On 17 September, a single bowhead was sighted incidentally although no survey transects were flown because of a low cloud ceiling. The sighting was near the north end of transect -3 (Fig. 5.19). Full array seismic was underway at the time. The whale was 68 km NNW of the seismic vessel and was resting at the surface (Table 5.3).

On 18 September, 14 bowheads were recorded during 875 km of surveys in the extensive and intensive grids. Fog and/or snow restricted visibility at the northern ends of many transects (Fig. 5.19). The surveys were flown during periods of full array seismic (349 km) and post-seismic (525 km). Two bowheads were seen during the full array period. Twelve bowheads were seen during the post-seismic period, including two sightings (3 whales) only 11.4 min after seismic ended. Sightings during both periods were aligned along a well-defined corridor 20 to 30 km from shore. The closest whale seen during full-array seismic was 27 km NNW of the seismic vessel and was travelling slowly to the east (Table 5.3). The two sightings 11.4 min after seismic ended were about 21 km NE of the seismic vessel, swimming east (2 whales) and west (1 whale) (Table 5.3).

The source vessel finished shooting seismic on the afternoon of 18 September. Thus, aerial surveys on 19 and 20 September were conducted during periods of no seismic. On 19 and 20 September, survey coverage of the extensive and intensive grids totalled 1128 and 1189 km, respectively. Seventeen bowheads were observed on 19 September and 12 were seen on 20 September (Fig. 5.20, 5.21). On both days there were sightings in both offshore and nearshore areas.

Summary of Northstar Surveys.—Overall, during the 1-21 September 1996 study period, 10,225 km of transect surveys were flown. Of this coverage, 6648.3 km was during periods with no seismic and 3576.2 km was during periods potentially influenced by seismic activities: 791.3 km during partial array seismic (all of it with five airguns), 2259.4 km during full array seismic, and 525.5 km during post-seismic periods (i.e. within 3.5 hours after the end of full array seismic).

In total, during BPXA/LGL surveys from 1 to 21 September there were 58 sightings of bowheads involving 77 individuals. Of these,

- 7 sightings and 7 individuals were with full array seismic,
- 2 sightings and 2 individuals were with partial array seismic (and within 3.5 h after the end of full-array seismic),
- 8 sightings and 12 individuals were during post-seismic periods, and
- 41 sightings and 56 individuals were during no-seismic periods.

There was no immediately obvious relationship between the numbers of bowheads sighted and the status of the seismic array during the aerial surveys (Fig. 5.22). Relatively large numbers of bowheads were seen during days with seismic (18 September) and without seismic (5 Sep.). Likewise, few bowheads were recorded on other days with seismic (10 Sep.) and without seismic (16 Sep.).

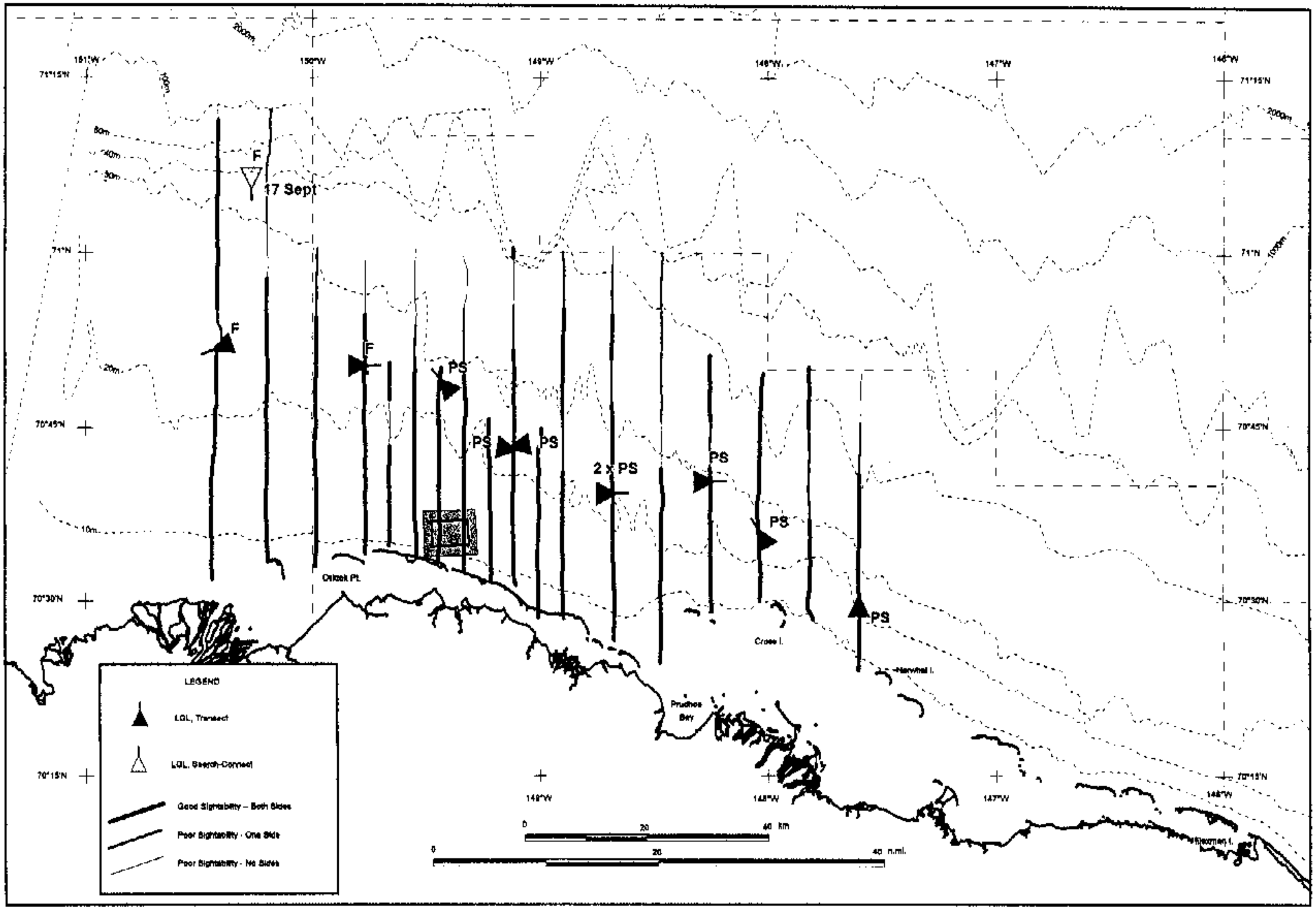

FIGURE 5.19 Aerial survey coverage of the extensive and intensive grids, 18 September 1996. Fog and/or snow obscured the northern portions of many extensive lines. Fourteen bowheads were sighted during full array (F) and post-seismic (PS) periods. (The location of a single incidental sighting from 17 September is also plotted here.) The area where the source vessel was shooting full array seismic on both 17 and 18 September is shaded.

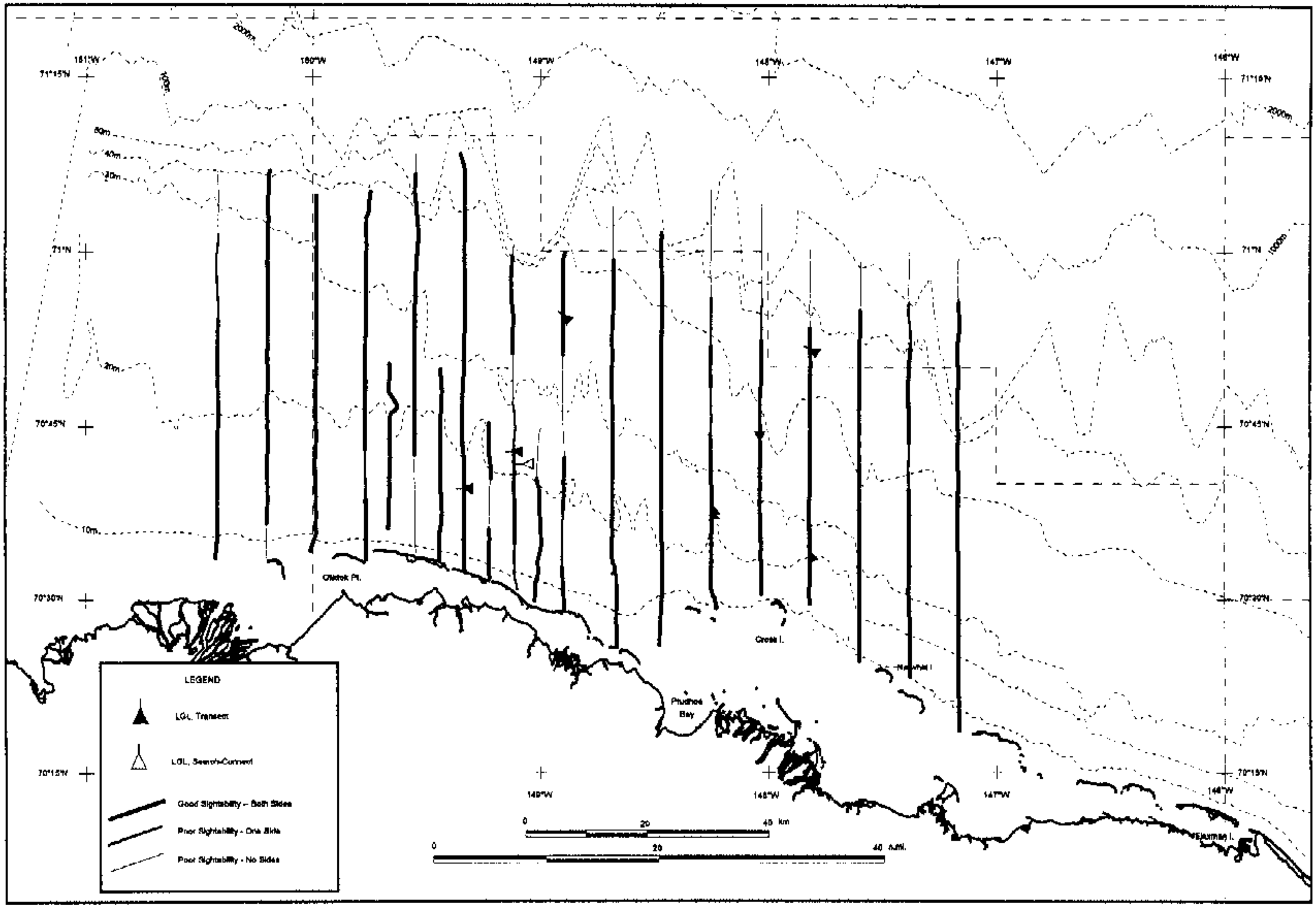

FIGURE 5.20. Aerial survey coverage of the extensive and intensive grids, 19 September 1996. The northern ends and some other portions of many transects had reduced visibility due to fog and/or snow. A total of 17 bowheads were sighted. Airgun operations had ended for the season on 18 September.

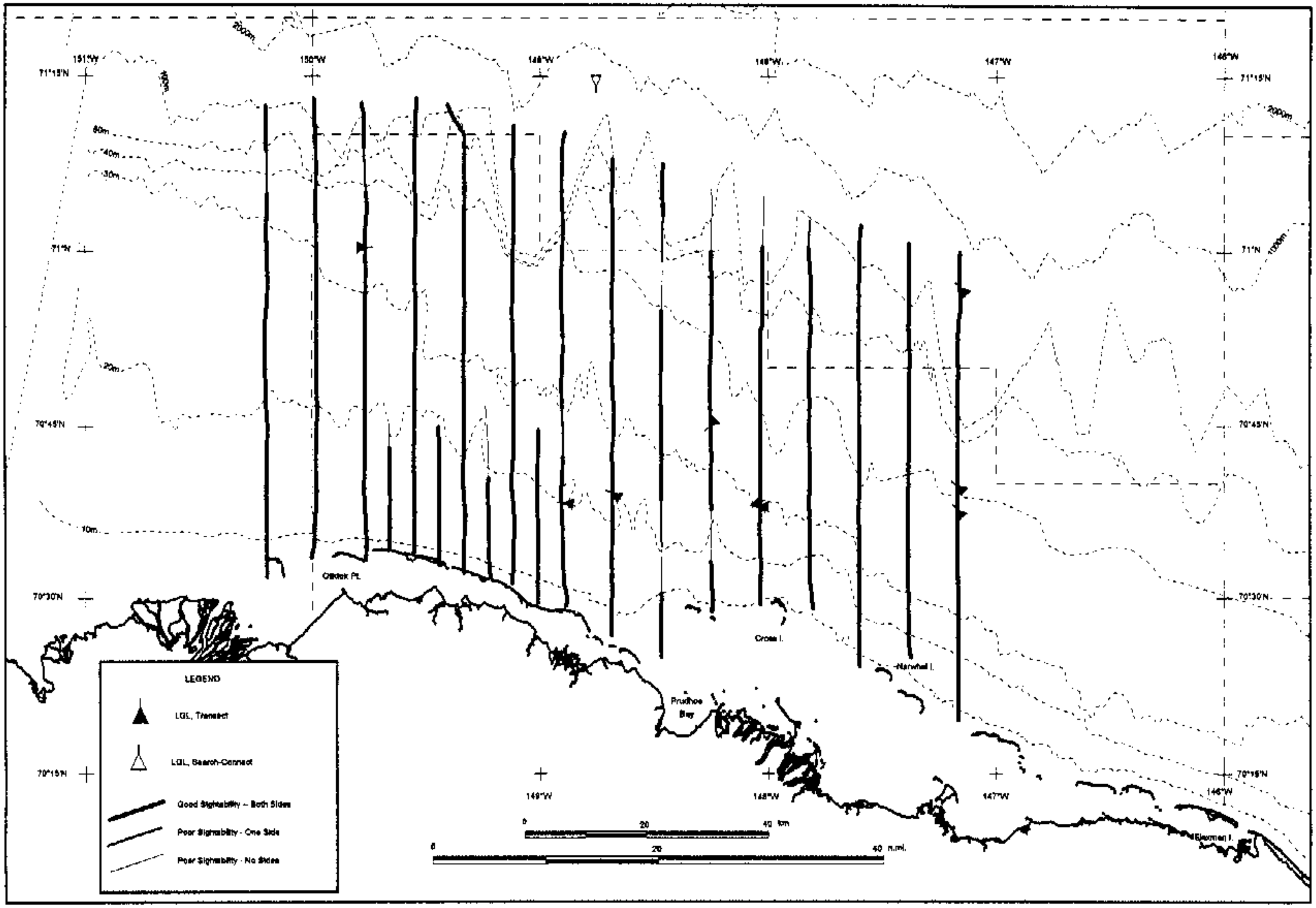

FIGURE 5.21. Aerial survey coverage of the extensive and intensive grids, 20 September 1996. Twelve bowheads were sighted. Airgun operations had ended for the season on 18 September.

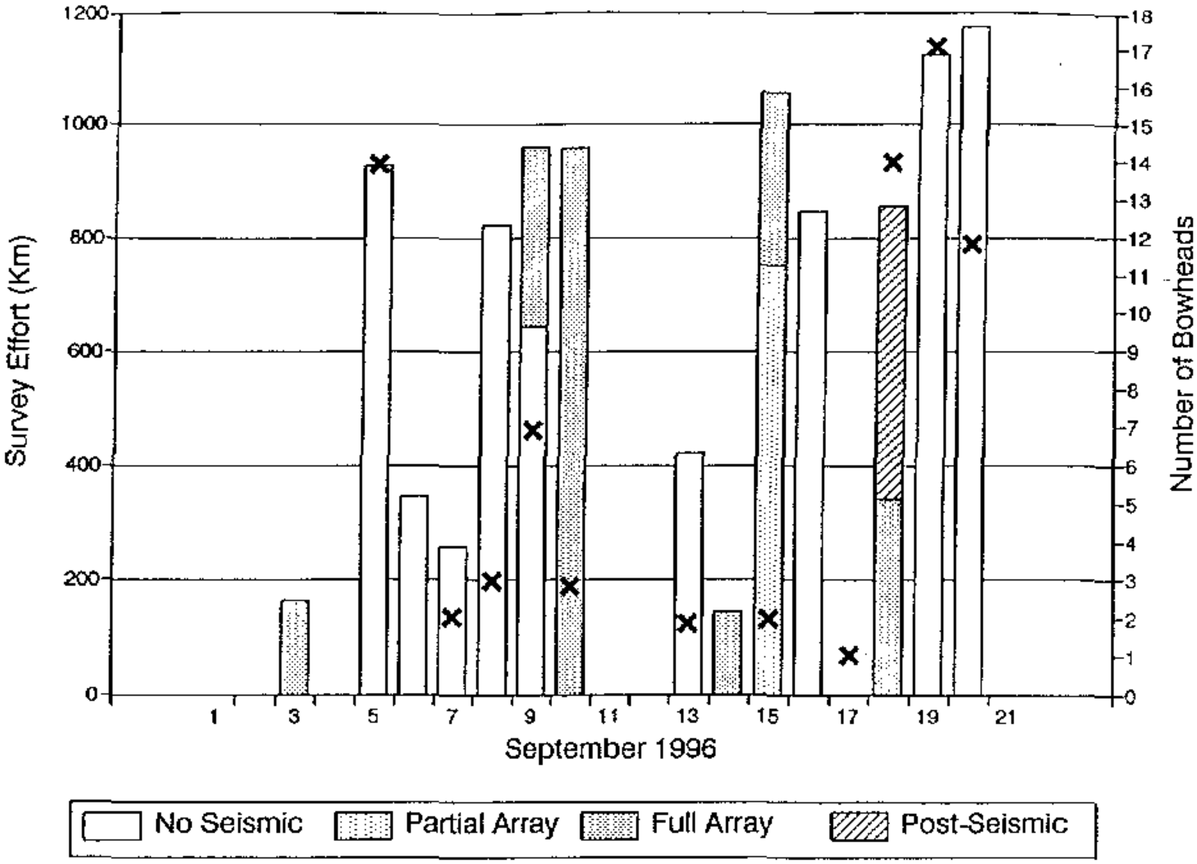

FIGURE 5.22. BPXA/LGL aerial survey coverage (bars) and the number of bowheads seen (X) in the Northstar region during each day of LGL aerial surveys, 1-21 September 1996. Shading of bars shows the amount of aerial survey coverage with various categories of seismic operations.

Overall, we saw an average of 0.59 bowheads per 100 km of surveys during all seismic conditions combined (n=17 sightings and 21 individuals), and 0.84 bowheads per 100 km of surveys without seismic (n=41 and 56). The sighting rates under partial, full, and post-seismic conditions were highly variable but based on low sample sizes: 0.25 bowheads/100 km with partial array seismic (n=2 sightings and 2 individuals), 0.31 with full array seismic (n=7 and 7), and 2.28 under post-seismic conditions (n=8 and 12).

