no survey effort during critical 5-day periods (Fig. 5.45E). No conclusions about effects of industrial activity on timing of bowhead migration can be drawn from these limited data.

Peak sighting rates/100 km were somewhat lower in light ice years with substantial industrial activity than in those with no or little industrial activity (2.4 vs. 3.8, respectively). However, peak numbers of individuals/100 km were similar (5.9 vs. 6.4).

It should be noted that some bowhead whales were apparently in the Northstar area before the first aerial survey by MMS on 2 September 1996. Bottom-mounted acoustic recorders (see Chapter 3) were tested seaward of Northstar during the 25-28 August 1996 period. Bowhead whale calls were detected during each of those four dates, with substantial numbers of calls being heard late on the 27$^{th}$ and on the 28$^{th}$. Bowheads were also seen within the general Northstar region (147°-150°30') as early as 28 August in 1995 (LGL and Greeneridge 1996) and 31 August in 1992 (Treacy 1993).

### *5.3.6 Bowhead Call Counts*

Bottom-mounted acoustic recorders operated simultaneously at sites offshore from Northstar and from Narwhal Island (45 km ESE of the Northstar recorder) from 31 August to 14 September 1996 (see Chapter 3). The recorders were near the 25 and 31 m depth contours, respectively. Both were in the zone that we define as being 20-25 km from the general trend of the shoreline (Fig. 5.7). The Northstar recorder was, in fact, 24 km offshore of the closest barrier island and 15 km from the closest part of the seismic exploration area. The Narwhal Island recorder was actually only 14 km north of that island (and 20 km ENE of Cross Isl.), but was in slightly deeper water than the Northstar recorder (Fig. 5.7).

Technicians at Greeneridge Sciences Inc. listened to the complete sequence of data from each recorder. They detected 6920 bowhead calls in the recordings from the Northstar recorder and 17,634 calls in the recordings from the Narwhal Island recorder during their 351 h of simultaneous operations on 31 August through 14 September 1996. (The Northstar recorder operated for one additional day, through 15 September, but the extra "unmatched" data from the Northstar recorder are not considered in this section.) The hourly call counts are plotted in relation to date and time in Figure 3.38 (Chapter 3).

The average call count per hour was 19.7 ± s.d. 29.8 off Northstar, vs. 50.2 ± s.d. 59.6 off Narwhal I. Of the 331 hours when call counts at the two sites differed, the count was higher near Narwhal I. on 235 occasions and higher off Northstar on 96 occasions. The difference was highly significant according to a Wilcoxon matched-pairs test on paired hourly counts (nominal $P<<0.001$). This test no doubt overstates the significance level, given that the counts in successive hours are autocorrelated. However, it is obvious that bowhead calls were much more commonly detected off Narwhal Island than off Northstar.

There must have been a real difference in the number of bowhead calls reaching the two recorders. Differences in background noise levels at the two sites cannot account for this:

- Seismic pulses were often detected by the Northstar recorder but were rarely detected (and weak) at the Narwhal Island recorder. However, the durations of the seismic pulses were <1 s at typical intervals of 15-18 s. During periods with seismic, less than 5% of the calls would have been simultaneous with seismic pulses. Masking cannot account for the much lower number of calls detected near Northstar than near Narwhal Island.
- Ambient noise levels were, on average, almost identical at the two sites (Chapter 3).

Bowhead sighting rates in the eastern and western parts of the Northstar area during previous years can be used to examine whether bowheads are normally more common in the eastern portion near Narwhal Island. The Northstar region was subdivided at 148°10', about 10 km east of the Northstar recorder's location (Fig. 5.7). We considered the zone 15-35 km from shore, i.e. from ~8 km inshore to 12 km offshore of the bottom recorder locations. In 1994-95, light ice years without much offshore industrial activity, bowheads were seen more commonly in the west than the east zone: 3.74 vs. 1.96 individuals/100 km. In the 1979-95 period as a whole, bowhead densities in the two zones were similar: 0.48 indiv./100 km in the west vs. 0.54 indiv./100 km in the east. Thus, sighting data from aerial surveys in prior years do not provide any basis for expecting a higher number of bowheads, and a higher call count, near the Narwhal Island recorder (east) than near the Northstar recorder (west).

The number of calls detectable per hour near Northstar was lower during hours when seismic pulses were detectable at that location (avg 12.6 calls/h, n=174) than when not detectable (avg 26.8 calls/h, n=177). If the hourly counts are treated as independent, this difference is highly significant (Mann-Whitney test, nominal $P<0.001$). A randomization test taking the autocorrelation structure into account also showed a significant decrease in calls with seismic pulses ($P<0.02$, N.S. Altman, Biometrics Unit, Cornell Univ., pers. comm.).

To help assess whether the above difference was attributable to the seismic sounds or to some other factor, it is useful to examine the relationship between the Northstar and the Narwhal Island counts during times with and without seismic. The number of calls detectable per hour was significantly lower near Northstar than near Narwhal Island in the absence of seismic as well as in the presence of seismic (nominal $P<0.001$ in each case; Wilcoxon matched-pairs tests). However, the Northstar/Narwhal difference in the number of calls per hour tended to be substantially greater with seismic than without seismic[7]:

| | Northstar | Narwhal | Hours |
|---|---|---|---|
| Seismic heard: | 12.6 ± s.d. 24.4 | 56.2 ± s.d. 67.9 | n=174 |
| No Seismic heard: | 26.8 ± s.d. 32.8 | 44.4 ± s.d. 49.7 | n=177 |

[7] The above results are based on call data from the 31 Aug. through 14 Sep. period. We wondered whether the lower average call counts near Northstar might have been caused by including data from the start of the bowhead migration season, before the vanguard of bowheads may have reached the Northstar area (*cf.* Fig. 3.38). However, the Northstar call counts again averaged higher without seismic than with seismic when we considered only the data from 3 to 14 Sep. (avg. 32.5 calls/h without seismic, n=143 hours; avg 15.3 calls/h with seismic, n=136 hours).

A simple (but not very powerful) way to examine these data is with a sign test. With audible seismic pulses off Northstar, the Northstar count exceeded the Narwhal count during only 37 of 174 hours (21%). Without seismic pulses off Northstar, the Northstar count exceeded the Narwhal count during 59 of 177 hours (33%). Assuming independence of hourly counts, this difference is significant ($\chi^2$=5.84, df=1, nominal P<0.05).

There was a weak overall positive correlation between the hourly call counts at the two sites (Spearman rank correlation 0.190, n=351). This trend was statistically significant if the hourly counts are assumed to be independent (nominal P<0.001). This trend was almost entirely attributable to hours without seismic, when the Spearman correlation was 0.353 (n=177, nominal P<0.001; see Fig. 5.46A). During hours with seismic, there was no obvious correlation between call counts at the two sites ($r_s$=0.061, n=174, nominal P>0.2; Fig. 5.46B). Inspection of Figure 5.46A vs. 5.46B confirms that the Northstar/Narwhal ratio tended to be lower with seismic than without seismic. Note the higher proportion of the hourly points below the diagonal in Fig. 5.46B than in Fig. 5.46A. Also note that the number of hours with no detectable calls at Northstar but some calls at Narwhal was much higher when seismic pulses were audible near Northstar.

In summary, the number of bowhead calls detectable per hour near Northstar was lower during hours when seismic pulses were detectable on the Northstar recorder. This was true both overall and relative to the paired Narwhal Island count. Ensonification of waters near Northstar by seismic sounds apparently had one or both of the following effects: it reduced the number of calls emitted by an average bowhead per hour, and/or reduced the number of bowheads within a several kilometer distance of the recording unit off Northstar.

Previous studies have shown that bowhead whales often continue to emit their usual repertoire of call types when exposed to seismic pulses. However, calling rate may tend to somewhat lower in the presence of seismic pulses (Richardson et al. 1986; Koski and Johnson 1987:114). Thus, the reduced numbers of calls heard during periods of seismic in this study might represent a change in the rate of calling by individual bowheads exposed to seismic sounds. However, it might also represent a reduction in the number of bowheads present nearby, or some combination of the two.

### *5.3.7 Sounds Received Near Bowheads*

LGL's aerial observers obtained nine bowhead sightings, each involving a single bowhead, at times when seismic exploration was underway with a partial array (2 sightings) or full array (7 sightings; Fig. 5.23). These sightings were made on 9, 10, 15, 17 and 18 September. On 9 September the only sighting was 74 km east of the seismic activities (Fig. 5.13), and no measurements of sounds received near the whale were obtained. On each of the other four days, a sonobuoy was dropped near the bowhead that was seen closest to the seismic activities on that date (ranges 25-66 km). In total six sonobuoys were dropped near bowheads at ranges 25-66 km from the seismic boat while either "full array" or "partial array" seismic was being conducted.

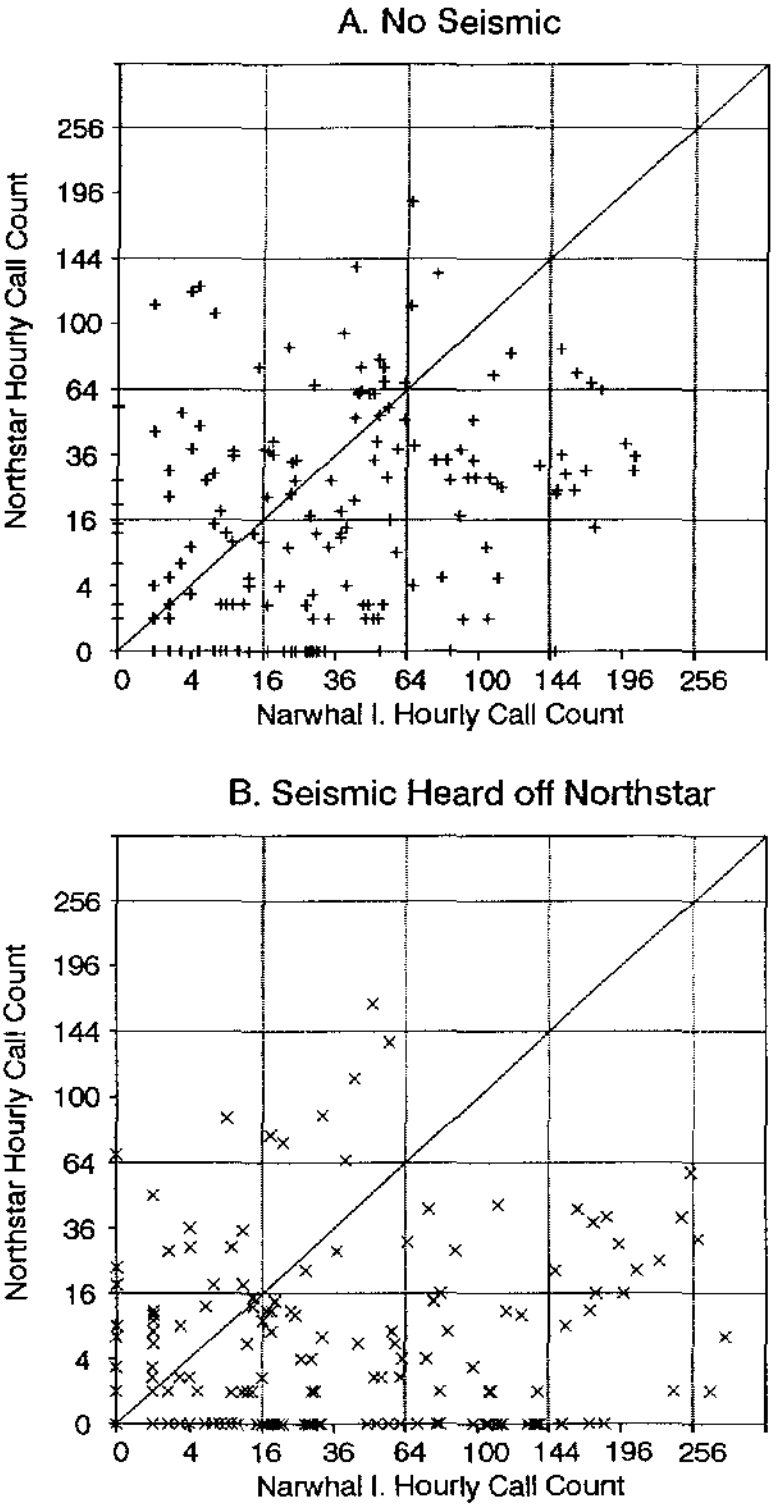


FIGURE 5.46. Number of bowhead calls detected per hour by bottom-mounted acoustic recorders off Northstar vs. Narwhal Isl. during hours when seismic pulses *(A)* were not detectable and *(B)* were detectable off Northstar (square root transformed). Paired hourly call counts were obtained from 31 Aug. to 14 Sep. 1996. Points above and below diagonal represent hours when Northstar call count was more and less, respectively, than the Narwhal count.

Seismic sounds were undetectable or barely detectable near four of these whales. Those four whales were 27-66 km from the seismic source vessel.

