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OBSERVATIONS ON BELUKHA FALL MIGRATION IN THE ALASKAN BEAUFORT SEA, 1982-87, AND NORTHEASTERN CHUKCHI SEA, 1982-91

1992

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ABSTRACT

Distribution, relative abundance and behavior data were collected on belukhas during aerial surveys in the Alaskan Beaufort Sea in fall 1982-87 and in the northeastern Chukchi Sea in fall 1982-91. A total of 2,412 belukhas were seen in the Alaskan Beaufort Sea during approximately 618 survey hours. Distribution was offshore in most years, with scattered sightings nearshore and along the coast. Sighting rate was highest in 1983 (Be/h =11 .04), when more than half (57%, n= 1378) of all belukhas were seen, and lowest in 1982 (Be/h= 1.06). Migration route, as defined by mean depth at random sightings, was significantly different among years (ANOVA F =5.132, $p < 0.0005$), and the mean heading was 263 oT. There was a significant positive correlation between belukha relative abundance and percentage of ice cover only in 1983 ($r = 0.8376$, $p < 0.005$). A total of 3,957 belukhas were seen in the northeastern Chukchi Sea during approximately 694 survey hours. Distribution varied among years. Sighting rate was highest in 1988 (BE/h =24.22) and lowest in 1987 (Be/h= 1.16), Belukha relative abundance was

significantly correlated with percentage of ice cover in the northeastern Chukchi Sea only in 1983 ($r = 0.7028$, $p < 0.05$). Swimming direction was southwesterly in the Chukchi Sea. Cumulative daily random sighting rate peaks in the northeastern Chukchi Sea were up to six times greater than those calculated in the Alaskan Beaufort Sea. The proportion of cumulative random sightings in water ≥37 m deep was significantly greater than the amount of survey time spent over that habitat (x^2=80.80, $p < 0.001$), indicating a preference for deeper-water in the Chukchi Sea. There appears to be a nearshore migration route roughly following Barrow Canyon, and an offshore route north of 720 N.

INTRODUCTION

Belukhas (*Delphinapterus leucas*) are widely distributed in Alaskan waters (Braham, Krogman and Carroll, 1984; Harrison and Hall, 1978; Seaman, Frost and Lowry, 1986; Frost and Lowry, 1990). One population remains in Cook Inlet, while a second and larger group ranges seasonally throughout the Bering, Chukchi and Beaufort seas. Belukhas summer in the Bering Sea, primarily in the Bristol Bay-Kuskokwim River area and the Norton Sound-Yukon Delta area, and in the coastal Chukchi Sea, principally in Kotzebue Sound and Kasegaluk Lagoon. However, the largest stock summers in the Canadian Beaufort Sea (Davis and Evans, 1982) and migrates in fall across the Alaskan Beaufort Sea into the Chukchi Sea. Data on the latter stock, known as the Beaufort Sea/Mackenzie Delta stock, were collected during broad-scale aerial surveys for bowhead whales (*Balaena mysticetus*) in September-October 1982-87 in the Alaskan Beaufort Sea (Ljungblad, Moore, Clarke, and Bennett, 1988) and in September-October 1982-91 in the northeastern Chukchi Sea (Moore and Clarke, 1992). The distribution, relative abundance and behavior data collected during this study complements data from other studies, and adds significantly to the belukha database for offshore Alaskan waters.

METHODS

The study area was divided into two regions: the Alaskan Beaufort Sea between 1400 W and 1540 W from the coastline out to 720 N, and the northeastern Chukchi Sea from 1540 W to 1690 W (International Date Line) between 690 N and 73o N (Fig. 1). These study areas were not defined by geographic or oceanographic features, but rather reflect a division of survey effort between Minerals Management Service-funded studies. The Alaskan Beaufort Sea study area comprised survey blocks 1 through 11, while the northeastern Chukchi Sea study area comprised blocks 12 through 21 and 12N through 16N (see shading on Fig. 1). All data analyses were based on these two regions or subregions within these regions. Aerial surveys in the Beaufort Sea were conducted in September and October 1982-87, and based out of Deadhorse, Alaska. Surveys in the northeastern Chukchi Sea were conducted in September and October 1982-91, and based out of Barrow, Alaska. The northernmost blocks (12N-16N) were not surveyed regularly until 1987. The study period varied each year depending on the status of the bowhead migration and annual study objectives. Surveys were flown in survey blocks south of the Chukchi Sea study area in some years, but no belukhas were seen. Belukhas were seen north of the Chukchi Sea study area in 1990 (Moore and Clarke, 1991), however results of those surveys are not presented here. Broadscale aerial surveys continued in the Alaskan Beaufort Sea from 1987-91 (Treaty, 1988, 1989, 1990, 1991, 1992), but results of those efforts were not available for incorporation here.

Two types of aerial surveys were conducted: transect surveys using randomly selected north-south (occasionally east-west) transect legs in survey blocks, and search surveys while transiting to offshore survey blocks. Data collected during both transect and search surveys were included in analyses unless otherwise noted. Surveys were flown in a *Grumman* Turbo Goose (model G21 G) or *deHavilland* Twin Otter, at altitudes of 152-458m and speeds of 222-296 km/h. Higher altitudes were used, when weather permitted, to maximize visibility and minimize disturbance to marine mammals. The aircraft was equipped with a *Global Navigation System (GNS)* 500 that provided continuous position updating (0.6km/survey hour, precision) and transect turning point programming.

A portable computer aboard the aircraft was used for entry of aircraft altitude, position (Lat° N, Long °W), ice conditions (type and percent cover), Beaufort sea state, visibility range (subjective), species, number of animals, number of calves, swimming direction, and behavior. Whale behavior classifications were developed for bowhead whales (Moore, Clarke and Ljungblad, 1986), and included resting, swimming, diving, displaying, feeding, milling and cow-calf association. However, since belukha data were collected incidental to bowhead data during these surveys, very little specific investigation of belukha behavior was possible.

Annual survey effort and distribution were plotted for each study area. Relative abundance (WPUE), representing a spatial or geographic index, was calculated annually as the number of belukhas seen per 100 transect-kilometers (t-km) for sub-blocks that were approximately 1,150 km^2 (15'N latitude by 10 W longitude). Abundance was calculated only for sub-blocks with at least 50 km (approx. 0.2h) of transect-survey effort during periods of good sea conditions (Beaufort ≤4), an approach modelled after that presented in Reilly and Thayer (1990) for multi-year blue whale sighting data.

