# Abundance of eastern North Pacific gray whales on the 1995/96 southbound migration

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ABSTRACT

Systematic counts of gray whales (*Eschrichtius robustus*) were conducted from 13 December 1995 to 23 February 1996 at Granite Canyon, California. This study was the second of three during the five-year period following the removal of gray whales from the US government list of endangered and threatened wildlife. The counts were made at the same research station used most years since 1975 by the National Marine Mammal Laboratory to observe the southbound migration of the eastern North Pacific stock. Counting methods were kept similar to those used in previous surveys and included double counting to assess observer performance. In addition, aerial surveys and high-powered binoculars provided documentation that a negligible fraction of migrating whales passed beyond the sighting range of the counting observers. A total of 2,151 pods (3,928 whales) was counted during 472.7hrs of standard watch effort with visibility recorded as fair to excellent. Data analysis procedures were substantially the same as in previous years with a modification to account for differential sightability by pod size. Population size is estimated to be 22,263 whales (CV=9.25%; 95% log-normal CI=18,700-26,500). This estimate is similar to the previous estimate of 23,109 (CV=5.42%; 95% CI=20,800-25,700) from the 1993/94 survey.

KEYWORDS: GRAY WHALE; ABUNDANCE ESTIMATE; PACIFIC OCEAN; SURVEY-SHORE-BASED

## INTRODUCTION

The eastern North Pacific stock of gray whales has a predictable migration which has allowed researchers to conduct counts at regular intervals (Reilly, 1984). From mid-December to mid-February each year, gray whales migrate south past the Granite Canyon research station near Carmel, California. Convenient access to this site and the narrowness of the whale's migratory corridor there have permitted an efficient counting process that has been repeated through many seasons (see Reilly, 1984 and Laake *et al*., 1994). In recent years, the counting procedure has been tested in several ways: (1) aerial surveys (Shelden and Laake, 2002) and shore-based surveys using high-power binoculars (Rugh *et al*., 2002) have documented the distribution of sightings on the seaward side of the migratory corridor; (2) comparison of aerial observations with shore-based observations has determined the bias in pod size estimates by shore-based observers (Laake *et al*., 1994); (3) paired, independent counts of observers have allowed an estimate of whales missed within the viewing range during adequate visibility periods (Rugh *et al*., 1990; 1993); and (4) data from radio-tagged gray whales near Granite Canyon (Swartz *et al*., 1987) and thermal sensor images (Perryman and Laake, 1994) have been used to estimate the ratio of night to daytime passage rates.

Analytical techniques have followed the method described in Buckland *et al*. (1993). Aspects of this method were developed for earlier abundance estimates in Reilly *et al*. (1983) and Breiwick *et al*. (1988); the method was applied to the 1992/93 and 1993/94 census results in Laake *et al*. (1994). Buckland and Breiwick (2002) estimate trends in abundance for this population.

The objective of the 1995/96 study was to make a systematic count of gray whales passing the research station during the southbound migration. The basic counting effort was kept comparable to efforts used in previous seasons including paired, independent counts. In addition, an aerial survey (Shelden and Laake, 2002) and a 25× binocular study (Rugh *et al*., 2002) documented offshore distribution, while a thermal sensor study (Perryman *et al*., 1999) estimated whale passage rates during non-watch periods. The additional studies will be reported in separate documents with results included here as available. This study was the second of three to be undertaken (in 1993/94, 1995/96 and 1997/98) in the five years following the removal of gray whales from the United States List of Endangered and Threatened Wildlife on 16 June 1994 (Federal Rule 59 FR 31095).

## METHODS

### Field study

Systematic counts of gray whales were conducted from 13 December 1995 to 23 February 1996, covering the duration of the southbound migration past the Granite Canyon research station. The site, 13km south of Carmel, California, has been used by the National Marine Mammal Laboratory (NMML) for most years since 1975. Observation sheds, set on a 20.5m bluff, provide some protection from the elements and help to maximise concentration on the viewing area. Although the field of view covers more than 150°, observers generally search through only 40-50° north of the standard azimuth, a line perpendicular to the coastline (241° magnetic) at the survey site. A total of eight people took part in the shore-based counts. Seven were experienced in cetacean surveys, and six had previous experience with gray whale counts at Granite Canyon. As in previous seasons, three three-hour standard watch shifts covered the nine daylight hours from 07:30 to 16:30 hours. Observers were rotated to maintain equal effort in each of the three shifts.

