve, Alaska. Rep to Natl Park Serv., Glennallen, AK

Loughlin TR. 1994. Abundance and distribution of harbor seals (*Phoca vitulina richardsi*) southeastern Alaska during 1993. Rep to NMFS, Seattle, WA. 42 pp.

Loughlin TR. 1992. Abundance and distribution of harbor seals (*Phoca vitulina richardsi*) in Bristol Bay, Prince William Sound, and Copper River Delta during 1991. Annual Report for 1991, NMFS, MMPA Popul. Assessment Program. Office of Protected Resources, NMFS, Silver Spring, MD. 27 pp.

Mathews EA. 1995. Long term trends in the abundance of harbor seals (*Phoca vitulina richardsi*) and development of monitoring methods in Glacier Bay National Park, southeast Alaska. NPS Report. IN: D. Engstrom (ed) Proc from 3rd Glacier Bay Sci Symposium, Sept., 1993.

Mathews EA and BP Kelly. 1996. Extreme temporal variation in harbor seal (*Phoca vitulina richardsi*) numbers in Glacier Bay, a glacial fiord in Southeast Alaska. Mar Mamm Sci. 12:483-489

Mineral Management Service. 1990. Outer continental shelf natural gas and oil resource management comprehensive program 1992 to 1997. US Dept Inter, Mineral Management Serv, Washington, D.C.

Pitcher KW. 1986. Assessment of Marine mammal-fishery interactions in the western Gulf of Alaska and Bering Sea: population status and trend of harbor seals in the southeastern Bering Sea. Final report to NOAA, National Marine Mammal Lab, Seattle, WA. (Contract No. NA-85-ABH-00029, 12pp.

Pitcher KW. 1989. Harbor seal trend count surveys in southern Alaska, 1988. Final report to Marine mammal commission, Washington, D.C. Contract MM4465853-1,

Pitcher KW. 1990. Major decline in number of harbor seals (*Phoca vitulina richardsi*) on Tugidak Island, Gulf of Alaska, Mar Mamm Sci, 6(2):121-134.

Appendix 1. Data analysis of individual sample days for harbor seals in
Icy and Disenchantment Bays in 1995.

Date: 8/16/95 Icy Bay

Strata	Area (x)	Seals (y)
low	0.41	2
low	0.27	14
low	0.11	2
low	0.08	2
Mean	0.21	5
Variance	0.02	36
Ratio		23.28
Total Area		8.64
y_hat_low R*X(low)=		201
Sampling Fraction:		0.10

C(x,y)=	0.15
ybar	5
v(y)	36
xbar	0.21
v(x)	0.02
f	0.10
n	4
y_hat	201
v(yhat)=	15060

Strata	Area (x)	Seals (y)
high	0.17	43
high	0.33	105
high	0.38	158
high	0.30	330
high	0.20	142
Mean	0.27	156
Variance	0.01	11461
Ratio		566.23
Total Area		3.20
y_hat_hi R*X(hi)=		1812
Sampling Fraction:		0.43

C(x,y)=	2.76
ybar	156
v(y)	11461
xbar	0.27
v(x)	0.01
f	0.43
n	5
y_hat	1812
v(yhat)=	165034

Combine Strata Estimates:

$$Y_hat = Y_hat(l) + Y_hat(h) = 2013$$

$$v(Y_hat) = v(y_hat(l)) + v(y_hat(h)) + 2 * c(x,y) = 180094$$

Approximate
95% CI

pop'n estimate	lower limit	upper limit
2013	1181	2845

Date: 8/18/95 Icy Bay

Strata	Area (x)	Seals (y)
low	0.453	39
low	0.438	51
low	0.406	14
Mean	0.43233	34.6667
Variance	0.00058	356.333
Ratio		80.185
Total Area		11.72
y_hat_low	R*X(low)=	939.769
Sampling Fraction:		0.11067

C(x,y)=	0.24211
ybar	34.6667
v(y)	356.333
xbar	0.43233
v(x)	0.00058
f	0.11067
n	3
y_hat	939.769
v(yhat)=	69976.6

Strata	Area (x)	Seals (y)
high	0.469	309
high	0.219	94
Mean	0.344	201.5
Variance	0.03125	23112.5
Ratio		585.756
Total Area		5.03
y_hat_hi	R*X(hi)=	2946.35
Sampling Fraction:		0.13678

C(x,y)=	13.4375
ybar	201.5
v(y)	23112.5
xbar	0.344
v(x)	0.03125
f	0.13678
n	2
y_hat	2946.35
v(yhat)=	1669588

Combine Strata Estimates:

$Y_{\text{hat}} = Y_{\text{hat}}(l) + Y_{\text{hat}}(h) = 3886.12$

$v(Y_{\text{hat}}) = v(y_{\text{hat}}(l)) + v(y_{\text{hat}}(h)) + 2 * c(x, y) = 1739565$

