Estimated trends in abundance of eastern Pacific gray whales from shore counts (1967/68 to 1995/96)[1]

S.T. Buckland[*] and J.M. Breiwick[+]

Contact e-mail: steve@mcs.st-and.ac.uk

ABSTRACT

Estimates of abundance of eastern Pacific gray whales (*Eschrichtius robustus*) are obtained from counts made during their southbound migration past a shore-based station near Monterey, California. Assuming an exponential rate of increase, the population is estimated to have increased at 2.5% per annum (SE = 0.3%) between 1967/68 and 1995/96. However, there is some indication that the population growth is slowing, so that an asymptotic growth curve may be more appropriate. The estimated asymptote from a logistic model is 26,046 (SE = 6,281) and the inflection point is approximately in 1971 (SE = 6.5). The onset of the migration, when 10% of the whales have passed the station, has occurred increasingly later through this sample period, by approximately one day every two years. Median dates show a similar trend of roughly one day every three years. However, there is no significant change in the date at which 90% of whales have passed the station.

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

INTRODUCTION

Data from shore-based censuses of eastern Pacific gray whales, carried out between 1967/68 and 1979/80, were analysed by Reilly *et al.* (1980; 1983) to estimate trends in abundance. However, data from subsequent censuses in 1984/85, 1985/86, 1987/88, 1992/93, 1993/94 and 1995/96 have not been analysed in a way consistent with those of Reilly *et al.* (1980; 1983). In 1986, simultaneous counts were made for the first time by observers operating independently in different sheds with identical viewing areas (Rugh *et al.*, 1990). Since then that test has been repeated each season (Rugh *et al.*, 1993) and has resulted in refinements to abundance estimates by correcting for whales in the viewing area not recorded by single observers. Using the new correction factor, Breiwick *et al.* (1988) provided an initial abundance estimate for the 1987/88 census, later revised by Buckland *et al.* (1993). Absolute abundance estimates have also been made for the 1992/93 and 1993/94 censuses (Laake *et al.*, 1994), and 1995/96 (Hobbs *et al.*, 1996).

At the 1989 meeting of the Scientific Committee of the International Whaling Commission, a Working Group was set up 'to specify pre- and post-1980 Monterey shore censuses to allow tests for trend through 1988' (IWC, 1990). The recommendations of that Working Group were:

(1) A relative abundance estimate should be calculated for each survey year. Each estimate should be calculated as far as possible in a consistent manner. The Hermite polynomial model will be used for the time-density model to estimate the number of whales missed during periods of poor visibility, no watch and at the 'tails' of migration.
(2) The three aerial surveys (1978/79, 1979/80, 1987/88) will be compared. Average distance offshore is known to vary with year, hence it is necessary to test whether detection probability at any given distance varies with year. This detection probability may be estimated by taking the ratio of number of pods seen from shore to number seen from aerial surveys for each of several distance intervals. The probabilities may be arbitrarily scaled so that the maximum is unity, or scaled to be consistent with results from double counting. A test of whether the probabilities are constant across the three survey years will then be carried out. (Note: There will be four sets of probabilities since there was both a north and a south station in 1987/88.)
(3) If the above test is not significant (i.e. aerial:shore probabilities are not different among the four cases), the aerial survey data will be pooled and the detection curve will be estimated either by the probabilities calculated by interval or by a hazard-rate or Hermite polynomial model fitted to those probabilities (scaled so that their sum equals total sample size). If this test is significant, pool 1978/89 and 1979/80 data and model as above. Fit the 1987/88 data separately.
(4) Adjust the number of pods according to the estimated detection curve, as found above, so that pods missed are corrected for. Should the test in Step 2 be significant, use the adjustments calculated from the two earlier aerial surveys to apply to all shore surveys carried out without reticle binoculars and use the adjustments calculated from the 1987/88 aerial survey (averaged across the north and south stations) to correct the remaining surveys (i.e. 1984/85; 1985/86 and 1987/88).
(5) In recent surveys, periods with Beaufort > 4 will be discarded. In earlier surveys (1967/68-1979/80), whole (5hr) watch periods in which Beaufort > 4 was recorded will be discarded.
(6) Since it is only necessary to estimate relative abundance to test for a trend, no corrections for biased estimation of pod size will be made.
(7) Independent estimates will be made for the north and south stations for analysis of the 1987/88 survey data and the average across both stations used. This will give greater comparability between that survey and earlier surveys, for which there was just one station.
(8) Once the series of relative abundance estimates has been calculated, it will be rescaled so that it passes through the best absolute abundance estimate available - considered to be the 1987/88 estimate, when double-counting was carried out throughout the season.