The strongest sound pulses received near any of these six bowheads were recorded near two whales seen on 10 and 15 September. On 10 September, peak and mean levels of seismic pulses near a whale 24-28 km NE of the "full array" (Fig. 5.14) were 120-122 and 109-114 dB re 1 µPa, respectively. On 15 September, peak and mean levels of seismic pulses near a whale 41-42 km WNW of the "partial array" (Fig. 5.17) were 119-121 and 101-102 dB re 1 µPa, respectively.

Thus, the strongest seismic pulses measured near bowheads observed during this project had peak levels near 122 dB and rms levels near 114 dB re 1 µPa. Levels received in the bowhead migration corridor vary as the seismic boat moves back and forth along its 7.3-km source lines from shallower to deeper water and back to shallow water. Also, some of the bowheads presumably were not at their closest points of approach to the seismic operation at the times when we sighted them. Thus, we probably did not record the strongest sounds received by the bowheads that were sighted during this project.

Figure 5.47 shows the estimated rms (= "mean square") levels of seismic pulses as they would be received at various distances directly offshore from Northstar, assuming that the full array was operating 10 km from shore (i.e. near the northern edge of the area of seismic operations during 1996). The estimated received level curves in this graph are the same as the "good propagation", "typical propagation" and "poor propagation" curves in Figure 3.35 (Chapter 3), but plotted on a linear rather than a logarithmic distance scale, and plotted with respect to a source located 10 km offshore. Also shown on Figure 5.47 are the 5th, 50th and 95th percentile ambient noise levels in the 50-400 Hz band (again from Fig. 3.35). The 50-400 Hz band contains most of the pulse energy as received at long range.

The distances offshore at which the three received level curves drop below these ambient noise levels are the approximate distances out to which bowhead whales should be able to hear the seismic pulses under various conditions of sound propagation and ambient noise. With poor, typical and good propagation, the received pulse levels are expected to drop below the median ambient level at ranges of 32, 46 and 68 km offshore if the airgun array is 10 km offshore. At a time with low ambient noise, the corresponding distances could be on the order of 52-108 km. At a time with high ambient noise, these distances could be on the order of 27-56 km. It is emphasized that these are the estimated distances offshore at which the seismic pulses would change from faintly audible to inaudible.

Available data indicate that bowheads usually do not react overtly (if at all) to the weak pulses received at such long distances. However, during one prior study, there was evidence of subtle but replicable effects on surfacing-respiration-dive cycles at distances up to 54-73 km (Richardson et al. 1986). In that study, some seismic sources were more powerful and were operating in deeper water. In addition, single cases of possible seismic-related changes in behavior have been observed or suspected at even longer distances (Reeves et al. 1983:24; Koski and Johnson 1987:114). Given the natural variability in bowhead behavior, it is impos-

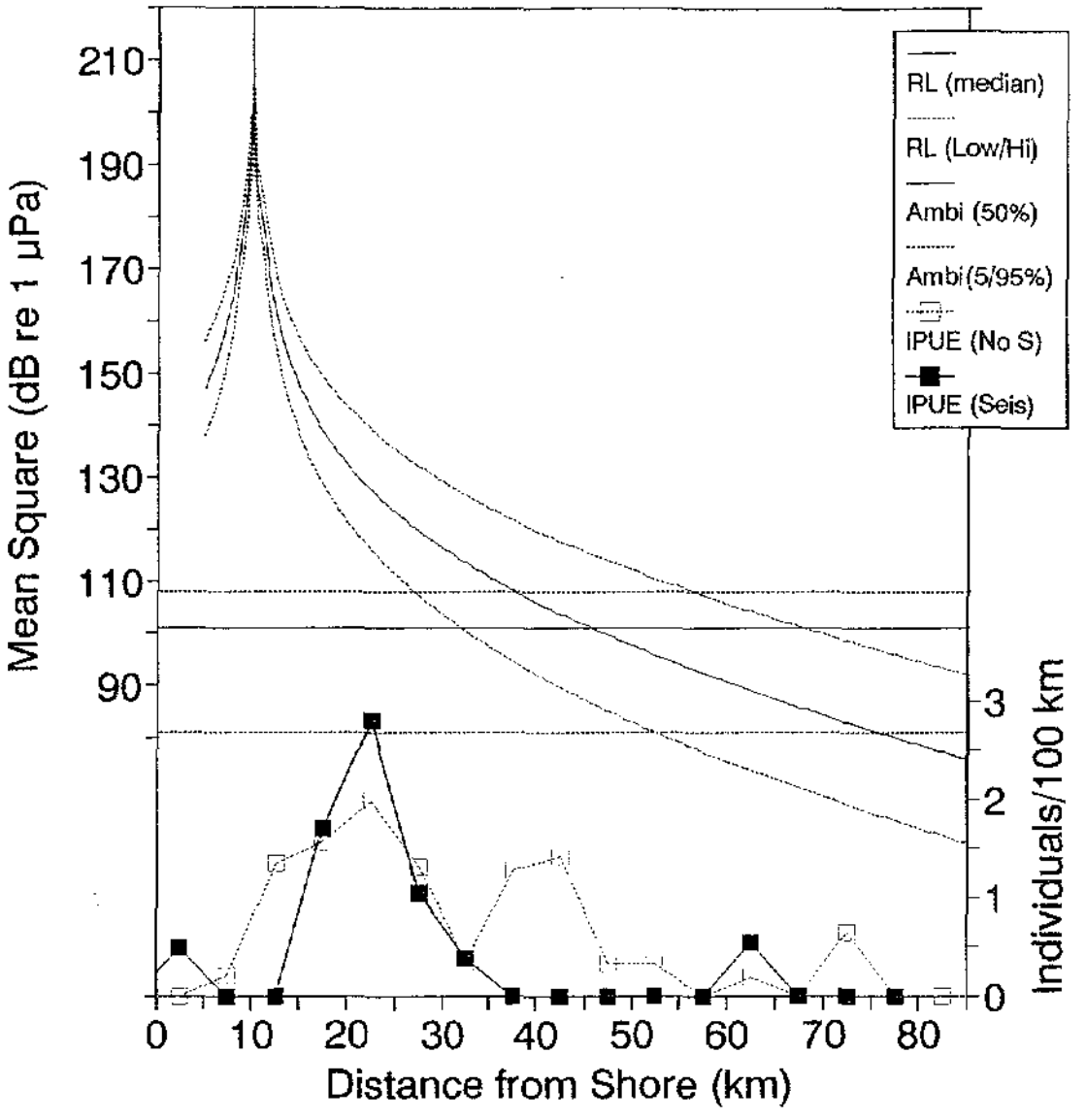


FIGURE 5.47. Estimated received levels of seismic pulses in the bowhead migration corridor when the full 11-airgun array was operating 10 km offshore. Red curves show the expected range of received levels vs. distance from shore; blue horizontal lines show the expected range of ambient noise levels (50-400 Hz band; from Fig. 3.35). Curves at the bottom, adapted from Fig. 5.28D, show relative numbers of bowhead whales sighted in various 5-km-from-shore categories at times during 1996 with and without seismic (filled and open squares, respectively).

sible to know whether any one such case represents a real reaction to seismic. Replicated observations are needed.

The curves near the bottom of Figure 5.47 show the number of bowheads seen per 100 km of aerial surveys within each 5-km distance from shore band, including observations under poor sightability conditions. These are the same data as shown in Figure 5.28D, but plotted by 5-km rather than 10-km intervals. Periods potentially affected by seismic (including 3.5-h post-seismic period) and not potentially affected by seismic are distinguished. As noted previously, there was a possible seaward displacement during seismic periods, but the sample size was small. In any case, most bowheads passing Northstar during "seismic" periods were 15-30 km offshore. With a seismic vessel operating 10 km from shore, received pulse levels 15-30 km offshore would be above ambient levels for most combinations of distance from shore (out to 30 km), propagation conditions, and ambient noise level. The only exceptions would be whales that passed Northstar 27+ km offshore at times with poor propagation and high ambient noise (Fig. 5.47). They might not have been able to hear the pulses.

Whales traveling west 15 km offshore could have been exposed to rms pulse levels approaching (but not exceeding) 160 dB re 1 µPa if they passed that area when the airgun array was operating near the northern edge of the seismic operations area (10-11 km offshore). Whales traveling west <15 km offshore could have been exposed to levels ≥160 dB if the animals did not deflect away from the seismic vessel. As shown by the bottom curves in Figure 5.47, some bowheads were seen <15 km from shore without seismic but (with one exception)[8] not with seismic. Note that rms levels as used here (averaging over the pulse duration) are about 10 dB lower than the peak levels normally referenced by geophysicists.

### *5.3.8 Estimated Bowhead "Take by Harassment"*

In the following analyses we have assumed that the received rms pulse levels from the seismic source could be as high as 180 dB re 1 µPa at distances as great as 1 km (Chapter 3). Also, it is assumed that received levels may exceed 160 dB re 1 µPa out to a maximum radius of 4.9 km. On average, however, the rms pulse levels are expected to diminish below 160 dB re 1 µPa at a radius of ~3.6 km from the source (Chapter 3).

***180 dB Criterion.***—NMFS (1995) concluded that noise pulses from a nearby seismic vessel might affect the hearing abilities of baleen whales if received levels exceed 180 dB re 1 µPa. Given this assumption, the Incidental Harassment Authorization (as modified on 6 Sep. 1996) called for immediate shutdown if cetaceans were detected within 750 m during operation of the airgun array, or within 650 m during operation of a single airgun. Subsequent analysis has shown that received levels were, at times, 180 dB re 1 µPa or more at radii as great as 1 km. In fact, no bowhead whales were seen by the marine mammal observers

[8] One bowhead was seen in the zone we classify as 0-5 km from the "general trend of the shoreline" during a period with partial-array seismic on 15 Sep. 1996 (Fig. 5.17; Table 5.3). This whale was 42 km WNW of the seismic vessel at the time. Its CPA to the operating seismic vessel is unknown.

or other personnel based on the seismic source vessel. The observers were on duty and watching for marine mammals at all hours when airgun operations were underway, for at least 30 min before all planned startups of the airguns, and at some times with no airgun operations. Also, aircraft-based observers saw no bowheads within 20 km of the operating source vessel (Table 5.3; Fig. 5.39).

It is recognized that some bowheads might have been present near the source vessel during periods of darkness or poor visibility, or below the surface. However, bowheads tend to avoid the immediate vicinity of operating seismic vessels (Richardson et al. 1986; Ljungblad et al. 1988). Thus, it is unlikely that any bowheads occurred within 1 km of BPXA's operating seismic vessel. It is also assumed that any bowheads present near the inactive vessel during poor visibility conditions would move away if a single airgun started and then additional airguns began to operate during a "ramp-up" toward full-array operation.

Thus, no bowheads (or other cetaceans) were seen within the 750 m "shutdown radius", or within the somewhat larger 1 km "maximum 180 dB radius", at any time during the Northstar seismic program. It is unlikely that there were unseen bowheads within 1 km of the operating source vessel.

***160 dB Criterion.***—Recent NMFS practice involving impulsive sounds such as seismic has been to assume that a "take by harassment" may occur if baleen whales are exposed to received levels of pulsed sounds that exceed 160 dB re 1 µPa. Takes of this type involve avoidance and short-term changes in behavior that occur at distances well beyond those where there is any likelihood of injury to the whales (NMFS 1995; Richardson et al. 1995: 372*ff*).

*No Direct Evidence of "Take":* The sonobuoy data discussed above showed that none of the bowhead whales seen by the aerial observers were within or near the areas where they might have been exposed to seismic pulses with received levels ≥160 dB re 1 µPa. However, the aerial observers saw only a very small percentage of the total number of bowheads that migrate west past the Northstar region during late summer and autumn. Thus, the lack of observations of bowheads exposed to ≥160 dB seismic pulses does not justify an assumption that no bowheads were exposed to strong seismic pulses.

*Bowheads Within 15 km of Shore:* The Bering/Chukchi/Beaufort Sea stock of the bowhead whale is currently estimated to contain about **8000 animals** (Zeh et al. 1995; Small and DeMaster 1995). For purposes of estimating take we will assume that all of these whales migrate west either north of or through the Northstar seismic exploration area.

Based on the acoustic measurements obtained during this study, rms received levels of seismic pulses would be ≥160 dB re 1 µPa at distances as great as 3.6 km from the source vessel on average, and as great as 4.9 km at the maximum (Chapter 3). The following assessment assumes that received levels exceeded 160 dB out to a radius of 4 km.