Migration timing was estimated by cumulative daily random sighting rates (rSR =no. whales seen during random-line transect surveys/transect survey hour) for subregions in the Alaskan Beaufort Sea (69-72o N, 140-143 °W) and the northeastern Chukchi Sea (70-73°N, 154-157°W). Variation in belukha migration route in the Alaskan Beaufort Sea region was determined through an analysis of variance (ANOVA) of annual mean depths for all random sightings using *SPSS* statistical software (Norusis, 1988). In the relatively shallow northeastern Chukchi Sea (157 0-169 °W), the relationship between belukha distribution and water depth categories (<37m and ≥37m) was examined to investigate the relationship between depth and migration route. Thirty-seven meters (20 fathoms) was chosen as the delineation between shallow water/shoal areas and deeper water/submarine canyon areas after Paquette and Bourke (1981). The percentage of transect survey time spent in the two depth categories was calculated using the program DEPTHTYM, which reads depths from a consistent depth database derived from NOAA bathymetric charts 16004 and 16005, and compared with the number of random belukha sightings in each depth category using Chi-square analysis (Zar, 1984). Migration route for cumulative belukha data was determined by an analysis of swimming direction for subregions delineated by observed belukha distribution (Zar, 1984). Belukhas that were resting, milling or feeding were excluded from swimming direction analyses. Significant difference in mean headings between data sets was tested using the Watson U^2 test for data containing tied values (Zar, 1984).

Habitat preference was analyzed annually for each region by correlating the amount of transect survey effort per ice cover class (O-1OYO ice cover, 11 -20% ice cover, etc.) and the number of random belukha sightings per transect survey hour (BE/h) in each ice cover class using *SPSS* statistical software.

RESULTS

Survey Effort

Nearly 618 survey hours were flown in the Alaskan Beaufort Sea in September-October 1982-87, with 56 percent (349.1 h) of the effort spent on random-line transect surveys (Table 1, Fig. 2). Survey effort in 1987 was limited to two flights in September and five flights in late October. Nearly 694 hours of aerial surveys were flown in the northeastern Chukchi Sea in September-October 1982-91, with 56 percent (388.6h) of the effort spent on random-line transect surveys. Survey effort varied among years. Surveys were not flown in the study area during the first half of September in 1982, 1984, 1985, 1989 and 1991, or during the entire month of September in 1988 or 1990. Broad-scale coverage of the northeastern Chukchi Sea did not begin until 1987, when the emphasis for the bowhead whale aerial survey program shifted to the west. Surveys in both regions were terminated on various dates from mid- to late October in all years.

Distribution and Relative Abundance

There were 408 sightings of 2,412 belukhas in the Alaskan Beaufort Sea from 1982-1987. Distribution in all years was generally offshore, with scattered nearshore and coastal sightings (Fig. 2). The distribution from 1983-86 was similar, but distribution in 1982 was limited, despite widescale survey coverage, to the western portion of the study area. Notably, no belukhas were seen in either the Alaskan Beaufort or Chukchi seas in September 1982. Belukha distribution in 1987 was limited to areas where surveys were flown; surveys were flown in the eastern Alaskan Beaufort Sea only in late October. There were 456 sightings of 3,957 belukhas in the northeastern Chukchi Sea (Fig. 2). Although belukha distribution varied greatly among years, two trends are suggested. First, in most years belukha distribution between 154-157o followed Barrow Canyon, a bathymetric feature that extends offshore north and east of Point Barrow and in a southwesterly direction parallel to the Alaskan coastline between Point Barrow and Point Franklin. Second, in years when survey effort extended to northern survey blocks (north of 720 N), belukha distribution appeared bifurcated, with a component of whales distributed north of 720 N, and a nearshore distribution along Barrow Canyon.

There was marked inter-annual variation in survey effort and belukha sighting rate among years (Table 1). Relative abundance was highest in 1983 (BE/h= 11 .89) and 1988 (BE/h =24.22), both years of heavy ice, as represented by a greater proportion of sub-blocks with high WPUE relative to other years (Fig. 3). In other years, sighting rates rnaged from 1.20 to 3.97 whales /survey hour (Table 1) and sub-blocks with WPUE of 0.1-10 prevail, with pockets of higher WPUE (10-50) interspersed (Fig. 3). Belukha relative abundance was especially limited in 1982 and 1990. No belukhas were seen in the eastern Alaskan Beaufort Sea in 1982, a moderately light ice year, despite broad-scale survey coverage. In 1990, an exceptionally light ice year when the ice edge remained near 740 N for most of fall, survey effort was greatly reduced due to other commitments of the survey aircraft.

Migration Timing and Route

Cumulative (1982-87) daily random sighting rate for the Alaskan Beaufort Sea subregion peaked on 6 September (11.28 whales/h) and 22 September (7.61 whales/h) (Fig 4A). In the Chukchi Sea subregion, peaks in the daily random sighting rate occurred on 5 September (16.99 whales/h), 18 September (37.14 whales/h), 24 September (65.16 whales/h, highest), 11 October (13.41 whales/h) and 17 October (68.70 whales/h) (Fig. 46). It is not apparent from the random sighting data that peaks in the Beaufort Sea were followed by peaks in the Chukchi Sea, although comparison of sighting rate peaks between the two regions is difficult because of differences in survey effort. Sighting rate peaks in the Chukchi Sea were up to six times higher than those in the Alaskan Beaufort Sea. The sighting rate peaks in the Chukchi Sea appear to overlap and extend beyond those dates calculated for bowhead whales (Moore and Clarke, 1992), indicating that the belukha fall migration may be more prolonged than that of bowhead whales or that belukhas observed in the Chukchi Sea in fall may be summer residents that did not migrate into the Alaskan Beaufort Sea.

Annual migration route in the Alaskan Beaufort Sea, as defined by mean depth at random sightings, was significantly different among years 1982-86 (ANOVA F= 5.132, p <0.0005); 1987 was excluded from analysis because survey effort was not similar to 1982-86. The mean depth in 1983 (1269m) was significantly deeper ($p < 0.05$) than the mean depth in 1984 (758m) and 1986 (848m). Mean depths in 1982 (542m) and 1985 (693m) were even shallower, but the differences were not statistically significant, perhaps because of the low number of sightings in those years. In the Chukchi Sea (157~69 °W), significantly more belukhas than expected were seen in water ≥37m deep in five of the ten survey years (Table 2). This trend was reversed in 1986, when there was a significantly higher proportion of belukhas in water <37m (x^2=4.31, $p < 0.05$).