In addition to the above, the National Marine Mammal Laboratory (NMML) requested that periods with visibility code > 4 be treated as for periods with Beaufort > 4 and that estimates would be presented to allow an assessment of whether there had been a trend in migration dates. This paper reports on the attempts to carry out the above analyses and tabulates estimates of abundance.

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[*] *School of Mathematics and Statistics, University of St. Andrews, North Haugh, St. Andrews, Fife, KY16 9SS, Scotland.*
[+] *National Marine Mammal Laboratory, Alaska Fisheries Science Center, NMFS, 7600 Sand Point Way NE, Seattle, WA 98115, USA.*

METHODS

The analysis methods used were as far as possible as laid down by the Working Group. They are reported in more detail by Breiwick *et al.* (1988) and by Buckland (1992).

Dates at which gray whale pods pass Monterey may be modelled as a probability density function of the following form:

$$f(y) \equiv \alpha(y_s) \cdot \left(1 + \sum_{j=1}^{m} a_j \cdot H_j(y_s) \right) \Big/ \beta$$

where:

y is the date (measured to the nearest minute) a pod passes;
$y_s = (y-\mu)/\sigma$, a standardised y value;
$\alpha(y_s) = \exp(-y_s^2 / 2)$;
$H_j(y_s)$ is the j^{th} Hermite polynomial, $j = 1,...,m$;
$a_j = 0$, if term j of $H_j(y_s)$ is not required, or is estimated by maximum likelihood;
β is a normalising function of the parameters alone.

Apart from a scaling factor, $\alpha(y_s)$ is the normal density. Hence the parameters μ and σ correspond to the first and second moments respectively, so that the first polynomial to be added is of order three, corresponding to an adjustment to the normal fit for skewness. The next term, of order four, adjusts the fit for kurtosis and so on.

Models with between zero (the normal density) and four terms were fitted to each dataset, except when convergence failed to occur after 1,000 iterations of the Newton-Raphson procedure. (Convergence problems occur when the likelihood surface is badly behaved, which happens with increasing frequency as more terms are added, indicating over-fitting.) Likelihood ratio tests were employed to select the ‘best’ fit. The resulting fits often yield a significantly high goodness-of-fit statistic. The variation in number of pods observed from one watch to another might be greater than Poisson for a variety of reasons. For example: speed of passage may vary with weather conditions; pods may not travel independently of each other; probability of detecting a pod depends on weather conditions, rate of passage, distance from shore, etc. We allow for this over-dispersion by multiplying the Poisson variance for the total count by a dispersion parameter, estimated as the ratio of the χ^2 goodness-of-fit statistic divided by its degrees of freedom (McCullagh and Nelder, 1989, p.296).

The data analysed are numbers of pods passing within each count period, so that the data are grouped; the group endpoints are the start and end of each period for which visibility code and Beaufort did not exceed four. Pods recorded travelling north were excluded from analyses; such records were rare, except in 1972/73, when counting ended late and over 100 pods were recorded going north in February, largely in the last few days of the survey. To estimate the number of pods passing, the total number of pods sighted during the migration was multiplied by the ratio of the total area under the fitted curve to the sum of the areas under the curve corresponding to watch periods. Estimation of tail areas (before the first watch of the season and after the last) was improved by adding two zero counts to the data, one on day zero, defined to be 1 December, which is prior to the onset of migration and the second on day 90, which is 1 March (or 29 February in a leap year), after the migration is believed to be complete. This modification was found to be necessary for seasons in which counting started late or finished early.