5.3.2 Distribution

LGL Sightings.—All of LGL's bowhead sightings during the 1996 Northstar monitoring program are shown in Figure 5.23. Nearly all were found in relatively nearshore waters, mainly between the 15 m and 40 m depth contours, approximately 10 to 50 km from shore. This was true during periods both with seismic exploration (large symbols) and without seismic (small symbols). Only six sightings occurred seaward of the 40 m depth contour, with four being between the 40 and 100 m contours, and two being north of the 100 m contour (Fig. 5.23). Only one of the six sightings beyond the 40 m contour occurred during a full array, partial array or post-seismic period.

In the Northstar area proper (west and northwest of Cross Island) the sightings closest to shore were all recorded during periods without seismic activity (Fig. 5.23). It is possible that this was related to the occurrence of seismic work. However, there was more survey effort at times without than at times with seismic exploration (6567 vs. 3495 km of surveys, respectively). The distribution of sightings is examined further under "1996 Seismic vs. 1996 No Seismic" (p. 5-52), taking account of MMS as well as BPXA/LGL sightings.

The closest bowhead sightings to the operating airgun array were 24-27 km away (Table 5.3). If these whales were traveling WNW parallel to shore, they apparently were not at their closest points of approach when seen (Fig. 5.14, 5.17, 5.19). There were two additional bowhead sightings 21 km from the vessel 11.4 min after seismic ended (Table 5.3; Fig. 5.19). Those bowheads were presumably no more than 22 km from the seismic vessel at the end of the preceding full-array seismic period.

MMS Sightings.—The Minerals Management Service, Alaska OCS Region, conducted aerial surveys of marine mammals in the Beaufort Sea from 1 September through 9 October 1996. MMS's bowhead data have been provided by S.D. Treacy, MMS (pers. comm.).

On 13 days during the late summer and autumn of 1996, MMS conducted transect surveys in their survey block 1, block 2, and the eastern part of block 3 (east of 150°30'W). These areas include the Northstar region and the area where the BPXA/LGL surveys were conducted. MMS sighted bowheads within this area on seven dates in 1996. In total, MMS obtained 29 sightings of 39 individual bowhead whales in this area (Fig. 5.24).

None of the sightings by MMS within the 146°W-150°30'W area were during periods of active seismic exploration or during the 3.5 hour periods following termination of full array seismic operations. Twelve MMS sightings, including a total of 17 bowheads, were obtained

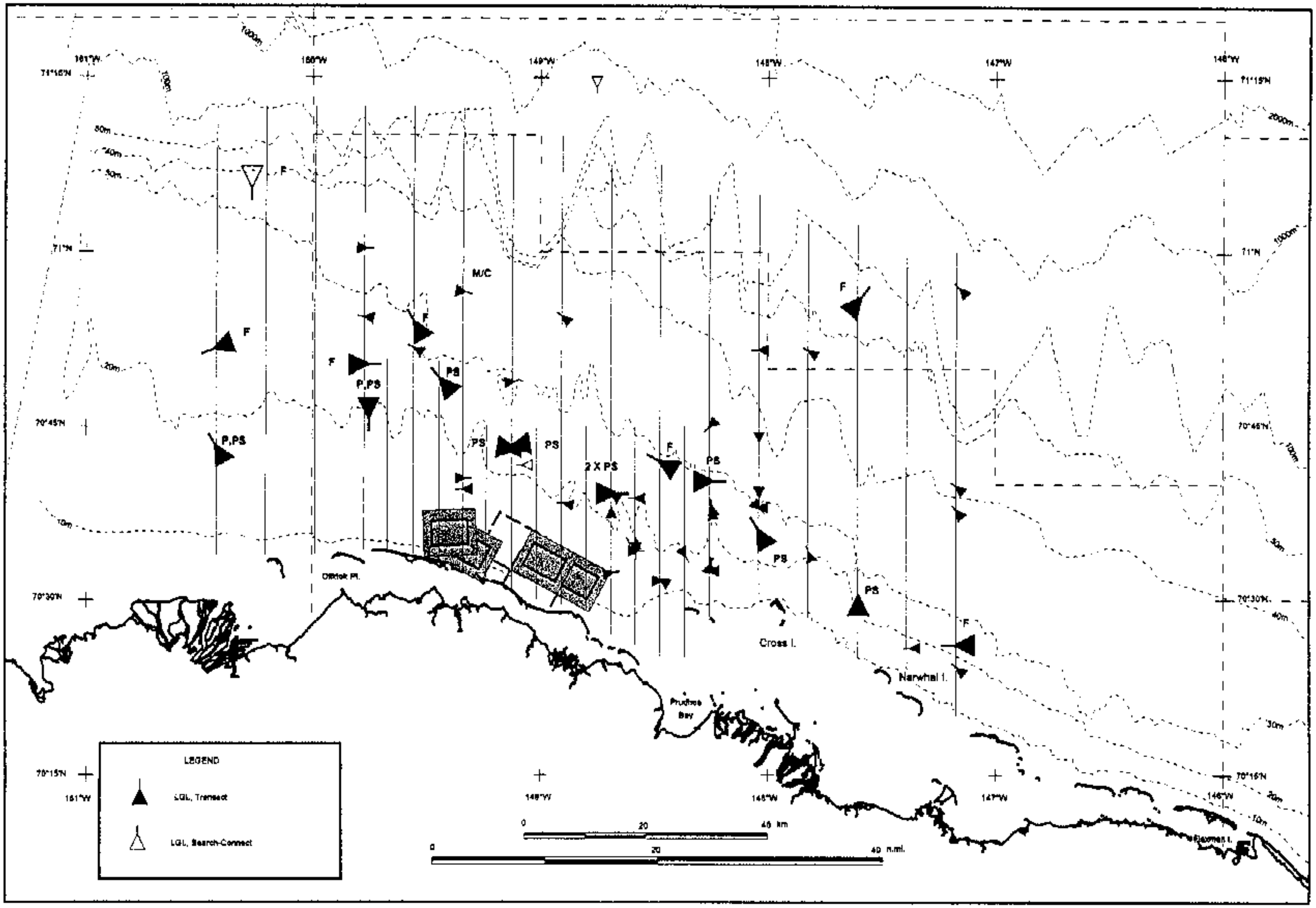

FIGURE 5.23. Bowhead whale sightings in the Northstar region of the central Alaskan Beaufort Sea during 1-21 September 1996 based on LGL aerial surveys. Nominal transect lines are shown, but only a portion of the grid was surveyed each day. All areas where the source vessel shot partial and full array seismic during September are indicated. Large symbols show sightings during "all seismic" periods. See daily sighting maps (Fig. 5.8-5.21) for the daily survey coverage and seismic vessel positions.

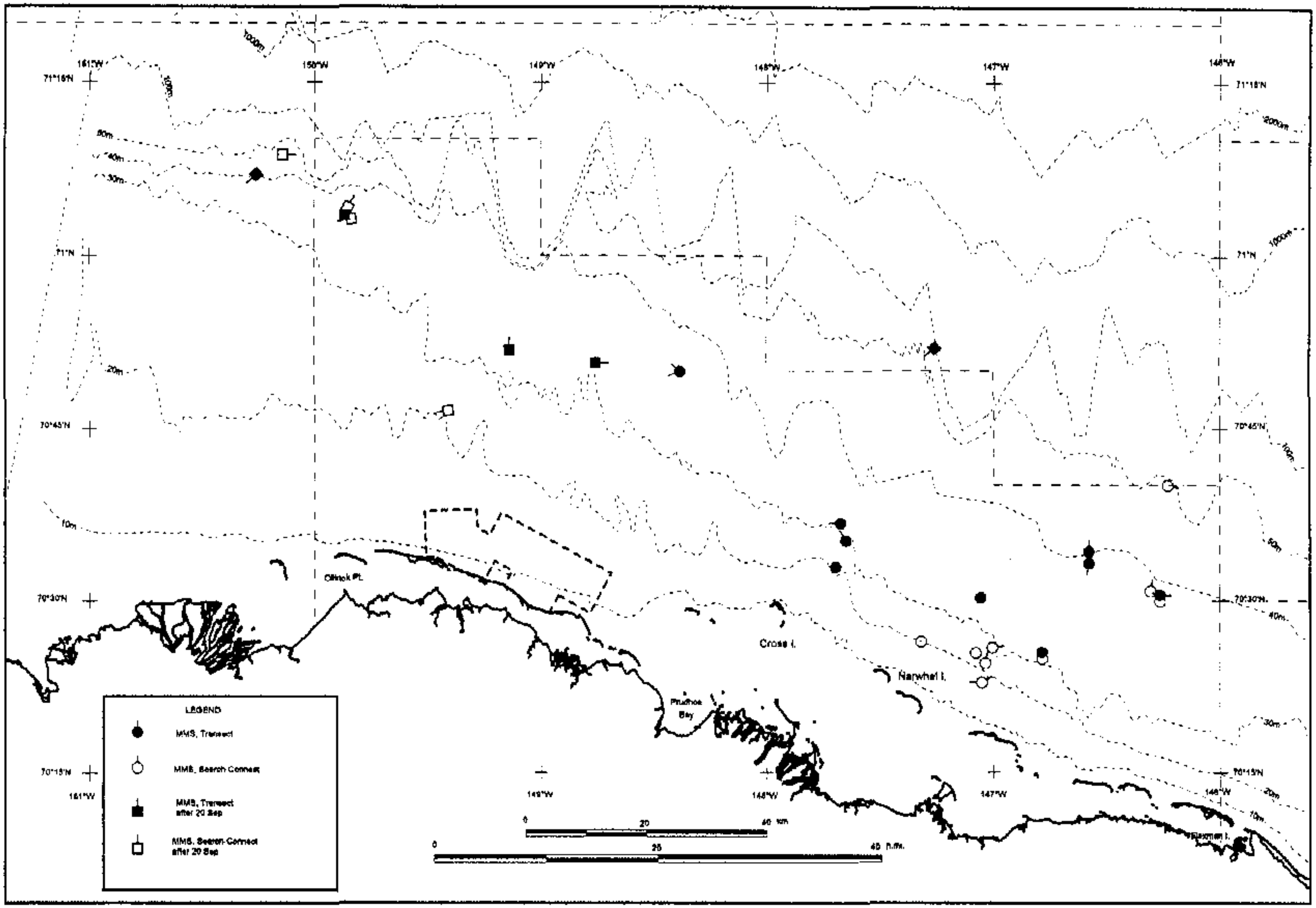

FIGURE 5.24. Bowhead whale sightings in the central Alaskan Beaufort Sea (146°-151°) during 1 September - 9 October 1996 based on MMS aerial surveys (data courtesy of S. Treacy, MMS). Sightings up to and after 20 September are distinguished. Seismic patches shot during 1-18 Sep. 1996 are outlined. All MMS sightings were during "no-seismic" periods.

prior to 18 September when seismic exploration ended. These sightings were on 2, 5 and 8 September at times 17.1-36.8 h after airgun operations had been interrupted. The remaining 17 sightings of 22 bowheads were on 19, 20, 27 and 30 September, 43 to 287 h after seismic activities were terminated for the season.

MMS's bowhead sightings in the eastern part of the study area (east of Cross Island and Northstar) tended to be closer to shore than were the MMS sightings farther west (Fig. 5.24).

Combined LGL and MMS Sightings.—The combined BPXA/LGL and MMS sightings of bowheads during late summer and autumn of 1996 are shown in Figure 5.25. In general, the MMS sightings, and especially the MMS "Transect" sightings, tended to be farther offshore than the LGL sightings. This was so even though most of MMS's transect surveys extended southward to the barrier islands (Fig. 5.3).

The combined BPXA/LGL and MMS 1996 sightings appear to be more widely dispersed, in terms of distance from shore, than the 1995 bowhead sightings (small symbols in Fig. 5.26). The 1996 sightings were recorded both farther from shore and closer to shore than 1995 sightings even though, in total, there were more sightings within the mapped area during 1995. For example, the number of sightings in "offshore waters", here defined as MMS block 2 or on the border between blocks 1 and 2, was 7 sightings in 1996 but only 1 in 1995 (Fig. 5.25 vs. 5.26). (Figure 5.2 shows MMS survey block numbers.) Likewise, the number of bowhead sightings shoreward of the 20 m contour was about 19 in 1996 compared to only 5 in 1995. Despite the broader distribution in 1996, the main clusters of sightings in the two years were along fairly similar corridors, with sightings concentrated in waters 20-50 km from shore in 1995 and 10 to 50 km from shore in 1996.

The few (nine) 1994 sightings were very broadly distributed across a wide range of depth and distance-from-shore categories (large symbols in Fig. 5.26). High proportions of these were in the offshore (3 of 9) and nearshore (4 of 9) regions described above. Thus, only two of nine 1994 sightings occurred in the medium depth waters where the great majority of both 1996 and 1995 sightings occurred.

Bowhead sightings in the Northstar region during 1979-93, years with widely varying ice and industrial activity conditions, were concentrated in water depths ranging from 10 to 100 m (Fig. 5.27). In 1979-93 there were a few sightings on or inshore of the 10 m contour, including a few within the area where seismic surveys were conducted in September 1996.

5.3.3 Distance from Shore

In this section, bowheads seen in the Northstar area in 1996 and various earlier years are plotted as a function of distance from shore, as described in §5.2, "Methods". A large number of graphs, comparisons, and statistical tests are included. Readers wishing to review just a summary of this material can skip to "Summary of Distances from Shore" on p. 5-68.

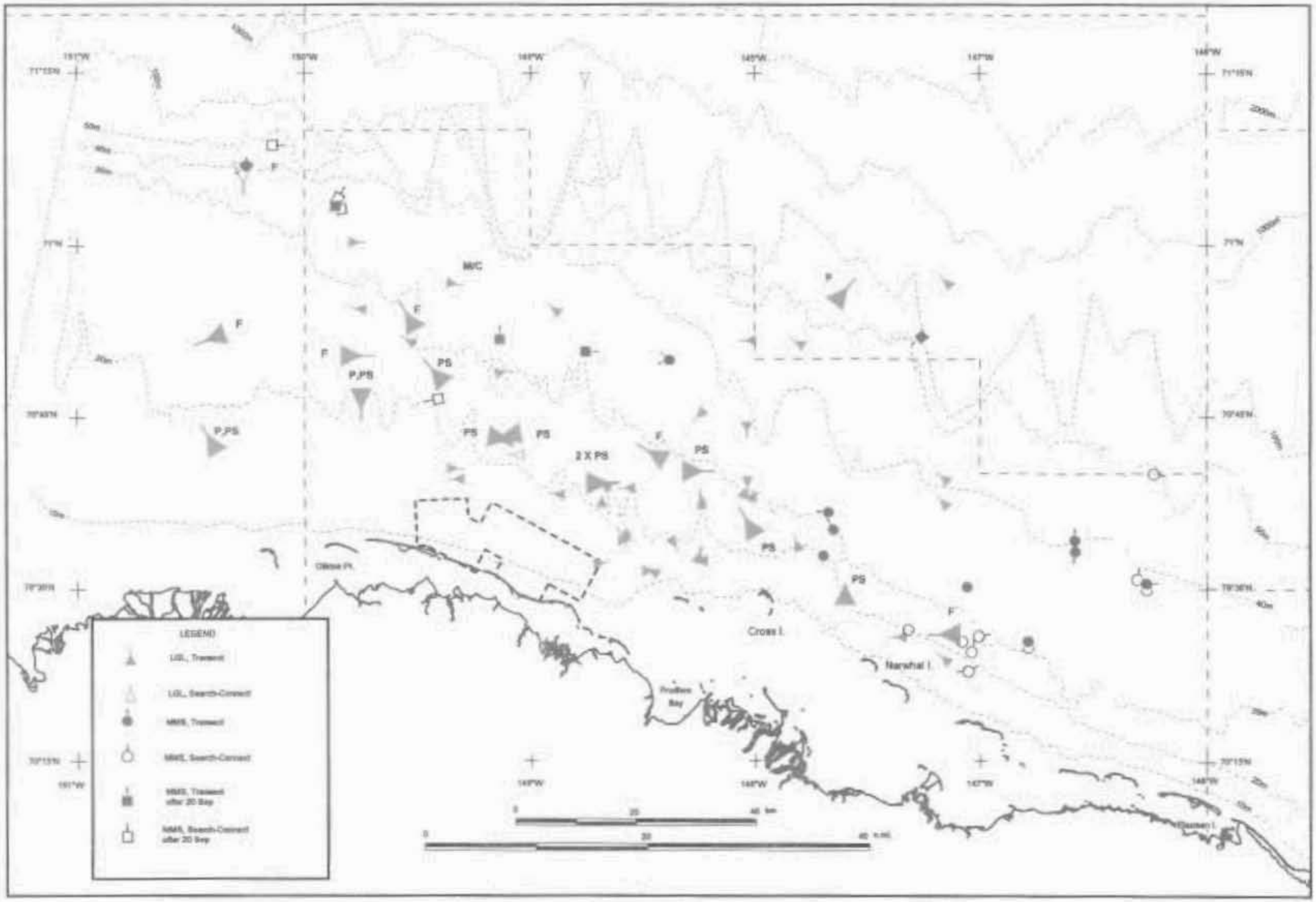

FIGURE 5.25. Bowhead whale sightings in the central Alaskan Beaufort Sea (146°-151°) during 1 September - 9 October 1996 based on LGL and MMS aerial surveys. MMS sightings up to and after 20 September are distinguished. All LGL sightings were in the 5-20 September period. Seismic patches shot during 1-18 Sep. 1996 are outlined. Large symbols show sightings during "all seismic" periods.