Standard watch procedures were as in previous surveys (Rugh *et al*., 1990; 1993; Laake *et al*., 1994). When a gray whale pod was first sighted, the time, horizontal bearing and vertical angle were recorded. Magnetic compasses in *Fujinon* 7×50 binoculars provided horizontal bearings (±2°), and 14 reticle marks in the binoculars provided vertical angles relative to the horizon (detailed in Rugh *et al*., 1993). The pod was tracked by the observer as it proceeded south past the survey site. A chart was available to predict the time and vertical angle at which the pod would cross the standard azimuth. The time, horizontal bearing and vertical angle were recorded a second time as close to the standard azimuth as possible. An estimate of pod size was recorded along with any unusual behaviour, the presence of a calf and the number of times the pod was seen as it passed the site. In addition to whale sightings, observers recorded start and end times of systematic search effort and times of environmental change. The observation environment was characterised by visibility (subjectively categorised from 1 to 6, i.e. excellent to unacceptable), sea state (Beaufort scale) and wind direction.

In addition to the primary watch, a second, independent watch was conducted once or twice daily from 3-26 January 1996. The field of view, shed and station conditions of this paired watch were nearly identical to those of the primary watch station. This provided an independent sighting record, allowing for comparisons between observers and estimation of the fraction of whales missed by the primary observer. Methods were as described in Rugh *et al.* (1990; 1993). The 'south shed', the primary watch station, was used for the standard counts; the 'north shed' was used only when paired counts were being made.

To document the offshore distribution of whales independently from the paired counts on the standard watch, searches through shore-based 25-power binoculars and an aerial survey were conducted. Two high-power binoculars were mounted in separate observation sheds. In this study, few pods were seen beyond 3 n.miles. Further details and results are described in Rugh *et al.* (2002). Aerial surveys were conducted from 13-23 January 1996, as described in Shelden and Laake (2002). Tracklines were flown perpendicular to the coastline within 3 n.miles north and south of the counting station. Most tracklines were 10 n.miles long, but samplings were also conducted out to 20 n.miles. Only 1.28% of the whales encountered were beyond 3 n.miles, so the paired, independent counts of shore-based observers are considered adequate to represent the drop-off in sighting rates as a function of distance from shore. Thus, it was determined that no correction, other than for probability of detection by distance, was necessary for whales passing the site beyond 3 n.miles offshore.

In January 1993 and January 1994, pod size estimation experiments were conducted. An airplane circled pods of whales as 10 shore-based observers estimated pod sizes independently. This test resulted in a total of 240 estimates from 60 pods. The data were used in Laake *et al.* (1994) to estimate bias in recorded pod size and have also been used in this analysis.

## Analysis

Population abundance calculations have been modified here from the analytical procedures developed in Buckland *et al.* (1993) and used by Laake *et al.* (1994) to account for: (1) differential sightability by pod size; and (2) covariance within the estimated number of whales sighted when corrections are applied to individual sightings of pods. Accordingly, the systematic counts of southbound whales are used to estimate the total number of whales passing the site during usable periods of watch effort. This was done by estimating the number of pods of each size passing during watch periods, multiplying by recorded pod size, then correcting for bias in estimating pod size and summing the result. The number thus obtained for total whales passing during watch periods was then multiplied by corrections for: (1) whales passing when no watch was in effect (including periods with poor visibility) ($f_t$); and (2) differences in diurnal/nocturnal travel rates ($f_n$). The total abundance estimate ($\hat{N}$) is calculated as:

$$\hat{N} = \hat{W} \cdot f_t \cdot f_n$$

where $\hat{W}$ is the estimated number of whales passing during watch periods. The coefficient of variation (CV) is estimated by:

$$CV(\hat{N}) \cong \sqrt{CV^2(\hat{W}) + CV^2(Q) + CV^2(f_t) + CV^2(f_n)}$$

where CV($Q$) represents variability in the observed passage rate of whales about the fitted passage rate used to estimate ($f_t$).