Belukha migration route, as described by swimming direction, complements that inferred from distribution. Four subregions were derived for swimming direction analysis based on observed distribution (Fig. 5):

region A, 140-154° W and northto720 N; mean heading 263 'T (r = 0.40, p <0.001);

region B, 154-157°W and north to 720 N; mean heading 245oT (r = 0.39, p<0.001);

region C, 154-169° W and between 72-730 N; mean heading 258 'T (r = 0.20, p<0.01);

region D, from shore to 1690 W and between 69-720 N; mean heading 253 OT (r = 0.37, p < 0.001).

Swimming directions in region C were significantly different from those in region A (U^2=0.2887, $p < 0.01$), region B (U^2=0.3401, $p < 0.005$), and region D (U^2=0.2260, p c 0.05), despite the apparent similarities in mean heading. No other regions were significantly different from one another. Swimming directions in region C were more variable and less directed than in other regions (Fig. 5).

Relative abundance (BE/h) was significantly correlated with ice cover percentage in the Alaskan Beaufort Sea (r=O.8615, p< 0.0028), but not in the northeastern Chukchi Sea (r = 0.2510, p < 0.5147; Table 3). However, correlation of belukha abundance (BE/h) with ice percentage on a year-by-year basis revealed that belukha relative abundance was significantly positively correlated with percentage ice cover in 1983 in both areas (Alaskan Beaufort Sea, r= O.8376, p <0.005; northeastern Chukchi Sea, r= O.7028, p <0.05), but not in either area in other years. To determine the possible effect of ice cover on sighting distance from the aircraft, an additional correlation was calculated for 1983 data only. Too little sighting distance data existed in the Chukchi Sea data set to determine a relationship, but there was a weak negative correlation (r= -0.15464, p <0.69) between ice cover class percentage and sighting distance in the Alaskan Beaufort Sea, which indicates that the increase in belukha relative abundance with ice percentage is probably not due to improved sighting conditions.

DISCUSSION

Incidental observations of belukhas during aerial surveys for bowhead whales in spring and summer were summarized in Moore, Clarke and Johnson (1992). The data summarized here were collected during the fall component of the same study. These data are not suitable for stock size estimates, behavioral classifications or estimates of calf recruitment, due to the incidental nature of data collection. However, despite these limitations, the observations summarized here provide additional clues to understanding belukha distribution and migration patterns in the offshore waters of Alaska.

Belukha distribution in the Alaskan Beaufort is predominantly offshore, but migration route, as defined by mean depth, varies from year to year. In the northeastern Chukchi Sea, the distribution is more variable, but generally appears bifurcated. A nearshore component apparently heads southwesterly after passing Point Barrow, while an offshore component remains largely north of 72o N maintaining a somewhat more westerly heading. The extent of the separation between the two components may be influenced by annual ice cover. In 1991, when ice cover in the Chukchi Sea varied from quite heavy to very light over the course of the season, belukha distribution did not appear bifurcated as in 1989, when the entire study area remained ice-free throughout September and October.

Belukha distribution and migration route in the northeastern Chukchi Sea may be influenced by bathymetrically-driven currents. Two principal water masses enter the Chukchi Sea through the Bering Strait (Aagaard, 1987): the saline Bering Sea water (BSW) and the low-salinity Alaskan coastal water (ACW). The inflow of the two water masses diverges near the latitude of Point Hope, with the BSW flowing northward through Herald Canyon in the central Chukchi Sea west of the study area, and the ACW flowing to the northwest along the Alaskan coast. Filaments of the ACW branch off the main coastal flow at three locations: west of Point Lay (approx. 69° 30'N, 167 °W), west of Peard Bay (approx.710 N, 1620 W); and northwest of Point Barrow (71030'N, 157°30'W). The ACW is bathymetrically directed around shoals where water depth is generally <37 m (Aagaard, 1987; Paquette and Bourke, 1981). Analysis of belukha depth at sightings in the Chukchi Sea indicated a preference for these deeper-water (≥37 m) areas, which was significant in 5 years. The basis for following bathymetrically-driven migratory routes is unclear, but may be connected with temperature/salinity cues or prey availability.

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Table 1. Summary of annual fall survey effort (hours), and number of belukhas (BE) and sighting rate (BE/h) in the Alaskan Beaufort and northeastern Chukchi seas study areas, September-October 1982-91.

	Alaskan Beaufort			Northeastern Chukchi			TOTAL		
	BE	Hours	BE/h	BE	Hours	BE/h	BE	Hours	BE/h
1982	*106*	100.41	1.06	268	31.70	8.45	374	132.11	2.83
1983	1 *378*	124.83	11.04	809	59.14	13.68	2187	183.97	11.89
1984	*394*	-115.90	3.40	243	38.10	6.38	637	154.00	4.14
1985	*134*	109.26	1.23	170	32.13	5.29	304	141.39	2.15
1986	*268*	136.75	1.96	139	100.00	1 ,39	407	236.75	1.72
1987	*132*	30.39	4.30	140	120.50	1.16	272	151.19	1.80
1988	0	0		1259	51.99	24.22	1259	51.99	24.22
1989	0	0		421	113.13	3.72	421	113.13	3.72
1990	0	0		33	27.57	1.20	33	27.57	1.20
1991	0	0		475	119.65	3.97	475	119.65	3.97
TOTAL	2412	617.84	3.90	3957	693.91	5.70	6369	1311.75	4.86

Table 2. Chi-square analysis of proportion of random-line transect belukhas with proportion of time spent on random-line transects in each depth class in the northeastern Chukchi Sea (69-73o N, 157-169°W).

YEAR	# BE		# transect hours		χ^2	p
	< 37m	≥37m	< 37m	≥37m		
1982	0	0	3.33	4.75		
1983	7	168	2.77	10.23	7.64	0.01
1984	0	35	1.69	7.78	6.24	0.025
1985	0	10	2.14	4.40	3.75	0.10
1986	6	4	7.02	21.95	4.31	*0.05
1987	2	17	5.81	24.43	0.65	0.50
1988	0	172	2.49	25.18	19.89	0.001
1989	0	257	5.97	40.50	33.16	0.001
1990	0	12	1.12	11.21	1.06	0.50
1991	10	282	6.60	41.89	9.11	0.001
Total	25	957	38.94	192.32	80.80	0.001

* Note: more belukhas than expected in shallow (<37 m) water

Table 3. Correlation analysis of random-line transect belukha sightings per transect survey hour (BE/h) with random-line transect survey effort per ice cover class (O-1 0% ice cover) category. n = number of ice class categories in which random-line transect survey effort was recorded.