To convert the estimated number of pods passing to an estimate of population size, an estimate of average pod size is required. Here the average of recorded pod sizes is used, first discarding pods sighted during poor visibility (> 4) or high Beaufort (> 4). The abundance estimates will be biased low unless two further corrections are made. One is an adjustment for underestimation of the size of pods detected and the other is a correction for pods missed during count periods, estimated for the 1987/88 season from independent sightings from two observers recording simultaneously. Details of these correction factors are given by Breiwick *et al.* (1988). The corrections are assumed to hold for all seasons, therefore allowing the conversion of our estimates of relative abundance to absolute abundance estimates.

The estimate of trend developed in this study is considered valid if the following assumptions are met:

(1) there is no trend in the proportion of pods missed during count periods, for example as a result of increased efficiency of observers or of an increase in average distance offshore of pods passing the counting station;
(2) there is no trend in any bias in estimating average pod size;
(3) there is no trend in weather conditions across years. Alternatively, rate of passage is independent of weather conditions and probability of detection is independent of weather conditions up to Beaufort 4 and visibility code 4;
(4) there is no trend over time in the proportion of whales that pass seaward of the observers’ viewing area, or in the proportion that fail to migrate south past the counting station.

The estimates of absolute abundance developed in this study are considered to be valid if the following assumptions are met:

(1) rate of passage is unaffected by poor visibility and rough weather;
(2) no whales pass seaward of the observers’ viewing area and all whales in this stock migrate south past the counting station;
(3) adjustments for pods missed during count periods and for biased estimation of pod size are correct and appropriate for all years in which counts were made;
(4) the Hermite polynomial model has an appropriate form for fitting migration dates; in particular, it fits the tails of the distribution adequately.

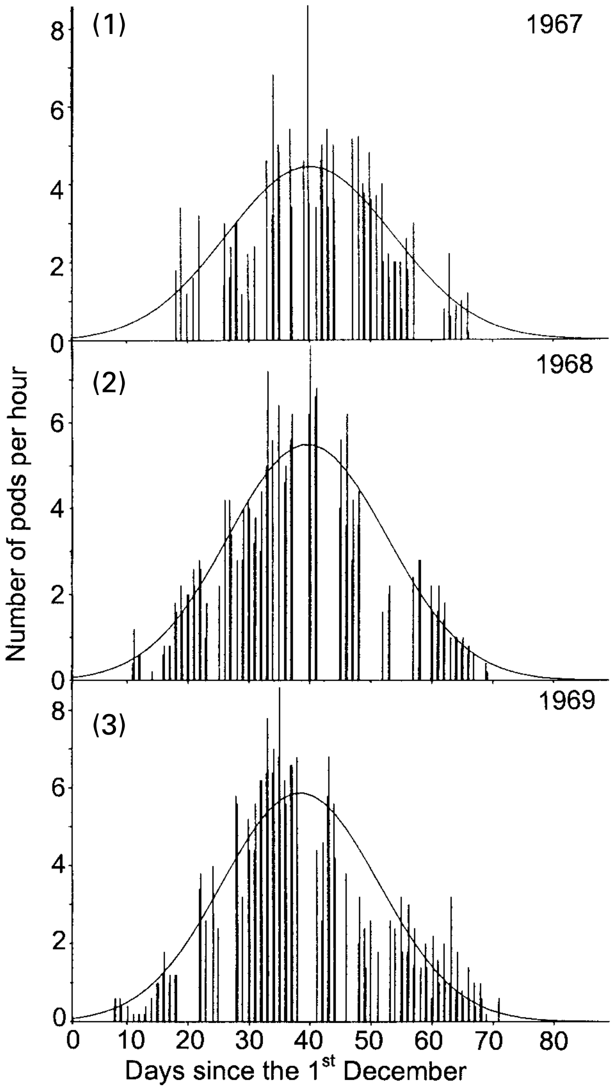
Adjustments to the abundance estimates to allow for changes in offshore distribution over time were requested by the Working Group. Since distances of pods from shore were recorded grouped, but the degree of grouping was not consistent, all distances were first grouped using the following group intervals: 0.01-0.25; 0.26-0.50; 0.51-0.75; 0.76-1.00; 1.01-1.50; 1.51-2.00; 2.01-8.00. These frequencies were then adjusted using data from aerial surveys as described in Recommendation 3 of the Working Group. A hazard-rate model was used to estimate the detection curve; since the distribution of offshore distances recorded from shore was markedly different in 1978/79 and 1979/80 from in 1987/88, separate detection curves were estimated for pre-1981 and post-1981 data. The estimated detection curves were used to evaluate, by numerical integration, the average distance expected in each of the above distance intervals; these average distances are in general smaller than the mid-points of the groups.