*Selection of usable effort periods*

The analysis began by calculating the time and vertical angle at which each pod crossed the standard azimuth, assuming a travel speed of 3kts and travel parallel to the coastline (see Rugh *et al.*, 1993). The time from the beginning of the survey to the end was partitioned into effort periods and non-effort periods. The effort periods were further partitioned so that change in observer, visibility, wind direction or Beaufort sea state began a new effort period. Each sighting was assigned to the effort period into which its azimuth crossing time fell. The average sightings per hour by visibility code were compared, to determine the threshold visibility below which sighting rates drop off significantly. Effort periods with poorer quality visibility than this threshold were considered non-effort periods in the subsequent analysis.

*Estimate of total whale pods passing during watch periods*

Corrections for whale pods missed within the viewing area during systematic watch were estimated from the paired, independent observation records from the north and south sheds. Comparison of sightings from the two locations provided capture-recapture data. Rugh *et al.* (1993) established a scoring algorithm that defined matches between records based on time, offshore distance and pod size. Iterative logistic regression (Buckland *et al.*, 1993) was used to identify significant covariates to the probability of detecting a pod and to estimate the detection probability associated with each recorded pod. Possible covariates were shed (north or south), watch period, day, observer, distance offshore, pod size, sea state, wind direction and whales per hour. Once the matching record was established, all covariates were examined individually as binned categorical data. For numeric data, functional forms were chosen or bins were combined to represent the data with as few parameters as possible. All covariates were then entered into the model, and a backward step-wise model selection was followed until no step decreased the Akaike Information Criterion (AIC). The logistic regression model was used to estimate $p_{ie}$, the detection probability of the $i$th pod of size $e$ recorded by the south shed observer. The total number of pods of size $e$ passing during the effort periods of the survey, $\hat{M}_e$, and its variance were estimated as:

$$\hat{M}_e = \sum_{i=1}^{m_e} \frac{1}{p_{ie}}, \; Var(\hat{M}_e) = \sum_{i=1}^{m_e} \left[ \frac{1 - p_{ie}}{p^2_{ie}} \right] + D_\beta(\hat{M}_e)^T \hat{\Sigma}_\beta D_\beta(\hat{M}_e)$$

where $m_e$ is the number of pods assigned size $e$ sighted from the south shed, $D_\beta(\hat{M}_e)$ is the vector of partial derivatives of $\hat{M}_e$ with respect to the vector of parameters $\beta$ estimated in the logistic regression evaluated at $\hat{\beta}$, the vector of parameter estimates, and $\hat{\Sigma}_\beta$ is the estimated variance-covariance matrix of $\hat{\beta}$ (c.f. Borchers, 1996). The estimated total number of pods passing the field site during watch periods, $\hat{M}$, is then:

$$\hat{M} = \sum_{e=1}^{E} \hat{M}_e,\ \mathrm{Var}(\hat{M}) = \sum_{e=1}^{E} Var(\hat{M}_e) + 2\sum_{j=1}^{E-1}\sum_{k=j+1}^{E} D_\beta(\hat{M}_j)^T \hat{\Sigma}_\beta D_\beta(\hat{M}_k)$$

where $E$ is the largest observed pod size.