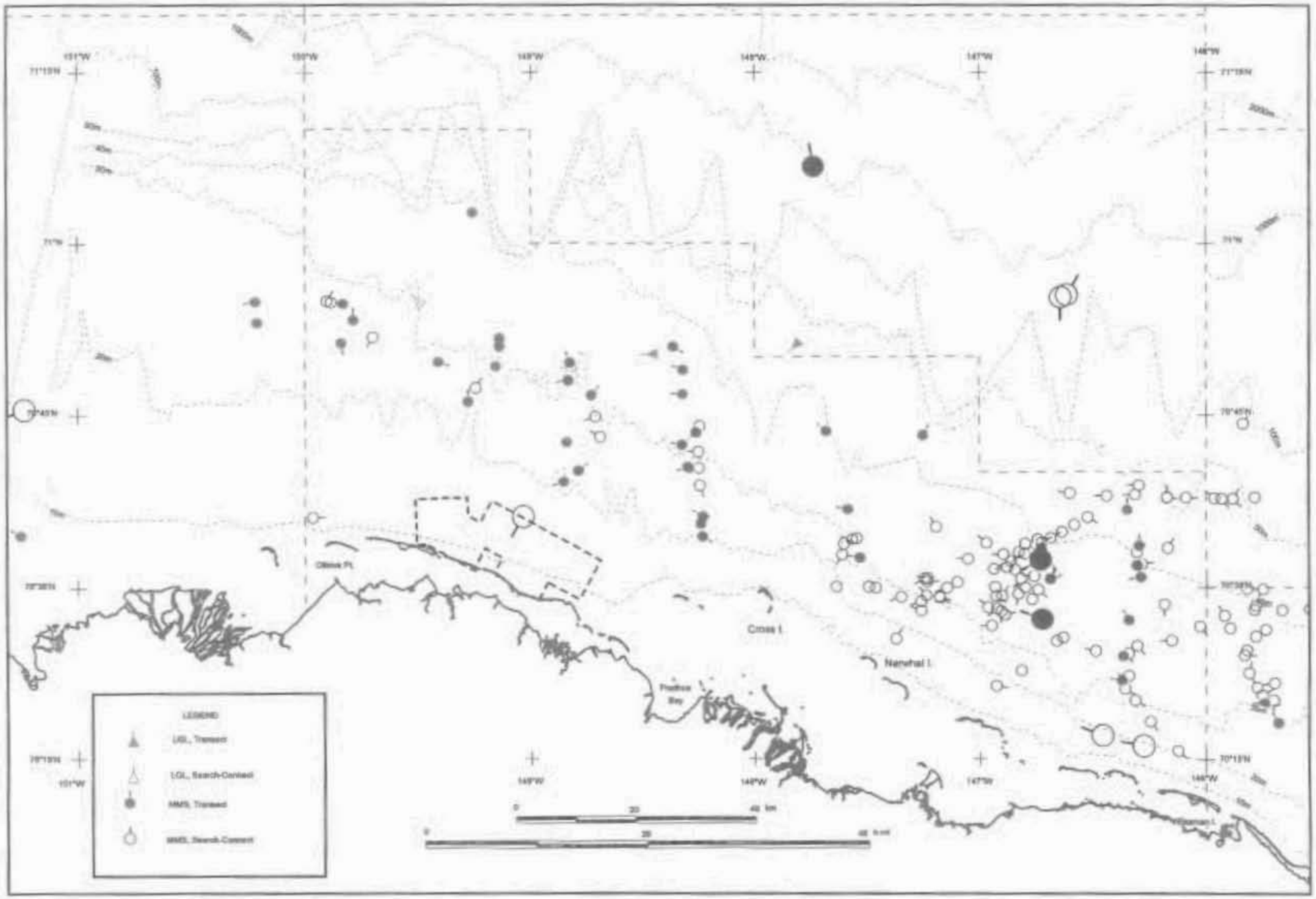

FIGURE 5.26. Bowhead whale sightings in the central Alaskan Beaufort Sea (146°-151°) during late summer and autumn of 1994-95 based on MMS and LGL aerial surveys. The few 1994 sightings are distinguished by large symbols. Seismic patches shot during 1-18 Sep. 1996 are outlined for cross-reference.

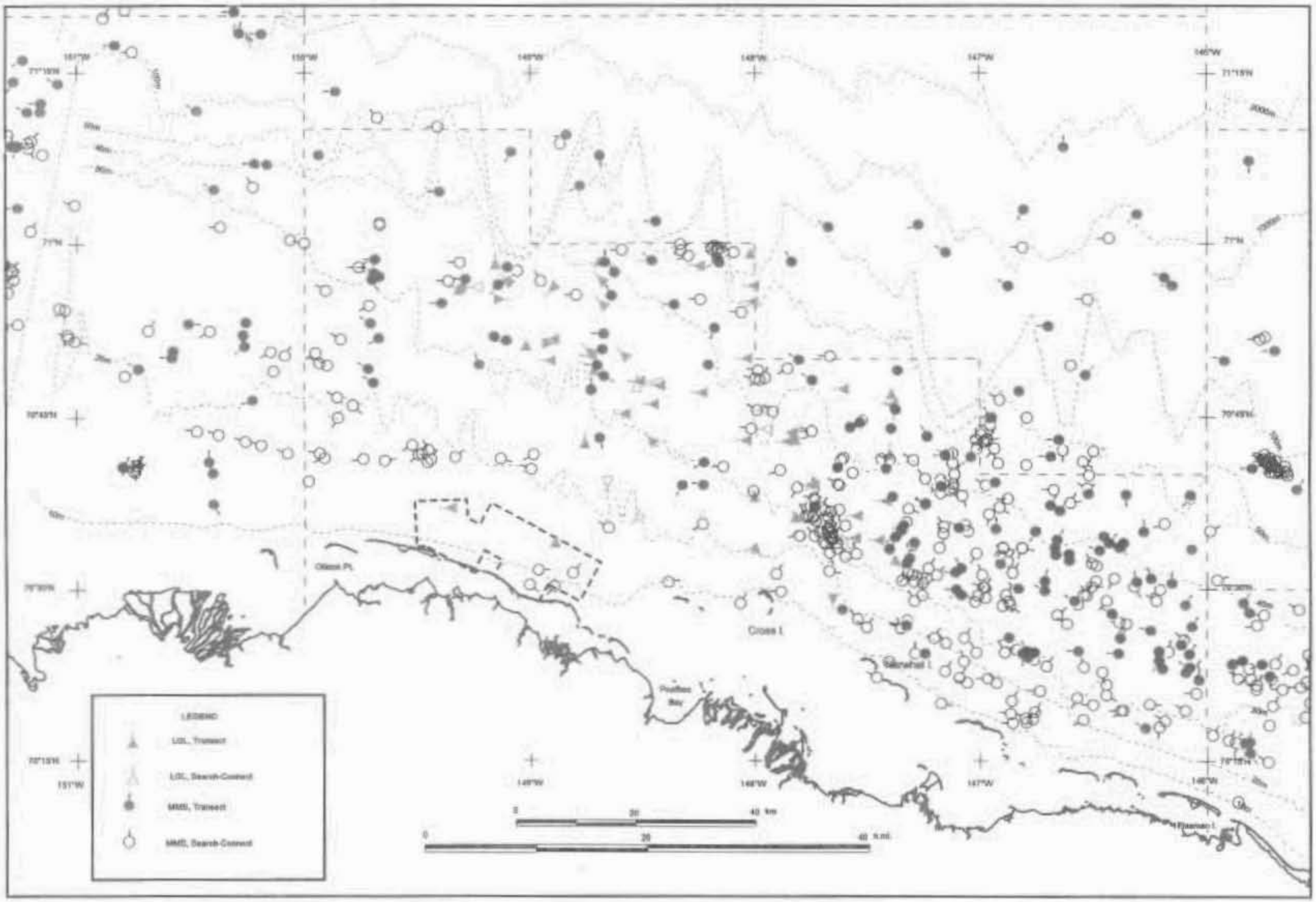

FIGURE 5.27. Bowhead whale sightings in the central Alaskan Beaufort Sea (146°-151°) during late summer and autumn of 1979-93 based on MMS and LGL aerial surveys. Seismic patches shot during 1-18 Sep. 1996 are outlined for cross-reference.

In previous related analyses for 1979-95 (e.g., LGL and Greeneridge 1996), we excluded bowhead sightings and survey effort during high sea states or periods of poor visibility, when the probability of detecting marine mammals is much reduced. This is a standard practice in analyses of aerial survey data, and results in more consistent and reliable data. In the 1979-95 period, this "correction" process excluded 8.8% (8396 of 94,940 km) of the "transect" survey effort and 7.7% (16 of 209) of the bowhead sightings.

In 1996, the "correction" process excluded 18.5% (2398 of 12,971 km) of the combined LGL and MMS survey effort within the 147°W-150°30'W area, and 23% (15 of 65) of the "Transect" sightings of bowheads in that area. We are reluctant to exclude such a large number of sightings from the 1996 dataset. Although the 1996 sighting data are substantial when compared to other individual years, the 1996 dataset—either with or without the "poor visibility" sightings—is small for the types of analyses we are conducting. In most cases, we have shown the results in two ways, both including and excluding the "poor sightability" survey coverage and sightings. As shown below, similar results were obtained with either approach.

The distance-from-shore data were originally graphed, analyzed, and statistically tested by 5-km distance-from-shore bands. However, when the small dataset was subdivided into so many narrow bands, the numbers of sightings in adjacent 5-km bands were often very irregular. Therefore, we have graphed the distance-from-shore data by 10-km bands, resulting in smoother curves that are easier to interpret and probably more reliable. The Kolmogorov-Smirnov (K-S) tests reported below are based on data summarized by 5-km bands, for the reason described in §5.2, "Methods". However, K-S tests of the data grouped by 10-km bands were also done. Although K-S tests based on 10-km and 5-km bands often gave slightly different "D" values, all but one comparison resulted in the same conclusion regarding the significance of observed differences in distance-from-shore distributions. The one exception was a minor difference in results for 1996 vs. 1994-95 (see below).

***1996 Seismic vs. 1996 No Seismic*.**—If westbound bowheads were displaced offshore by the seismic operation, distances from shore would be expected to be greater at times with than at times without seismic. The numbers of bowheads seen during late summer/autumn 1996 are plotted as a function of distance from shore in Figure 5.28, including periods with poor sightability. Sightings during "no-seismic" and "seismic" conditions are distinguished. The "seismic" category includes full array seismic, partial array seismic, and post-seismic (0-3.5 h after termination of full array airgun operations).

All Bowheads: The modal distance-from-shore was farther offshore during "seismic" periods than during "no-seismic" periods, but the difference was not statistically significant. During periods that may have been influenced by seismic noise, the peak number of sightings was in the 20-30 km from shore band (Fig. 5.28A). During no-seismic periods, the peak number of sightings was in the 10-20 km from shore band with a slightly lower number in the 20-30 km band (16 and 13 sightings, respectively). During no-seismic periods, relatively high numbers of sightings also occurred in the 30-40 and 40-50 km bands. Thus, the distance-from-shore distribution was broader without seismic than with seismic. Sightings

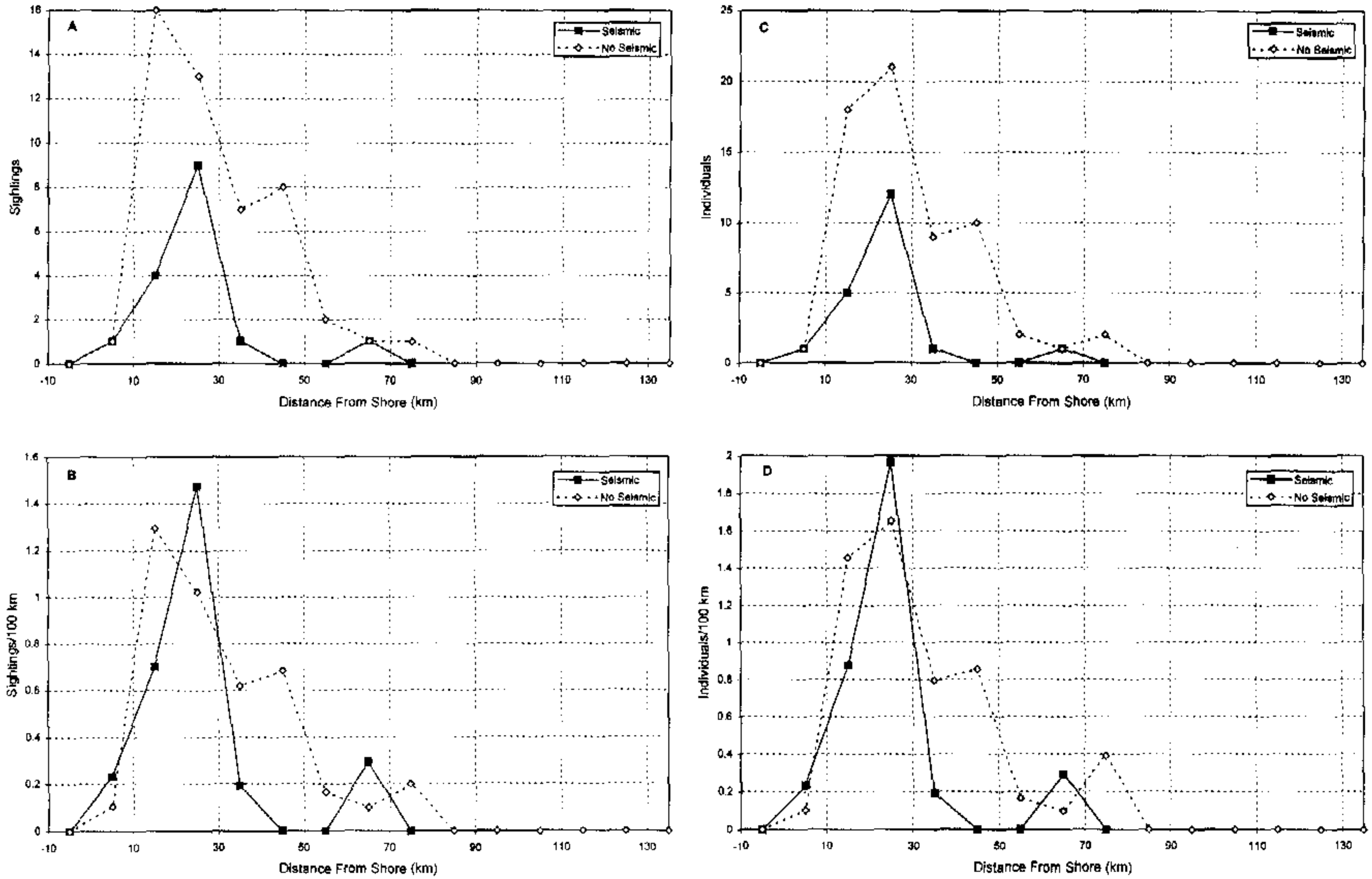

FIGURE 5.28. Distributions of bowheads vs. distance from shore during "all seismic" periods vs. periods with no seismic, late summer/autumn 1996, including periods of poor sightability. Based on LGL and MMS "Transect" aerial surveys in the Northstar region of the central Alaskan Beaufort Sea (147°-150°30'). ***(A)*** Sightings, ***(B)*** sightings per 100 km of surveys, ***(C)*** individuals, and ***(D)*** individuals per 100 km of surveys. See Fig. 5.29A for survey effort vs. distance from shore.

tended to extend both closer to shore and farther offshore in the absence of seismic, but the modal distance from shore was ~10 km farther offshore with seismic.

The difference in these two distributions was not statistically significant (Kolmogorov-Smirnov D=-0.284, two-tailed P>0.10).[4] The negative D value indicates that, in the distance from shore band with the largest observed difference in cumulative distribution, the cumulative no-seismic distribution was *farther* offshore than the cumulative "seismic" distribution. This resulted from the larger proportion of sightings 30-50 km offshore without seismic.

The same pattern persisted when we considered the number of individual bowheads seen per 100 km (Fig. 5.28C). The K-S test cannot be applied to the "individuals" data because individuals in a single group are not statistically independent.

All Bowheads per Unit Effort: In Fig. 5.28B,D the distance-from-shore data have been converted to sightings or individuals seen per 100 kilometers of aerial surveys. This was done using the data on survey effort by 5-km distance-from-shore band (Fig. 5.29A). When adjusted for the lesser amount of survey coverage during seismic periods, the sighting rates in the modal 10-km distance-from-shore categories were higher during seismic periods than no-seismic periods (1.5 vs. 1.3 sightings/100 km, respectively; Fig. 5.28B).

The modal distance-from-shore category during times potentially affected by seismic was 10 km farther offshore than that for bowheads sighted during periods with no seismic (20-30 km vs. 10-20 km, respectively). Despite this, the cumulative distribution of sightings/100 km was again centered *farther* offshore without seismic than with seismic, given the higher sighting rates 30-50 km offshore with no seismic than with seismic. The differences between the two distributions remained statistically non-significant (D=-0.282, two-tailed P>0.10).[5]

The individuals/100 km distributions with and without seismic were more similar than the sightings/100 km distributions (Fig. 5.28D vs. 5.28B). The 10-km band with the highest individuals/100 km figure was the 20-30 km band during both seismic and no-seismic periods.

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[4] For a Kolmogorov-Smirnov D of 0.284 to be significant with 2-sided $\alpha = 0.05$, sample sizes would have to increase by a factor of 1.9, i.e. from the present 49 sightings without seismic and 16 with seismic to 93 without and 30 with seismic. Alternatively, if sample sizes under the two conditions were equal, n = 46 + 46 would be sufficient for D=0.284 to be significant at α=0.05.

The 0.284 D_{max} value was in the opposite direction to that predicted (whales farther offshore without seismic). D_{max} for the predicted effect (whales farther offshore with seismic) was 0.121. A large increase in sample size, to about n = 200 + 200, would be needed before such a small D_{max} would become significant based on a 1-sided $\alpha = 0.05$.

[5] For D = 0.282 to be significant with 2-sided $\alpha = 0.05$, sample sizes would have to increase by a factor of 1.92, i.e. from 49 + 16 to 94 + 31, or to equal samples of 47 + 47. D_{max} for the predicted effect (whales farther offshore with seismic) was 0.100. A very large increase in sample size, to about n = 295 + 295, would be needed for such a small D_{max} to be significant based on 1-sided $\alpha = 0.05$.

