Chukotka Peninsula counts and estimates of the number of migrating bowhead whales

V. Melnikov and J. Zeh

ABSTRACT

In May and June 1999-2001, shore-based counts of migrating bowhead whales were conducted in the Cape Dezhnev area of the Chukotka Peninsula. It is unknown if the same whales migrate along the Chukotka coast each spring, nor is it known if they form a sub-population. The 1999 count was a feasibility study, and the counts from Cape Pe'ek in 2000 and 2001 were designed to permit estimation of the number of whales migrating past Cape Dezhnev. These surveys were similar to those of bowhead whales near Barrow, AK and of gray whales near Monterey, CA except that no experiments designed for estimating detection probabilities P were conducted. The number of migrating bowheads was estimated using three alternatives for P: (1) $P = 1$ (all whales passing during watch with acceptable visibility conditions were seen); (2) $P = Pb$, bowhead detection probabilities estimated for the surveys near Barrow (except that >10km range from Cape Pe'ek was treated as equivalent to offshore distance >2km near Barrow because observation perch height was so much greater at Cape Pe'ek) and (3) Pg as analogous as possible to detection probabilities estimated for the gray whale surveys near Monterey. Whales/sighting were estimated as (number recorded)/P. Methods of estimating the number of migrating whales from the Cape Pe'ek data and the assumptions on which they were based were as similar as possible to those of the surveys near Barrow. The migration period at Cape Pe'ek was assumed to extend from the first day a bowhead was seen through the last day a bowhead was seen in each year. Whales were assumed to migrate continuously throughout this period, regardless of weather, time of day and whether or not observers were counting them. Days were assumed to be "watched" if observers counted for more than 2h with fair to excellent visibility and "unwatched" otherwise during this period. The day estimate for a watched day is $(N + C/2) \times 1440$ / (watched minutes). N and C are the total whales/sighting summed over sightings scored as not previously seen (N) and uncertain whether previously seen (C), respectively. The season total estimate for each year is the sum of the day estimates over all the days in the migration period, with a weighted mean estimate used for the unwatched days. The weighted mean estimate, based on the watched days, was computed on a square root scale to give day estimates appropriate weight, considering the minutes of watch and the rate and variability of whale passage each day. A jackknife on watched days provided the SE for the season total estimate. The 2000 migration period was 14 May – 13 June with 18 (58%) watched days; 155 N whales and no C whales were seen. The 2001 migration period was 23 May – 15 June with 14 (58%) watched days; 148 N whales and 26 C whales were seen. Weighted geometric means of the 2000 and 2001 estimates of the number of migrating bowheads for the three alternatives for P with their 95% confidence intervals are: (1) 426 (301, 603); (2) 841 (601, 1176) and (3) 774 (558, 1073). Given observed migration speeds of bowheads in 2001, it is unlikely that any of the 94 N and 18 C whales seen from Cape Pe'ek in June of 2001 were counted by the survey near Barrow that year.

INTRODUCTION

It has been known for some time (e.g. Bogoslovskaya *et al*., 1982) that bowhead whales (*Balaena mysticetus*) can be found around the Chukotka Peninsula in summer and early autumn. In 1990, a new program of shore-based observations of bowhead whales from capes of the Chukotka Peninsula began. Melnikov *et al*. (1998) summarized summer and early autumn sightings made between 1990 and 1996, as well as earlier sightings reported in the literature. It is not known whether the whales seen around the Chukotka Peninsula spend all or part of some summers in the Beaufort Sea or, alternatively, represent a separate feeding aggregation. It is also not known whether they represent a separate biological stock or, alternatively, mix with the rest of the Bering-Chukchi-Beaufort Seas stock during the breeding season.

Bowhead whales are subject to a subsistence hunt by Russian and Alaskan Eskimos. From 2000 through 2004, the average number of bowheads struck in the Russian hunt was 1.8 per year, and 51.2 per year in the Alaskan hunt. Since 2002, the International Whaling Commission Scientific Committee (IWC SC) has provided advice to the Commission on the maximum number of strikes that should be allowed using a Strike Limit Algorithm, the *Bowhead SLA* (IWC, 2003). The *Bowhead SLA* was developed and tested under the assumption that there is a single Bering-Chukchi-Beaufort Seas stock of bowheads. If the whales found around the Chukotka Peninsula in summer could represent a separate population, precautionary management requires that the *Bowhead SLA* be tested under two-stock scenarios to determine whether the catches set by the SLA are sustainable for both populations. A key piece of information needed for designing plausible two-stock SLA trials is an estimate of the abundance of the population around Chukotka, if indeed it is a separate population.

In May and June 1999-2001, shore-based counts of migrating bowhead whales were conducted in the Cape Dezhnev area of the Chukotka Peninsula. The objective of these surveys was "to count whales migrating from the Bering Sea through the western Bering Strait into the Chukchi Sea from an observation post in the Cape Dezhnev area." (Melnikov *et al.*, 2004) The 1999 count was a feasibility study, and the counts from Cape Pe'ek in 2000 and 2001 were designed to permit estimation of the number of whales migrating past Cape Dezhnev. The Cape Pe'ek surveys were similar to those of bowheads near Barrow, AK (George *et al.*, 2004) and of gray whales near Monterey, CA (Buckland *et al.*, 1993; Rugh *et al.*, 1993) except that no experiments designed for estimating detection probabilities were conducted, and the Cape Pe'ek observation perch was higher above sea level (around 65m, making it possible to see whales at ranges exceeding 20km when visibility conditions were adequate).