*Bias in recorded pod sizes*

Bias in the mean recorded pod size results from differential sightability of pods by size and from underestimation of pod size by observers. The differential sightability was accounted for by using the estimated number of pods passing during a watch, $\hat{M}_e$, in place of the number of pods recorded, $m_e$, (c.f. Buckland *et al*., 1993; Laake *et al*., 1994). An additive correction for pod size estimation bias was estimated for each pod size, $e$, from data collected during earlier surveys. Variances and covariances for these corrections and the standard deviation of the sub-sample were estimated by a bootstrap method in which seven observers and 60 pods were drawn at random, with replacement, from a pod size estimation experiment dataset to generate 10,000 samples of equivalent size. The variances and covariances were estimated from the correction factors calculated from these datasets. The total number of whales passing the observation site during watch periods represented by pods recorded as size $e$, $\hat{W}_e$, was estimated as:

$$\hat{W}_e = \hat{M}_e(e+b_e) \quad , \quad Var(\hat{W}_e) = Var(\hat{M}_e)(e+b_e)^2 + \hat{M}_e^2 \hat{\sigma}_{be}^2 + \hat{M}_e s_e^2$$

where $b_e$ is the estimated additive bias correction for pods estimated as size $e$ from Laake *et al.* (1994), $\hat{\sigma}_{be}^2$ is the bootstrap estimate of the variance of $b_e$, and $s_e$ is the bootstrap estimate of the standard deviation of the bias estimation samples for pods estimated as size $e$. Note that the variance consists of three summands. The left and center summands represent the estimation errors in $\hat{M}_e$ and $b_e$, and the right summand is the variation due to classification errors in assigning pod size. The total number of whales passing the site during usable watch periods was estimated as:

$$\hat{W} = \sum_{e=1}^{E} \hat{W}_e \quad , \quad CV(\hat{W}) = \frac{1}{\hat{W}} \sqrt{ \sum_{e=1}^{E} Var(\hat{W}_e) + 2\sum_{j=1}^{E-1}\sum_{k=j+1}^{E} \left[ \begin{array}{l} (j+b_j) D_\beta(\hat{M}_j)^T \hat{\Sigma}_\beta\ D_\beta(\hat{M}_k)(k+b_k) \\ +\hat{M}_j\ \hat{M}_k \hat{\sigma}_{bjk} \end{array} \right] }$$

where $\hat{\sigma}_{bjk}$ is the bootstrap estimated covariance of $b_j$ and $b_k$.

*Correction for whales passing during non-watch periods ($f_t$)*

The rate of whales passing the site through time was modelled by a normal distribution with Hermite polynomials added to adjust for skewness, kurtosis and higher moments (Buckland *et al*., 1993). The model defines a bell-shaped rate function, $q(t)$, of expected whales per day integrated to correct for periods when no watches were conducted. The correction factor, $f_t$ , was defined as the ratio of the total area under the function, $Q$, to the sum over all watch effort periods of the area under the function during each effort period, (for the $k$th effort period). Components of $CV(N)$ that resulted from this analysis were the $CV(f_t)$, from the variance of the parameters of $q(t)$, and $CV(Q)$, which represents the variance about the $Q_k$ of the corrected number of whales in the $k$th effort period.

*Correction for difference in diurnal/nocturnal travel rates ($f_n$)*

The night passage rate, $f_n$ , used by Buckland *et al.* (1993) was also used here. It was based on data from radio-tagged gray whales near Granite Canyon (Swartz *et al*., 1987).

## RESULTS

There was a total of 524.5 hours of survey effort during the 73 days on which standard watches were conducted from 13 December 1995 to 23 February 1996. The average encounter rate of pods per hour in fair to excellent viewing conditions (visibility $\leq$4) was 4.550 (SE=0.409) and dropped off significantly to 2.991 pods per hour (SE=0.437, $p$=0.005) at visibility below fair (>4) (Table 1). Visibility 4 was thus selected as the threshold value for usable effort periods. There was a total of 472.7 hours of watch in usable effort in the standard watch and 51.8 hours when visibility was too poor (>4) to be included in the analysis. During the standard watch, a total of 2,300 southbound pods (4,197 whales) were recorded, of which 2,151 pods (3,928 whales) were seen with visibility $\leq$4 (Table 1). Average recorded pod size was 1.83 (CV=1.46%) during usable effort periods.