	Alaskan Beaufort Sea			northeastern Chukchi Sea		
Year	n	r	p	n	r	p
1982	10	0.4865	p<0.20	9	0.5729	p<0.20
1983	10	0.8376	p<0.005*	10	0.7028	p<o.05**
1984	10	-0.1284	p<0.50	10	0.3444	p<0.50
1985	10	0.2317	p<0.50	10	0.2180	p<0.50
1986	10	-0.0997	p<0.50	10	0.1881	P<0.50
1987	10	-0.4796	P<0.50	10	0.0023	P<0.50
1988				10	-0.1609	P<0.50
1989		-	-	10	-0.3586	P<0.50
1990				7	-0.5119	P<0.20
1991				10	-0.1877	p<0.50
Total	10	0.8615	p< 0.0028	10	0.2510	p<o.5147

* negative correlation between ice cover class category and sighting distance; r=-0.15464, p< 0.6912

** insufficient data on sighting distance to calculate relationship between sighting distance and ice cover class

FIGURE CAPTIONS

1. Alaskan Beaufort Sea and northeastern Chukchi Sea study areas and aerial survey blocks.

2. Annual survey effort and belukha distribution; symbols represent one sighting of one or more belukhas.

3. Annual relative abundance (WPUE=number of random-sighting belukhas/100 transect-kilometers) for 1,150 km^2 sub-blocks.

4. Cumulative daily random sighting rate (no. transect belukhas/transect survey hour) for subregions in the Alaskan Beaufort Sea (69-73° N, 140-143°W) (A) and northeastern Chukchi (70-73° N, 154-1 57°W) (B).

5. Cumulative belukha swimming direction by geographic region.

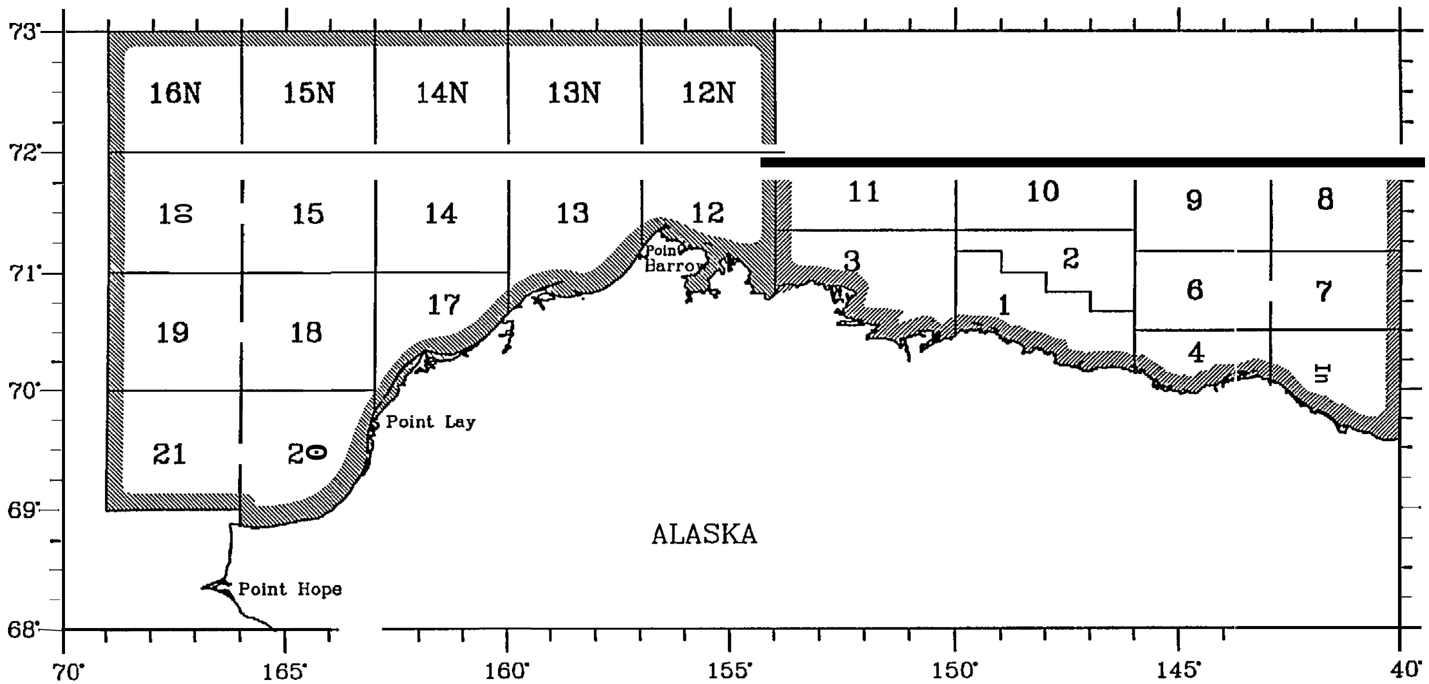

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Figure 1.