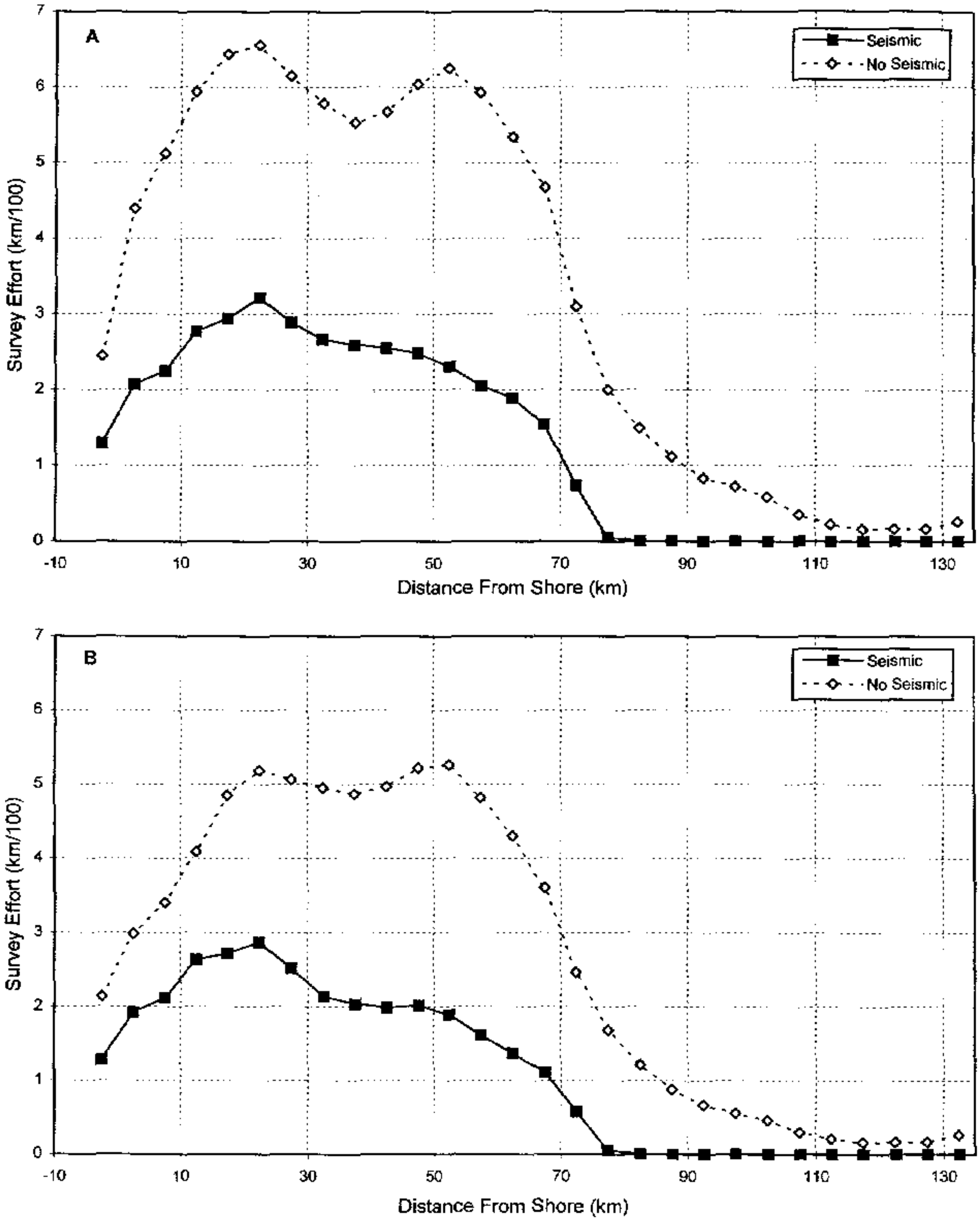


FIGURE 5.29. Aerial survey effort at various distances from shore during "all seismic" periods vs. periods with no seismic, late summer/autumn 1996; periods of poor sightability *(A)* included and *(B)* excluded. Based on LGL and MMS "Transect" aerial surveys in the Northstar region of the central Alaskan Beaufort Sea (147°-150°30').

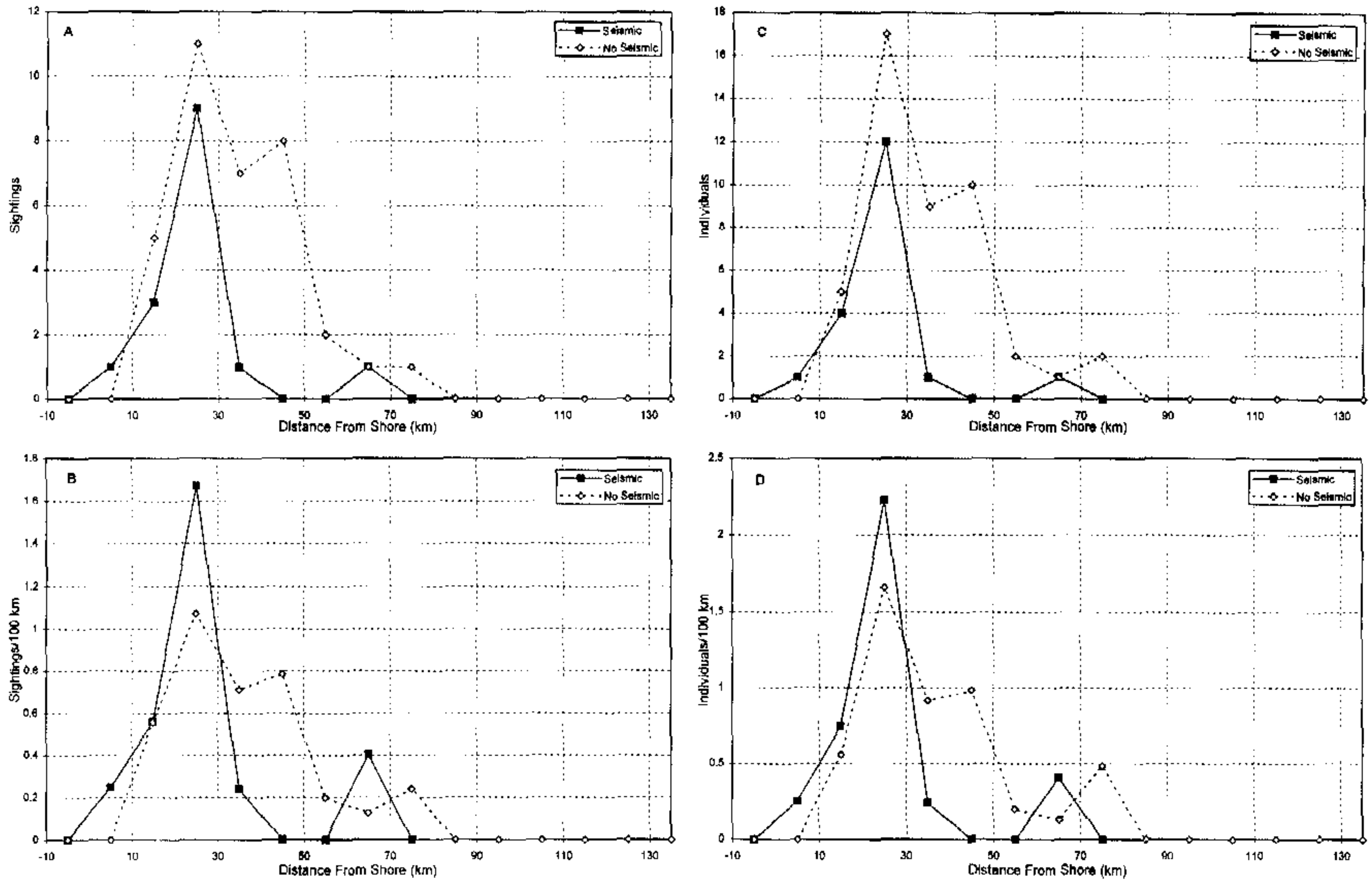


FIGURE 5.30. Distributions of bowheads vs. distance from shore during "all seismic" periods vs. periods with no seismic, late summer/autumn 1996, excluding periods of poor sightability. See Fig. 5.29B for survey effort vs. distance from shore. Otherwise as in Fig. 5.28.

Poor Sightability Data Excluded: Figure 5.30 shows the corresponding results excluding sightings and effort under poor visibility and high sea state (mainly on 5 Sep 1996; see Table 5.3). Figure 5.29B shows the associated survey effort. Excluding sightings under poor survey conditions, the modal distance from shore is in the 20-30 km band under both "seismic" and "no-seismic" conditions. Sightings tended to extend farther from shore under no-seismic than seismic conditions (Fig. 5.30). For sightings, this difference between seismic and no-seismic conditions was marginally significant (D=-0.419, 0.1>P>0.05, two-tailed). However, sightings/100 km during seismic vs. no-seismic periods were similar (D=-0.376, two-tailed P>0.10).

The sighting distributions plotted in Fig. 5.28A-D, including poor sightability data, are based on only 16 "seismic" and 49 "no-seismic" sightings during the BPXA/LGL and MMS surveys combined. The distributions plotted in 5.30A-D, excluding the poor sightability data, are based on only 15 "seismic" and 35 "no-seismic" sightings.

This dataset is too small to justify firm conclusions about the occurrence or extent of displacement of the migration corridor when bowhead whales are migrating past a seismic operation in nearshore waters. The tendency for the highest proportion of the bowhead sightings to occur 20-30 km from shore with seismic vs. 10-20 km from shore during no-seismic periods (Fig. 5.28) is consistent with the possibility of seaward displacement of sightings during seismic. This tendency was not evident when data from poor sightability conditions were omitted (Fig. 5.30). Also, one test suggested a marginally significant tendency for sightings to occur *farther* offshore during no-seismic periods than during seismic periods. In any case, the main migration corridor during periods potentially influenced by seismic (including periods 0-3.5 h after seismic ended) was apparently within 20-30 km from shore, and thus within ~10-20 km from the northern edge of the area of seismic exploration (Fig. 5.30).

***1996 East vs. 1996 West*.**—Another approach to examining whether seismic exploration affected bowhead distribution in the Northstar area in 1996 is to compare the distance-from-shore distributions of bowheads in eastern and western portions of the study area. The distributions of bowheads east of 148°10'W (most of which would be approaching Northstar) and west of 148°10'W (passing or past Northstar) are compared in Figure 5.31, using all data, including those from periods with poor sighting conditions. The 20 sightings in the eastern portion of the study area tended to be farther from shore than the 40 sightings in the western portion of study area, contrary to the possible expectation that seismic exploration near Northstar might push bowheads farther offshore. Peak numbers of sightings in the eastern and western portions of the study area occurred in the 20-30 and 10-20 km bands, respectively (Fig. 5.31A). However, the sighting distributions in the two regions were not significantly different (K-S test, D=-0.325, two-tailed P>0.10). For individual bowheads, the 20-30 km from shore band was the modal band in both the eastern and western areas, but again with some tendency for more individuals to be seen close to shore in the west (Fig. 5.31B).

When corrected for survey effort (Fig. 5.32A) the sightings/100 km data again indicated a tendency for bowhead sightings to be farther offshore in the east than in the west. However, the difference was not statistically significant (D=-0.232, two-tailed P>0.10).

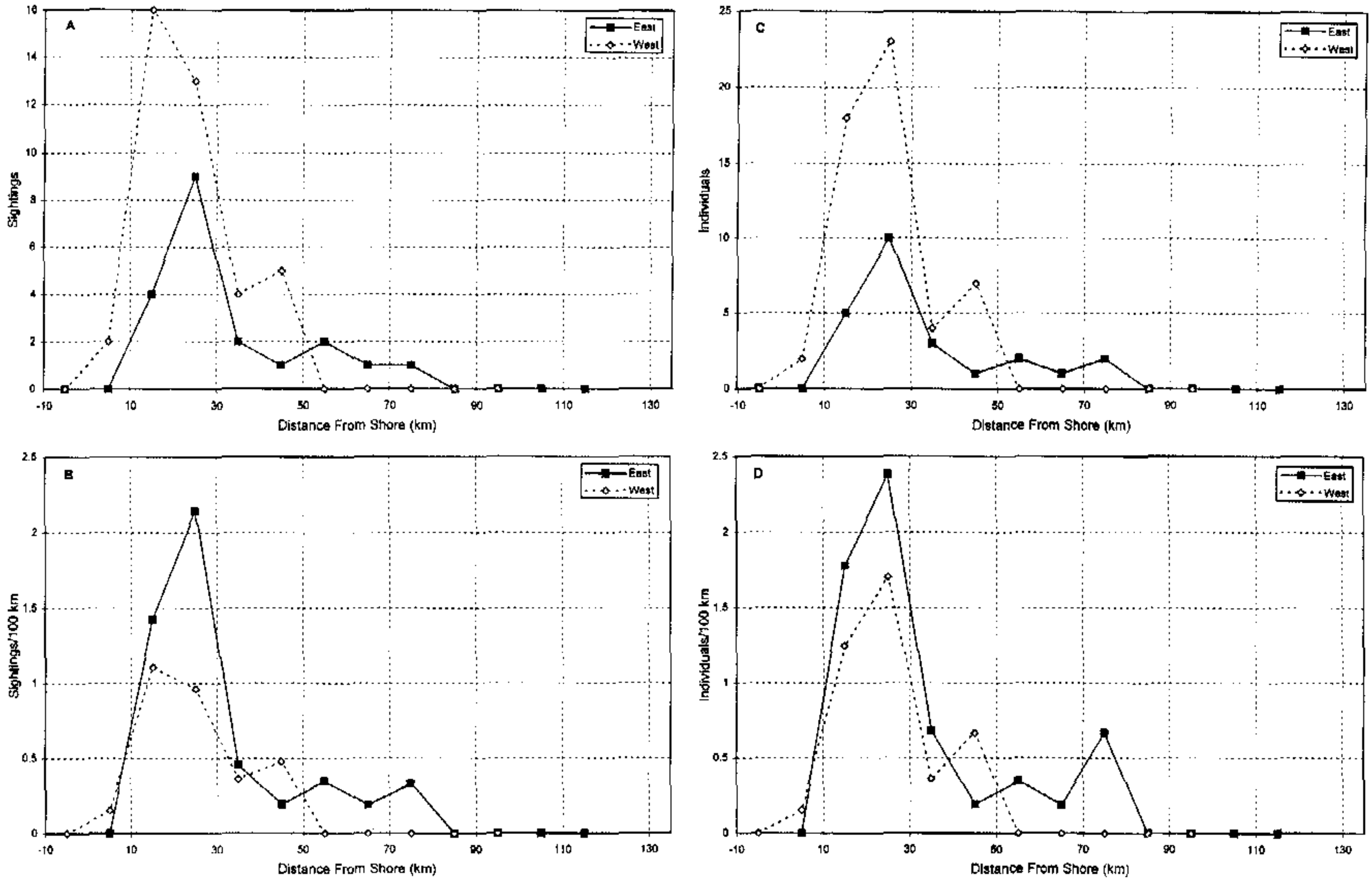


FIGURE 5.31. Distributions of bowheads vs. distance from shore in areas east and west of 148°10'W, late summer/autumn 1996, including periods of poor sightability. See Fig. 5.32A for survey effort vs. distance from shore. Otherwise as in Fig. 5.28.

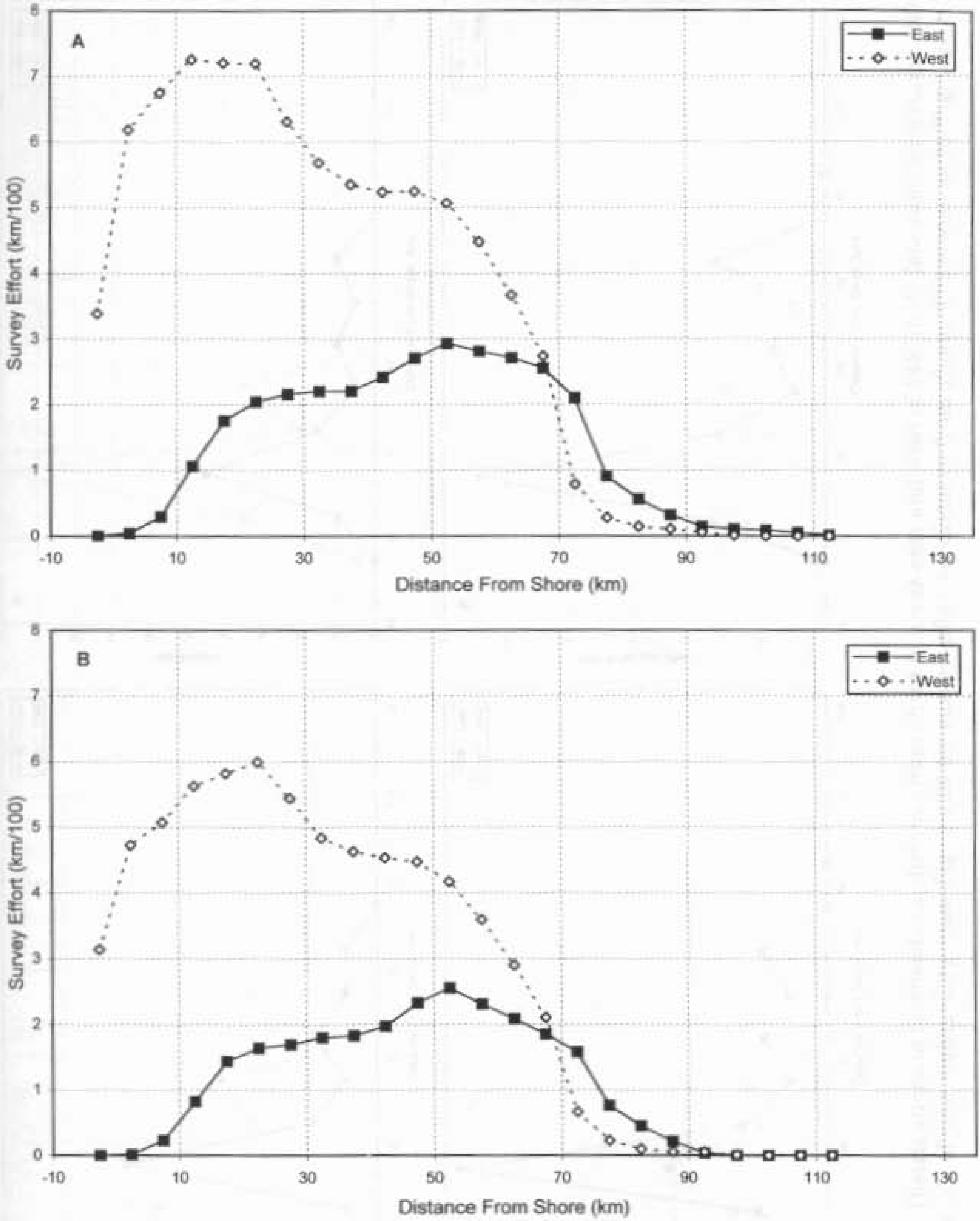


FIGURE 5.32. Aerial survey effort at various distances from shore in areas east and west of 148°10'W, late summer/autumn 1996; periods of poor sightability *(A)* included and *(B)* excluded. Based on LGL and MMS "Transect" aerial surveys in the Northstar region of the central Alaskan Beaufort Sea (147°-150°30').