METHODS

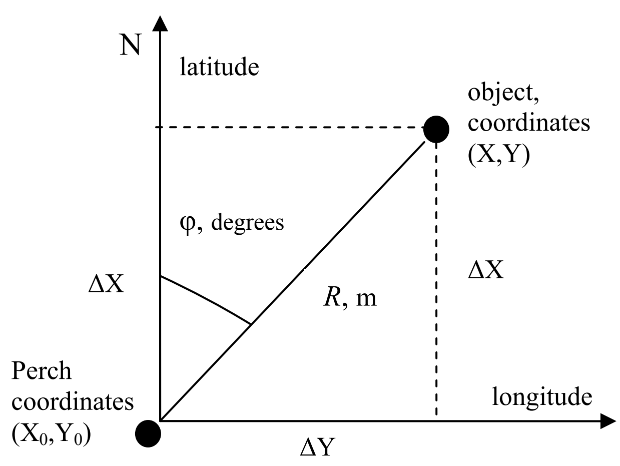
In general, teams of 2 observers stood watch twice a day for 4h, using binoculars with built-in compass and vertical and horizontal scale so that bearing and range could be estimated. When a bowhead sighting was made, the time, compass information and number of whales were recorded. The whales were scored as new (N = not previously recorded), conditional (C = status uncertain) or duplicate (D = previously recorded). Information on whale behaviour and environmental variables were also recorded. Visibility, a key environmental variable, was coded on the same scale – excellent (EX), very good (VG), good (G), fair (F), poor (P), unacceptable (UN) – used by George *et al.* (2004) and Buckland *et al.* (1993).

Range R from the observation perch to a whale was estimated as

$$R = (\ \arcsin[\ \sin(\pi/2 - \theta) \times (r_3 + h) / r_3\ ] - (\pi/2 - \theta)\ ) \times r_3$$

where r_3 = radius of the earth = 6,371,200m, h = height (m) of the observation perch and θ = angle in radians from the horizon to the target. This method, equivalent to that of Lerczak and Hobbes (1998), takes account of the curvature of the earth. This expression for R is only usable when $\theta \geq 0.0046$ radians, so θ was replaced by max(0.0046, θ) in our calculations. Therefore all whales with $R > 18.2$km were estimated to have $R = 23.8$km.

The geographic coordinates of the observation stations were determined using a personal navigator. Based on the azimuth and the distance to the whale from the observation station, the whale's coordinates were calculated (Fig. 1).



(X_0,Y_0) – coordinates of the observation perch,
(X,Y) – coordinates of the sighted object,
R – distance to the sighted object, meters,
φ – azimuth to the object,
ΔX and ΔY – change in the coordinates, m.

$\Delta X = R \times \sin(90-\varphi)$, $\Delta Y = R \times \cos(90-\varphi)$

Fig. 1. Method for determining the geographic coordinates of the whales' surfacings.

To convert from the metric system to the geographic coordinate system, it was assumed that 1 nautical mile (1,863m) equals 1 longitudinal minute. The equivalent in degrees of 1m on the earth's surface was determined to be:

$$\text{for latitude}: \ 1\text{m} = \frac{1^\circ}{60 \times 1863} = k_X,$$

$$\text{for longitude}: \ 1\text{m} = \frac{180^\circ}{\pi \times r_3 \times \sin(90^\circ - \alpha)} = k_Y,$$

where: r_3 – the earth's radius (6,371,200m);

α – latitude of the observation station.

The coordinates of the sighted object are calculated from the formulas:

$$X = X_0 + R \times \sin(90-\varphi) \times k_X$$

$$Y = Y_0 + R \times \cos(90-\varphi) \times k_Y$$

For graphic mapping of the calculated coordinates of the animal's position and for simplifying how they are used in the Geographic Information System (e.g. ArcView 3.2a) a conversion was made to the geographic coordinates system. In doing so it was assumed that along the entire extent of the route, the angle formed by the direction to the magnetic pole and the latitude equaled 102° taking into account magnetic declination there at that time was 12 degrees and 10' E.

Species determination was sometimes difficult, so screened bowhead datasets for 2000 and 2001 were created. These eliminated any sightings that might have been gray whales. We estimated whales/sighting as (number recorded)/(detection probability P). Three alternatives for P were examined: (1) $P = 1$ (all whales passing during watch under EX-F conditions were seen); (2) $P = Pb$, the bowhead detection probabilities of Zeh and Punt (2005), except that >10km range from Cape Pe'ek was treated as equivalent to offshore distance >2km near Point Barrow because perch heights were so much greater at Cape Pe'ek and (3) $P = Pg$, as analogous as possible to the gray whale detection probabilities used by Buckland *et al.* (1993). In computing Pb, range from Cape Pe'ek was taken to be range to the closest N or D sighting for linked sightings. If range was unknown, it was assumed to be ≤10km. The single sighting at P visibility each year was treated as if visibility were F.