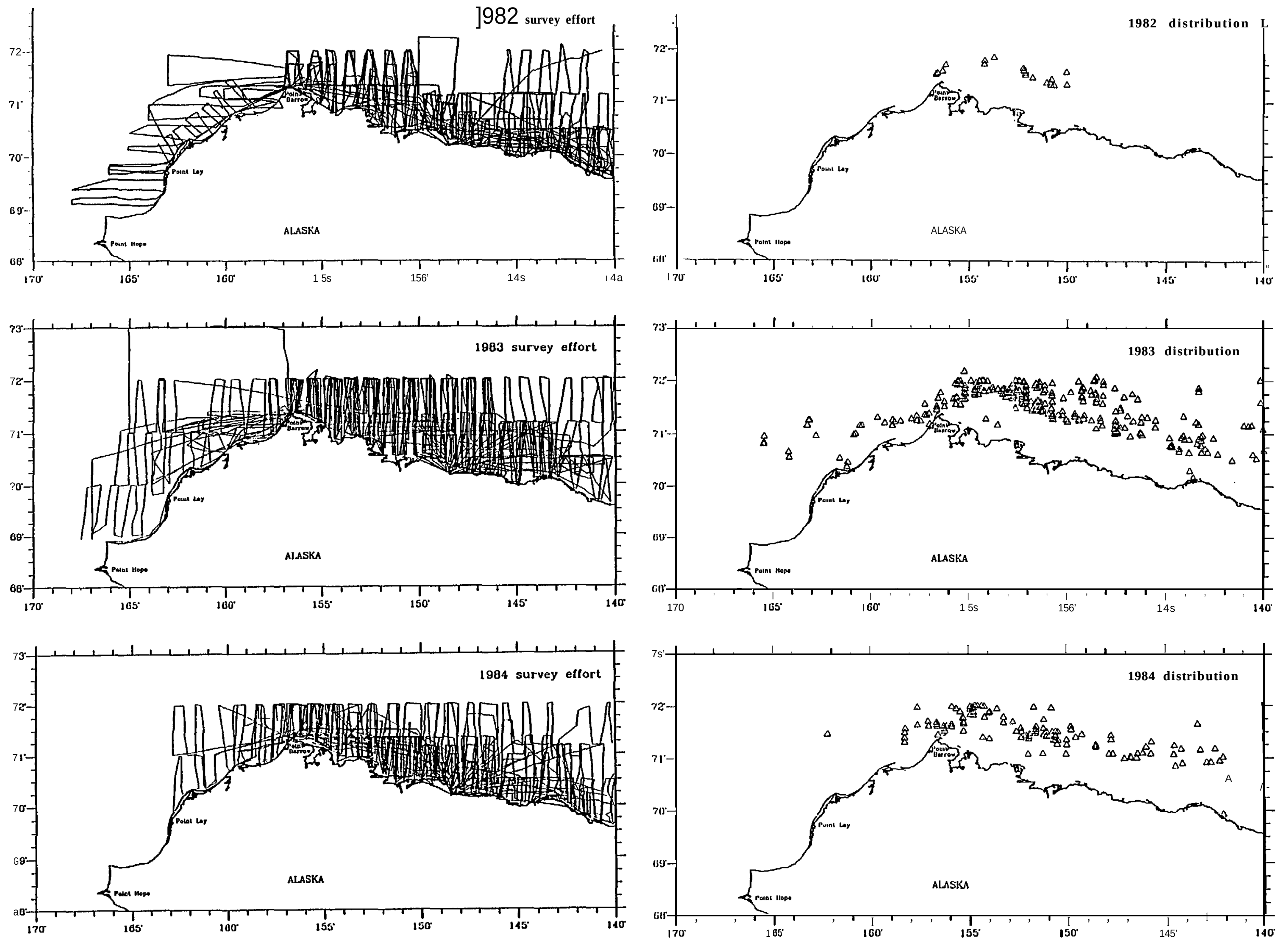

Figure 2.

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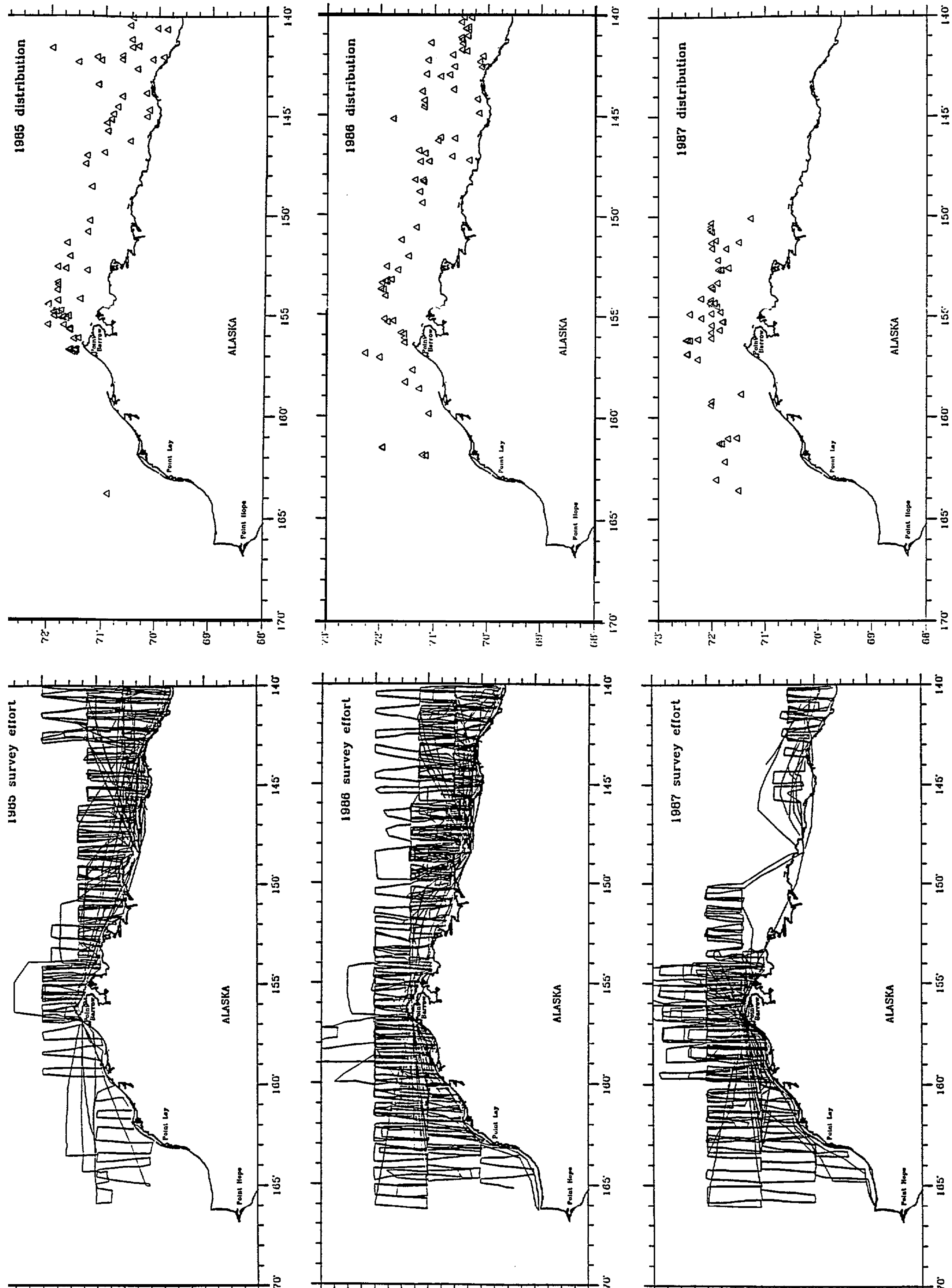