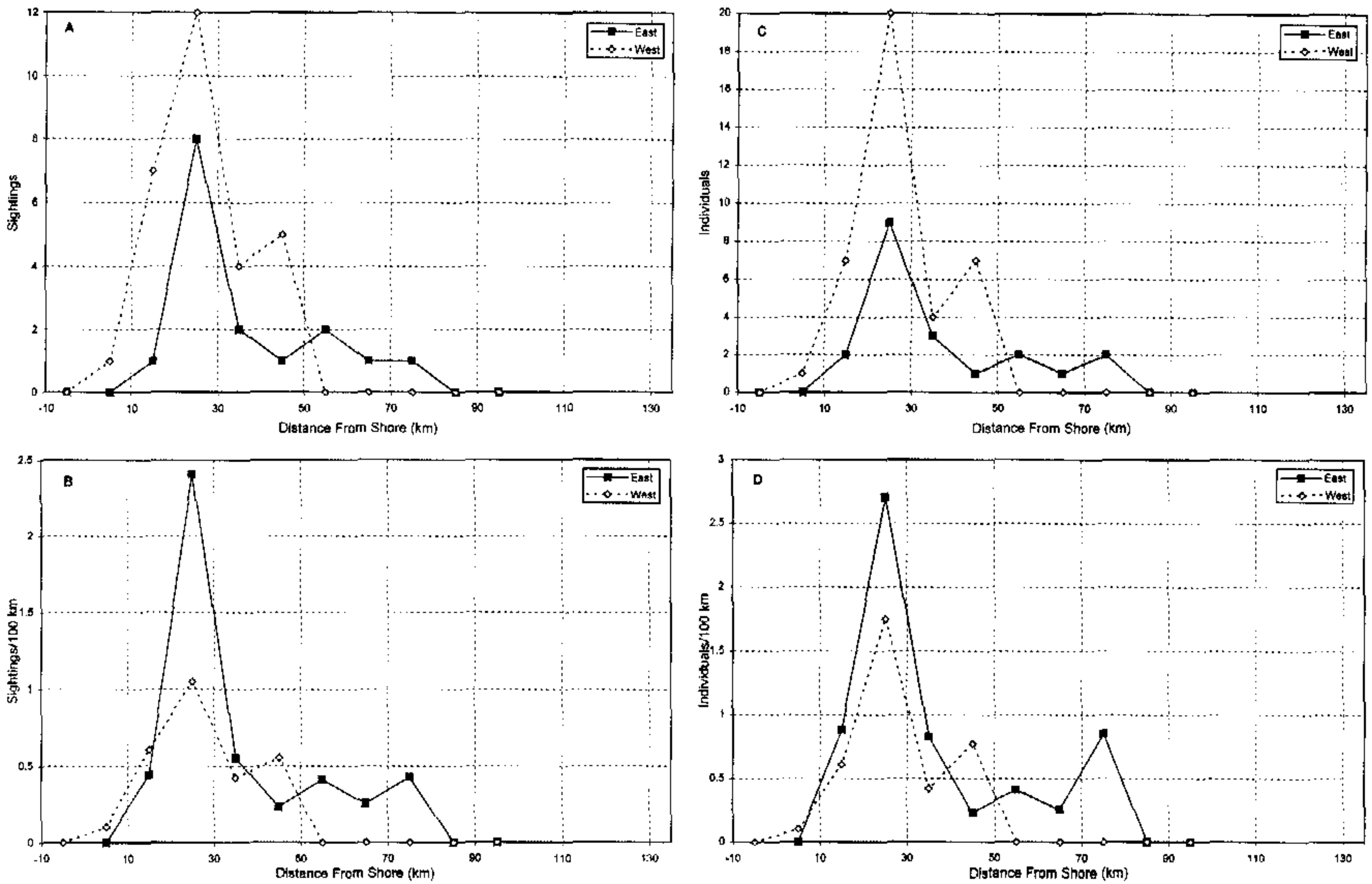


FIGURE 5.33. Distributions of bowheads vs. distance from shore in areas east and west of 148°10'W, late summer/autumn 1996, excluding periods of poor sightability. See Fig. 5.32B for survey effort vs. distance from shore. Otherwise as in Fig. 5.28.

The same E-W comparisons were conducted with the smaller dataset excluding sightings under poor visibility/high sea state conditions. This reduced dataset included 16 sightings in the east and 29 in the west (Fig. 5.33). Figure 5.32B shows the associated survey coverage. In both areas, the modal distance from shore was 20-30 km for sightings, individuals, sightings/100 km, and individuals/100 km (Fig. 5.33A-D). Sightings and individuals again tended to extend farther offshore in the eastern than in the western area. However, this tendency was not statistically significant for either sightings or sightings/100 km (D= -0.302 and -0.227, respectively; two-tailed P>0.10 in each case).

Whether or not bowheads really tend to be farther offshore in the eastern than in the western area, there certainly was no tendency for sightings to be farther offshore in the western area near and just west of Northstar.

The above east-west comparisons include all 1996 sightings, whether or not seismic operations were underway at the time of each sighting. Logically, we should also compare the distances from shore in the eastern and western areas at times with seismic. There were nine bowhead sightings during seismic plus eight sightings <3.5 h after seismic ended. Of these 17 sightings, 13 were in the west and only four in the east (Fig. 5.23). The sample sizes, especially in the east, were too low for meaningful comparison.

1996 vs. 1994-95.—If westbound bowheads were displaced offshore by the seismic operation, distances from shore would be expected to be greater in 1996 than in years with similar ice cover but little offshore industrial activity, e.g. 1994-95. Figure 5.34 compares the data from 1996 vs. 1994-95, including sightings and survey effort during periods with poor sightability. There were 65 "Transect" sightings in 1996 and 44 in 1994-95 (mainly from 1995).

As noted in §5.2, 1996 was classed as a light ice year by the Naval Ice Center. In the Northstar area, 1996 perhaps should be considered a moderate ice year. Given this, and the need for as large a "baseline" sample as possible, we considered adding the data from any prior years with moderate ice but little industrial activity to the 1994-95 baseline dataset. However, there were no years with moderate ice but little industrial activity during the 1979-93 period for which aerial survey data are available.

Bowheads tended to be seen closer to shore in 1996 than in 1994-95 (Fig. 5.34). Peak numbers of sightings and of individuals were in the 20-30 km from shore band in both 1996 and 1994-95. However, in 1996 (unlike 1994-95) there were almost as many sightings and individuals in the 10-20 km band (Fig. 5.34A,C). The distribution of sightings was significantly closer to shore in 1996 than in 1994-95 (K-S test, D=-0.293, two-tailed P<0.05). The associated survey effort is shown in Figure 5.35A. When reanalyzed based on sightings per unit effort (Fig 5.34B), bowhead distribution was again found to be concentrated significantly closer to shore in 1996 than in 1994-95 (D=-0.284, two-tailed P<0.05).

Within the smaller dataset that excluded the "poor sightability" data, there were 50 sightings in 1996 and 43 in 1994-95. With these data, the bowhead distribution again tended to be slightly closer to shore during 1996 than during 1994-95, but the tendency was weak

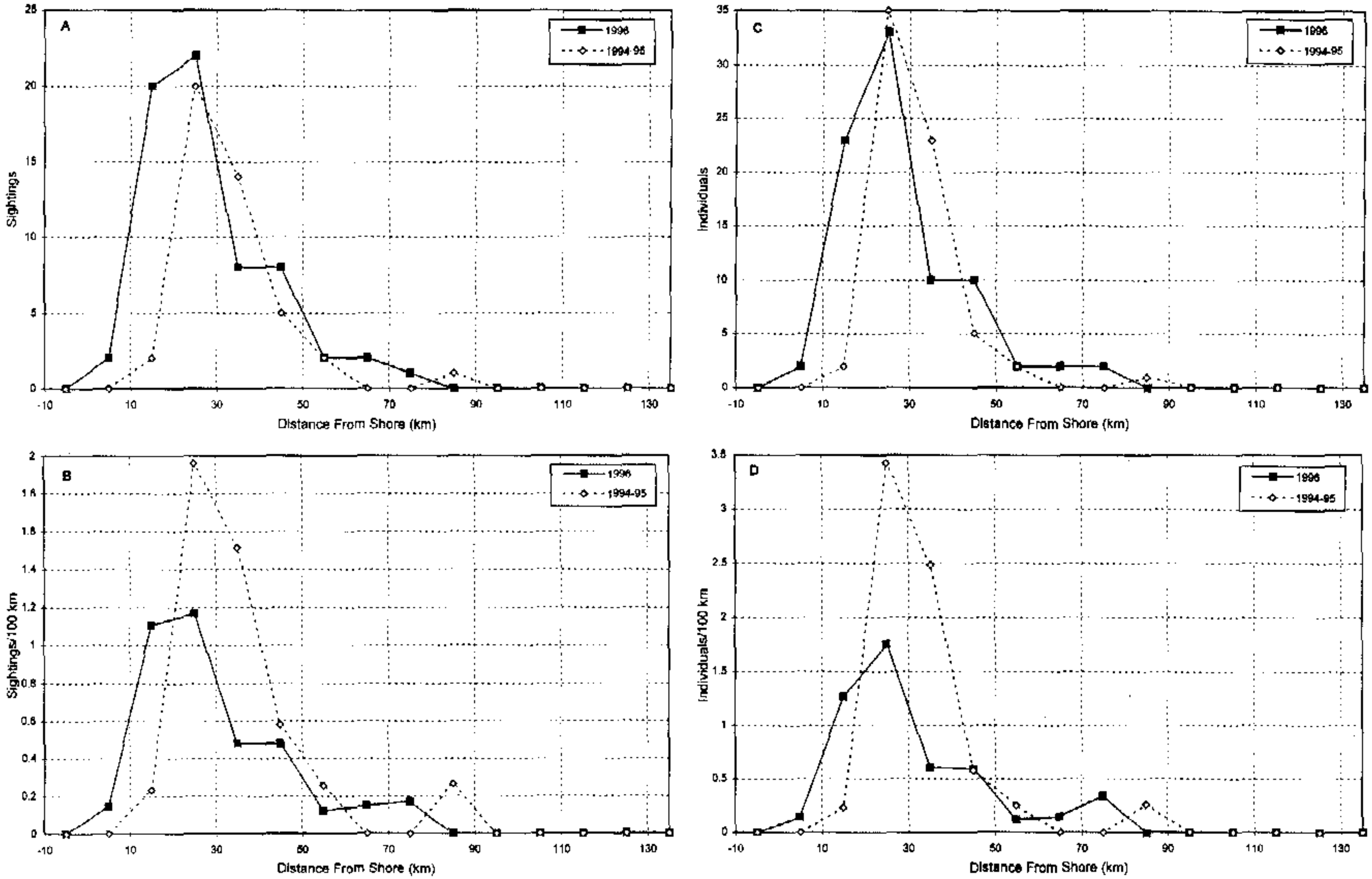


FIGURE 5.34. Distributions of bowheads vs. distance from shore during late summer/autumn of 1996 vs. 1994-95 (light ice years with nil/little industrial activity), including periods of poor sightability. See Fig. 5.35A for survey effort vs. distance from shore. Otherwise as in Fig. 5.28.

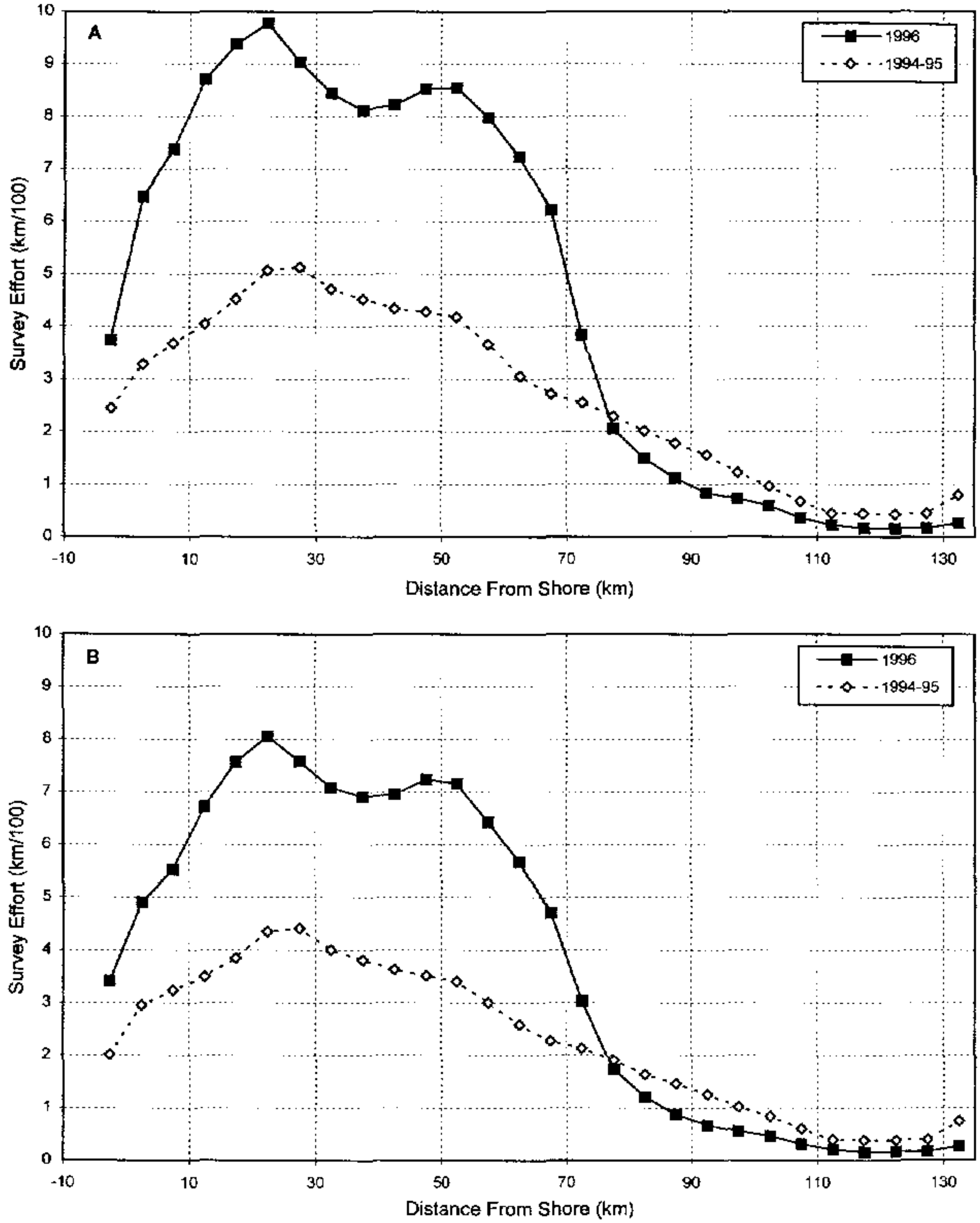


FIGURE 5.35. Aerial survey effort at various distances from shore during late summer/ autumn of 1996 vs. 1994-95 (light ice years with nil/little industrial activity); periods of poor sightability *(A)* included and *(B)* excluded. Based on LGL and MMS "Transect" aerial surveys in the Northstar region of the central Alaskan Beaufort Sea (147°-150°30').

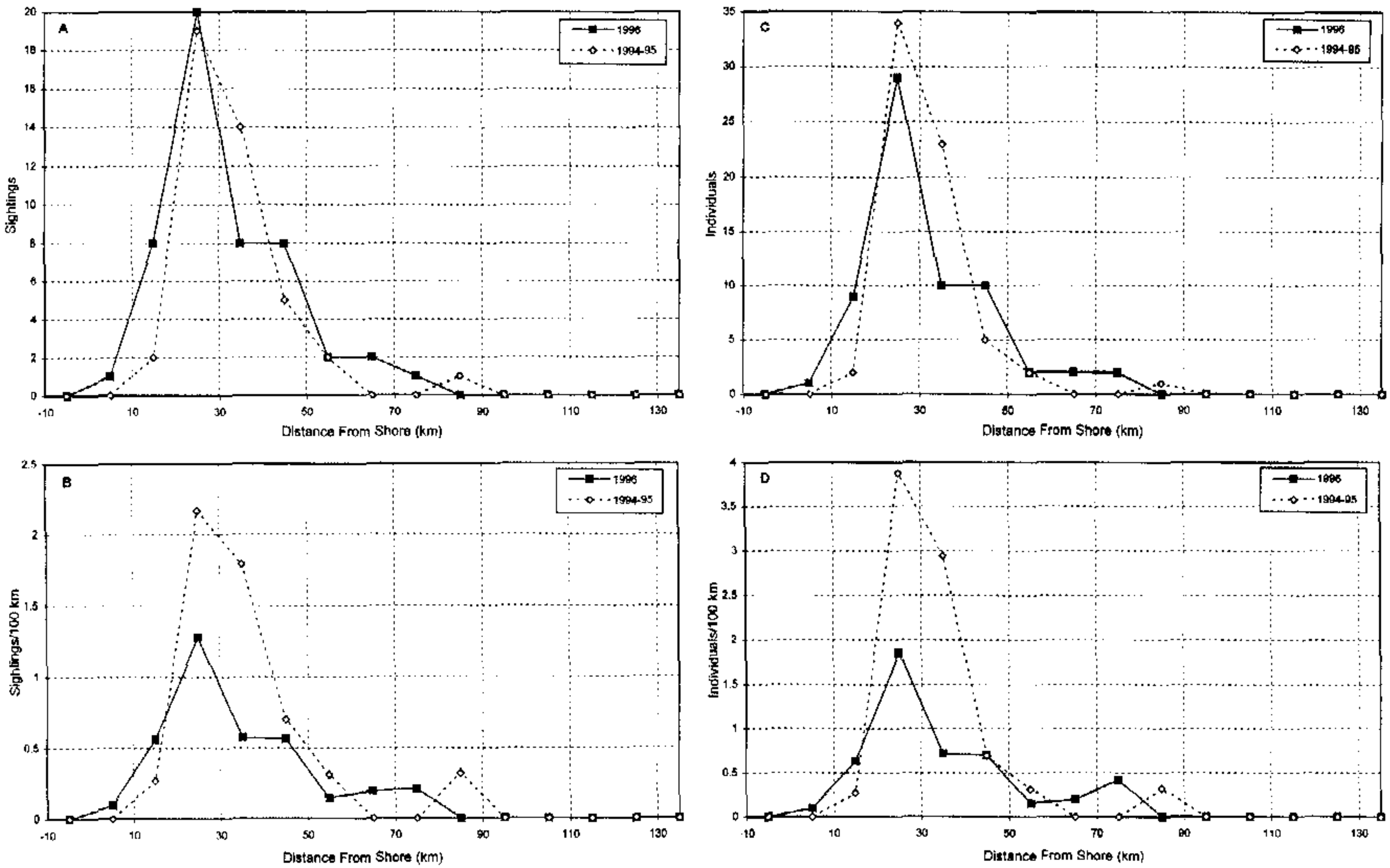


FIGURE 5.36. Distributions of bowheads vs. distance from shore during late summer/autumn of 1996 vs. 1994-95 (light ice years with nil/little industrial activity), excluding periods of poor sightability. See Fig. 5.35B for survey effort vs. distance from shore. Otherwise as in Fig. 5.28.

and less conspicuous than in the larger dataset (Fig. 5.36 vs. 5.34). The difference was not statistically significant when based either on sightings (D=-0.133, two-tailed P>0.10) or on sightings per 100 km of survey effort (D=-0.137, two-tailed P>0.10).