RESULTS

Originally, this analysis examined the 1978/79, 1979/80 and 1987/88 aerial and shore-based sighting frequencies of pods by distance offshore; it was found that the offshore distribution of whales was similar in the three aerial surveys. Shelden and Laake (2002) and Withrow (1990) come to similar conclusions and extended the study by incorporating additional aerial survey data acquired since 1987/88. They found that the offshore distribution (> 2.25 n.miles) of gray whale pods did not differ significantly between survey years (1979, 1980, 1988, 1993, 1994 and 1996). In our initial analysis there appeared to be a significant shift in mean estimated distance offshore from 1979/80 and earlier compared with subsequent estimates from shore surveys. However, it was subsequently discovered that the elevation of the counting site at Granite Canyon was overestimated and that an incorrect conversion factor was used to convert binocular reticles to distances (J. Laake, pers. comm.). Thus, the 1985/86 and 1987/88 shore-based mean distance estimates are now quite similar (1.23 n.miles *vs* 1.26 n.miles) and the probable explanation for the much smaller mean distance estimates prior to 1984/85 compared to the more recent estimates is that the latter were based on binoculars with reticles while the former were based on visual estimates by observers (without reticle binoculars). We have therefore omitted analyses of aerial and shore-based sighting frequencies of pods by distance.

Mean offshore distances of pods recorded from shore, calculated as described above, are given in Table 1. The estimated multipliers for pods missed during count periods are given in Table 2.

Given the inconsistencies in recorded offshore distances (discussed below), Hermite polynomial models were fitted to the unadjusted pod frequency counts. Although the intention of the Working Group was that only the parts of a watch for which Beaufort or visibility code exceeded four would be deleted for the more recent surveys, it was found that a change of conditions was frequently only noted when a sighting was made. Thus to avoid bias from including periods of search in unrecorded poor conditions and from ending watch periods immediately prior to a sighting, whole watches for which Beaufort or visibility code exceeded four at any time were discarded. Hermite polynomial fits to the remaining census data are shown for each survey in Figs 1-17.



Figs 1-17. Histograms of number of pods sighted, adjusted for watch length, by date. Counts made during watches in which either Beaufort or visibility code exceeded four are not included. Also shown are the Hermite polynomial fits to the histograms.

Fig. 1. 1967/68 survey; Fig. 2. 1968/69 survey; Fig. 3. 1969/70 survey.

Table 1

Mean estimated distance offshore (n.mile) of pods recorded from shore by year. ('67' represents the 1967/68 season etc.; 87N is the north station in 1987/88, 87S the south station.) Estimates for 1992/93 and 1993/94 are not available.

Year	67	68	69	70	71	72	73	74	75	76	77	78	79	84	85	87N	87S	95
Mean	0.44	0.33	0.40	0.44	0.62	0.55	0.49	0.66	0.34	0.29	0.26	0.63	0.48	1.03	1.23	1.27	1.25	1.05

Table 2

Estimated adjustments to allow for whales missed during count periods, adopting the recommendations laid down by the Working Group. No adjustment corresponds to 1.0; a value of 2.0 would indicate that the abundance estimate should be doubled. ('67' represents 1967/68 season etc.; 87N is the north station in 1987/88, 87S the south station.)