The source vessel conducted seismic surveys ≤11 km north of the "0-km line" shown in Fig. 5.7. Thus, whales that were more than ~15 km offshore relative to the "0-km line" (Fig. 5.7) when passing the operating source vessel would not have been exposed to seismic sounds that exceeded 160 dB re 1 µPa. During 1996 transect surveys with good sightability, 4 of the 65 individual bowheads seen (6.2%) were inshore of the 15-km line shown in Fig. 5.7, and therefore *might* have been exposed to sounds that could elicit short-term changes in behavior (Fig. 5.48C). When the differing amounts of survey effort at different distances offshore (Fig. 5.35B) were taken into account, the percentage of individual bowheads that occurred within 15 km of shore in 1996 is estimated as **7.0%** (Fig. 5.48D).

For several reasons, this 7.0% figure greatly overestimates the percentage of the bowhead population that could have been exposed to 160 dB sounds:

- This percentage does not take into account the bowheads that migrate west through offshore waters, farther north than the northern extent of survey coverage at 71°12.5'.
- Many bowheads migrate past Northstar after the 18 September termination of the 1996 seismic program.
- There were no airgun operations during many of the hours prior to 18 September

Additional complications are that

- this percentage is based on a small number of sightings, and
- if bowheads are displaced offshore by seismic work in nearshore waters, this figure might *under*estimate the percentage of bowheads that would have occurred inshore of the 15-km line in the absence of seismic exploration.

The proportion of bowheads migrating inshore of the 15-km line in years other than 1996 may provide a better basis for estimating the numbers that might have been exposed to seismic pulses with received levels ≥160 dB re 1 µPa in 1996. For this purpose we used the 1994-95 period, which had similar ice conditions to those in 1996, but little or no offshore industrial activity in the Northstar region. During the 1994-95 period none (**0.0%**) of the 67 individuals seen during systematic transect surveys by MMS and LGL in the 147°-150°30'W area were inshore of the 15-km line (Fig. 5.48C).

*Proportion of Bowheads Passing by 18 September:* The proportion of bowheads passing the longitude of Northstar up to 18 September (the date when 1996 seismic exploration ended) was estimated based on the MMS survey data from 1996. Their surveys extended from 1 September to 9 October. Some whales probably passed Northstar before 1 September: MMS and LGL surveyors saw numerous bowheads in the survey area during the initial 1996 surveys on 2-3 September, and bottom-mounted acoustic recorders seaward of Northstar detected bowhead calls during late August 1996. Also, the migration probably continued after 9 October. Substantial numbers of bowheads were present along the Yukon coast as late as mid-October 1985 (Evans and Holdsworth 1986), the only year when surveys have been conducted that late in Canadian waters. In prior years, some bowheads have been seen in the present study area during mid-late October. In any event, 12 of 29 (**41.4%**) of MMS's 1996

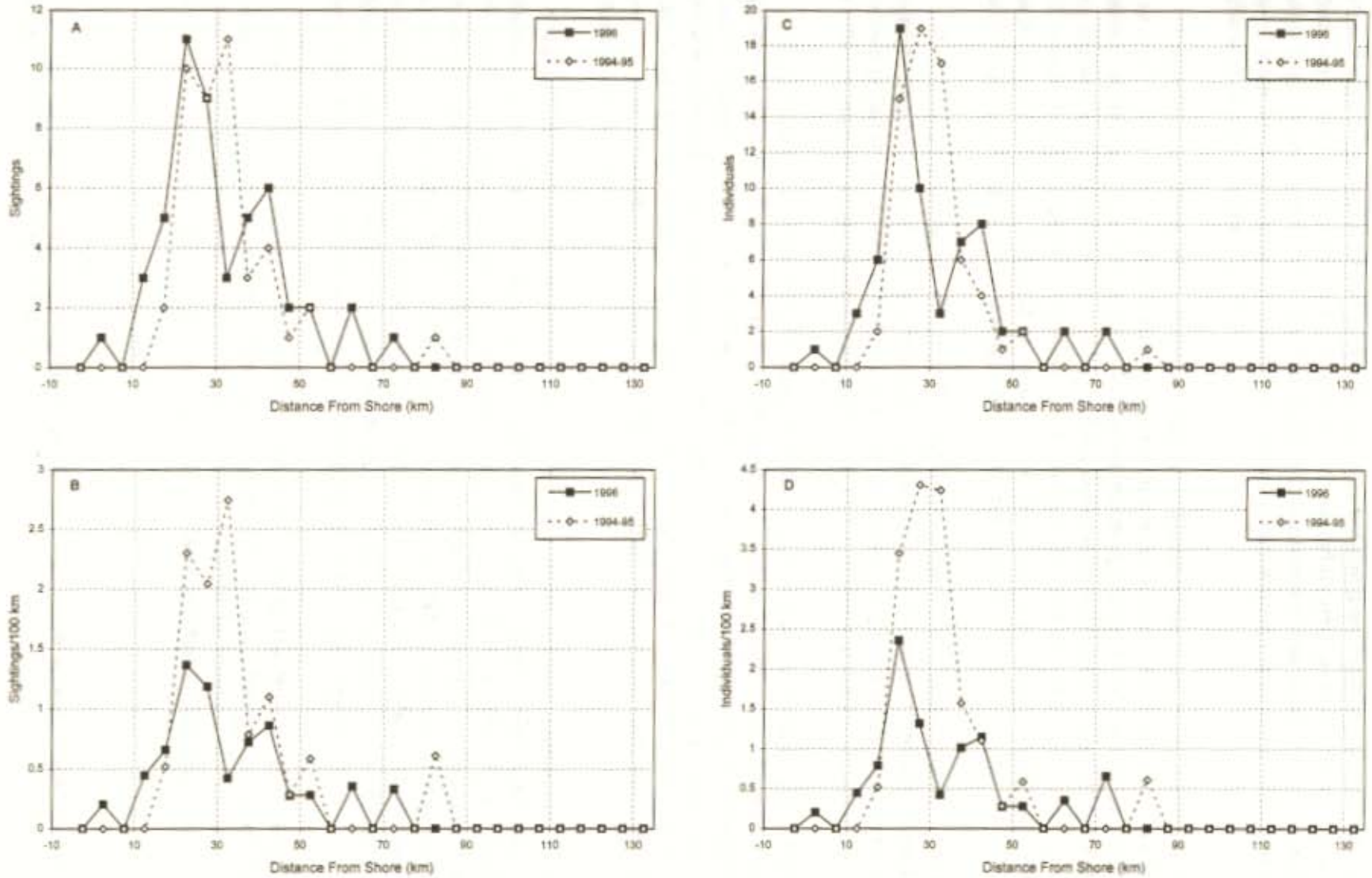


FIGURE 5.48. Distributions of bowheads by 5-km distance-from-shore intervals during late summer/autumn of 1996 vs. 1994-95 (light ice years with nil/little industrial activity), excluding periods of poor sightability. See Fig. 5.35B for survey effort vs. distance from shore, and Fig. 5.36 for the same data plotted by 10-km intervals. Otherwise as in Fig. 5.28.

bowhead sightings in the 146°-151°W region were obtained on dates up to 18 September, the period when seismic was being conducted. If we arbitrarily assume that the number of whales that passed prior to the first survey on 2 September was similar to the number that passed after the last survey on 9 October, then we can assume that about 41% passed prior to the end of seismic operations.

*Proportion of Time With Seismic Surveys:* During the 1-18 September 1996 period, there were 168 h when seismic survey operations were being conducted and 264 h with no seismic operations. The 168 h includes times when operations with a full or partial array were underway.[9] Thus, strong seismic pulses were being produced during only **38.9%** of the 1-18 September 1996 period. Furthermore, during ~56 h of the 168 h, only a partial array was in use, and the 160 dB radius would have been less than 4 km. Thus, the number of whales that might have been taken is again overestimated.

*Proportion of Bowheads Passing During Seismic Surveys:* Combining the factors in the two preceding paragraphs, it is estimated that, up to 18 September 1996, about **16.1%** of the bowhead population moved westward past the Northstar seismic survey area during periods with full or partial array seismic operations (0.414 × 0.389 × 100%).

*"Worst Case" Estimate of Take:* Based on this approach and considering the 1996 survey data, the "worst-case" estimate is that 90 bowhead whales might have encountered seismic pulses as strong as 160 dB re 1 µPa and so could be considered "taken by harassment". This estimate is based on a population size of 8000 whales x 0.0701 for the proportion inshore of 15-km line x 0.161 for the proportion passing during periods with airgun array operations). Based on the 1994-95 survey data, the corresponding "worst case" estimate is 0 bowhead whales (8000 × 0.0 × 0.161).

*Allowance for Source Boat's Variable Distance From Shore:* These are "worst case" estimates in that they assume that any bowhead inshore of the "15-km line" while seismic work was underway was exposed to seismic pulses ≥160 dB re 1 µPa. This would require that the seismic vessel always be operating about 11 km from shore. In fact, of the area shot during 1-18 September 1996, 70% was <6 km offshore. When the vessel was operating <6 km from shore, received sound levels would be <160 db re 1 µPa at distances >10 km offshore. Thus, the numbers of bowheads exposed to pulses with received levels ≥160 dB were undoubtedly much lower than suggested by the previous paragraph.

The estimates can be made more realistic by making the following assumptions: (1) During the 30% of the time that the vessel operated 6-11 km offshore, some of the whales within 15 km of shore (mostly 10-15 km offshore) would be exposed to levels ≥160 dB re 1 µPa. (2) During the 70% of the time that the vessel operated <6 km from shore, only the

[9] The 168 h excludes an additional 9 h of operations with a single airgun, when the 160 dB radius was much less than 3 km (Chapter 3).

very few whales that might occur within 10 km from shore could be exposed to ≥160 dB levels.

1. During the 30% of the operating time when (1) would apply, the estimated "take by harassment" would be 27 based on the bowhead distribution observed in 1996, and 0 based on the bowhead distribution observed in 1994-95. (These values are 30% of the "worst case" estimates, 90 and 0, derived previously.)

2. To estimate take during the 70% of the operating time when (2) would apply, we need to consider the percentage of the individual whales that migrate within 10 km of shore. This was estimated as **2.20%** based on the 1996 surveys (allowing for varying survey effort at different distances offshore) and **0.0%** based on the 1994-95 surveys (Fig. 5.48D). The total numbers of bowheads passing within 10 km of shore when airguns were operating within 6 km of shore would be ~20 based on the 1996 data (8000 x 0.0220 x 0.161 x 0.70), and 0 based on the 1994-95 data (8000 x 0.0 x 0.161 x 0.70).

*Combining (1) and (2), the take estimates based on the "160 dB re 1 µPa criterion" are 47 bowheads based on the distribution observed in 1996 and 0 bowheads based on the sample from light ice years with little offshore industrial activity (1994-95). The latter figure (0) is no doubt an underestimate,* as a few bowheads do occur within 15 km of shore in certain years. However, the former figure (47) is an overestimate: it effectively assumes that the seismic boat was operating 6 km from shore whenever it was ≤6 km offshore (70% of the operating hours), and that it was operating about 11 km from shore whenever it was more than 6 km offshore (30% of the operating hours).

Further refinements in the estimates could be made by examining both the bowhead sightings and the seismic survey activities on a finer spatial scale. Allowance could also be made for the fact that the seismic signals undoubtedly attenuate more rapidly when the vessel is in shallow water than when it is in deeper water. However, it does not seem appropriate or necessary to incorporate further levels of refinement and complexity into the estimation process, given

- the many assumptions that are inevitably involved,
- the very small sample sizes for sightings in nearshore waters,
- the fact that the estimated take is already small, and
- the fact that the type of "taking" being discussed is avoidance and short-term behavioral changes with no known long-term consequences to the animals.

***Displacement Criterion.***—Bowheads whose migration corridor is deflected offshore by a seismic program in nearshore waters could be considered to be disturbed or "taken by harassment". The 1996 Northstar monitoring program found hints of possible offshore displacement of some bowheads during periods of active seismic exploration. The proportion of the bowheads traveling within 20 km of shore was apparently lower during seismic periods (Fig. 5.28). More data are needed to confirm whether this apparent effect was actually caused by the seismic vessel. However, it is instructive to estimate the number of bowheads

that might have been "taken by harassment" if bowheads migrating past Northstar within 20 km of shore actually were displaced or otherwise disturbed by the seismic.

Based on 1996 aerial survey results from times without seismic exploration, 19 of 64 (29.7%) individuals seen were within 20 km from shore (Fig. 5.28C). Allowing for varying survey effort at different distances from shore, it was estimated that ~33.5% of the individual bowheads passing through the surveyed area without seismic were <20 km from shore (Fig. 5.28D). During 1994-95, 2 of 68 (2.9%) individual bowheads seen were shoreward of the 20 km line. Corrected for variable survey effort at different distances from shore, ~3.1% of the individual bowheads migrating through the surveyed area were within 20 km of shore during 1994-95 (5.47C,D).