Thus, comparison of 1996 sighting data with data from two years having similar ice conditions but little industrial activity revealed no evidence that bowheads were distributed farther from shore in 1996. In fact, the bowhead migration corridor tended to be closer to shore in 1996 than in 1994-95.

The above analyses include all 1996 sightings, whether or not seismic operations were underway at the time of each sighting. It is also relevant to compare distances from shore for bowheads seen during "seismic" periods of 1996 ("seismic" curves in Fig. 5.28-5.30) vs. those for all bowheads seen in 1994-95, the "quiet" light-ice years (Fig. 5.34-5.36).

The modal distance-from-shore category was 20-30 km offshore both during the 1996 seismic periods and during 1994-95 as a whole. However, proportionally more bowheads were found <20 km offshore and proportionally fewer were found >30 km offshore during the 1996 seismic periods than during 1994-95. This was true whether or not "poor sightability" data were excluded, and for all methods of analysis (sightings, individuals, sightings/100 km, or indiv./100 km). The difference between 1996 seismic data and 1994-95 data was statistically significant when all data were included and compared by 5-km intervals (D=-0.415 for sightings and D=-0.402 for sightings/100 km; n=16 and 44 and two-tailed P<0.05 in each case).[6] The difference was marginal or non-significant when "poor sightability" data were excluded (D=-0.388 for sightings, 0.1>P>0.05, and D=-0.361 for sightings/100 km, P>0.1; n=15 and 43 in each case).

Thus, there was no indication that the migration corridor was farther from shore with seismic in 1996 than during the "quiet" seasons of 1994-95. If anything, the migration corridor tended to be farther offshore without seismic in 1994-95. However, this result should be interpreted cautiously given the small number of "seismic" sightings in 1996, and the fact that some of these whales were seen 0-3.5 h after seismic ended.

Years With Little vs. Substantial Industrial Activity.—If westbound bowheads were displaced offshore by industrial activities in general, including both seismic and drilling activities, distances from shore would be expected to be greater in years with substantial industrial activity. Distance-from-shore data for bowheads seen in the Northstar area are plotted for light ice years with nil or little vs. substantial offshore industrial activity in Figure 5.37. This Figure excludes data from periods with poor sightability. Years with substantial industrial activity included years with substantial seismic exploration, offshore drilling, or both in the central Alaskan Beaufort Sea, including the western Camden Bay area. There

[6] Both differences were only marginally significant (0.1>P>0.05) when the analysis was done based on 10-km intervals. These were the only K-S tests reported in this Chapter in which use of 5- vs. 10-km intervals resulted in different significance levels.

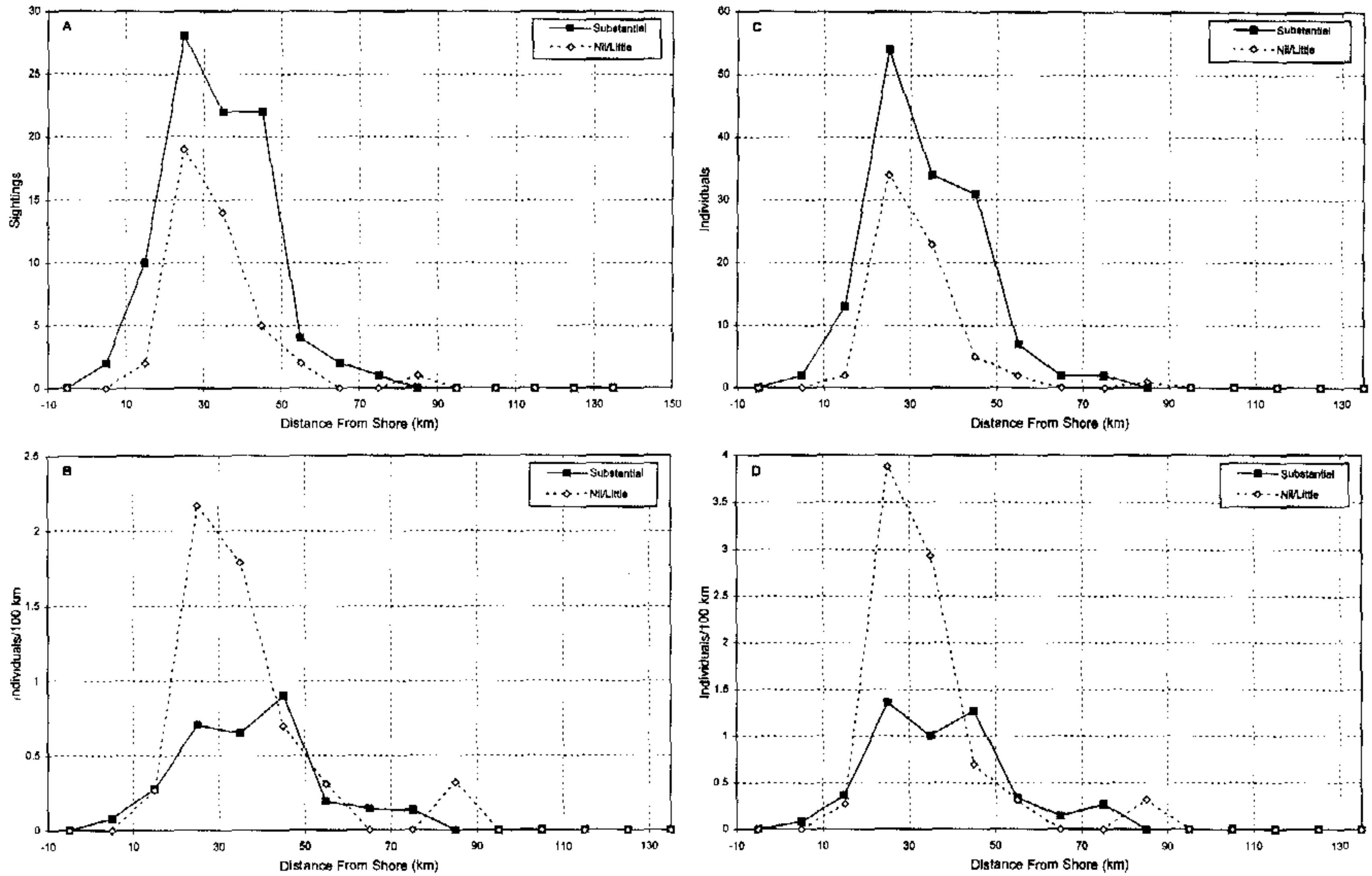


FIGURE 5.37. Distributions of bowheads vs. distance from shore during late summer/autumn of light ice years with substantial industrial activity vs. nil/little industrial activity, excluding periods of poor sightability. See Fig. 5.38 for survey effort vs. distance from shore. Otherwise as in Fig. 5.28.

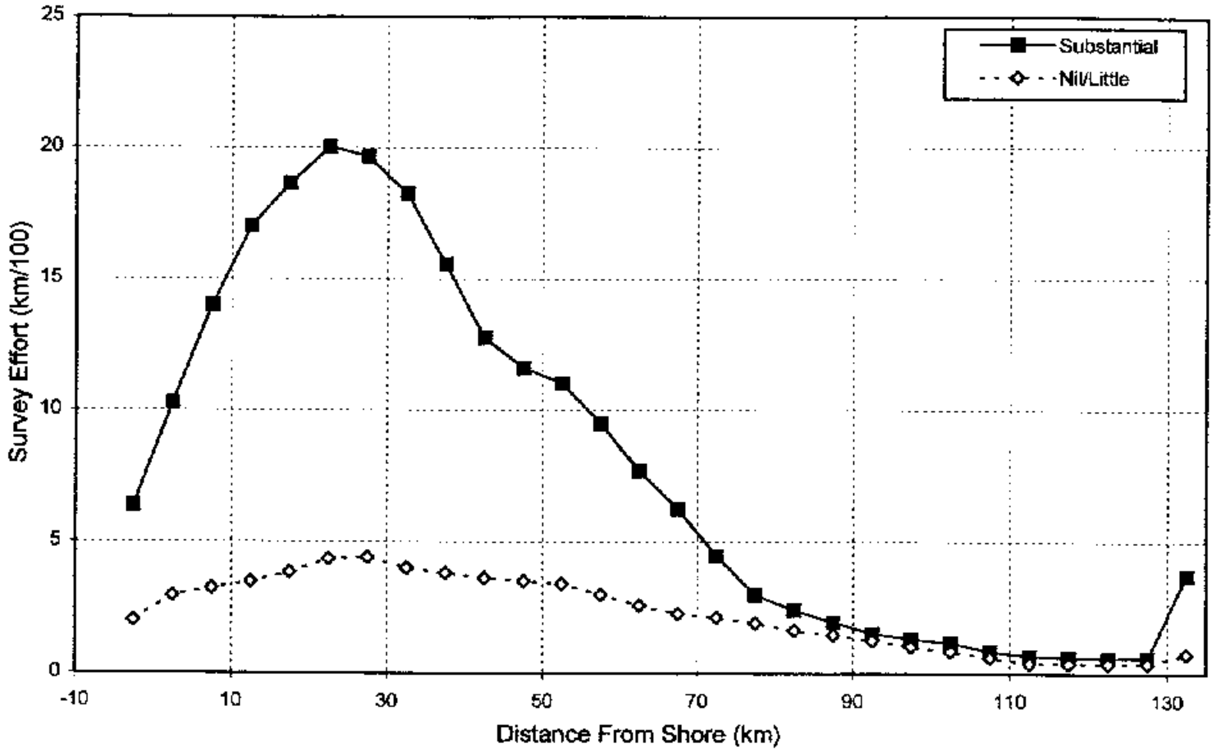


FIGURE 5.38. Aerial survey effort at various distances from shore during late summer/ autumn of light ice years with substantial vs. nil/little industrial activity; periods of poor sightability excluded. Based on LGL and MMS "Transect" aerial surveys in the Northstar region of the central Alaskan Beaufort Sea (147°-150°30').

were 43 bowhead sightings in the two light-ice years with little or no industrial activity (1994-95) and 91 sightings in the five light-ice years classed as having substantial industrial activity (1982, 1987, 1989, 1990 and 1996).

Peak numbers of sightings and of individuals in the Northstar region were in the 20-30 km distance-from-shore zone in both groups of years (Fig. 5.37A, C). The overall distribution of sightings tended to extend somewhat farther offshore during "industrial" years than in years without much industrial activity. However, the difference was not statistically significant (K-S D=0.196, two-tailed P>0.10).

When the sightings were corrected for the onshore-offshore distribution of survey effort (*cf.* Fig. 5.38), the main migration corridor again seemed to extend farther from shore during years with industrial activity (Fig. 5.37B). High sighting rates (/100 km) occurred in the 20-

40 km distance-from-shore zone in years with little industrial activity, and in the 20-50 km zone during "industrial" years. The modal categories were 20-30 km vs. 40-50 km. This difference was statistically significant (D=0.253, n = 91, 43; two-tailed 0.05>P>0.01).

Overall, bowhead sightings tended to be slightly farther offshore during five light ice years with substantial industrial activity than during two light ice years without much activity. This difference was statistically significant when allowance was made for survey effort at each distance from shore.

Summary of Distances from Shore.—The number of bowhead sightings within the Northstar region (147°-150°30'W) during LGL and MMS aerial surveys in 1996 was small, and only a minority of these sightings were during (n=9) or within 3.5 h after (n=8) periods of seismic exploration. For this and other reasons, it is not appropriate to draw general conclusions about effects of seismic exploration on the position of the bowhead migration corridor based on this 1996 monitoring study alone. However, the following points were evident from the data available:

1996 Seismic vs. 1996 No Seismic

If westbound bowheads were displaced offshore by the seismic operation, distances from shore would be expected to be greater at times with than at times without seismic. Bowheads tended to be seen both closer to shore and farther offshore without seismic. *The modal distance from shore was ~10 km farther offshore with seismic, consistent with the possibility of seaward displacement by seismic*, when data collected under poor sightability conditions were included. However, the distributions with and without seismic overlapped broadly, and when poor sightability data were excluded sightings tended to be *closer* to shore with seismic than without seismic. The main migration corridor during periods potentially influenced by seismic was apparently 20-30 km from shore, or ~10-20 km from the northern edge of the area of seismic exploration.

1996 East vs. 1996 West

If westbound bowheads were displaced offshore by the seismic operation, distances from shore would be expected to be greater in the western than in the eastern part of the Northstar region. No evidence of this was found when we considered 1996 as a whole (periods with and without seismic combined).

We wanted to compare distances from shore in the east and west considering only the times with seismic. However, the number of sightings with seismic was too small, especially in the east.

1996 vs. 1994-95

If westbound bowheads were displaced offshore by the seismic operation, distances from shore would be expected to be greater in 1996 than in years with similar ice cover but little offshore industrial activity, e.g. 1994-95. We found no evidence that bowheads were distributed farther from shore in 1996 (either overall or during times with seismic) than in 1994-95. If anything, bowhead migration tended to be closer to shore during 1996, the year with seismic.

Years with Little vs. Substantial Industrial Activity

If westbound bowheads were displaced offshore by industrial activities in general, including both seismic and drilling activities, distances from shore would be expected to be greater in years with substantial industrial activity in the Northstar area and/or western Camden Bay. *Consistent with this hypothesis, bowhead sightings tended to be slightly farther offshore during five light ice years with substantial industrial activity than during two light ice years without activity.* This difference was statistically significant (P<0.05).

Available data are insufficient to determine whether the tendency for the southern edge of the main bowhead migration corridor to be farther offshore with seismic or other industrial activities is indicative of a causal relationship. The tendency was not statistically significant for seismic. However, considering the larger sample of data from five light-ice years having substantial amounts of offshore industrial activity (seismic and/or drilling), bowheads were distributed significantly farther offshore during those years than in two light ice years without much industrial activity.

The observed tendencies, although statistically weak, are qualitatively consistent with the experience of bowhead hunters, who have reported that seismic exploration and other industrial activities displace the migration corridor of bowhead whales (e.g., Jolles [ed.] 1995; Rexford 1996; Kanayurak et al. 1997). However, there was much overlap between the migration corridors in years with vs. without seismic or other industrial activities. Also, most bowheads seen during periods with seismic exploration were within ~20-30 km from shore, and thus apparently passed within ~10-20 km of the northern edge of the seismic area. (The closest direct sightings during or immediately after periods of airgun array operations were 22-27 km from the airguns—see p. 5-45.) Data from additional years with seismic exploration will be required to confirm statistically that nearshore seismic exploration has measurable effects on the autumn migration corridor of bowheads and to estimate the magnitude of any effects.

5.3.4 Behavior and Headings

Previous sections have mapped the bowhead sightings during seismic periods (Fig. 5.23) and plotted their distances from shore (Fig. 5.30-5.32). In Figure 5.39 bowhead sightings with seismic are plotted in relation to the source vessel's position at the time of the sighting or, in the case of post-seismic sightings, at the time the source vessel stopped shooting seismic. The 17 sightings in Figure 5.39 ranged from 20.8 to 73.5 km from the source (Table 5.3). All but two of the sightings occurred within a ESE-WNW band paralleling the coastline north of the source. If the whales were traveling along the band from ESE to WNW, most would pass the source at distances of about 20-30 km north of the source. Two sightings were notably farther offshore in areas well to the NE and NW of the source.

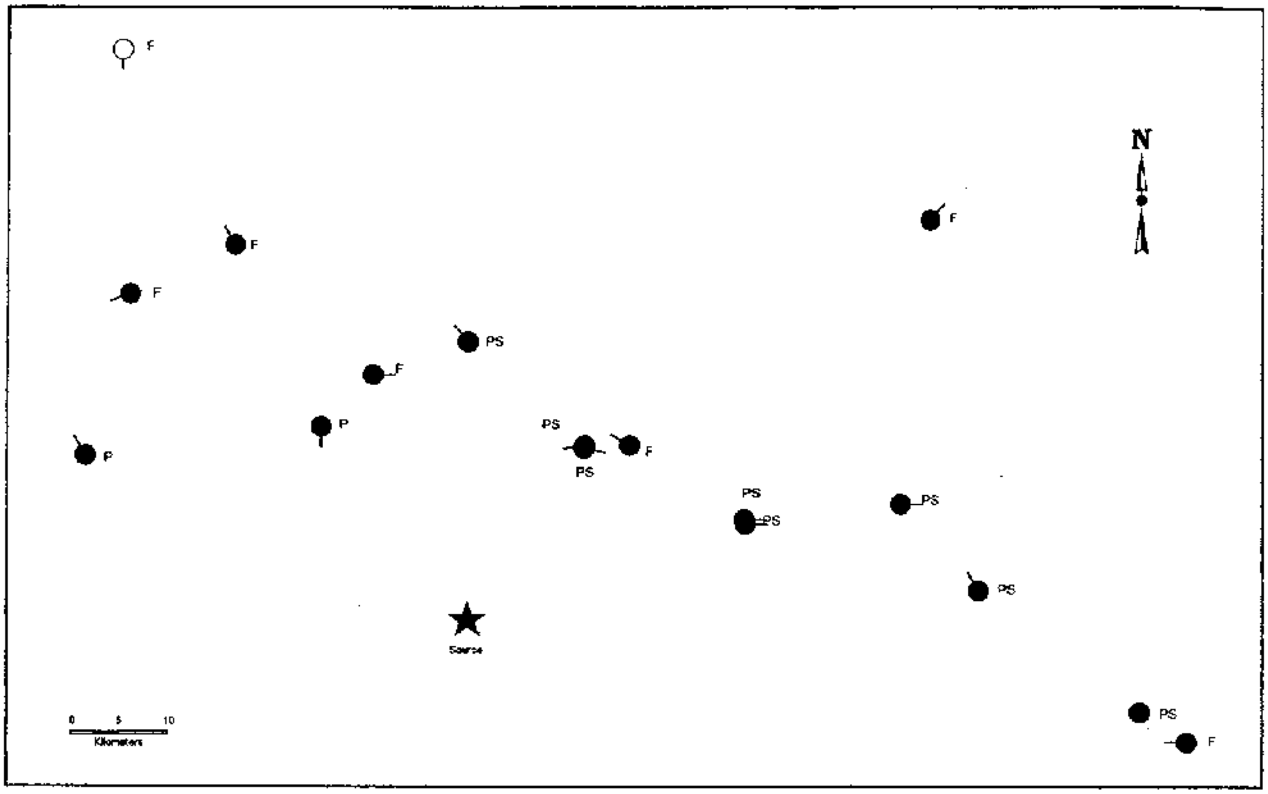


FIGURE 5.39. Bowheads sighted during "all seismic" periods plotted in relation to the location of the source vessel (star). F = full array, P = partial array, and PS = ≤3.5 h after end of a lengthy full array period. For PS cases, whale positions are plotted in relation to the position of the source vessel at the time when seismic operations ended. The single open symbol denotes an incidental sighting; solid symbols show "Transect" sightings. Based on LGL aerial surveys in the Northstar region of the central Alaskan Beaufort Sea, including periods of poor sightability. (There were no MMS sightings during F, P or PS periods.)