Year	67	68	69	70	71	72	73	74	75	76	77	78	79	84	85	87N	87S
Adj.	2.89	1.44	1.76	2.44	3.51	4.00	3.51	5.61	1.83	1.37	1.27	3.49	2.16	1.002	1.002	1.008	1.007

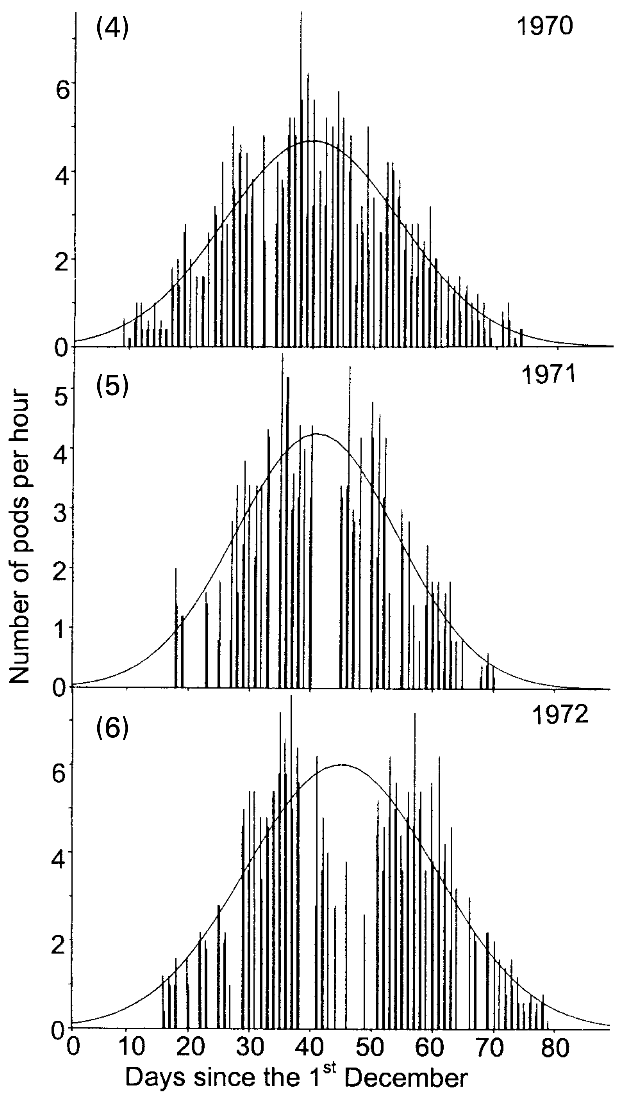


Fig. 4. 1970/71 survey; Fig. 5. 1971/72 survey; Fig. 6. 1972/73 survey.