Table 1

Rates of sightings of gray whale pods by visibility code.

| Visibility | Visibility code | Pods/hr | SE | Hours of effort | Number of pods |
|---|---|---|---|---|---|
| Excellent | 1 | 10.800 | 0.480 | 2.5 | 27 |
| Very good | 2 | 5.483 | 0.729 | 76.8 | 421 |
| Good | 3 | 4.157 | 0.303 | 240.1 | 998 |
| Fair | 4 | 4.596 | 0.358 | 153.4 | 705 |
| Poor | 5 | 2.991 | 0.437 | 49.8 | 149 |
| Unacceptable | 6 | 0.000 | 0.000 | 2.0 | 0 |
| All effort | | | | 524.5 | 2,300 |
| Usable effort | 1 - 4 | 4.550 | 0.409 | 472.7 | 2,151 |

The passing rate of the migration was symmetrical around the peak of the migration on 16 January 1996 (day 47.8 with 1 December 1995 = day 1) with a standard deviation of 12.1 days (Fig. 1). No Hermite polynomial corrections to the normal distribution were necessary. The correction factor for whales passing when no watches were in effect, $f_t$ ,was estimated to be 3.30 (CV=0.10%). The mean sighting rate during visibility $\leq$4 for the period 15-19 January 1996 of 9.1 pods/hr, was lower than the 11 pods/hr seen during 15-19 January 1994 and 10.7 pods/hr seen during 15-19 January 1995.

The mean offshore distance of gray whale pods seen with visibility $\leq$4 was 1.05 n.miles (1.94 km; SD=0.397 n.miles; Fig. 2). When corrected for differential sightability by pod size and distance, the mean offshore distance was 1.25 n.miles (2.31km; SD=0.807 n.miles, SE=0.17 n.miles). This was comparable to the mean sighting distance of 1.21 n.miles (SE=0.06) found during aerial surveys conducted in January 1996 (Shelden and Laake, 2002).

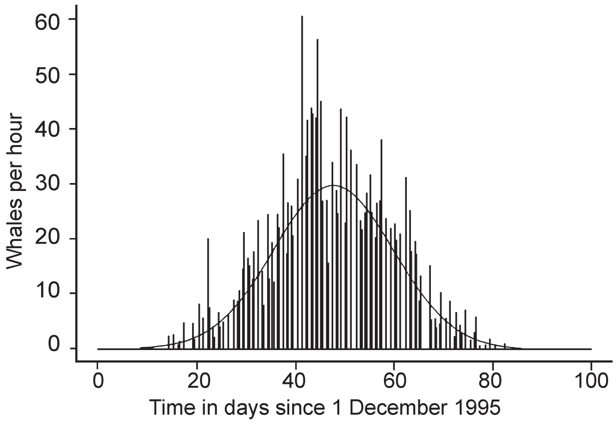


Fig. 1. Sighting rates of gray whales in the standard watch effort periods 13 December 1995 to 23 February 1996 during the southbound migration past Granite Canyon, California. Only effort periods with visibility ≤4 were included. Curve is fitted passage rate, $q(t)$.

A total of 640 pods passed during periods of double counts with visibility ≤4. Of these, 456 were seen by both observers and 184 by only one observer. Examination of the individual categorical parameter fits of the possible covariates indicated that a third order polynomial would be sufficient to model the effect of distance offshore. The pod size effect appeared linear up to size five where it levelled off. Consequently, pod size was truncated at five and entered as a linear effect. All other numeric data were entered as linear effects. A stepwise logistic regression model selection resulted in significant effects of distance offshore (a second order polynomial), pod size, sea state and observer (Table 2). Pair-wise interactions were considered between each of these factors, the interaction between distance offshore and pod size was found to be significant. The resulting model was applied to the south shed data to estimate the correction for pods missed during watch. The logistic regression showed differential sightability by pod size and it was thus necessary to correct each pod size class separately.

Bias estimates (Table 3) from Laake *et al.* (1994) were used to correct the pod sizes (Table 4) so that mean corrected pod size was estimated as 2.56 (CV=8.80%). The estimated number of whales passing during watch periods was 6,611 (CV=8.62%). The total number of whales passing Granite Canyon during the 1995-96 southbound migration was estimated to be 22,263 (CV=9.25%; 95% CI=18,700-26,500; Table 5).