The factors derived earlier for proportions of bowheads passing Northstar by 18 September (**0.414**) and during times with active airguns (**0.389**) apply here as well. Therefore, we estimate that, in 1996, 5.4% of the bowhead population (0.414 × 0.389 × 0.335) would have passed within 20 km of the northern edge of the exploration area while the airguns were in operation if there were no deflection. The comparable estimate based on 1994-95 data is 0.5% (0.414 × 0.389 × 0.03). Applying these proportions to the total estimated number of bowheads (8000) passing through or north of the Northstar area results in estimates of about 430 and 40 bowheads that might have been disturbed by seismic operations, based on 1996 and 1994-95 data, respectively. Of these, the estimated numbers exposed to rms sound levels ≥160 dB re 1 μPa were <47 based on 1996 data and 0 based on 1994-95 data.

***20 Nautical Mile Criterion.***—During a meeting in Seattle on 21 May 1996, a review team requested that one of the objectives of the Northstar monitoring study be to estimate the proportion of the bowhead whales that migrate past the Northstar study site within 20 n.mi. of the northern edge of the site when the airguns are in operation. The northern edge of the exploration area was 11 km offshore, and 20 n.mi. (37 km) beyond that would be 48 km offshore. We rounded this off to 50 km to correspond to one of the 5-km distance from shore categories used in this analysis (Fig. 5.7).

We include the "20 n.mi. estimate" in this section as it is closely related to the previous "take" estimates. There is some evidence that, in summer, seismic vessels may have subtle effects on surfacing, respiration and dive cycles of bowheads at distances exceeding 20 n.mi. (37 km) (Richardson et al. 1986). Also, Inupiat whalers believe that migrating bowheads can be "displaced from their normal migratory path by as much as 30 miles" (Kanayurak et al. 1997). However, the 1996 Northstar data provide no indication that disturbance responses extended as much as 20 n.mi. (37 km) from the operating seismic vessel.

Based on 1996 data, 59 of 65 (90.8%) individuals seen were within 50 km from shore (Fig. 5.48C). Allowing for varying survey effort at different distances from shore, ~86.1% of the individual bowheads passing through the surveyed area were <50 km from shore (Fig. 5.48D). During 1994-95, 64 of 67 (95.5%) individual bowheads seen were shoreward of the

50 km line. Corrected for variable survey effort, ~92.8% of the individual bowheads migrating through the surveyed area were within 50 km of shore during 1994-95 (5.47C,D).

The factors derived earlier for proportions of bowheads passing Northstar by 18 September (**0.414**) and during times with active airguns (**0.389**) apply here as well. Therefore, we estimate that, in 1996, 13.9% of the bowhead population (0.414 × 0.389 × 0.861) passed within 20 n.mi. of the northern edge of the exploration area while the airguns were in operation. The comparable estimate based on 1994-95 data is 14.9% (0.414 × 0.389 × 0.928). Applying these proportions to the total estimated number of bowheads (8000) passing through or north of the Northstar area gives estimates of ~1100 and 1200 bowheads migrating shoreward of the 50 km line during periods of seismic operation, based on 1996 and 1994-95 data, respectively.

The percentages and numbers quoted above are presumably overestimated to a minor degree. They assume that all bowheads travel west within the area sampled by BPXA/LGL and MMS aerial surveys, which were mainly within 85 km of shore during 1996 (Fig. 5.6A). In prior years MMS has conducted more surveys of waters >85 km offshore of Northstar (Fig. 5.6B). The earlier surveys, summarized in LGL and Greeneridge (1996), show that a small proportion of bowheads occur farther north than the northernmost 1996 sighting. If 10% of the bowheads occur in those offshore waters, then the number within 20 n.mi. of the northern edge of the seismic exploration area during periods of 1996 with airgun operations may have been ~1000-1100 rather than 1100-1200.

A substantial but unknown proportion of the estimated 1000-1200 bowheads passing within 20 n.mi. of the Northstar area during times with seismic operations were exposed to seismic pulses with rms received levels below 160 dB re 1 µPa but high enough to be detectable. As discussed earlier, the number exposed to levels ≥160 dB was estimated as less than 47 bowheads. To obtain realistic estimates of the proportions of the bowhead population exposed to various other levels, e.g. 150, 140, 130 and 120 dB, it would be necessary to take account of the proportion of the time that the seismic vessel was operating in various water depths and detailed information about long-distance seaward propagation of seismic sounds in relation to source depth. By taking the available ambient noise data (Chapter 3) into account, these received level estimates could be converted to estimates of the proportion of the bowhead population exposed to seismic pulses stronger than ambient noise and presumably audible, >10 dB above ambient, >20 dB above ambient, etc. These types of analysis were beyond the scope of the present project.

***Summary of Estimated "Take by Harassment".***—(1) The best estimate of the number of bowheads exposed to seismic pulses at received levels ≥180 dB re 1 µPa was zero. (2) All observed bowheads were in areas where received levels of the pulses (rms measurement method) were well below 160 dB re 1 µPa. (3) Based on the distance-from-shore distributions of all bowheads seen in 1996 and earlier years, a small number of bowheads would be expected either to occur within the 160 dB radius around the seismic source vessel or to exhibit avoidance of that area. (4) Estimates of the numbers of bowheads that might occur within the 160 dB radius at some time during the late summer/autumn period are <47 bow-

heads (based on 1996 data) and 0 bowheads (1994-95 data), i.e. <0.6% and 0.0% of the population. (5) The small numbers expected to be "taken" in this way are likely to exhibit displacement and short-term behavioral changes, but no long-term effects on individuals or the population are expected. (6) Bowheads that would have migrated within 20 km of shore in the absence of seismic may have been displaced or otherwise disturbed during periods with seismic. If so, as many as 400 bowheads (based on 1996 data only) or 40 bowheads (considering 1994-95 data) may have been affected in these ways.

On the order of 1000-1200 bowheads may have moved west within 20 n.mi. of the northern edge of the seismic exploration area during times when airguns were operating. Many of these whales would have been exposed to seismic pulses, but this study provided no evidence that disturbance effects or "take" extended 20 n.mi. offshore of the seismic exploration area. Inupiat hunters believe that migrating bowheads can be "displaced from their normal migratory path by as much as 30 miles", and previous behavioral studies suggest that subtle behavioral effects may sometimes extend to 20+ n.mi. from seismic vessels.

All of the above estimates are imprecise given the small numbers of bowhead sightings in 1996 and in 1994-95, the two "control" years with similar ice conditions and little industrial activity, and other limitations of the data. 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.

A general "Summary and Conclusions" section concerning bowheads and other cetacean species appears as §5.6 of this Chapter.

## *5.4 Gray Whale*

The Eastern North Pacific stock of gray whales has recovered significantly over the past several decades; based on 1993-94 counts, this stock consists of about 23,100 individuals (Small and DeMaster 1995). This stock is not considered a strategic stock and it was recently (1994) removed from the List of Endangered and Threatened Wildlife. Most of these gray whales spend the summer on feeding grounds in the northern Bering and southern Chukchi seas, with significant numbers occurring northeast to Point Barrow (Clarke et al. 1989).

Gray whales are rare in the Beaufort Sea, but occasional sightings have been recorded. Maher (1960) listed records at Foggy Island, the mouth of the Shaviovik River, Flaxman Island, and Barter Island. A few single gray whales have been seen as far east as the Canadian Beaufort Sea (Rugh and Fraker 1981; W.J. Richardson, unpubl. data). These records indicate that small numbers must travel through Alaskan Beaufort waters during summer and autumn in some years. A single gray whale was reported taken by hunters at Cross Island in 1933 (Maher 1960).

A single dead gray whale was sighted by MMS on 3 September 1988 in Mikkelsen Bay near Tigvariak Island, about 60 km southeast of the eastern edge of the Northstar seismic

area (Treacy 1989). No other gray whales were sighted by MMS or LGL in the Northstar region during aerial surveys conducted within the 17 year period from 1979 to 1995 (LGL and Greeneridge 1996).

During 1996, no gray whales are known to have occurred in the Northstar region. None were seen by aerial or boat-based observers during the 1996 Northstar monitoring program. None were seen during MMS's aerial surveys in the Northstar area.

The reaction thresholds of gray whales to seismic noise are similar to those of bowheads (Malme et al. 1984, 1988; Richardson et al. 1995:293*ff*). Given the historical rarity of the species in the Northstar region and the lack of sightings during 1996, it is highly unlikely that any gray whales were exposed to strong noise pulses from the 1996 Northstar seismic exploration program. Therefore, the estimated "take by harassment" during the 1996 Northstar seismic program is zero.

## *5.5 Beluga Whale*

### *5.5.1 Survey Effort and Sightings, 1996*

***LGL and MMS Aerial Surveys, 1996.***—BPXA/LGL aerial surveys were conducted on 14 days during the 1-21 September study period. Substantial coverage of the survey transects was obtained on 9 of these days (Table 5.2). On 13 days during the late summer and autumn of 1996 (1 Sep.-9 Oct.), MMS conducted transect surveys in one or more of their survey blocks 1, 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. BPXA/LGL and MMS beluga sightings during the 1 September-9 October period are mapped in Figure 5.49. A total of 88 beluga sightings and 436 individuals were recorded within the central Alaskan Beaufort Sea (146°-151°W).

Only 43 (49%) of the sightings and 152 (35%) of the individuals observed were "Transect" sightings within the Northstar area (147°-150°30'W). Most of the sightings were near or beyond the north ends of the BPXA/LGL extensive survey lines in water depths >100 m (Fig. 5.49). No belugas were seen within the Northstar seismic area in 1996. However, two groups totalling 6 whales were seen close to shore (water depth about 12 m) west of the Northstar area on 19 September, and may have passed through that area. There were only three sightings within 50 km of the seismic area (Fig. 5.49); all of those were on occasions without seismic exploration.

***LGL and MMS Aerial Surveys, 1979-95.***—The distributions of beluga sightings during 1996 and 1979-95 were similar (Fig. 5.49 vs. 5.50). The 1979-95 period included years with widely varying ice conditions and levels of offshore industrial activity. Therefore, the pooled 1979-95 data are not entirely comparable to those from 1996—a light-to-moderate ice year with a nearshore seismic program. However, the sightings from the 1979-95 period demonstrate that the autumn migration of the beluga through the central Alaskan Beaufort Sea consistently occurs well offshore, largely beyond the northern ends of the BPXA/LGL survey

transects. Most sightings in 1979-95, like most of those in 1996, were in deep offshore waters beyond the 100 m depth contour. Even so, the offshore nature of beluga distribution is undoubtedly understated by the distributions mapped in Figures 5.50 and especially 5.48 because survey effort was limited far offshore, especially in 1996 (Fig. 5.6). Many beluga sightings in prior years were north of 71°20' (MMS survey block 10), even though aerial survey coverage there was very limited.

The only sightings in the immediate Northstar area during MMS and LGL aerial surveys from 1979 to 1995 consisted of one LGL sighting in a lagoon immediately south of Northstar during 1984 (Fig. 5.50). There were four other sightings within ~20 km of Northstar, in waters ranging from <10 to <25 m deep.

***1996 Seismic vs. 1996 No Seismic.***—During 1996, sightings *and* sightings per 100 km of survey effort were highest 70-80 km from shore during both seismic and non-seismic periods (Fig. 5.51). Based on these data, there is no evidence that belugas were distributed farther offshore during periods with seismic activity. However, during seismic periods there was virtually no survey effort >75 km from shore and none >80 km from shore (Fig. 5.29B). Therefore, these surveys could not have detected an offshore shift in beluga distribution if one had occurred. There were 4.8 sightings/100 km during seismic periods and 5.5 sightings/100 km during non-seismic periods. Again, the survey coverage far offshore was too limited to justify any interpretation of those values.

Overall, the combined LGL and MMS aerial survey coverage in the central Alaskan Beaufort Sea during 1996 sampled only the southern margin of the main beluga migration corridor. For this reason the data are not suitable for the detailed analyses of the types done for bowhead whales.

***Timing***.—In 1996, belugas were most frequently recorded in the Northstar region during the 6 to 10 September period (Fig. 5.52). However, when standardized to allow for the highly variable amounts of survey effort during different 5-d periods (Fig. 5.52E), peak sightings/100 km and individuals/100 km were recorded during the 21-25 September period.

We considered comparing the seasonal pattern of migration in 1996 with that observed in other years, e.g. 1994-95 (light ice years with nil/little offshore industrial activity). However, gaps in survey coverage during some critical 5-day time periods make this a dubious comparison (Fig. 5.44E, 5.52E).