Eleven bowhead sightings were during active seismic periods (full and partial array) or within 12 minutes of the the end of a full-array seismic period. We include two sightings 11.4 min after seismic ended because these whales could not have traveled far within this short interval. These 11 sightings also occurred within 20.8 - 73.5 km of the source. Many of these sightings were well to the east or west of the source vessel. Thus, it is not known how closely some of these more distant bowheads may have approached the source during migration. However, the 11 "active seismic" sightings included five bowheads that were seen within about 21-27 km of the source.

Behavior.—The behaviors recorded for bowheads sighted during seismic periods included swimming and resting. Whales resting at the surface during active seismic work would not be exposed to such strong seismic pulses as would whales that dove. Thus, it is of interest to assess whether the proportion of whales resting at the surface was higher during seismic periods. Excluding the single search-connect sighting (a resting whale), there were 5 sightings of resting bowheads (31%) and 11 sightings of swimming bowheads (69%) during "all seismic" periods. Considering only the 9 sightings with full- or partial-array seismic at the actual time of the sighting (i.e. excluding "post seismic" cases), there were 4 sightings of resting bowheads (44%) and five sightings of swimming bowheads (56%). By comparison, behaviors were recorded for 48 of 49 "Transect" sightings without seismic (sightings during poor sightability included). Of these, 15 (31%) were resting, 25 (52%) were swimming, and 8 (16%) were involved in other behaviors (diving, milling, breaching).

Thus, the percentages of the bowhead sightings recorded as resting were identical during "all seismic" and "no-seismic" periods (31% of 16; 31% of 48) and slightly higher during active seismic (44% of 9). The percentages recorded as swimming were similar with "all seismic", "active seismic", and "no seismic" (69%, 56% and 52%, respectively). Overall, there was no indication that resting at the surface was appreciably more common during seismic than no-seismic periods, but the small sample sizes prevent firm conclusions.

Of the 11 sightings of swimming whales during "all seismic" periods, 6 (55%) were traveling at slow speed and 5 (45%) at medium speed. Within the comparable non-seismic sample, 13 of 25 sightings (52%) were recorded as swimming at slow speed and 12 (48%) at medium speed. These percentages were very similar (χ^2=0.05, df=1, P>0.75).

Headings During 1996.—During 1996 "Transect" surveys conducted by LGL and MMS within the Northstar region (147°-150°30'W), headings were recorded for 58 sightings of bowhead groups or single individuals. Of these, 35 (60%) were sightings of bowheads whose behavior was recorded as swimming, as opposed to resting, milling or some other activity.

The headings of the 35 "swimming" bowheads or groups (Fig. 5.40A) were bimodal. They included 23 headings (66%) concentrated around westward and northwestward directions (221-330°T, a 110° range) and 12 headings (34%) in other directions, primarily eastward. The vector mean heading was 313°T with an angular deviation of 66°, based on the method of Batschelet (1981). However, with a strongly bimodal distribution of this nature, the vector mean and angular deviation must be interpreted with caution.

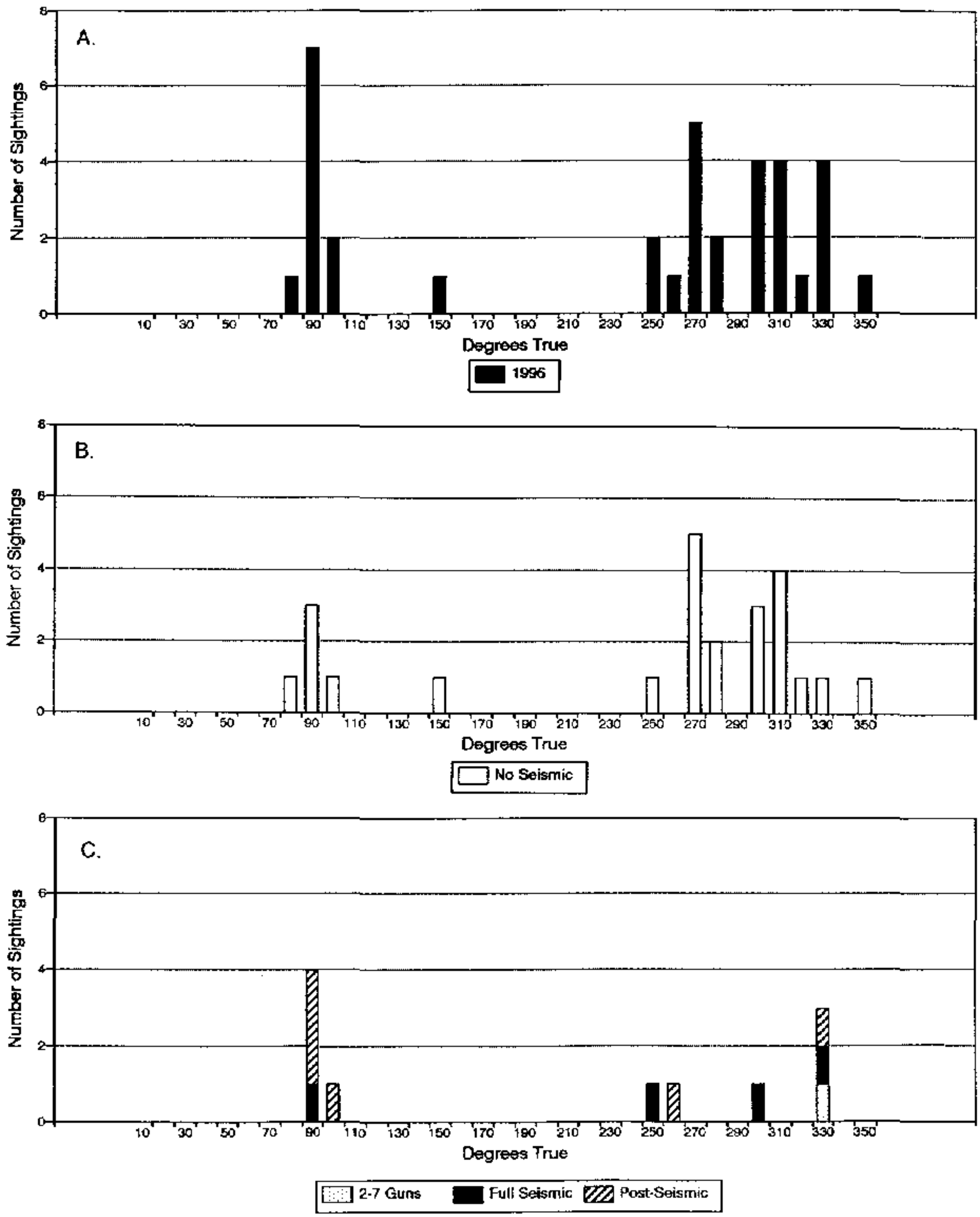


FIGURE 5.40. Headings of bowhead whales recorded as "swimming" in the Northstar region (147°-150°30'W) during late summer/autumn of 1996 comparing *(A)* all periods, *(B)* periods with no seismic, and *(C)* periods with partial array seismic, full array seismic, and post-seismic. The single partial array case also occurred during a "post-seismic" period. Based on sightings during "Transect" flying by LGL and MMS; each sighting counted once regardless of number of whales in group. Labels along the x-axis represent the maximum heading within a 10° range, e.g. "90" represents 81°-90°T.

The headings of "swimming" bowheads were bimodal both with and without seismic exploration (Fig. 5.40B,C). Without seismic, 17 bowheads or groups (71%) were oriented to the W or NW and seven were oriented in other directions, mainly E (vector mean 301°T ± ang. dev. 59°; Fig. 5.40B). With seismic, six bowheads or groups (55%) were heading W or NW and five were heading E (16°T ± ang. dev. 71°; Fig. 5.40C). The proportions of sightings oriented to the W or NW vs. other directions were not significantly different (71% vs. 55%; χ^2=0.89, df=1, P>0.3). Also, although a lower percentage of the "swimming" bowheads were traveling W or NW during times classified as "seismic", only one of the five cases of eastward swimming with "seismic" was actually during a period of seismic operations. The other four were during post-seismic periods (<3.5 h after active seismic operations; Fig. 5.40C).

If the headings of bowhead sightings in the Northstar region during 1996 were influenced by the presence of seismic activity, then it might be expected that bowheads in different locations relative to Northstar might have exhibited different headings. In particular, bowheads farther from shore—and therefore farther from the source of seismic noise—might show tendencies to head in different directions than those closer to shore. Also, bowheads in the eastern portion of the study area (approaching Northstar) might travel in different directions than those in the western portion of the study area (passing or past Northstar). We compared the headings of bowhead sightings inshore and offshore of the 30-km-from-shore line, and east and west of a N-S line located at 148°10'W (*cf.* Fig. 5.7). We used the 221°-330° category mentioned above to represent typical or expected headings. These analyses did not include the headings of any bowheads observed after 20 September, and therefore did not include any late season headings obtained more than two days after the end of the 1996 Northstar seismic exploration season.

The headings of bowhead sightings in offshore and inshore parts of the study area during 1996 are compared in Figure 5.41, considering "swimming" bowheads only. In waters >30 km from shore, the vector mean heading was 312°T ± ang. dev. 55° (n=14, Fig. 5.41A). In these offshore areas, 11 of 14 (79%) of the headings were in "expected" W and NW directions. In waters ≤30 km from shore, the vector mean heading was 315°T ± ang. dev. 72° (n=21, Fig. 5.41B). In nearshore waters, 12 of 21 (57%) sightings were heading in "expected" W and NW directions. These percentages are not significantly different (79% vs. 57%; χ^2=0.89 with Yates correction, df=1, P>0.25).

Bowhead headings in eastern and western portions of the study area are compared in Figure 5.42, considering "swimming" bowheads only. Only 7 headings were recorded in the eastern region (Fig. 5.42A). The vector mean heading for these sightings was 305°T with a relatively low angular deviation of 23°. All headings in this small sample were in the "expected" W and NW directions. Most (28) of the 1996 headings were recorded west of the N-S dividing line at 148°10'W (Fig. 5.42B). The vector mean heading was 321°T ± ang. dev. 72°, indicative of a wide scatter in headings. In this region, 16 of 28 (57%) sightings were heading in "expected" W and NW directions vs. 12 (43%) traveling in "other" (primarily easterly) directions. This east-west difference was statistically significant (Fisher's Exact Test, two-tailed P=0.033).

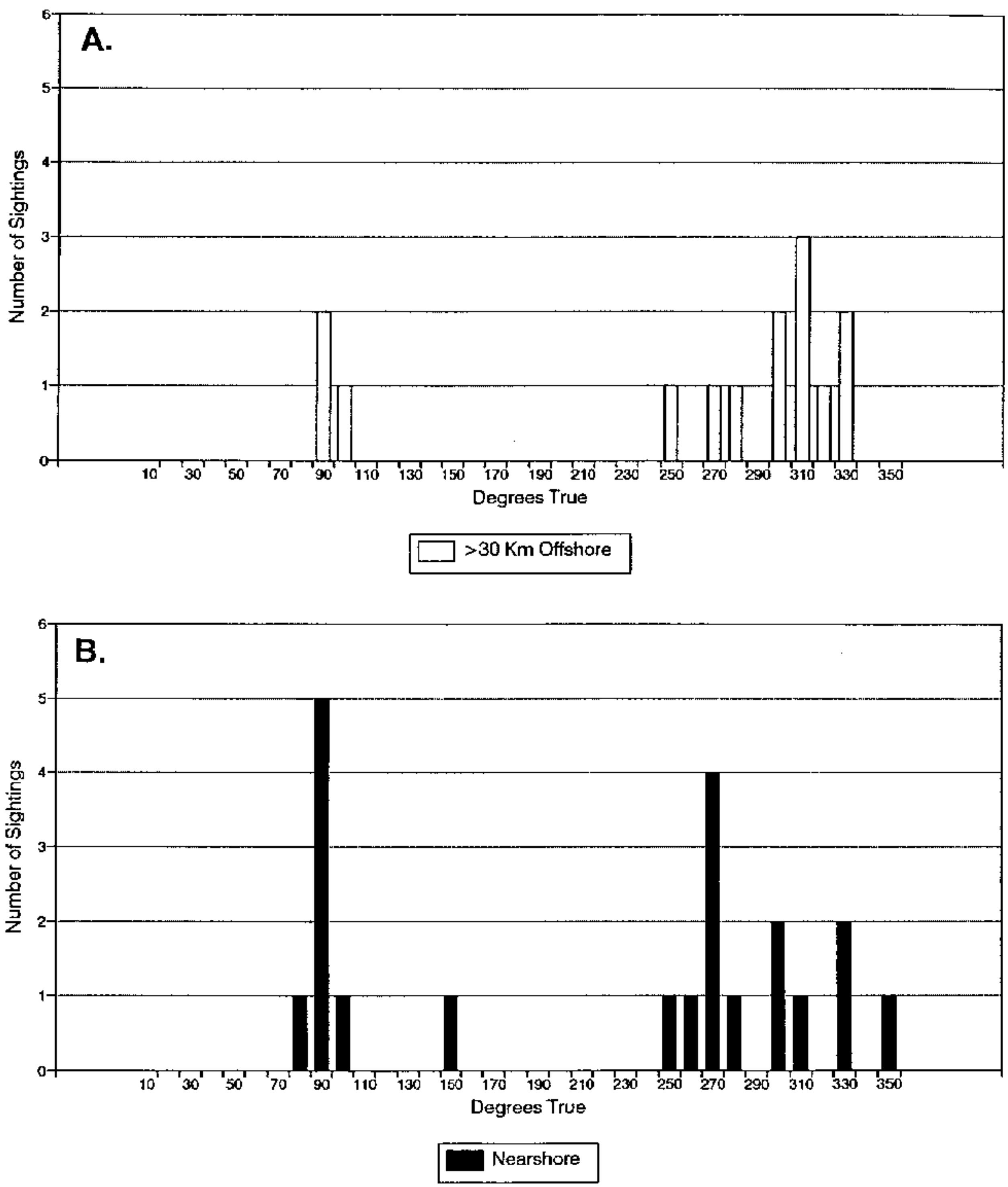


FIGURE 5.41. Headings of bowhead whales recorded as "swimming" in the Northstar region (147°-150°30'W), 1-20 September 1996, comparing headings ***(A)*** >30 km from shore vs. ***(B)*** ≤30 km from shore. Otherwise plotted as in Figure 5.40.

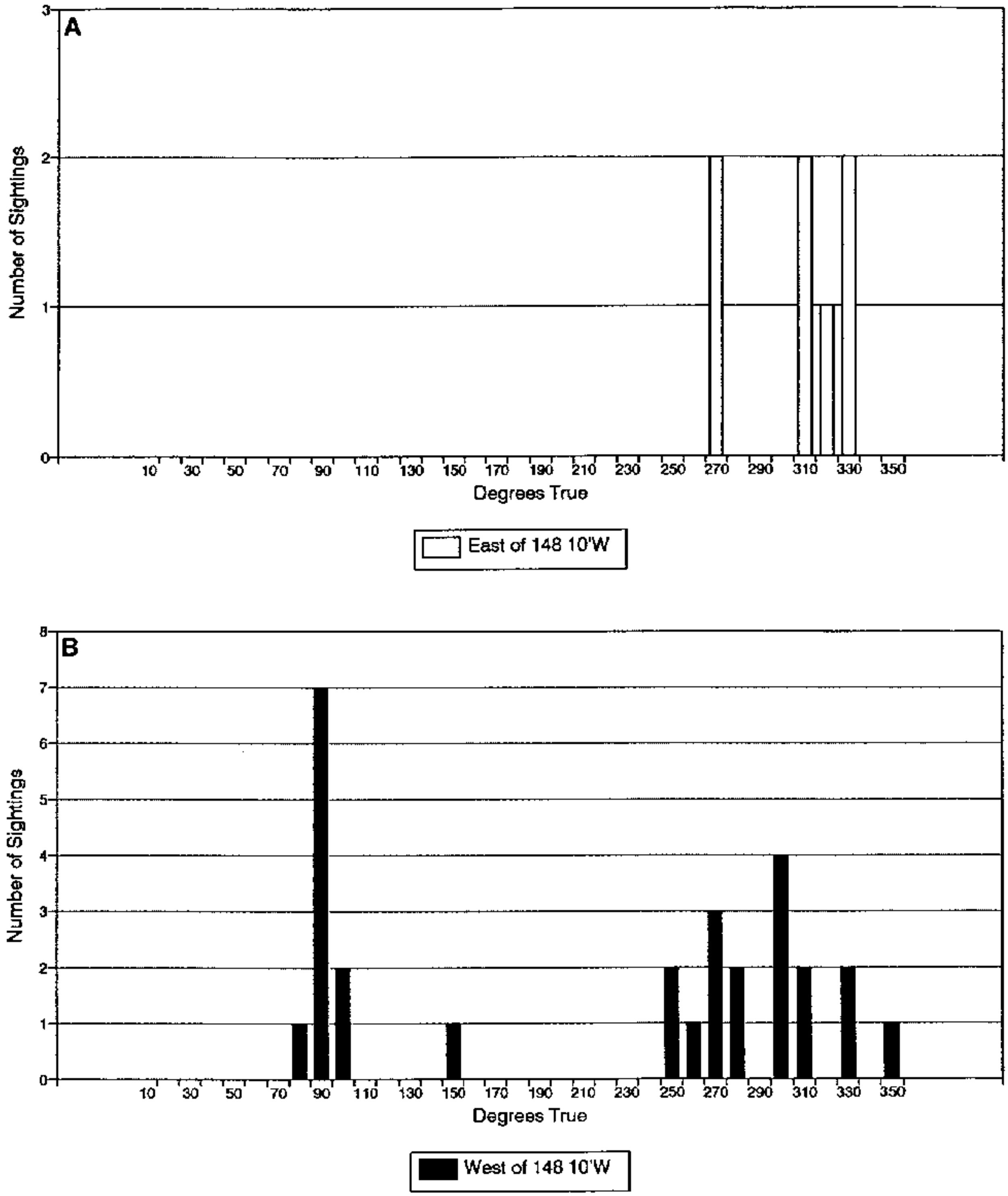


FIGURE 5.42. Headings of bowhead whales recorded as "swimming" in the Northstar region (147°-150°30'W), 1-20 September 1996, comparing headings *(A)* east of 148°10' vs. *(B)* west of 148°10'. Otherwise plotted as in Figure 5.40.