Table 2

Covariates and fitted parameters used to model the pod detection probability. Covariates are distance (D), pod size (PS), sea state (SS) and observer (OBS).

| | Value | SE | t-value | Df | Sum of squares | Residual sum of squares |
|---|---|---|---|---|---|---|
| Constant | -1.407 | 1.094 | -1.287 | | | 1,245.4 |
| D(n.mile) | 4.504 | 1.354 | 3.326 | 1 | 11.1 | 1,256.5 |
| $D^2$ | -1.681 | 0.423 | -3.971 | 1 | 15.8 | 1,261.2 |
| PS | 1.421 | 0.714 | 1.990 | 1 | 4.0 | 1,249.4 |
| DxPS | -1.681 | 0.875 | -1.921 | 1 | 3.7 | 1,249.1 |
| $D^2$xPS | 0.517 | 0.259 | 1.999 | 1 | 4.0 | 1,249.4 |
| SS | 0.178 | 0.086 | 2.063 | 1 | 4.3 | 1,249.7 |
| OBS | | | | 7 | 25.2 | 1,270.6 |

Table 3

Estimated biases by pod size from Laake *et al.* (1994) where $b_e$ is the additive pod size correction, $s_e$ is the bootstrap derived standard deviation around $b_e$ and $\hat{\sigma}^2_{be}$ is the bootstrap derived standard error of $b_e$.

| Pod size | $b_e$ | $s_e$ | $\hat{\sigma}^2_{be}$ |
|---|---|---|---|
| 1 | 0.941 | 1.273 | 0.071 |
| 2 | 0.646 | 1.262 | 0.064 |
| 3 | 0.607 | 1.229 | 0.155 |
| 4+ | 0.250 | 1.916 | 0.432 |

## DISCUSSION

The population estimate calculated for the 1995/96 season (22,263) was very close to the Laake *et al.* (1994) estimate for 1993/94 (23,109; CV=5.42%, 95% CI=20,800-25,700) and that for 1987/88 (21,296; CV=6.05%, 95% CI=18,900-24,000) (Buckland *et al.*, 1993), but all of these were significantly higher than the Laake *et al.* (1994) estimate for 1992/93 (17,674; CV=5.87%, 95% CI=15,800-19,800). Variations in estimates may in part be due to undocumented vagaries in sampling or to differences in the proportion of the gray whale population that migrates as far south as

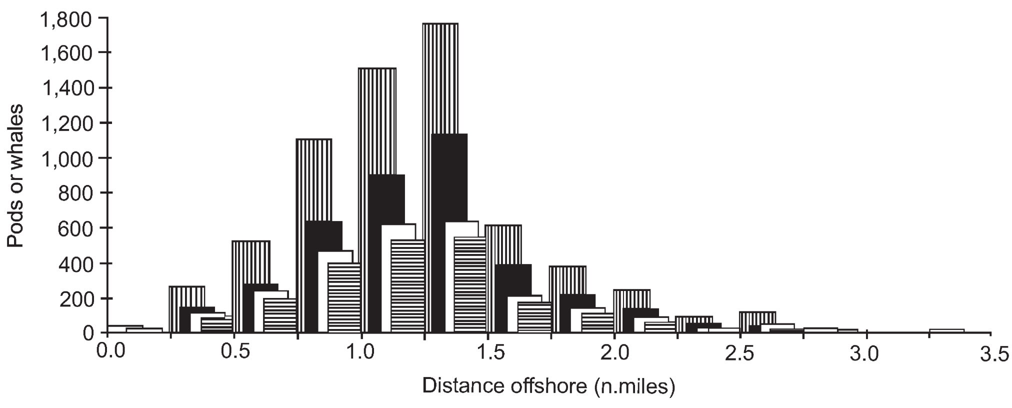


Fig. 2. Offshore distribution of: (1) total recorded pods (horizontal shading); (2) corrected total pods (white); (3) total recorded whales (black); (4) corrected total whales (vertical shading) from sightings of gray whales made between 13 December 1995 and 23 February 1996 during the southbound migration past Granite Canyon, California. Only effort periods with visibility ≤4 were included.