Also, standardization by total survey effort in each 5-day period does not does not take into account varying survey effort at different distances from shore. This is an important factor for belugas, which concentrate far offshore. Years like 1996, in which BPXA/LGL surveys contributed relatively large amounts of nearshore survey effort, are not directly comparable to years like 1994, when only MMS was flying surveys. This is so even when the results are standardized for survey effort, because MMS surveys often extended farther offshore (Fig. 5.6). For this reason, and because the combined LGL and MMS 1996 surveys sampled only the southern edge of the main migration corridor, we have not attempted to

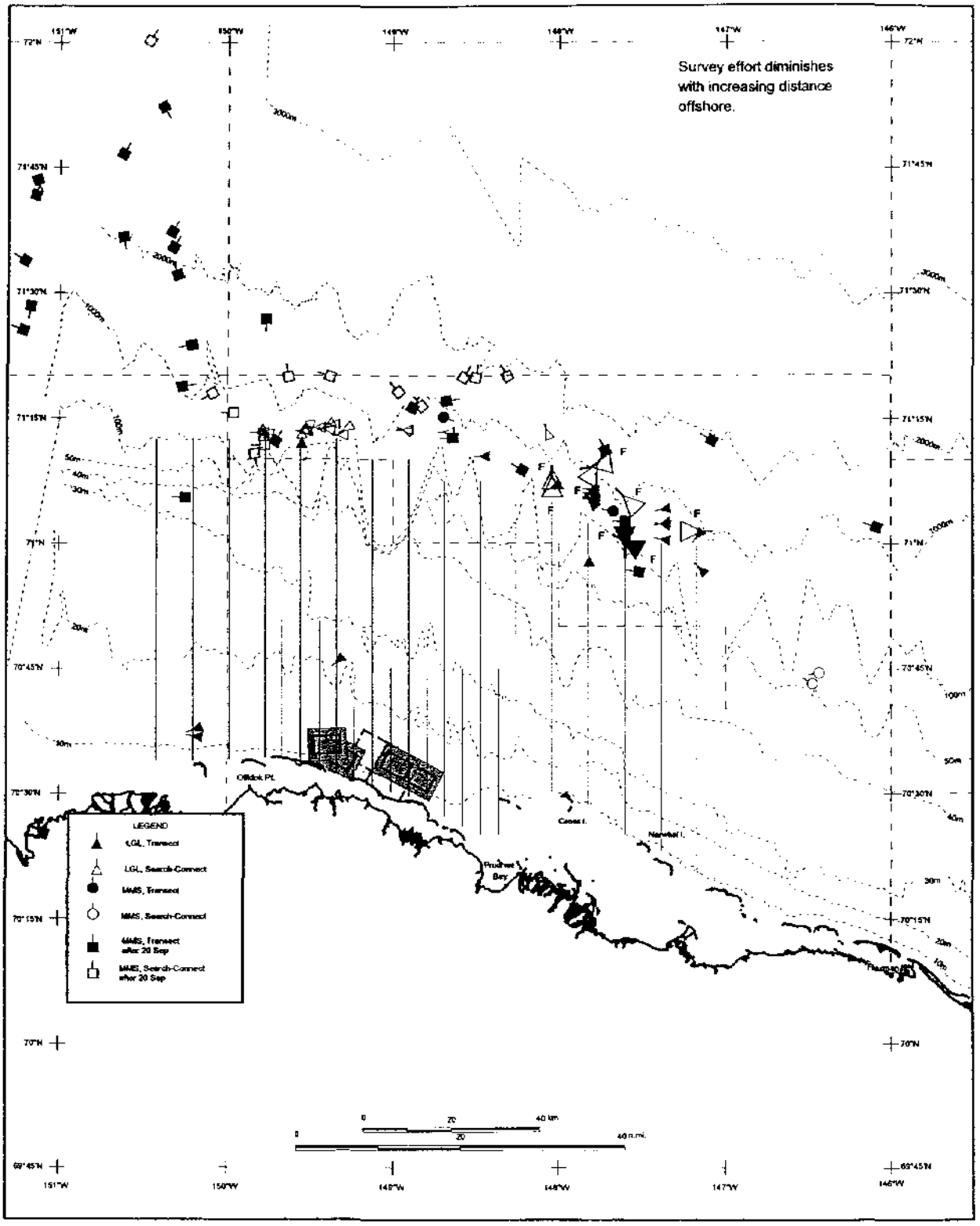


FIGURE 5.49. Beluga whale sightings in the central Alaskan Beaufort Sea (146°-151°W) during 1 September - 9 October 1996 based on LGL and MMS aerial surveys. Large symbols are sightings during "seismic" periods. Nominal LGL transect lines are shown. Dashed lines show boundaries of MMS survey blocks (*cf.* Fig.5.2). MMS sightings up to and after 20 September are distinguished. Seismic patches shot during September 1996 are outlined.

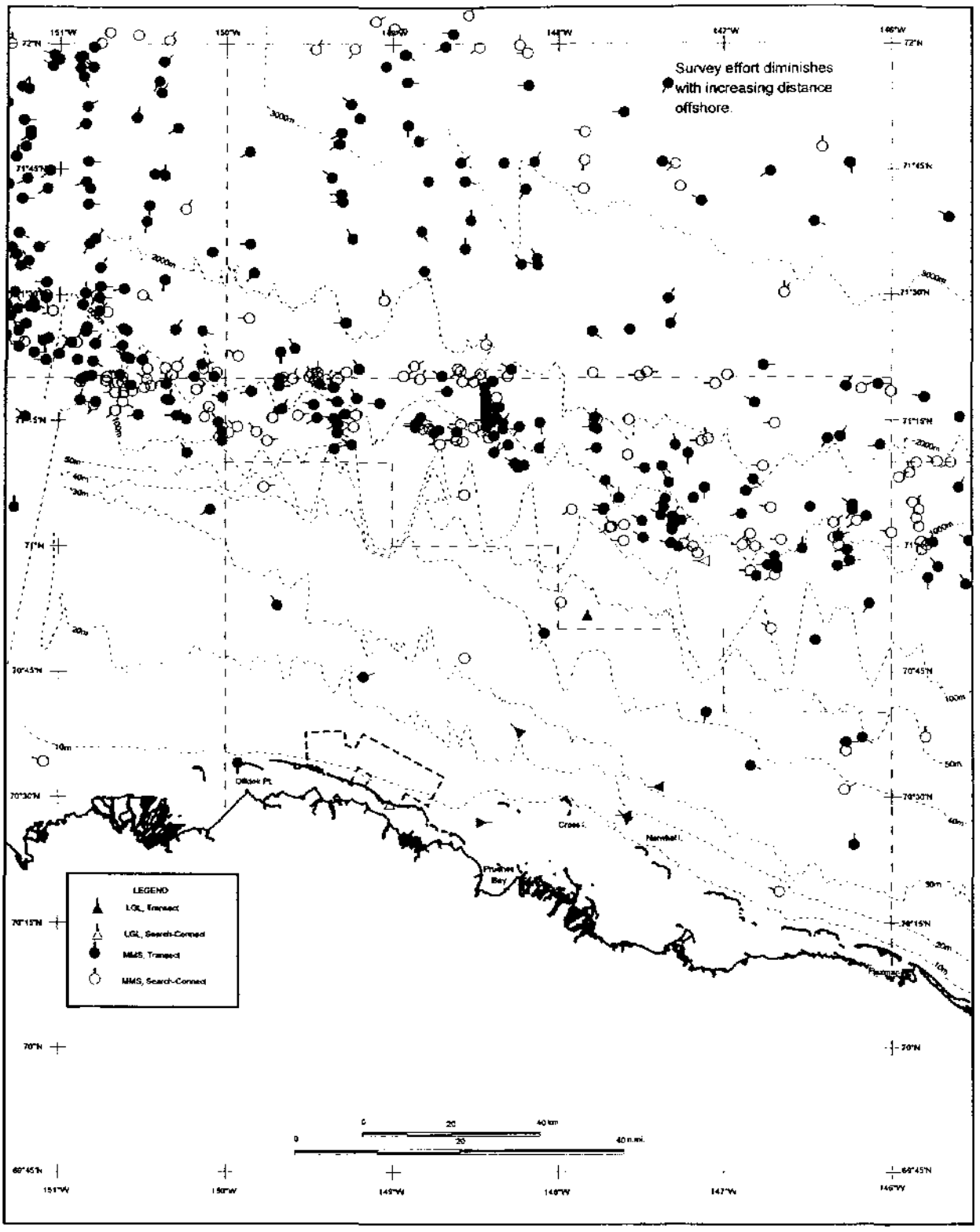


FIGURE 5.50. Beluga whale sightings in the central Alaskan Beaufort Sea (146°-151°) during late summer and autumn of 1979-95 based on MMS and LGL aerial surveys. Dashed lines show boundaries of MMS survey blocks (*cf.* Fig.5.2). Seismic patches shot during September 1996 are outlined for cross-reference.

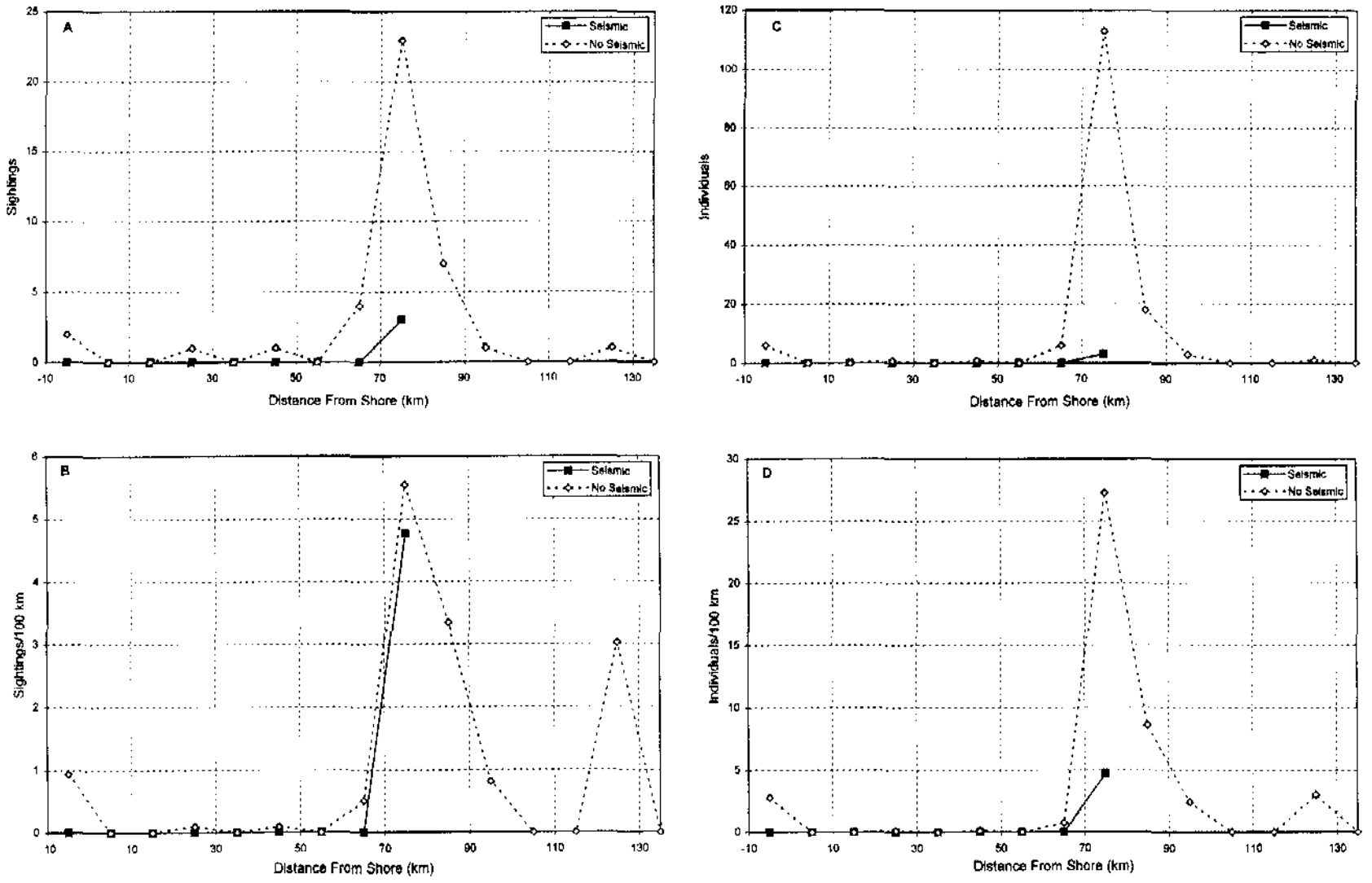


FIGURE 5.51. Distributions of belugas vs. distance from shore during "all seismic" periods vs. periods with no seismic, late summer/autumn 1996, excluding periods of poor sightability. Based on LGL and MMS "Transect" aerial surveys in the Northstar region of the central Alaskan Beaufort Sea (147°-150°30'). ***(A)*** Sightings, ***(B)*** sightings per 100 km of surveys, ***(C)*** individuals, and ***(D)*** individuals per 100 km of surveys. See Fig. 5.29 for survey effort vs. distance from shore.