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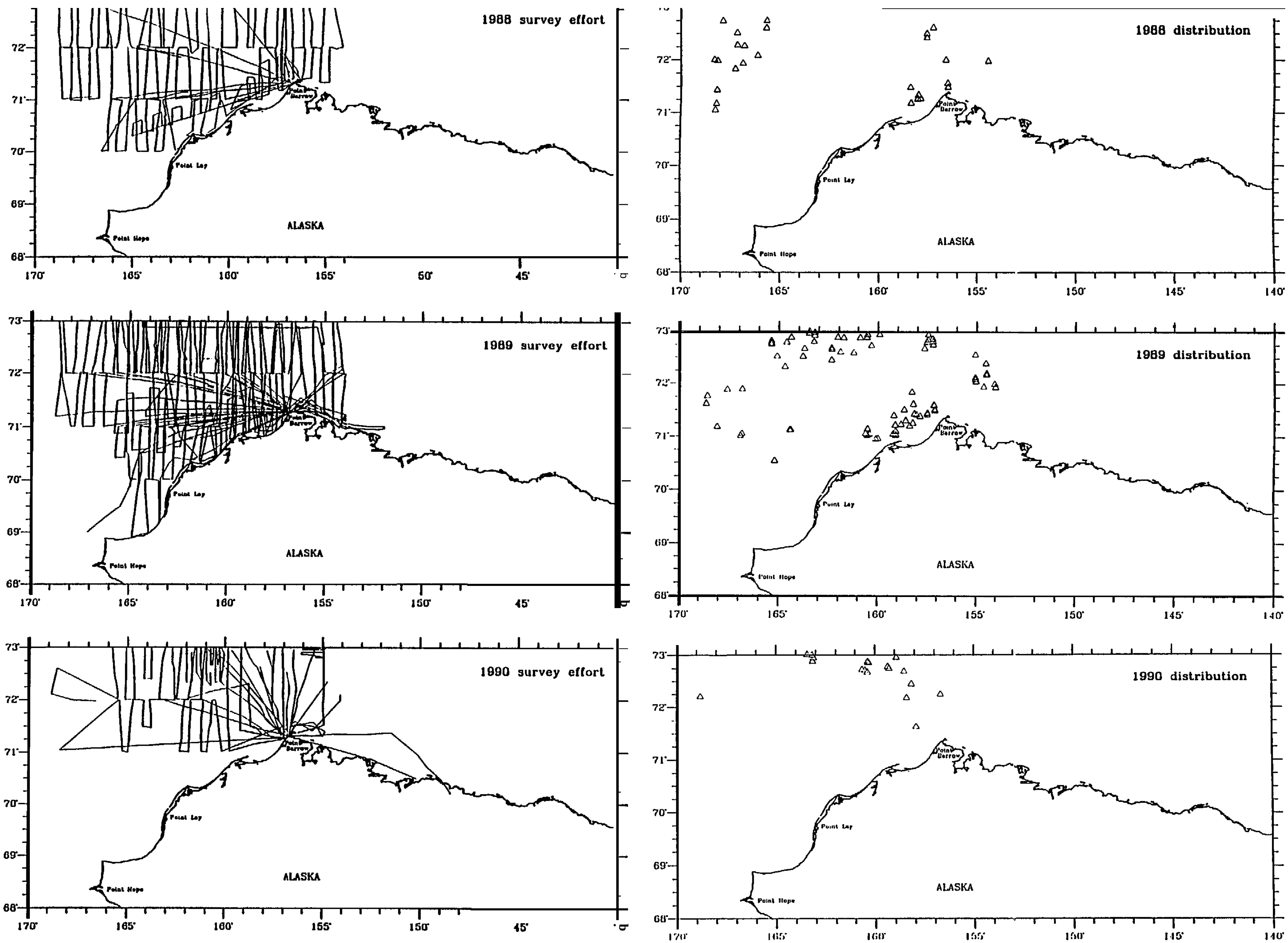


Figure 2 (cont).

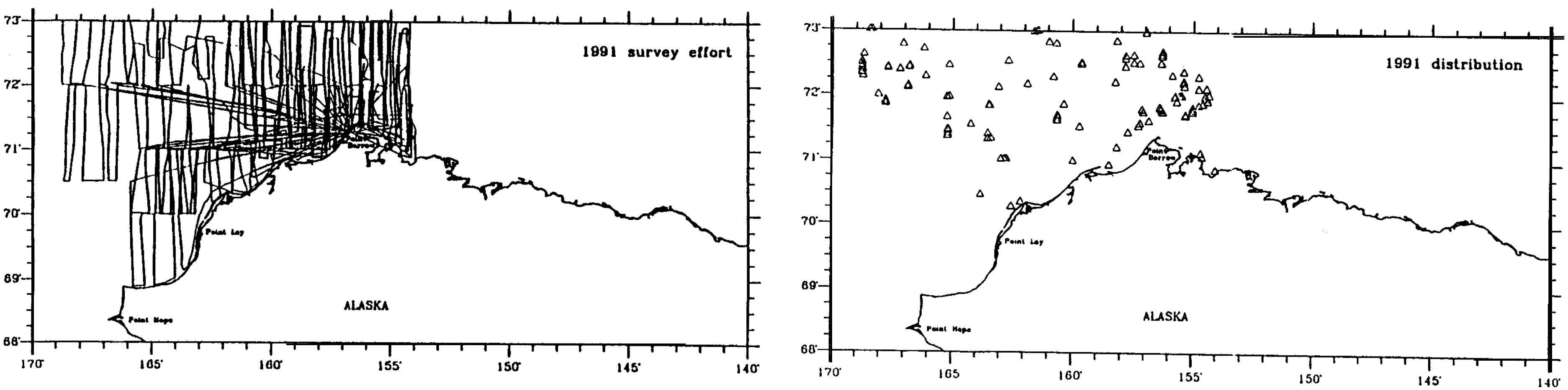


Figure 2 (cont.)