Table 4

Estimation of total whales passing during watch periods.

| Pod size | Number of recorded pods | Average correction for missed pods | Corrected pod size | Estimated total whales | CV of total whales (%) |
|---|---|---|---|---|---|
| 1 | 1,180 | 1.234 | 1.941 | 2,826 | 14.9 |
| 2 | 538 | 1.161 | 2.646 | 1,653 | 10.8 |
| 3 | 235 | 1.157 | 3.607 | 980 | 12.6 |
| 4 | 105 | 1.138 | 4.250 | 507 | 17.9 |
| 5 | 50 | 1.127 | 5.250 | 295 | 15.6 |
| 6 | 19 | 1.187 | 6.250 | 140 | 16.8 |
| 7 | 14 | 1.085 | 7.250 | 110 | 14.3 |
| 8 | 6 | 1.110 | 8.250 | 55 | 18.2 |
| 9 | 3 | 1.068 | 9.250 | 30 | 20.4 |
| 10 | 1 | 1.071 | 10.250 | 11 | 31.9 |
| All | 2,151 | 1.198 | | 6,611 | 8.62 |

Carmel each year. Gray whale migrations have become increasingly delayed, particularly since the 1970s (Buckland and Breiwick, 2002). The 1995/96 migration continued this trend with its median date being later than for nearly all other surveyed years. In the autumn of 1995, sea ice in the northern Chukchi Sea was unusually late in forming (J.C. George, pers. comm.). The mild ice conditions may have meant that whales were distributed farther in the Arctic than usual and thus took longer to migrate south. This may explain the lower peak and perhaps the broader shape (reflected in the standard deviation) of the migration distribution observed in 1995/96 (Fig. 1) relative to previous years. This trend in increasingly later dates for the onset of southbound migrations may be a function of increased population size. Possibly, with the increased density of gray whales in the summer feeding areas, food resources have become more limited such that whales are dispersed more prior to their migration south while building up fat reserves (Rugh *et al*., 2001). An alternative would be that the number of pregnant females has not increased as much as the rest of the population in the past decade, owing to a slowing growth rate in the population. Pregnant females lead the southbound migration (Rice and Wolman, 1971), and thus the difference between numbers of pregnant females and numbers of all other whales would result in an apparent delay in the first phase of the migration.

The analysis followed a slightly different course to that of Buckland *et al*. (1993) and Laake *et al*. (1994) because detection probability of pods varied significantly with recorded pod size. If this effect were to be ignored and the method of Buckland *et al*. (1993) and Laake *et al*. (1994) followed, the abundance estimate would be 22,571 whales (CV=5.24%; 95% CI=20,400-25,000). Although that results in a slightly decreased abundance (*ca* 1.5%), the CV is nearly double, primarily owing to the use of bootstrap variances for pod size corrections and to including the covariance components of the variance of total whales passing during watch periods, thereby suggesting that CV(*N*) has been underestimated for earlier years.

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Table 5

Estimated abundance and intermediate parameters, Eastern North Pacific stock of gray whales, 1995/96.

| Parameter | Estimate | SE | CV (%) |
|---|---|---|---|
| Total pods recorded by south observer during watch periods ($m$) | 2,151 | | |
| Estimated total pods ($\hat{M}$) | 2,578 | 46.8 | 1.82 |
| Mean recorded pod size | 1.83 | 0.027 | 1.46 |
| Corrected mean pod size | 2.56 | 0.226 | 8.80 |
| Estimated number of whales passing Granite Canyon during watch periods ($\hat{W}$) | 6,611 | 570 | 8.62 |
| Correction for pods passing outside watch periods ($f_t$) | 3.30 | 0.003 | 0.09 |
| Estimated total whales without night travel correction (Q) | 21,827 | 1,882 | 8.62 |
| Correction for night travel ($f_n$) | 1.02 | 0.023 | 2.25 |
| Estimated number of whales passing Granite Canyon ($\hat{N}$) | 22,263 | 2,060 | 9.25 |

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