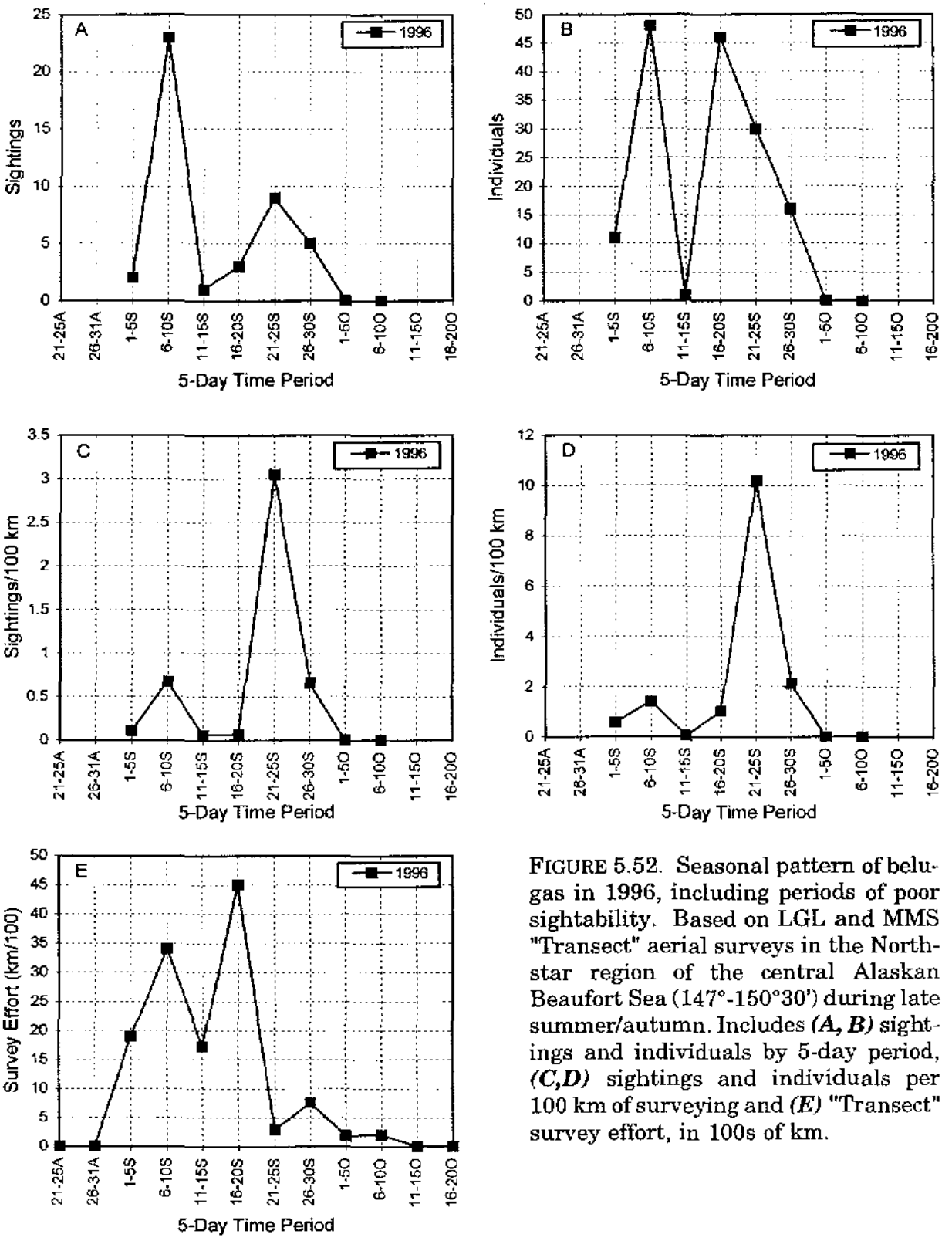


FIGURE 5.52. Seasonal pattern of belugas in 1996, including periods of poor sightability. Based on LGL and MMS "Transect" aerial surveys in the Northstar region of the central Alaskan Beaufort Sea (147°-150°30') during late summer/autumn. Includes ***(A, B)*** sightings and individuals by 5-day period, ***(C,D)*** sightings and individuals per 100 km of surveying and ***(E)*** "Transect" survey effort, in 100s of km.

compare the seasonal pattern of beluga migration observed in 1996 with the patterns observed in other years or combinations of years.

### *5.5.2 Estimated Beluga "Take by Harassment"*

In the following analyses we have again assumed that the received rms pulse levels from the seismic source could be as high as 180 dB re 1 µPa at distances up to 1 km. They may be ≥160 dB re 1 µPa out to an average radius of 3.6 km and occasionally to a maximum of 4.9 km (Chapter 3).

***180 dB Criterion.***—NMFS (1995) concluded that it is unlikely that noise pulses from a nearby seismic vessel would harass odontocetes (other than sperm whales) even at a received level of 190 dB re 1 µPa. In this project, BPXA proposed a 180 dB shutdown criterion for belugas as well as bowheads, and the IHA issued by NMFS adopted that criterion for both species. The shutdown (180 dB) radius around the seismic boat was estimated in advance of the project as 650 m. On 30 August, this radius was adjusted to 750 m (except for single-gun operations), based on results of preliminary sound measurements that are now further analyzed in Chapter 3. Those analyses have shown that received levels were, at times, 180 dB re 1 µPa or more at radii as great as 1 km.

In any event, no belugas were seen within a 1 km radius of the source vessel (or anywhere nearby) at any time during either the boat-based or the aerial monitoring. At least one boat-based observer was on duty and watching for marine mammals at all hours when airgun operations were underway, for at least 30 min before all planned startups of the airguns, and at some times with no airgun operations. The boat-based observers' detection capabilities were greatly reduced at night. Even so, given the rarity of belugas in nearshore waters in this area during late summer and autumn, it is unlikely that any belugas were exposed to seismic pulses with rms received levels at or above 180 dB re 1 µPa at any time during the 1996 Northstar project.

***160 dB Criterion.***—The IHA indicates that, during this project, the designated zone of potential harassment for belugas is the area within which received levels of seismic pulses can exceed 160 dB re 1 µPa. The rationale for this is not identified. Insofar as we know, there are no specific data in the literature on the reaction thresholds of belugas or other small-moderate size toothed whales to seismic pulses. Beluga hearing is not very sensitive at the low frequencies where seismic sounds are strongest (Awbrey et al. 1988; Johnson et al. 1989). Nonetheless seismic sounds are strong enough to be detectable to belugas or other toothed whales at long ranges (Richardson et al. 1995:354*ff*; Richardson and Würsig in press).

*No Direct Evidence of "Take":* Fig. 5.49 shows that none of the beluga whales seen during the aerial surveys were within 60 km of the operating source vessel. Chapter 3 describes the transmission loss relative to the source vessel and indicates that received levels of 160 dB re 1 µPa did not normally extend beyond 3.6 km from the source vessel (maximum 4.9 km). No beluga whales seen by the aerial observers were within or near the areas where they might have been exposed to seismic pulses with received levels ≥160 dB re 1 µPa.

However, the aerial observers saw only a very small percentage of the total number of belugas that migrated west past the Northstar region during late summer and autumn in 1996. Thus, the lack of observations of belugas exposed to ≥160 dB seismic pulses does not justify an assumption that none were exposed to strong seismic pulses.

*Belugas Within 15 km of Shore:* The Beaufort Sea stock of the beluga whale is currently estimated to contain about **41,610 animals** (Small and DeMaster 1995). For purposes of estimating take we will assume that all of these whales migrate west north of or through the Northstar seismic exploration area. As for the bowhead, the following assessment assumes that received levels may exceed 160 dB out to a radius of 4 km. The seismic exploration area extended out to ~11 km from shore, so levels ≥160 dB could occur out to ~15 km from shore.

The Northstar seismic area is far south of the main migration corridor for the Beaufort Sea stock of beluga whales. Thus, information collected during this project on the timing and distribution of their movements is not necessarily representative of the entire beluga migration. The actual proportion of the beluga whale population that passes through the area where BPXA/LGL Northstar aerial surveys were conducted (out to about 65-85 km offshore) is unknown, but probably less than **20%**.

Based on 1996 "Transect" surveys, 3.9% (6 of 152) of the belugas that passed through the aerial survey area passed within 15 km of our "0-km line" (Fig. 5.53C). When numbers of individuals are standardized for different survey coverage in the different offshore zones, an estimated **2.1%** of the belugas passing through the aerial survey area out to 65-85 km offshore came within 15 km of the "0-km line" during 1996 (Fig. 5.53D).

The migration extends until early-to-mid-October and on the order of **60%** of the migration may occur up 18 September, when seismic work ended. As described in §5.3 Bowheads/Estimated Take, strong seismic pulses were being produced for only **38.9%** of the time during the 1-18 September period.

Summarizing the relevant factors, of the estimated 41,610 belugas in the Beaufort Sea stock, less than 20% come within the aerial survey area, about 2.1% of those passing through the aerial survey area in 1996 were within 15 km of shore, about 60% of the population migrates west through the area off Northstar during dates up to 18 September, and seismic work was underway during 38.9% of the hours from 1-18 September

If all of these percentages are applied to the stock size to estimate the maximum number of belugas that might have passed Northstar within 15 km of shore while strong seismic sounds were being emitted, the result is 41 belugas (41,610 x 0.20 × 0.021 x 0.60 × 0.389).

For reasons discussed in the bowhead section, this approach is expected to overestimate the numbers exposed to pulses with rms received levels of 160 dB re 1 µPa. It does not account for the fact that many of the estimated 41 belugas coming within 15 km of shore would be >4 km from the seismic source vessel, given that it worked within 6 km of shore 70% of the time. Thus the actual number exposed to 160 dB pulses was probably

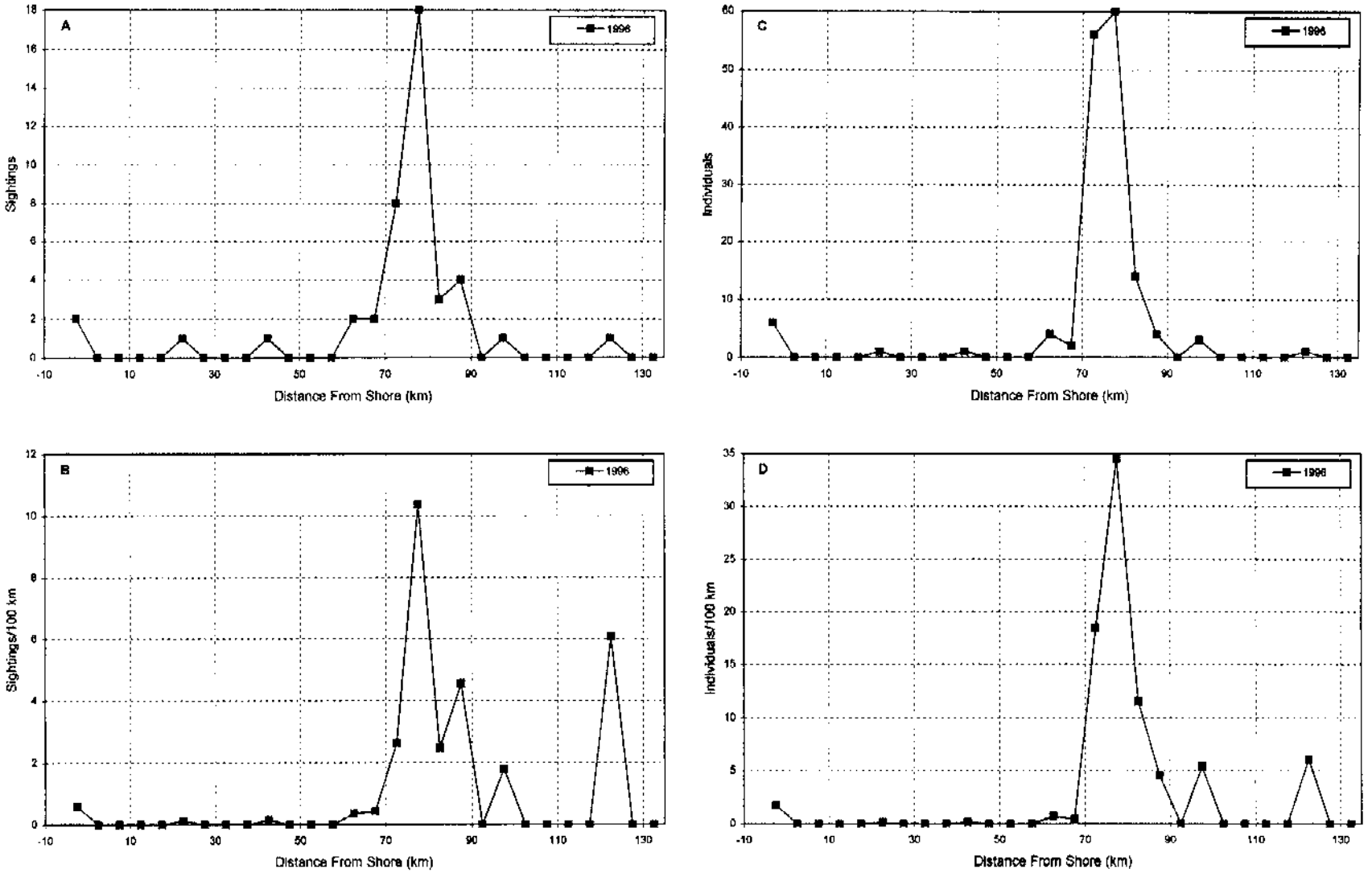


FIGURE 5.53. Distributions of belugas by 5-km distance-from-shore intervals during late summer/autumn of 1996, excluding periods of poor sightability. See Fig. 5.35B for survey effort vs. distance from shore. Otherwise as in Fig. 5.50.

considerably lower than 41, and possibly zero.