The Pg values were computed as $Pg = \exp(z)/[1 + \exp(z)]$ where

$$z = -0.285 + 0.0893x_1 + 0.309x_2 + 0.00834x_3 + 0.0979x_4 - 0.0677x_5$$

and $x_1,\ldots,x_5$ were defined for bowheads as similarly as possible to their definitions for gray whales. We used

x_1 = number of new or conditional sightings of bowheads per hour in a 6-hour period containing the sighting. For gray whales it was defined as the number of pods recorded per hour over a 3h or 3.5h watch period (Buckland *et al*., 1993; Rugh *et al*., 1993).

x_2 = pod size, taken to be the number recorded.

x_3 = migration date, chosen to correspond as well as possible to the range of 10 to 69 for the gray whale count of 1987-88 that was analyzed by Buckland *et al*. (1993).

x_4 = wind speed, scaled to range from –1.6 at the highest wind speed at which bowheads were seen to 0, the lowest wind speed at which bowheads were seen. Only 8 sightings had $x_4 < -1.2$. In Buckland *et al.* (1993) this variable was actually a wind direction component, ranging from –1 to 1, with the negative values resulting in lower detection probability. Since Melnikov *et al*. (2004) reported that high wind speed adversely affected the ability to see whales, we used this predictor to reflect that. We do not have wind direction data.

x_5 = visibility code from 1 = EX to 5 = P as in Buckland *et al*. (1993).

Although Pb and Pg cannot be assumed to apply to the Cape Pe'ek surveys, they indicate what the numbers of migrating whales might be if detection probabilities at Cape Pe'ek are more like those of similar surveys than like $P = 1$. We treated Pb and Pg as known constants in variance computations.

Methods of estimating the number of migrating whales from the Cape Pe'ek data and the assumptions on which they were based were as similar as possible to those of the surveys near Barrow. The migration period at Cape Pe'ek was assumed to extend from the first day a bowhead was seen through the last day a bowhead was seen in each year. Whales were assumed to migrate continuously throughout this period, regardless of weather, time of day and whether or not observers were counting them. Days were assumed to be "watched" if observers counted for more than 2h with EX-F visibility and "unwatched" otherwise during this period. The day estimate for a watched day is $(N + C/2) \times 1440$/(watched minutes). N and C are the total whales/sighting summed over sightings scored as N and C, respectively. Watched minutes are those with EX-F visibility. To estimate a standard error (SE) for each day estimate, the watched minutes in the day were divided into 5min intervals. The SE of the day estimate is $288 \times s$, where s is the SE of the mean N + C/2 whales per 5min interval and 288 = 1440/5, the number of 5min intervals in a day. This formulation treats counts in different 5min intervals within a day as uncorrelated. Exploratory analyses indicated that within-day correlations were negligible.

The season total estimate for each year is the sum of the day estimates over all the days in the migration period, with a weighted mean estimate used for the unwatched days. The weighted mean estimate, based on the watched days, was computed on a square root scale to give day estimates appropriate weight, considering the minutes of watch and the rate and variability of whale passage each day. The weights in the weighted mean were the inverses of the variances of the day estimates on that scale. The square root transformation was chosen because exploratory analyses indicated that the variances of the untransformed day estimates were proportional to the estimates. Let y_t denote the day estimate for watched day t. Then $\mathrm{var}(\sqrt{y_t}) = \mathrm{var}(y_t) / (4\, y_t)$. The weighted mean used for the unwatched days was $([\sum \sqrt{y_t} / \mathrm{var}(\sqrt{y_t})] / [\sum 1 / \mathrm{var}(\sqrt{y_t})])^2$. A jackknife on watched days provided the SE for the season total estimate. Confidence intervals (CI) were computed as recommended by Buckland (1992).

The weighted averages of the 2000 and 2001 season total estimates T were computed on a log scale to give the two years more equal weight; the coefficients of variation (CV) of the season total estimates were more nearly constant than the SE. $\mathrm{CV}^2(T)$ estimates var[log(T)], where log is the natural logarithm. Thus the weighted geometric mean estimate is

$$\exp([\log(T_{2000}) / \mathrm{CV}^2(T_{2000}) + \log(T_{2001}) / \mathrm{CV}^2(T_{2001})] / [1 / \mathrm{CV}^2(T_{2000}) + 1 / \mathrm{CV}^2(T_{2001})]).$$

Unweighted geometric means were also computed.

RESULTS

Fig. 2 shows Cape Pe'ek, as well as the villages on the Chukotka Peninsula, in the Bering Sea and along the coast of Alaska where whales may be taken. Fig. 3 shows the locations of the whales seen in 2000 and Fig. 4 shows the locations of the whales seen in 2001.

The 2000 migration period as defined above was 31days long (14 May – 13 June) with 18 (58%) watched days; 155 N whales and no C whales were seen. The 2001 migration period was 24 days long (23 May – 15 June) with 14 (58%) watched days; 148 N whales and 26 C whales were seen. In 2001, watches began on 20-22 May and continued through 16-17 June, but visibility was predominantly P-UN, and no bowheads were seen on those days. See Melnikov *et al*. (2004) for more detailed information regarding visibility conditions by day throughout the 2000 and 2001 counts. All watched days in both years had at least 300 watched minutes = 5h.