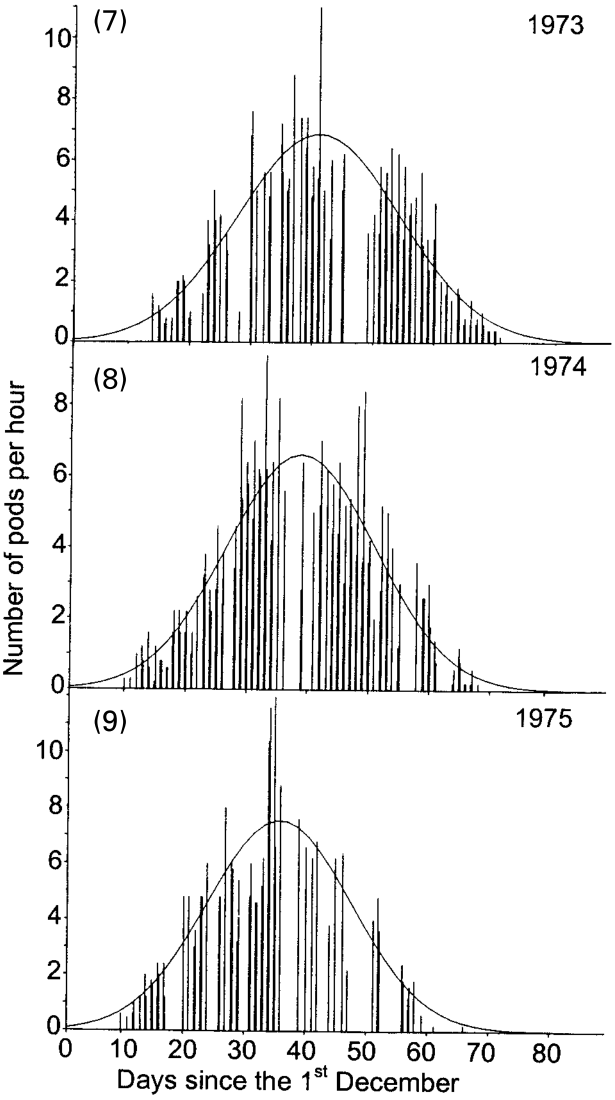


Fig. 7. 1973/74 survey; Fig. 8. 1974/75 survey; Fig. 9. 1975/76 survey.

In Table 3, estimates of the number of pods, the average pod size and the number of whales are given by year. As directed by the Working Group, no adjustment for biased pod size estimates is incorporated and, for reasons discussed below, no adjustments for pods missed during watch periods were made. Instead, the 'best' estimate of abundance available, given by Buckland *et al.* (1993), was taken and the relative abundance estimates in the penultimate column of Table 3 were rescaled to pass through this best estimate for 1987/88. Thus, the last column of Table 3 (adjusted abundance estimates) is the same as column 2 (absolute population size estimates) of table 3 in Buckland *et al.* (1993), through to 1987/88. They used double counting to estimate the number of pods missed during watch periods and also adjusted for underestimation of pod size. The CV of the product of these two adjustments was estimated by calculating the value required such that adjusting the relative abundance estimate for 1987/88 to the absolute estimate gave, via the delta method, the same standard error on the absolute estimate as that quoted by Buckland *et al.* (1993). Since the estimates of abundance from the south station and the north station for 1987/88 cannot be assumed independent, the worst possible assumption that the correlation between them was unity was made to obtain the estimated standard error for the average relative abundance estimate in that year. This yields a standard error close to the average of the standard errors of the two separate estimates.

A regression of abundance estimate on time (1967/68 to 1995/96), assuming a Poisson error distribution with over-dispersion, a logarithmic link function and the weighting of each estimate by the reciprocal of the squared coefficient of variation, yields an estimate of average annual increase of 2.53% (SE = 0.31%). The predicted abundance by year from this regression is shown in Fig. 18. The recent abundance estimates shown in Fig. 18 suggest that the rate of increase may be slowing. In this situation, a logistic curve would be more appropriate than an exponential curve. The abundance estimates were therefore fitted to a logistic model using unweighted non-linear regression, assuming an additive error model. The estimated asymptote is 26,046 animals (SE = 6,281) and the inflection point is approximately in 1971 (SE = 6.5 years). The predicted logistic curve, extrapolated back to 1900 and forward to 2025, is shown in Fig. 19.

For each Hermite polynomial fit, the 10th, 50th (i.e. median) and 90th percentile of the distribution was evaluated. These are given by year in Table 4. The date by