Approximate
95% CI

pop'n estimate	lower limit	upper limit
3886.12	1,301	6,471

Date: 8/21/95 Icy Bay

Strata	Area (x)	Seals (y)
low	0.203	14
low	0.0469	0
Mean	0.12495	7
Variance	0.01218	98
Ratio		56.0224
Total Area		7.26
y_hat_low R*X(low)=		406.723
Sampling Fraction:		0.03442

C(x,y)=	0.54635
ybar	7
v(y)	98
xbar	0.12495
v(x)	0.01218
f	0.03442
n	2
y_hat	406.723
v(yhat)=	122279

Strata	Area (x)	Seals (y)
high	0.516	272
high	0.531	273
high	0.531	241
high	0.211	41
high	0.281	61
high	0.251	66
high	0.203	39
Mean	0.36057	141.857
Variance	0.02463	12834.8
Ratio		393.423
Total Area		8.78
y_hat_hi R*X(hi)=		3454.26
Sampling Fraction:		0.28747

C(x,y)=	15.0734
ybar	141.857
v(y)	12834.8
xbar	0.36057
v(x)	0.02463
f	0.28747
n	7
y_hat	3454.26
v(yhat)=	288909.2

Combine Strata Estimates:

$Y_{\text{hat}} = Y_{\text{hat}}(l) + Y_{\text{hat}}(h) = 3860.98$

$v(Y_{\text{hat}}) = v(Y_{\text{hat}}(l)) + v(Y_{\text{hat}}(h)) + 2 * c(x, y) = 411188$

Approximate
95% CI

pop'n estimate	lower limit	upper limit
3860.98	2,604	5,118

Date: 8/15/95 Disenchantment Bay

	Area	Seals
Strata	(x)	(y)
low	0.031	0
low	0.109	0
low	0.094	0
low	0.125	0
low	0.141	6
low	0.031	0
low	0.031	3
low	0.031	0
low	0.031	3
low	0.063	8
low	0.078	11
Mean	0.06955	2.81818
Variance	0.00179	15.1636

C(x,y)=	0.02164
ybar	2.81818
v(y)	15.1636
xbar	0.06955
v(x)	0.00179
f	0.57519
n	11
y_hat	53.8954
v(yhat)=	230.868

Ratio 40.5229
 Total Area 1.33
 y_hat_low R*X(low)= 53.8954
 Sampling Fraction: 0.57519

	Area	Seals
Strata	(x)	(y)
high	0.172	88
Mean	0.172	88
Variance	0	0

Ratio 511.628
 Total Area 0.31
 y_hat_hi R*X(hi)= 158.605
 Sampling Fraction: 0.55484

C(x,y)=	0
ybar	88
v(y)	0
xbar	0.172
v(x)	0
f	0.55484
n	1
y_hat	158.605
v(yhat)=	0

Combine Strata Estimates:

Y_hat=Y_hat(l)+Y_hat(h)= 212.5

v(Y_hat)=v(y_hat(l))+v(y_hat(h))+2*c(x,y)= 230.868

Approximate
 95% CI

pop'n	lower	upper
estimate	limit	limit
212.5	183	242

Date: 8/17/95 Disenchantment Bay

Strata	Area (x)	Seals (y)
low	0.031	2
low	0.234	0
low	0.203	0
low	0.172	0
Mean	0.16	0.5
Variance	0.00804	1

Ratio 3.125
 Total Area 2.72
 $y_{\text{hat}}_{\text{low}} R \cdot X(\text{low}) = 8.5$
 Sampling Fraction: 0.23529

$C(x, y) =$	-0.0645
ybar	0.5
v(y)	1
xbar	0.16
v(x)	0.00804
f	0.23529
n	4
y_hat	8.5
v(yhat)=	81.8588

Strata	Area (x)	Seals (y)
high	0.156	74
high	0.156	65
Mean	0.156	69.5
Variance	0	40.5

Ratio 445.513
 Total Area 0.84
 $y_{\text{hat}}_{\text{hi}} R \cdot X(\text{hi}) = 374.231$
 Sampling Fraction: 0.37143

$C(x, y) =$	0
ybar	69.5
v(y)	40.5
xbar	0.156
v(x)	0
f	0.37143
n	2
y_hat	374.231
v(yhat)=	369.053

$Y_{\text{hat}} = Y_{\text{hat}}(l) + Y_{\text{hat}}(h) = 382.731$

$v(Y_{\text{hat}}) = v(y_{\text{hat}}(l)) + v(y_{\text{hat}}(h)) + 2 \cdot c(x, y) = 450.912$

Approximate
 95% CI

pop'n estimate	lower limit	upper limit
382.731	341	424