Estimation results by year are summarized in Table 1. Fig. 5 shows the day estimates that were summed to obtain the season total estimates in Table 1. In each plot of this figure, a horizontal line shows the value used for the unwatched days. Weighted and unweighted geometric means of the 2000 and 2001 results are given in Table 2, with SE, CV and 95% CI.

Table 1

Season total estimates of the number of bowhead whales migrating past Cape Pe'ek in May and June of 2000 and 2001. Results are shown under three different detection probability assumptions, described above.

Year		2000			2001	
Detection probability	1	*Pb*	*Pg*	1	*Pb*	*Pg*
Weighted mean, watched days	10.56	19.42	20.56	16.72	35.18	31.44
Season total	380	721	699	514	1030	899
SE (CV)	86 (23%)	165 (23%)	152 (22%)	149 (29%)	271 (26%)	237 (26%)
95% CI	(245, 589)	(463,1123)	(459,1065)	(295, 897)	(620,1710)	(541,1494)

Table 2
Estimates of the number of bowhead whales migrating past Cape Pe'ek in May and June based on weighted and unweighted geometric means of the 2000 and 2001 estimates.

Type of average		Weighted			Unweighted	
Detection probability	1	*Pb*	*Pg*	1	*Pb*	*Pg*
Total migrating	426	841	774	442	862	793
SE (CV)	76 (18%)	145 (17%)	130 (17%)	81 (18%)	150 (17%)	136 (17%)
95% CI	(301, 603)	(601,1176)	(558,1073)	(310, 631)	(614,1209)	(568,1107)

DISCUSSION

We believe that the estimates based on detection probabilities *Pb* and *Pg* are more likely to be approximately unbiased than those based on the assumption that detection probability = 1. Melnikov *et al*. (2004) noted that bowheads migrating past Cape Pe'ek appeared to be spread somewhat evenly over the 40km distance between Cape Pe'ek and Ratmanov (Big Diomede) Island, with over half of the whales sighted at distances exceeding 10km. This is quite different from the situation at Point Barrow, where the whales are generally constrained by ice conditions to be closer to the observation perches. Only when visibility was excellent was it possible to see Ratmanov Island from Cape Pe'ek, so whales migrating far offshore were clearly missed when visibility was poorer.

Evidence that distant whales are missed by counts like the one conducted at Cape Pe'ek is provided by Rugh and Cubbage (1980). They counted bowhead whales from sites 100-281m high on a bluff near Cape Lisburne, Alaska, during the spring migration of 1978. The whales passed at an average distance of 4.5km, and the maximum distance recorded was 14.8km.

During the spring migration of 1978, whales were also being counted near Point Barrow (Braham *et al*., 1979). If hourly rates for each day computed from the Point Barrow counts are compared to the hourly rates tabled by Rugh and Cubbage (1980), 25% of the days at Point Barrow have higher rates than the maximum rate recorded at Cape Lisburne. A total of 1394 N and 216 C whales were counted from South Perch at Point Barrow in 1978, compared to 280 whales categorized as either N or C at Cape Lisburne. In other words, many more whales were missed at Cape Lisburne than at Point Barrow.

According to Rugh and Cubbage (1980), 14.8km "approaches the outer limit of reliable visibility under excellent conditions." It is likely that their distances were computed as $h \times \tan(\pi/2 - \theta)$ and did not incorporate a correction for curvature of the earth. Had we computed distances using this formula, our maximum computed distance would have been 14.1km, reasonably comparable to theirs, instead of 23.8km.

The equation we use to estimate the distance R is extremely sensitive to small changes in the angle θ when θ is small. This is because it treats the expression $\sin(\pi/2 - \theta) \times (r_3 + h) / r_3$ as the sin of an angle, so this expression must be 1 or less. When θ is small, $\sin(\pi/2 - \theta)$ is very close to 1, and the expression can exceed 1, so that R cannot be computed. For example, when θ increases from 0.0046 to 0.005, R decreases from 23.8km to 18.2km. Large values of R should be viewed as only approximate.

For the Point Barrow survey in 2001, where the height of the observation perch at the end of May was h = 8.1m instead of h = 65m at Cape Pe'ek, R at the smallest usable θ was 5-6km. This suggests that our use of 10km at Cape Pe'ek as equivalent to 2km at Point Barrow in computing *Pb* was reasonable, since $2/5 \approx 10/23.8$.

In addition to distant whales at Cape Pe'ek, visibility was a problem. In 2000, 53.2% of hours during the migration had P or UN visibility, and in 2001, 59.3% (Melnikov *et al*., 2004). This resulted in 42% of the days during the migration period being unwatched in both years. With such a large fraction of unwatched days, significant pulses of whales may have been missed, as noted by Melnikov *et al*. (2004). In 2001, there were also unwatched days before the first whale was seen and after the last whale was seen, so whales may have been missed at the start or end of the migration.

However, it is also possible that the unwatched days had lower rates of passage than the watched days. If that were the case, our estimates would be too high. Melnikov *et al*. (2004) stated that the migration seemed to stop when there were high winds or storms. If this is true, we may have overestimated the number of migrating whales by assuming that the migration continued even on stormy days. However, stormy weather does not appear to stop the migration near Barrow. It is possible that the lack of sightings from Cape Pe'ek during bad weather related to shorter watches on stormy and windy days or to greater difficulty in seeing whales on those days.