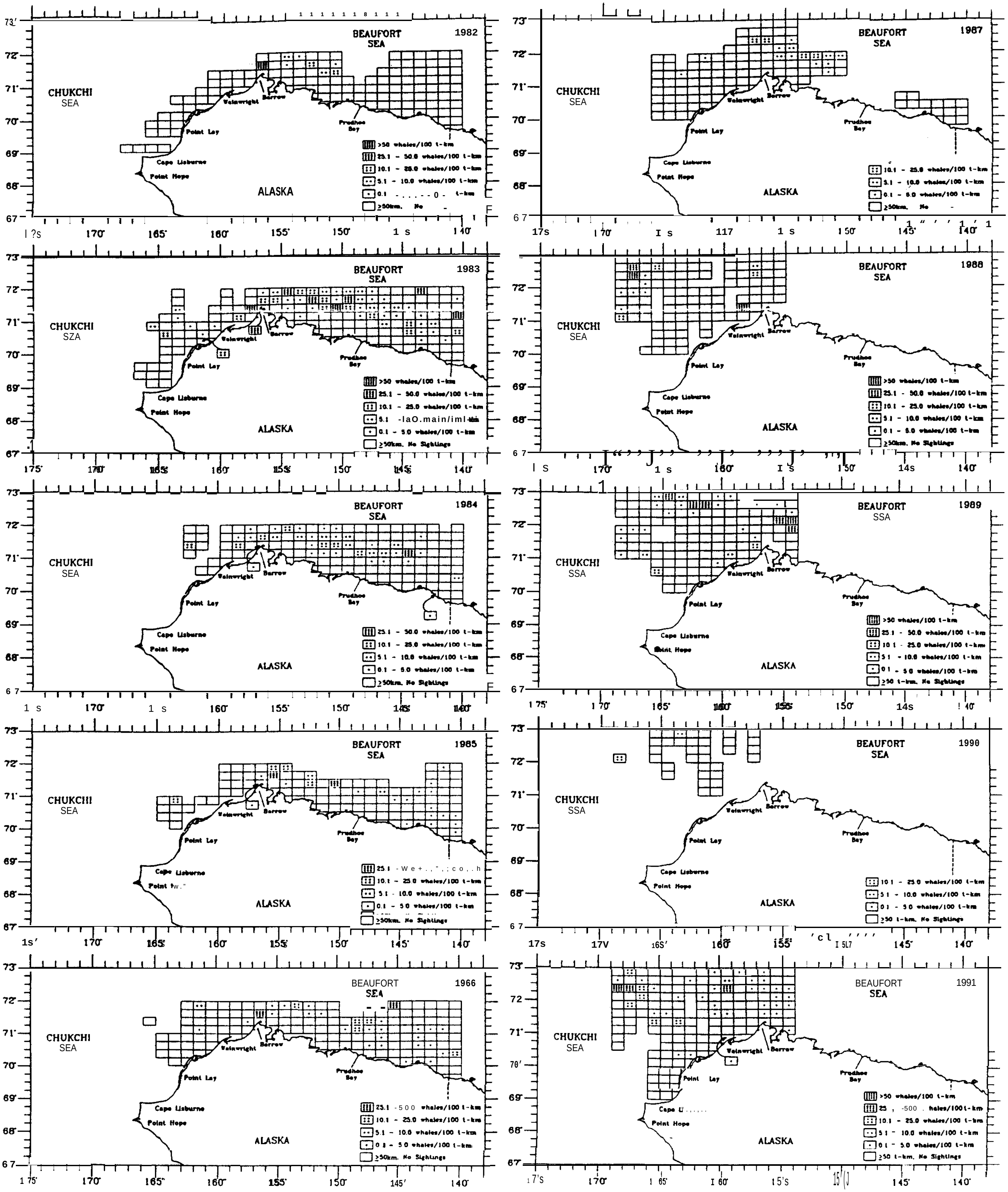

BEAUFORT SEA
CHUKCHI SEA
ALASKA
Wainwright
Barrow
Point Lay
Prudhoe Bay
Cape Lisburne
Point Hope
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
>50 whales/100 t-km
25.1 - 50.0 whales/100 t-km
10.1 - 25.0 whales/100 t-km
5.1 - 10.0 whales/100 t-km
0.1 - 5.0 whales/100 t-km
≥50km, No Sightings
73°
72°
71°
70°
69°
68°
67°
175°
170°
165°
160°
155°
150°
145°
140°

Figure 3.