Furthermore, if 160 dB is a reasonable disturbance threshold for bowhead whales with their (presumed) sensitive low frequency hearing, it is doubtful that belugas with poor hearing sensitivity at low frequencies would be disturbed by seismic pulses at received levels of 160 dB re 1 µPa.

***20 Nautical Mile Criterion.***—During a meeting in Seattle on 21 May 1996, a review team requested that one of the objectives of the Northstar monitoring study be to estimate the proportion of the bowhead whales *and other marine mammals* that migrate past the Northstar study site within 20 n.mi. (37 km) of the northern edge of the site when the airguns are in operation. As described for bowheads, 20 n.mi. from the northern edge of the seismic exploration area is 48 km offshore, which we round-off to 50 km offshore. There is no evidence that belugas 20 n.mi. from a seismic vessel are disturbed or "taken by harassment".

Based on 1996 "Transect" data, 8 of 152 (5.3%) individuals that were sighted were within 50 km from shore (Fig. 5.53C). After allowing for varying amounts of survey effort at different distances from shore, an estimated 2.4% of the individual belugas occurring within the 147°-150°30'W area were inshore of the 50 km from shore line (Fig. 5.53D).

Using this **2.4%** figure together with the correction factors derived earlier for proportions of belugas passing through the BPXA/LGL survey area (**0.20**), passing Northstar by 18 September (**0.60**), and during seismic surveys (**0.389**), we estimate that **0.11%** (0.024 × 0.20 × 0.60 × 0.389) of the beluga population passed within 20 n.mi. of the northern edge of Northstar in 1996. By applying this proportion to the total estimated number of belugas (41,610) passing through or north of the Northstar area, we estimate that roughly 47 belugas traveled west shoreward of the 50 km from shore line in 1996, i.e. within about 20 n.mi. of the northern edge of Northstar.

***Summary of Estimated "Take by Harassment".***—It is very unlikely that any belugas were exposed to seismic pulses with rms received levels ≥180 dB re 1 µPa during the 1996 Northstar seismic program. No belugas were directly observed to be exposed to pulses with received levels of ≥160 dB either. Even allowing for belugas migrating past the seismic operation at times when they could not be observed, only a very low proportion of the Beaufort Sea stock, probably well under 41 animals, might have exposed to seismic pulses with received levels ≥160 dB re 1 µPa on a rms basis. If these animals were disturbed by hearing the seismic sounds, the effect was likely short term and localized, with no lasting consequences for individuals or the population. The disturbance threshold may be above 160 dB, in which case the number potentially "taken by disturbance" would be predicted to be even lower.

## 5.6 Summary and Conclusions

No cetaceans were seen in the Northstar study area by the boat-based marine mammal observers. During July through September 1996, the observers watched for marine mammals at all times while airgun operations were in progress, for at least 30 min before all planned startups of the airguns, and at some times with no airgun operations

Partial or complete BPXA/LGL aerial surveys were flown on 14 dates from 3 to 20 September 1996, including 6648.3 km of survey coverage during periods with no seismic and 3576.2 km 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. 0-3.5 hours after the end of full array seismic).

The Minerals Management Service conducted transect surveys in the same area on 13 days in 1996. Only 2% of the transect surveys flown by MMS in the Northstar area were during seismic periods (51 of 2747 km with 5-gun "partial array" or "post-seismic").

### *5.6.1 Bowhead Whale*

During the BPXA/LGL aerial surveys, 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. Relatively large numbers of bowheads were seen during some days with seismic and some days without seismic. Likewise, few bowheads were recorded on other days with seismic and without seismic. 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 closest sightings of bowheads with respect to the operating airgun array were 22-27 km away.

MMS obtained 29 sightings of 39 individual bowheads in this area. Twelve MMS sightings including 17 individual bowheads were recorded up to 18 September when seismic exploration ended. None of these sightings were during seismic periods.

***Distance from Shore.***—The number of bowhead sightings within the Northstar region 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. 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:* Bowheads tended to be seen both closer to shore and farther offshore without seismic than with 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.

*1996 East vs. 1996 West:* There was no evidence that distances from shore were greater in the western than in the eastern part of the Northstar region.

*1996 vs. 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 (years with little or no offshore industrial activity). If anything, bowhead migration tended to be closer to shore during 1996, the year with seismic.

*Years with Little vs. Substantial Industrial Activity:* Bowhead sightings tended to be slightly farther offshore during 1996 plus four other 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 but was significant considering the larger sample of data for industrial activities in general. The observed tendencies are consistent with the experience of bowhead hunters.

Most bowheads seen 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. There was much overlap between the migration corridors in years with vs. without seismic or other industrial activities.

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.

***Behavior, Headings and Migration Timing.***—Based on small sample sizes, there was no indication that resting at the surface was appreciably more common during seismic than no-seismic periods.

The headings of bowheads engaged in "swimming" were bimodal both with and without seismic exploration during 1996. The percentage of bowheads heading in unexpected directions in the Northstar region during 1996 was not significantly different from that in 1994-

95, when there were no offshore industrial activities. Headings during five years with substantial offshore industrial activity did not differ significantly from those during 1994-95. However, 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 (i.e. near Northstar).

Bowhead numbers in the Northstar region, averaged by 5-day periods, seemed fairly steady during the 1-30 September period of 1996. On average, peak sighting rates occurred ~10 days later during during five light ice years with substantial industrial activity than during two light ice years with little industrial activity (1994-95). However, the 1994-95 data were limited, and no conclusions can be drawn about industry effects on migration timing.

***Bowhead Call Counts***.—Bottom-mounted acoustic recorders operated simultaneously at sites offshore from Northstar and from Narwhal Island (45 km ESE of the Northstar recorder) from 31 August to 14 September 1996. The recorders were near the 25 and 30 m depth contours, respectively, in the zone defined as being 20-25 km from shore. They recorded 6920 and 17,634 bowhead calls, respectively, during 351 h of simultaneous operations.

The number of calls detectable per hour near Northstar was significantly lower, both overall and relative to the paired Narwhal Island count, during hours when seismic pulses were detectable on the Northstar recorder. Ensonification of waters near Northstar by seismic sounds apparently had one or both of the following effects: it reduced the number of calls emitted by an average bowhead per hour, and/or reduced the number of bowheads within a several kilometer distance of the recording unit off Northstar.

***Sounds Received Near Bowheads***.—The strongest seismic pulses measured near bowheads observed during this project had peak levels near 122 dB and rms levels near 114 dB re 1 µPa. However, we probably did not record the strongest sounds received by the bowheads that were sighted during this project. Whales traveling west 15 km offshore could have been exposed to rms pulse levels approaching (but not exceeding) 160 dB re 1 µPa if they passed when the airgun array was operating near the northern edge of the seismic operations area (10-11 km offshore). Whales traveling west <15 km offshore, as some did in the absence of seismic, could have been exposed to levels ≥160 dB if they animals did not deflect away from the seismic vessel.

***Estimated "Take by Harassment"***.—The best estimate of the number of bowheads exposed to seismic pulses at received levels ≥180 dB re 1 µPa was zero. All observed bowheads were in areas where received levels of the pulses (rms measurement method) were well below 160 dB re 1 µPa.

Based on the distance-from-shore distributions of all bowheads seen in 1996 and selected earlier years, a small number of bowheads would be expected either to occur within the 160 dB radius around the seismic source vessel or to exhibit avoidance of that area. Estimates of the numbers of bowheads that might occur within the 160 dB radius at some

time during the late summer/autumn period are <47 bowheads (based on 1996 data) and 0 bowheads (1994-95 data), i.e. <0.6% and 0.0% of the population. The small numbers expected to be "taken" in this way are likely to exhibit displacement and short-term behavioral changes, but no long-term effects on individuals or the population are expected.

Bowheads that would have migrated within 20 km of shore in the absence of seismic may have been displaced or otherwise disturbed during periods with seismic. If so, as many as 430 bowheads (based on 1996 data only) or 40 bowheads (considering 1994-95 data) may have been affected in these ways.

On the order of 1000-1200 bowheads may have moved west within 20 n.mi. (37 km) of the northern edge of the seismic exploration area during times when airguns were operating in 1996. Many of these whales would have been exposed to seismic pulses. This study provided no evidence that disturbance effects or "take" extended 20 n.mi. offshore of the seismic exploration area. Inupiat hunters believe that migrating bowheads can be "displaced from their normal migratory path by as much as 30 miles", and previous behavioral studies suggest that subtle behavioral effects may sometimes extend to 20+ n.mi. from seismic vessels.

### *5.6.2 Gray and Beluga Whales*

Gray whales are rare in the Northstar region, and none were sighted during BPXA/LGL or MMS surveys in 1996. For gray whales, the estimated "take by harassment" during the 1996 Northstar seismic program was zero.

Beluga migration during 1996 was predominantly far offshore, as in other years. Almost all sightings during 1996 were at the extreme northern edge of the study area. However, as usual, a few small groups traveled west through nearshore waters.

The combined LGL and MMS aerial surveys during 1996 sampled only the southern margin of the main beluga migration corridor. For this reason the data are not suitable for the detailed analyses of distances offshore with and without seismic, in various years, etc.

Roughly 47 belugas were estimated to have traveled west within about 20 n.mi. (37 km) of the northern edge of the seismic exploration area during periods with seismic work.

The number of belugas "taken by harassment" was small and perhaps zero. It is very unlikely that any belugas were exposed to rms received levels ≥180 dB re 1 µPa. No belugas were directly observed to be exposed to rms received levels ≥160 dB. Allowing for belugas migrating past the seismic operation at times when they could not be observed, a very low proportion of the Beaufort Sea stock, probably under 41 animals, might have been exposed to ≥160 dB. The disturbance threshold may be above 160 dB, in which case the number potentially "taken by disturbance" would be predicted to be even lower.

### *5.6.3 Summary Organized by Objectives*

Eight analysis objectives were identified at a meeting held in Seattle on 21 May 1996 to review the draft monitoring plan (see §1.2 in Chapter 1). All of these objectives dealt with whales either in whole or in part:

*(a) "Estimate the proportion of the bowhead whales (and other marine mammals) that migrate past the Northstar study site within 20 nm of the northern edge of the site when the air guns are in operation."*

> On the order of 1000-1200 bowheads may have moved west within 20 n.mi. (37 km) of the northern edge of the seismic exploration area during times when airguns were operating in 1996. Many of these whales would have been exposed to seismic pulses. [Based on §5.3.8, page 5-93*ff*].

*(b) "Estimate the number of other marine mammals within 20 nm of the northern edge of the study site when the air guns are in operation."*

> An estimated 47 belugas traveled west within about 20 n.mi. of the northern edge of the seismic exploration area during times when airguns were operating in 1996. [Based on §5.5, page 5-105].

*(c) "Estimate the number of baleen whales within 2130 ft of the sound source when the air guns are in operation."*

> The radius within which the rms level of the seismic pulses was expected to be ≥180 dB re 1 µPa was initially estimated as 650 m (2130 ft). The 180 dB radius was later determined to be up to 1.0 km on some occasions (Chapter 3). The best estimate of the number of bowheads exposed to seismic pulses at received levels ≥180 dB re 1 µPa was zero. [Based on §5.3.8, page 5-87]. No gray whales were seen during this study, and presumably none were exposed to a received level ≥180 dB re 1 µPa.

*(d) "Estimate the number of other marine mammals within 500 ft of the sound source during seismic operations."*

> No belugas were seen or suspected to occur within 500 ft (150 m) of the sound source. [Based on §5.5, page 5-102]. Results for seals are given in Chapter 4.

*(e) "Estimate the distribution of observed distances between the (closest) active seismic vessel and bowhead whales seen on effort during the aerial survey."*

> The distances of observed bowheads from the active or recently-active seismic vessel are listed in Table 5.3 in §5.3.1; the distances ranged from 21 to 74 km. However, most of these whales were probably not at their closest points of approach when seen. Figure

5.47 (page 5-86) shows the location of the whale migration corridor in 1996 relative to the outer (northern) edge of the seismic exploration area.

*(f) "Test the hypothesis that the distribution of bowhead whales (and other marine mammals) is independent of the estimated received sound level produced by all of the vessels associated with the Northstar study."*

The southern edge of the main bowhead migration corridor tended to be farther offshore at times with seismic than at times without seismic during 1996. The 1996 data were insufficient to determine statistically whether this trend was indicative of a causal relationship, given the small sample size available from a single year of surveys (see §5.3.3, page 5-52*ff*]. However, the observed tendency was consistent with the experience of bowhead hunters.