To resolve some of the uncertainties discussed above, it would be useful to repeat the Cape Pe'ek survey in a future year with some methodological additions, if possible. First, an 'independent observer' experiment designed to permit estimation of detection probability at Cape Pe'ek should be designed and carried out. Second, acoustic monitoring and location analysis (George *et al*., 2004) or visual counts from Ratmanov Island should be used to estimate how many whales pass beyond the visual range from Cape Pe'ek. Acoustic monitoring would also provide information about whale passage on unwatched days. The use of theodolites instead of, or in addition to, binoculars for determining the positions of sightings should be considered. Some additional research on limits of visual range and estimation of R near these limits might also be useful.

Because bowheads were counted at Point Barrow in 2001 as well as at Cape Pe'ek, it is of interest to consider whether the same whales might have been counted in both places. Cape Dezhnev is about 930km from Point Barrow. Melnikov *et al*. (2004) estimated a mean migration speed of 8.4km/h in 2001. A whale travelling at that speed from Cape Dezhnev to Point Barrow would arrive at Point Barrow on 27 May or 28 May if it passed Cape Dezhnev on the first day of the 2001 migration period. No bowheads seen at Point Barrow between 27 May and 6 June (the last day any were seen) in 2001 were travelling at a speed that high. The median speed at Point Barrow during that period was 4.6km/h.

Melnikov *et al*. (2004) noted that northbound currents are stronger near Cape Dezhnev than on the other side of the Bering Strait. If any whales counted at Cape Pe'ek travelled to Point Barrow, their average migration speed over the entire route was probably between 4.6 and 8.4km/h. A migration speed of 6.5km/h translates into a transit time between Cape Dezhnev and Point Barrow of 6d. Therefore, we can say with some confidence that the 94 N and 18 C whales seen from Cape Pe'ek in June of 2001 could not have reached Point Barrow before the end of the ice-based survey there. The whales passing Cape Pe'ek in June of 2001 represented 64% to 68% of the season total estimates given in Table 1 for 2001.

ACKNOWLEDGEMENTS

We gratefully acknowledge the funding provided by the North Slope Borough Department of Wildlife Management (NSB DWM) to support this work. We also thank Craig George (NSB DWM) and Dave Rugh (NOAA) for helpful discussions.

REFERENCES

Bogoslovskaya, L.S., Votrogov, L.M. and Krupnik, I.I. 1982. The bowhead whale off Chukotka: migrations and aboriginal whaling. *Rep. int. Whal. Commn* 32:391-9.

Braham, H., Krogman, B., Leatherwood, S., Marquette, W., Rugh, D., Tillman, M., Johnson, J. and Carroll, G. 1979. Preliminary report of the 1978 spring bowhead whale research program results. *Rep. int. Whal. Commn* 29:291-306.

Buckland, S.T. 1992. Proposal for standard presentation of abundance estimates. Report of the Scientific Committee, Annex H. *Rep. int. Whal. Commn* 42:235.

Buckland, S.T., Breiwick, J.M., Cattanach, K.L. and Laake. J.L. 1993. Estimated population size of the California gray whale. *Marine Mammal Science* 9(3):235-49.

George, J.C., Zeh, J., Suydam, R. and Clark, C. 2004. Abundance and population trend (1978–2001) of western Arctic bowhead whales surveyed near Barrow, Alaska. *Marine Mammal Science* 20(4):755-73.

International Whaling Commission. 2003. Report of the Scientific Committee. *J. Cetacean Res. Manage.* 5(Suppl.):1-92.

Lerczak, J.A. and Hobbs, R.C. 1998. Calculating sighting distances from angular readings during shipboard, aerial, and shore-based marine mammal surveys. *Marine Mammal Science* 14(3): 590-9.

Melnikov, V.V., Zelensky, G.M. and Ainana, L.I. 1998. Observations on distribution and migration of bowhead whales (*Balaena mysticetus*) in the Bering and Chukchi Seas. Paper SC/50/AS3 presented to the IWC SC, April 1998.

Melnikov, V.V., Litovka, D.I., Zagrebin, I.A., Zelensky, G.M. and Ainana, L.I. 2004. Shore-based counts of bowhead whales along the Chukotka Peninsula in May and June 1999 – 2001. Arctic 57(3):290-8.

Rugh, D.J. and Cubbage, J.C. 1980. Migration of bowhead whales past Cape Lisburne, Alaska. *Marine Fisheries Review* 42(9-10):46-51.

Rugh, D.J., Breiwick, J.M., Dahlheim, M.E. and Boucher, G.C. 1993. A comparison of independent, concurrent sighting records from a shore-based count of gray whales. *Wildl. Soc. Bull*. 21:427-37.

Zeh, J.E. and Punt, A.E. 2005. Updated 1978-2001 abundance estimates and their correlations for the Bering-Chukchi-Beaufort Seas stock of bowhead whales. *J. Cetacean Res. Manage.* 7(2):169-75.

.