Given this apparent east-west difference, it is important to examine how many of the eastern and western sightings were during "seismic" periods. During the 1996 "Transect" surveys, there were 11 sightings of bowheads "swimming" on known headings during "seismic" periods: five sightings during periods of active seismic work (full- or partial array), and six during post-seismic periods. Only 1 of these 11 sightings was in the eastern region, and it was during a post-seismic period (heading 330°T). Of the five "active seismic" sightings in the western region, one was heading east (90°T) and four were heading W or NW (260°-330°T). The five post-seismic headings in the western region consisted of four easterly (90°-100°T) and one westerly (260°T) heading. This concentration of easterly headings among such a small sample of post-seismic headings is intriguing. However, all post-seismic sightings in 1996 were from surveys on the afternoon of 18 September (Fig. 5.19; Table 5.3). As such, there is some question about the statistical independence of these observations.

Headings in 1996 vs. Other Years.—The high percentage (34%) of the traveling bowheads that were heading in directions other than west or northwest during the late summer and autumn of 1996 (Fig. 5.43A) seemed unusual. However, further analysis showed that, in the Northstar region, bowheads seen during late summer and autumn of other years also were swimming in "other" directions more often than might be expected.

In the late summer and autumn of 1994 and 1995 (light ice years with nil/little industrial activity), headings were determined for 38 bowhead sightings in the Northstar region. Of these sightings during MMS and LGL "Transect" surveys, 28 (74%) were recorded as "swimming". The vector mean heading of the swimming whales was 267°T ± ang. dev. 56°. Of those, 18 (64%) were heading in the "expected" W and NW directions (221°-330°T). Ten (36%) were heading in other directions, but none of those were heading directly east (Fig. 5.43B). The percentages of headings oriented W or NW vs. other directions were very similar during 1994-95 as compared with 1996 (64% vs. 66%; χ^2=0.02, df=1, P>0.75). This comparison is limited in that 1994 contributed only one of the headings observed during the 1994-95 period. Thus, the comparison is basically a comparison of two years, 1995 with little industrial activity vs. 1996 with frequent seismic exploration.

During the 1979-96 period there were 5 years, including 1996, that were identified as years with light ice conditions *and* substantial industrial activity. During these years headings were observed for 95 bowhead sightings, of which 63 (66%) were "swimming". The vector mean heading of the swimming whales was 292°T ± ang. dev. 58° (Fig. 5.43C). Of these 63 headings, 44 (70%) were in "expected" W and NW directions and 19 (30%) were in "other" directions. The percentage oriented W or NW did not differ significantly from that observed during the 1994-95 light ice years with little/nil industrial activity (70% vs. 64%; χ^2=0.08, df=1, P>0.75). However, as noted above, this comparison is limited by the fact that the data from the 1994-95 period are almost entirely from 1995.

In summary, the bimodal distribution of headings observed among "swimming" bowheads in the Northstar region during 1996 initially seemed surprising. However, it was not significantly different from the distributions in 1994-95, when there were no offshore

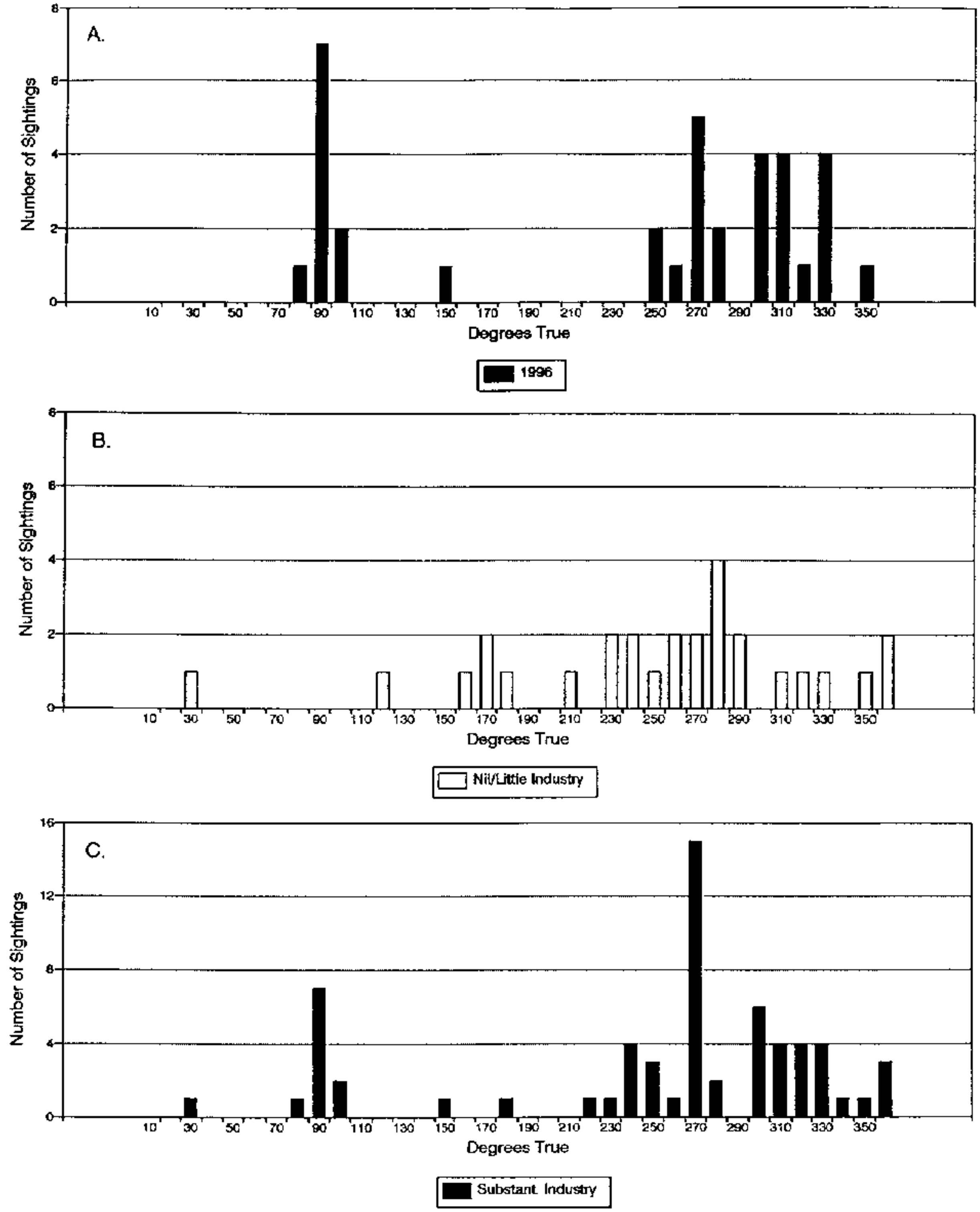


FIGURE 5.43. Headings of bowhead whales recorded as "swimming" in the Northstar region (147°-150°30'W) during late summer/autumn comparing *(A)* 1996, *(B)* light ice years with nil/little industrial activity (1994-95), and *(C)* five light ice years with substantial industrial activity (1982, 1987, 1989, 1990 and 1996). Otherwise plotted as in Figure 5.40.

industrial activities in the area. Likewise, headings during five years with substantial offshore industrial activity did not differ significantly from those during 1994-95. In 1996, the distributions of headings during seismic and no-seismic periods were similar, as were the distributions for bowheads within vs. beyond 30 km from shore. One 1996 result that might be indicative of a seismic effect was that, based on a very small sample, bowhead headings in eastern and western portions of the study area differed significantly, with more bowheads heading in "other" directions in the western portion.

5.3.5 Migration Timing

Taken together, the BPXA/LGL and MMS aerial surveys in the Northstar area during 1996 extended from 2 September to 7 October. The seasonal timing of bowhead sightings during this period was examined using data that include poor sighting conditions. Peak numbers of bowhead sightings (29) and individuals (42) were recorded during the 5-day period from 16 to 20 September (Fig. 5.44). However, survey effort was also highest during that period (Fig. 5.44E). When the data were standardized by survey effort, the number of sightings per 100 km of survey was marginally higher during the 1-5 September period, when there were 0.8 sightings/100 km and 1.0 individuals/100 km (Fig. 5.44C,D). Overall, bowhead numbers in the Northstar region, averaged by 5-day periods, seemed fairly steady during the 1-30 September period, although no bowheads were seen during the 21-25 September period when there was little survey effort (295 km).

In light ice years with little or no offshore industrial activity in the central Alaskan Beaufort Sea (1994-95), the seasonal pattern of bowhead sightings in the Northstar region was hard to discern because of irregular and infrequent survey coverage. There was <500 km of surveys per five day period during 3 of the 6 five-day periods in September 1994-95, and minimal coverage after late September (Fig 5.44E). However, during the 11-15 September period of 1994-95, very high bowhead sighting rates were recorded: 2.85 sightings/100 km and 4.6 individuals/100 km (Fig. 5.44C,D). These sighting rates were heavily influenced by the unusually large number of sightings during MMS surveys in 1995. The very restricted period (11-15 Sep.) when substantial numbers of bowheads were recorded near Northstar during 1994-95 is probably related to the limited and irregular survey coverage in the Northstar area during those years.

Bowhead sightings during light ice years with substantial industrial activity in the central Alaskan Beaufort (1982, 1987, 1989, 1990, and 1996) peaked in the 16-20 September period; numbers of individuals peaked during the 21-25 September period (Fig. 5.45A,B; periods of poor sightability excluded). After standardizing for survey effort, the highest rates of sightings/100 km and individuals/100 km both occurred during the 21-25 September period.

The period with peak sighting rates was about 10 days later during light ice years with substantial industrial activity (21-25 Sept) than during light ice years with nil or little industrial activity (1994-95). This difference is consistent with the hypothesis that industrial activity delays bowhead migration. However, as noted above, the apparent migration peak observed in the 11-15 September period of 1994-95 may have been an artefact of limited or

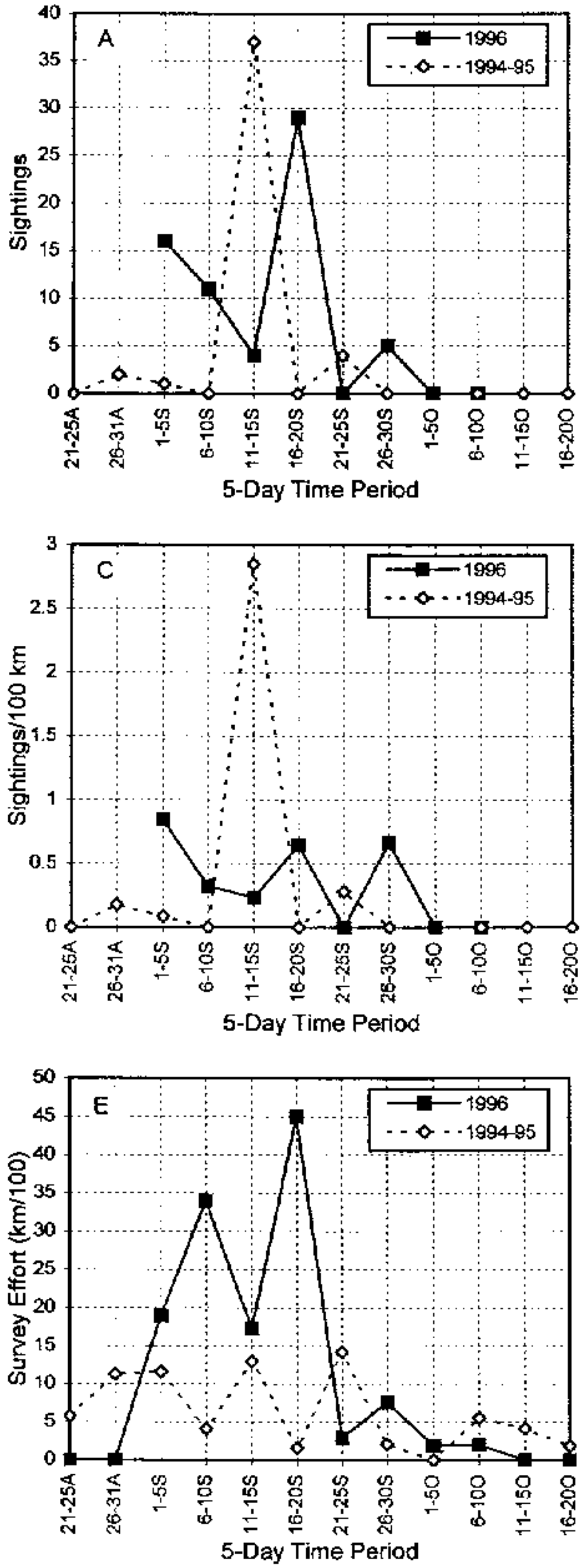
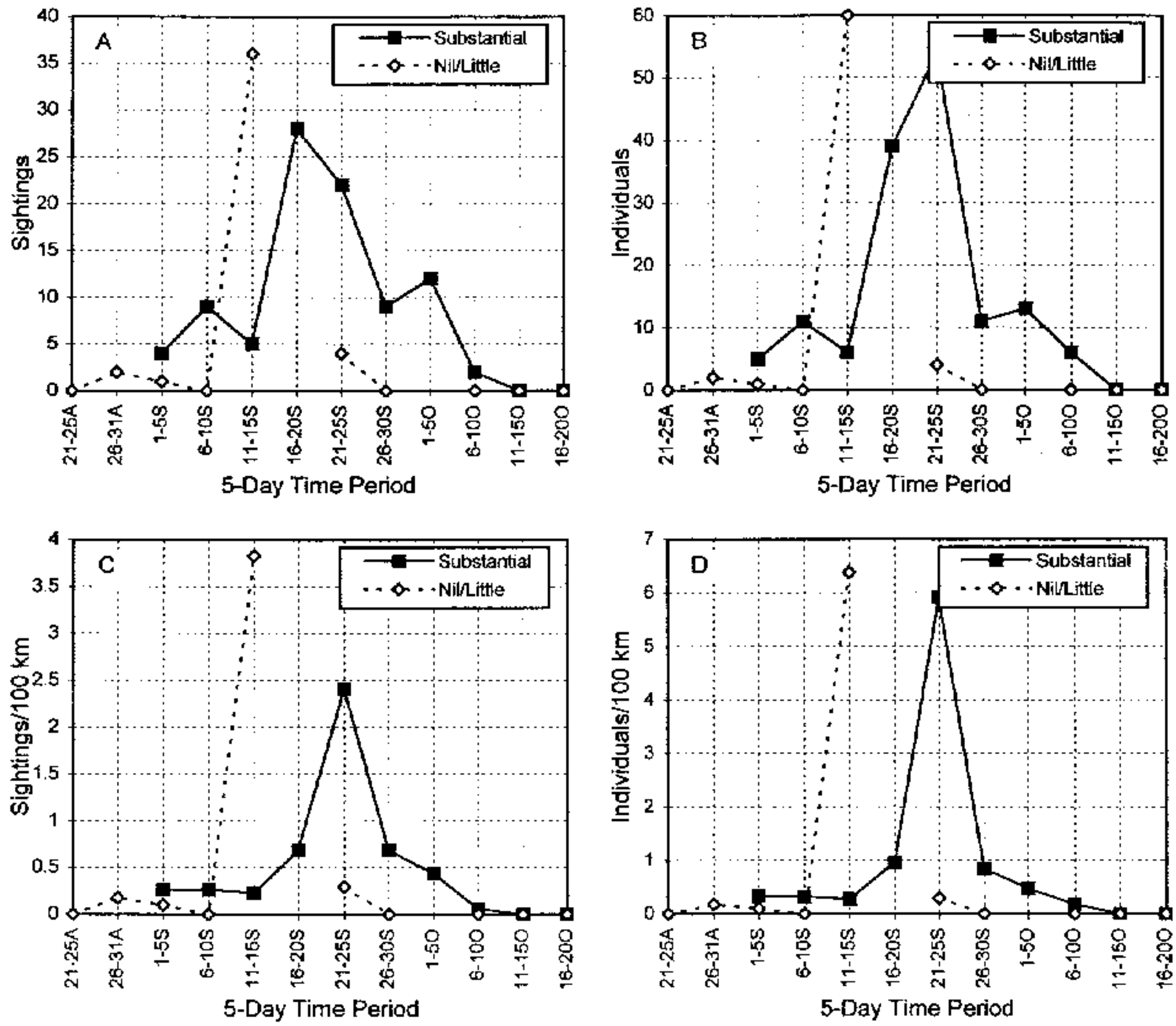


FIGURE 5.44. Seasonal pattern of bowheads in 1996 vs. two light ice years with little/nil offshore industrial activity (1994-95), including periods of poor sightability. Based on LGL and MMS "Transect" aerial surveys in the Northstar region of the central Alaskan Beaufort Sea (147°-150°30') during late summer/autumn. Includes ***(A,B)*** sightings and individuals by 5-day period, ***(C,D)*** sightings and individuals per 100 km of surveying, and ***(E)*** "Transect" survey effort, in 100s of km.



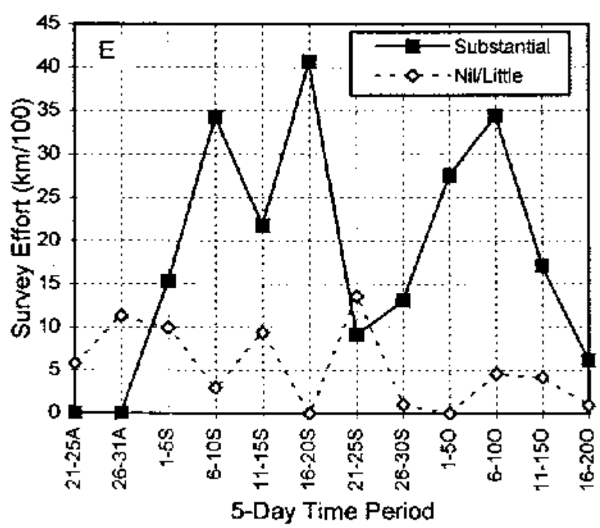


FIGURE 5.45. Seasonal pattern of bowheads in two light ice years with nil/little offshore industrial activity (1994-95) vs. five light ice years with substantial offshore industrial activity (1982, 1987, 1989, 1990, 1996), excluding periods of poor sightability. Otherwise plotted as in Fig. 5.44.