*(g) "Test the hypothesis that the swimming direction of bowhead whales is independent of the estimated received sound level produced by all vessels associated with the Northstar study."*

The headings of bowheads engaged in "swimming" were bimodal both with and without seismic exploration during 1996. The percentage of bowheads heading in unexpected directions during 1996 was not significantly different from that in 1994-95, when there were no offshore industrial activities. However, based on a very small sample, more bowheads headed in unexpected directions in the western part of the study area (near Northstar) than in the eastern part (farther away). [Based on §5.3.4, page 5-71*ff*].

*(h) "Test the hypothesis that vocalization rates of bowhead whales are independent of the estimated received sound level produced by all vessels associated with the Northstar study (using some type of remote data collection system)."*

The number of calls detectable per hour near Northstar was significantly lower, both overall and relative to the paired Narwhal Island count, during hours when seismic pulses were detectable on the Northstar recorder. Ensonification of waters near Northstar by seismic sounds apparently had one or both of the following effects: it reduced the number of calls emitted by an average bowhead per hour and/or reduced the number of bowheads within a several kilometer distance of the recording unit off Northstar. [Based on §5.3.6 (page 5-81*ff*) and §3.8 in Chapter 3].

## 5.7 Acknowledgements

The aerial surveys were conducted as authorized by an Incidental Harassment Authorization issued by the U.S. National Marine Fisheries Service to BP Exploration (Alaska) Inc. for BPXA's Northstar seismic program. The monitoring work was funded by BPXA via a contract to LGL and Greeneridge Sciences. We thank Dr. Chris Herlugson of BPXA for support and assistance throughout the project. We also thank Michelle Gilders for assistance during the early stages and for reviewing the draft report.

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Tom Cook and Joe King kindly provided information on the locations and activities of the whalers, which permitted us to obtain maximum information on whale distribution without interfering with the whale hunt.

We are grateful to the marine mammal monitoring crew aboard the seismic source vessel, the *Point Barrow*, for their long hours of effort in watching for cetaceans as well as seals. We also appreciate the assistance that many other individuals and organizations provided to the boat-based observers. Full acknowledgements concerning the boat-based work are given in Chapter 4, SEALS.

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# APPENDIX 1:

## SIGHTINGS OF WALRUSES AND POLAR BEARS

BP Exploration (Alaska) Inc. (BPXA) conducted an open-water seismic program in shallow waters of the central Alaskan Beaufort Sea during the 24 July through 19 September period of 1996. Incidental (unintentional) takes of polar bears and Pacific walruses during BPXA's exploration activities were authorized by a letter dated 15 May 1996 from the U.S. Fish & Wildlife Service (USFWS) under Section 101(a)(5) of the Marine Mammal Protection Act. One requirement of this authorization was that all sightings and/or interactions with polar bears and walruses be reported to the Marine Mammal Management Office. The following writeup is extracted from a brief report by LGL Ltd. for BPXA and USFWS, dated January 1997. That report summarized all polar bear and walrus sightings during BPXA's 1996 open water seismic exploration program and its associated marine mammal monitoring program.

Additional background information, including a detailed description of the seismic program and of the marine mammal monitoring methods, can be found earlier in the present report. The marine mammal monitoring work described there was designed to satisfy the requirements of the Incidental Harassment Authorization (IHA) issued by NMFS to BPXA. The IHA authorized incidental disturbance to whales and seals, and required a comprehensive boat-based, aerial and acoustic monitoring program to document the "take" of these mammals. Corresponding information about polar bears and walruses was also collected during the monitoring program.

## *Walrus*

Two Pacific walruses were sighted during the 1996 Northstar open-water seismic program (Table 1). One sub-adult walrus was sighted by marine mammal monitors aboard the seismic source vessel *Pt. Barrow* on 6 August 1996. The *Pt. Barrow* was transiting between seismic lines when the walrus was first sighted. The walrus followed the vessel for about 50 minutes and was at one time within about 50 m of the *Pt. Barrow*. The *Point Barrow* eventually out-distanced the walrus by increasing its speed. The walrus was almost out of sight (≥400 m behind the vessel) when the vessel reached the start of its line and began firing a single airgun.

A single adult walrus was observed on 10 September 1996 from the survey aircraft used for marine mammal monitoring (Table 1). This walrus was located about 36 km from the source vessel, which was operating the full airgun array at the time of the sighting (Fig. 1). The walrus responded to the aircraft by turning in the water to look at the aircraft. The aircraft passed at a lateral distance of about 200 m from the walrus at an altitude of 280 m above sea level. The walrus did not dive during the brief period that it remained in sight.

Table 1. Sightings of Pacific walrus and polar bears during the 1996 Northstar open-water seismic program.

| Species | Observation Platform | | Da/Mo/Yr | Local Time | Lat. | Long. | Behavior/ Reaction | Number | | | Percent Ice cover |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Type | Name | | | | | | Total | Ad. | Sub-ad. | |
| P. Walrus | Vessel | Pt. Barrow | 06/08/96 | 093900 | 70 20.5 | 147 37.7 | Follow vessel | 1 | | 1 | 0 |
| " | Aircraft | N7UP | 10/09/96 | 102412 | 70 51.3 | 149 19.9 | Look at aircraft | 1 | | 1 | 6-25 |
| Polar Bear | Aircraft | N7UP | 05/09/96 | 124354 | 70 41.8 | 148 27.9 | Resting/sitting/standing | 2 | | | 6-25 |
| " | " | " | 07/09/96 | 105500 | 70 54.3 | 147 22.9 | Resting/sitting/standing | 2 | 1 | 1 | 76-90 |
| " | Vessel | Sag River | 10/09/96 | 171900 | 70 36.5 | 149 11.3 | Swim away from vessel | 2 | 2 | | + |
| " | " | Peregrine | " | 202500 | 70 34.9 | 149 10.1 | Climbing on ice | 2 | 1 | 1 | + |
| " | Aircraft | N7UP | 19/09/96 | 123610 | 70 47.7 | 149 20.4 | Resting/sitting/standing | 3 | 1 | 2 | 76-90 |
| " | " | " | " | 125158 | 70 40.8 | 149 06.9 | Feeding | 1 | | | 91-99 |
| " | " | " | " | 142830 | 70 43.7 | 149 39.7 | Unknown | 1 | | | 26-50 |
| " | " | " | " | 172255 | 70 52.9 | 147 48.9 | Travel | 1 | | | 91-99 |
| " | " | " | " | 180525 | 70 53.1 | 147 22.6 | Resting/sitting/standing | 1 | | | 51-75 |
| " | " | " | 20/09/96 | 112616 | 70 49.7 | 148 54.1 | Resting/sitting/standing | 2 | | | 91-99 |
| Ringed Seal* | Vessel | Pt. Barrow | 17/09/96 | 094700 | 70 36.8 | 149 17.7 | Dead on ice | 1 | 1 | | + |

* Killed by polar bear

## *Polar Bear*

There were two vessel-based sightings of polar bears on 10 September 1996 (Table 1). Two polar bears, reported to be adults, were sighted by the crew of the *Sag River* at 17:19 local time. The bears were estimated to be about 300 m from the vessel. The vessel came to a stop and the bears were observed both on ice and swimming away from the vessel. The encounter lasted about 10 minutes. At the time of the sighting the source vessel *Pt. Barrow* was about 10 km to the ESE. The source vessel had been shooting full-array seismic throughout the day, and the array was being ramped-up in preparation for starting a new line when the bears were first sighted.

The second sighting on 10 September was also of two bears, reported to be a sow and a cub, at 20:25. This sighting, by the crew of the *Peregrine,* was about 3 km south of the *Sag River*'s earlier sighting. This pair was observed climbing onto a large ice pan as the *Peregrine* picked up buoys on either side of the ice pan. The bears were estimated to be about 200 m from the vessel and the encounter lasted about 10 minutes. At the time of this sighting the source vessel *Pt. Barrow* was shooting full-array seismic about 4 km SE of the bears.

Eight sightings of including a total of 13 polar bears were recorded by the biologists on board the survey aircraft used for marine mammal monitoring (Table 1, Fig. 1). No seismic shooting occurred in the Northstar area on the days (5, 7, 19, 20 September) when these polar bears were sighted. No reactions to the aircraft were observed.

A dead ringed seal, believed to have been killed by a polar bear, was observed on an ice pan by marine mammal monitors on board the source vessel *Pt. Barrow* on 17 September. This seal was about 6 km west of the area where bears had been sighted on 10 September.

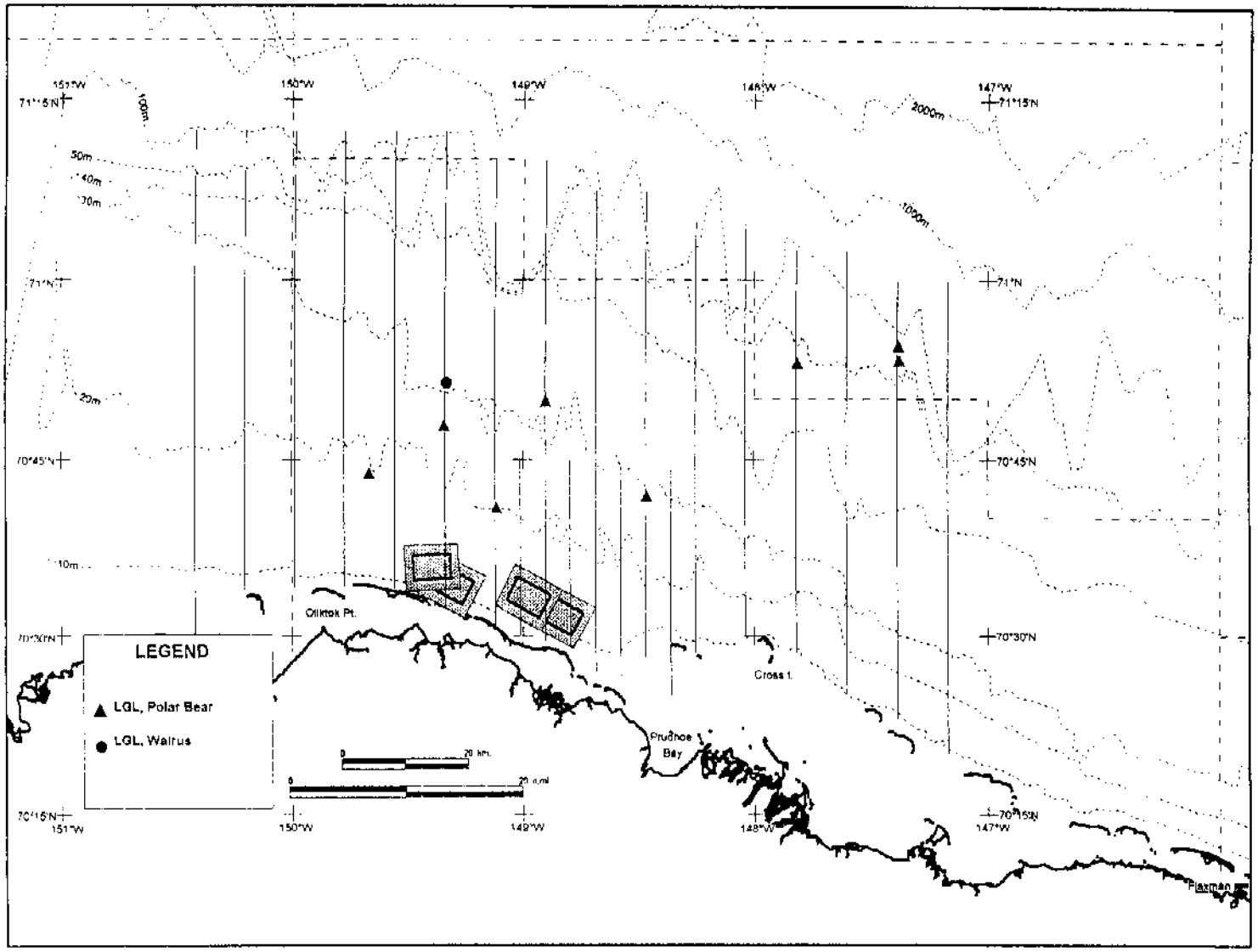


FIGURE 1. Sightings of polar bears (triangles) and walrus (circle) during aerial surveys conducted as part of the Northstar marine mammal monitoring program, 1-21 September 1996. Aerial surveys of a standard grid (shown) were conducted daily, weather permitting. A total of 10,225 km of surveys were conducted on 14 dates; not all lines were surveyed on each date. See Chapter 5 for a description of the aerial surveys. Shaded rectangles show the areas where the source vessel shot full-array and partial-array seismic during the dates when aerial surveys were done.