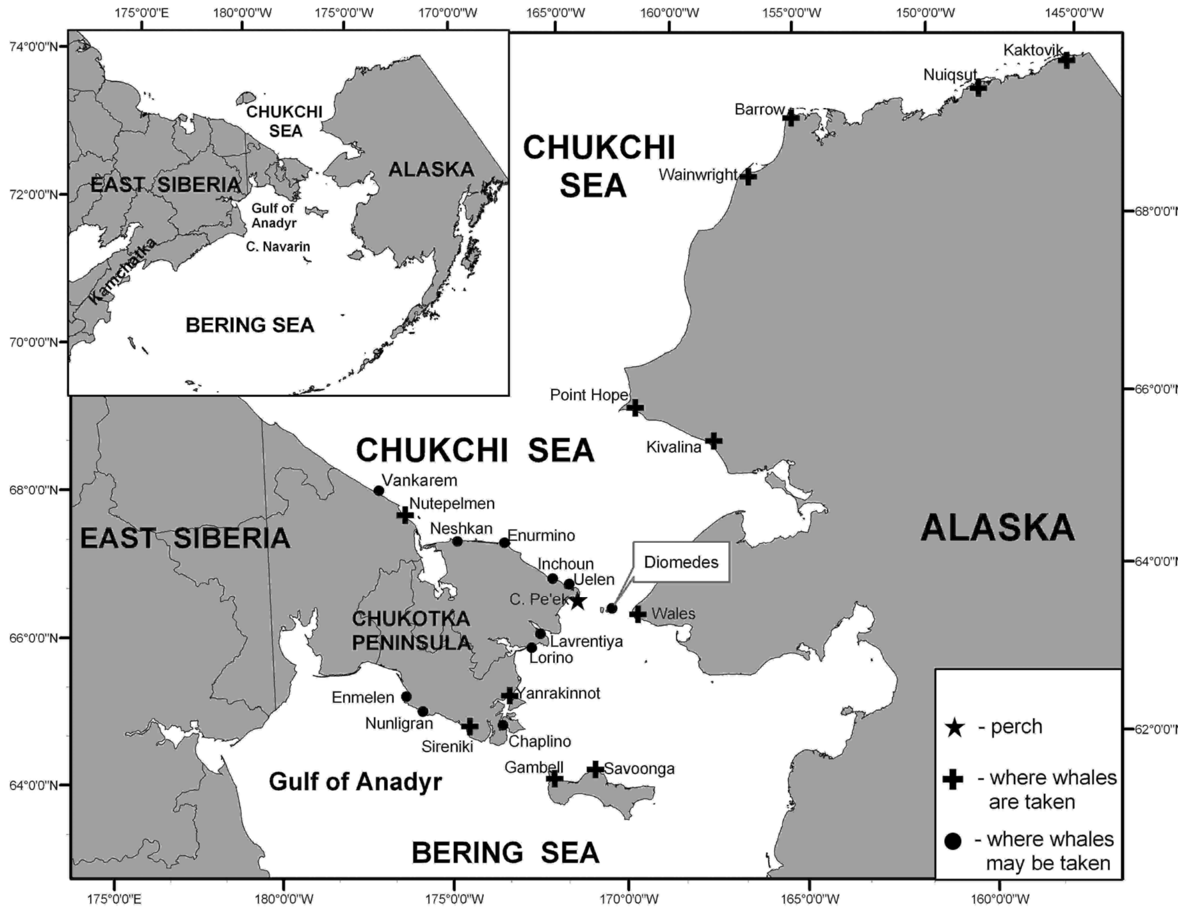


Fig. 2. Location of Cape Pe'ek, the observation perch from which whales were counted as they migrated along the Chukotka coast. Villages where bowhead whales may be taken in the aboriginal subsistence hunt on the Chukotka Peninsula, in the Bering Sea and along the coast of Alaska are also shown.