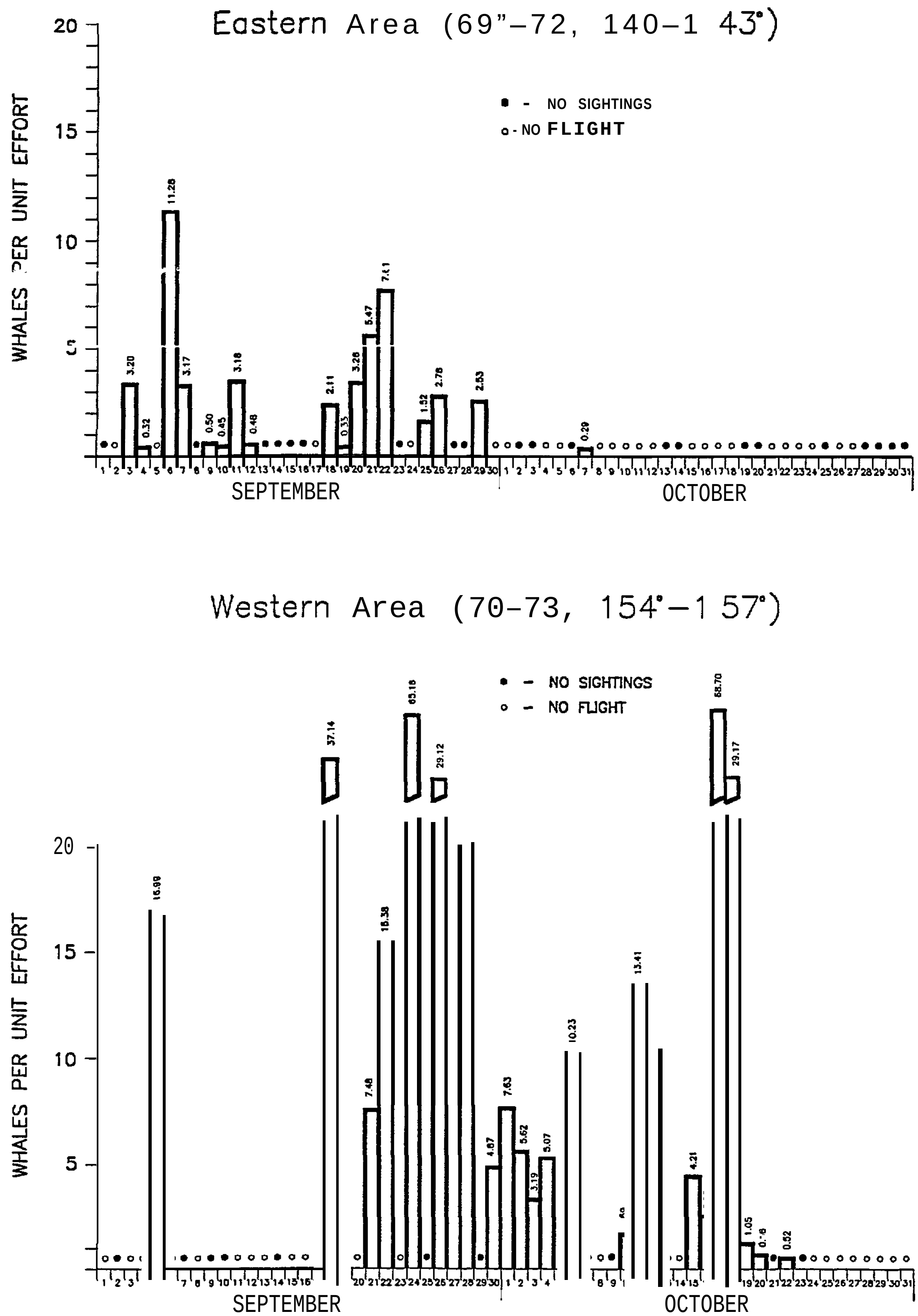
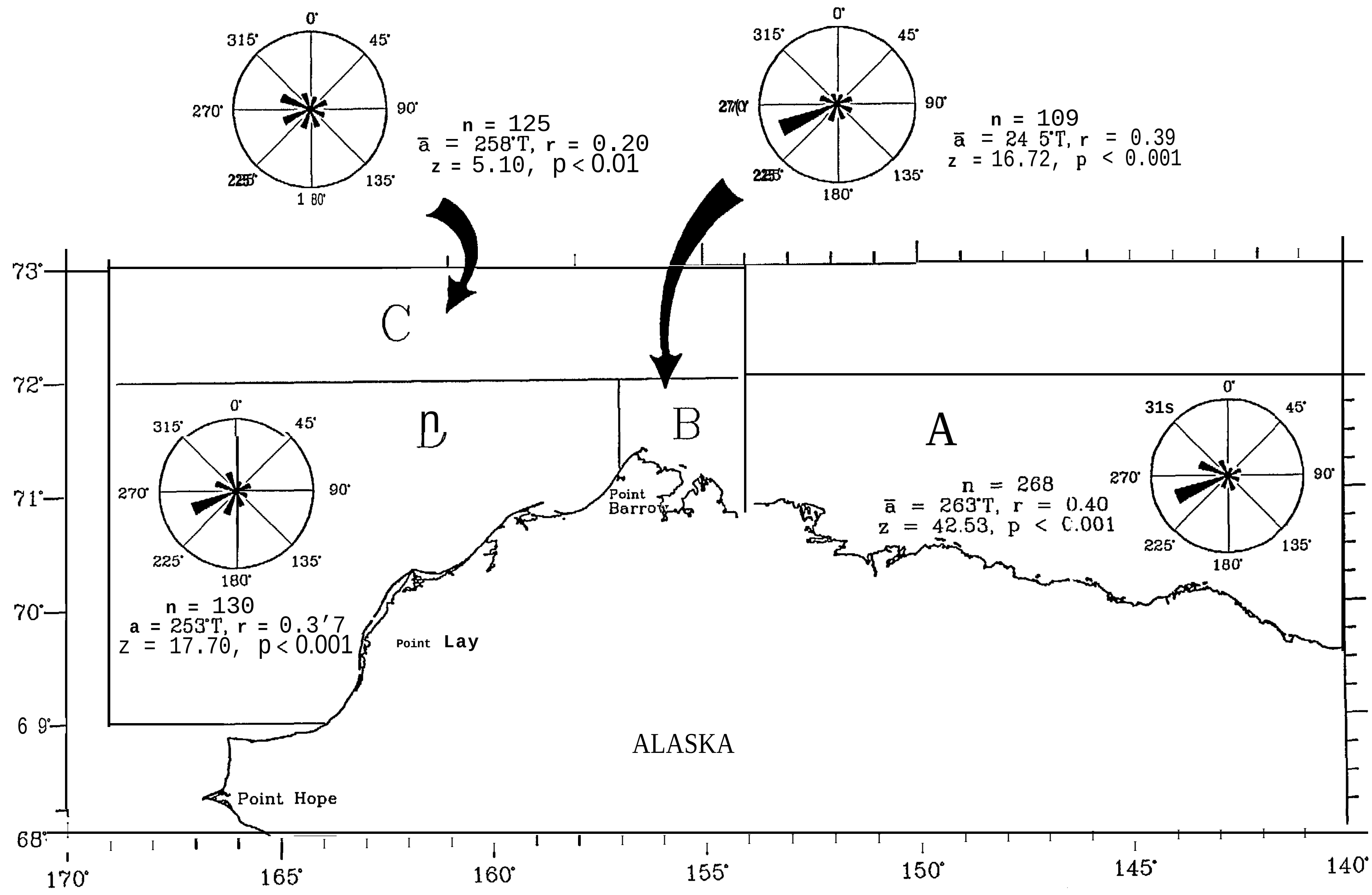

Eastern Area (69"–72, 140–1 43°)
● - NO SIGHTINGS
○ - NO FLIGHT
WHALES PER UNIT EFFORT
SEPTEMBER
OCTOBER
Western Area (70–73, 154°–1 57°)
● – NO SIGHTINGS
○ – NO FLIGHT
WHALES PER UNIT EFFORT
SEPTEMBER
OCTOBER

Figure 4.



n = 125
ā = 258°T, r = 0.20
z = 5.10, p < 0.01
n = 109
ā = 24 5°T, r = 0.39
z = 16.72, p < 0.001
C
B
A
D
n = 268
ā = 263°T, r = 0.40
z = 42.53, p < 0.001
n = 130
a = 253°T, r = 0.37
z = 17.70, p < 0.001
Point Barrow
Point Lay
Point Hope
ALASKA
73°
72°
71°
70°
69°
68°
170°
165°
160°
155°
150°
145°
140°
0°
45°
90°
135°
180°
225°
270°
315°

Figure 5.