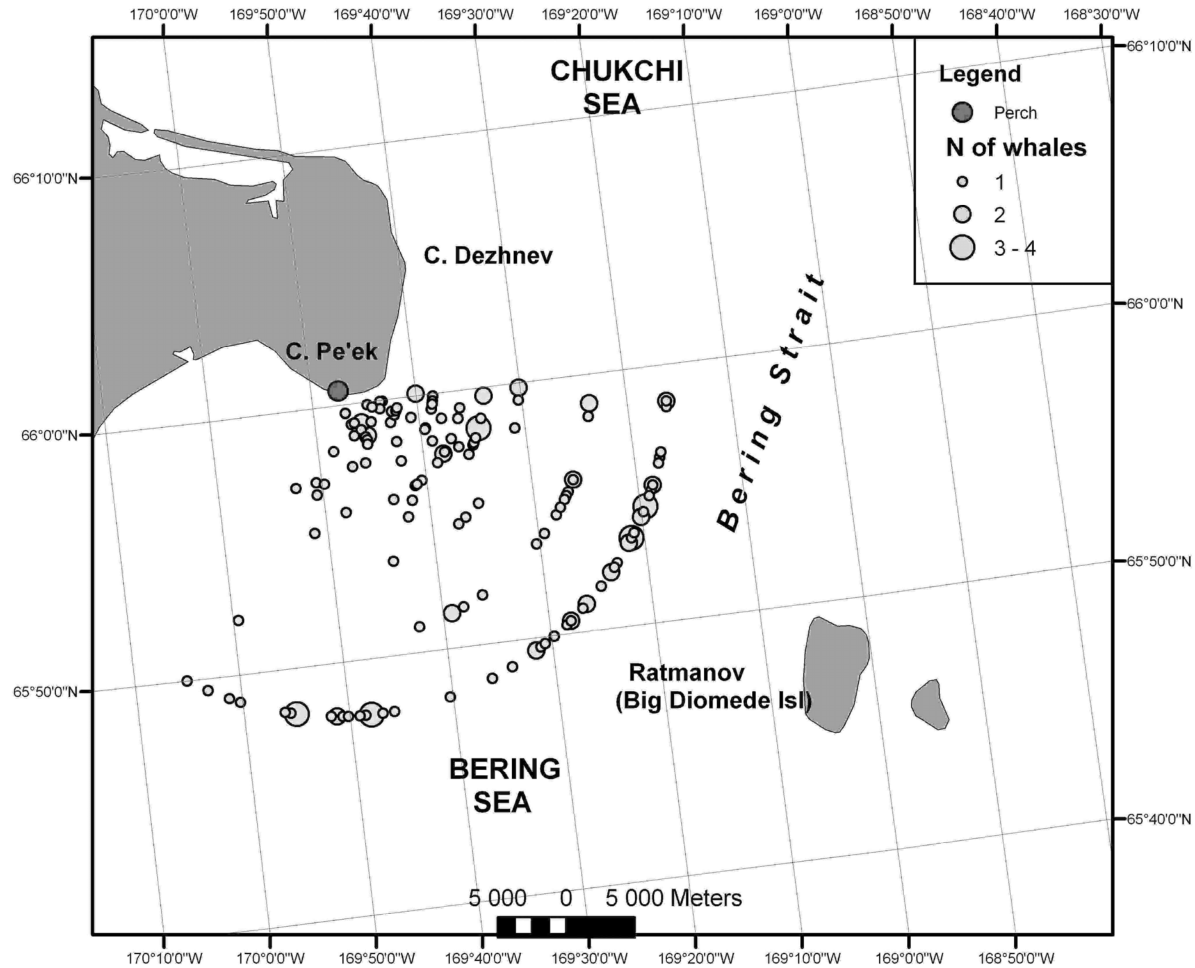


Fig. 3. Locations where bowhead whales were seen during the Cape Pe'ek count in 2000.

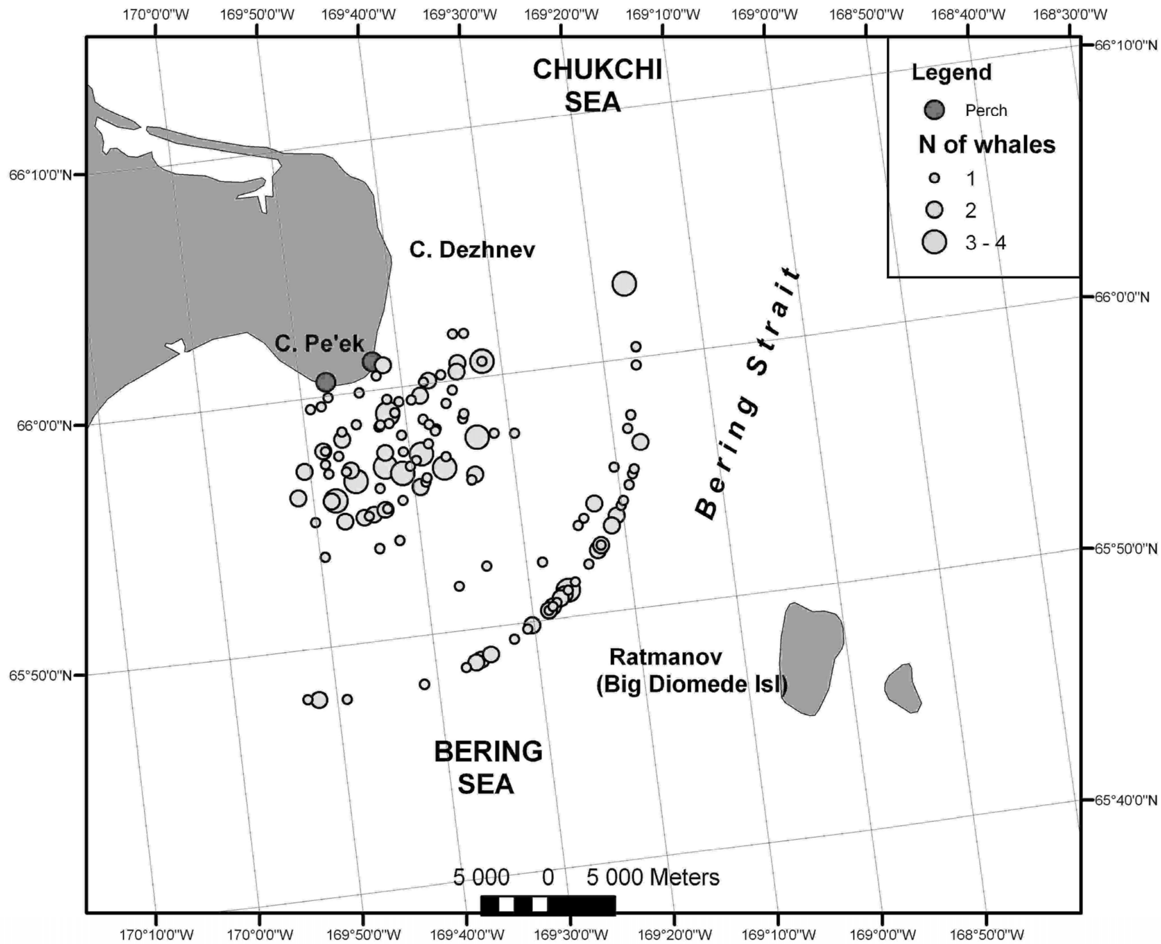


Fig. 4. Locations where bowhead whales were seen during the Cape Pe'ek count in 2001.

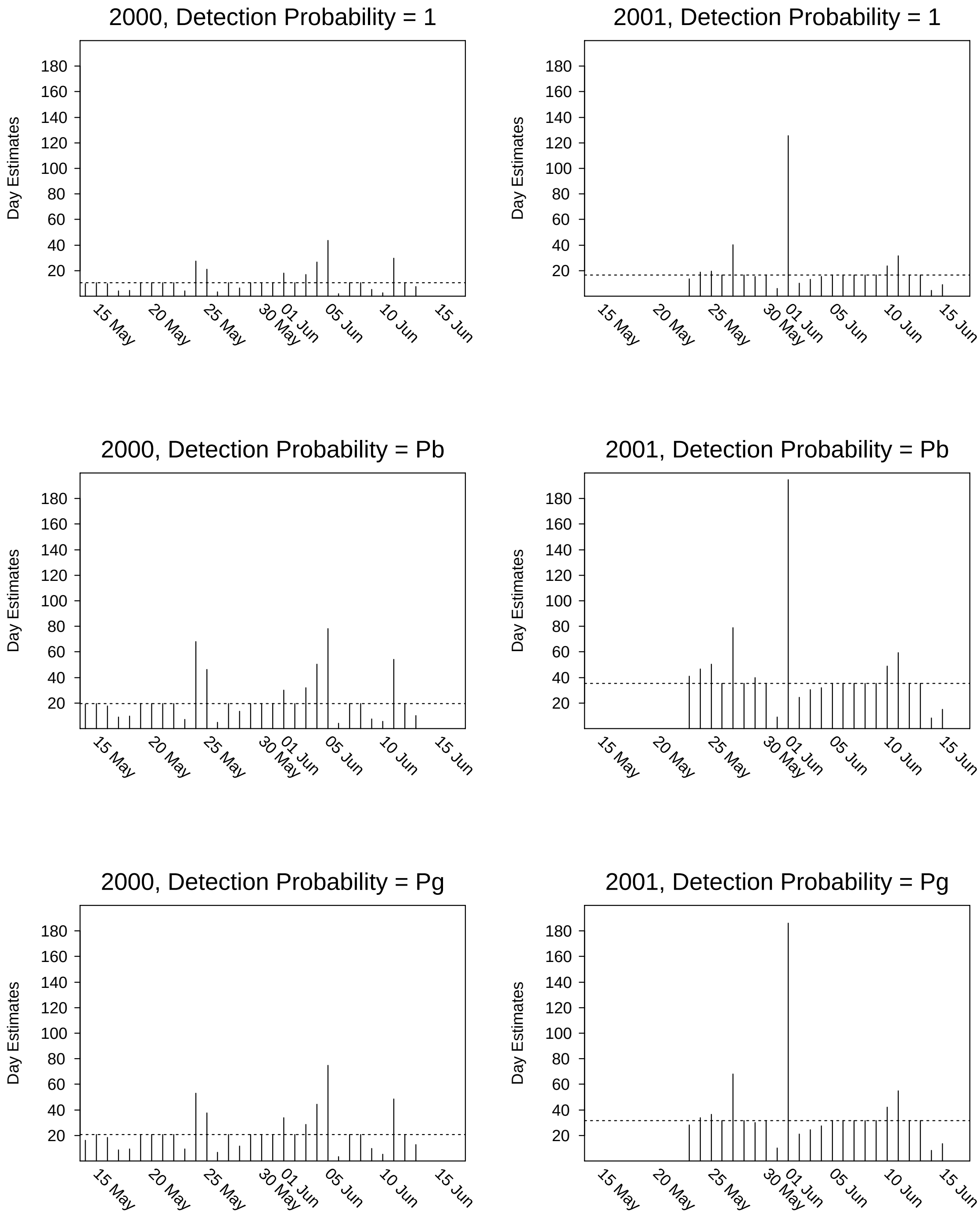


Fig. 5. Day estimates for both years and all three assumed detection probabilities, with dotted lines giving the day means used for unwatched days. Detection probabilities are:
1 = all whales passing during watch with fair to excellent visibility are assumed to have been seen,
Pb = detection probabilities analogous to those of Point Barrow bowhead surveys and
Pg = detection probabilities analogous to those of gray whale surveys near Monterey.