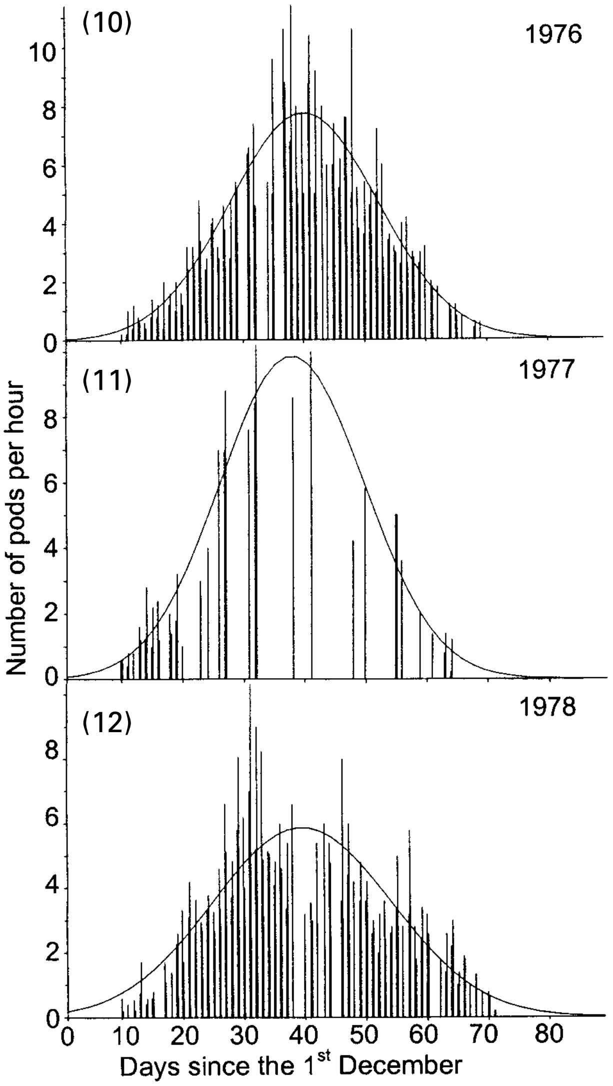


Fig. 10. 1976/77 survey; Fig. 11. 1977/78 survey; Fig. 12. 1978/79 survey.

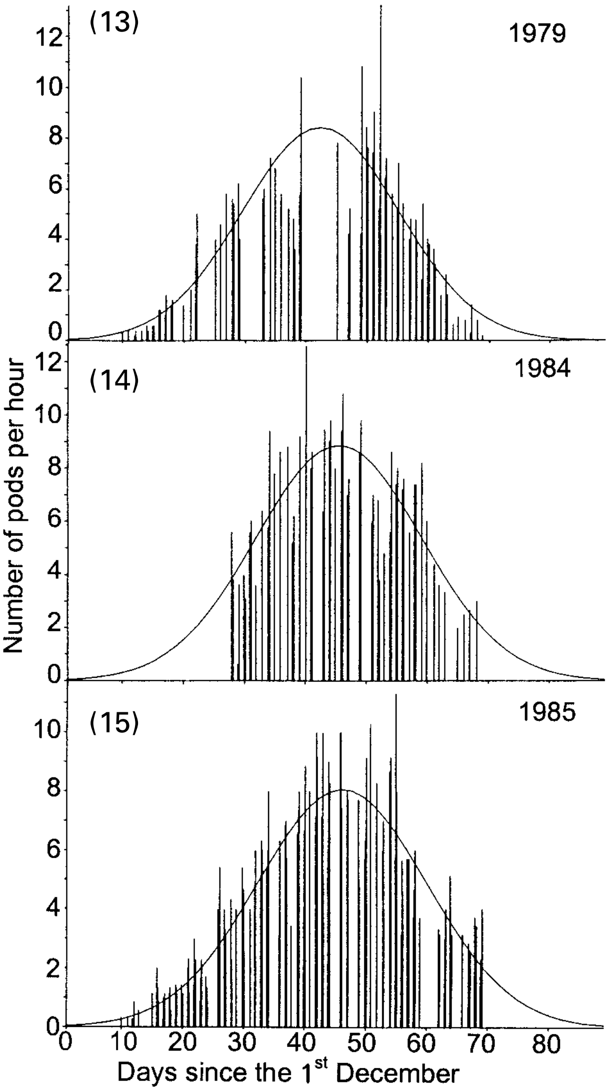


Fig. 13. 1979/80 survey; Fig. 14. 1984/85 survey; Fig. 15. 1985/86 survey.

which roughly 10% of whales had passed was typically around 24 December during the 1970s and became significantly later with time ($p < 0.001$), on average by a half-day per year. The change was greatest after 1979/80. The median passage date was typically around 10th January during the 1970s and also occurred later in more recent years ($p < 0.001$). The average change in date was around one day every three years and again the change is most apparent since 1979/80. On average, 90% of whales have passed by about 28 January, with no evidence of a trend with time.

DISCUSSION

Changes to the procedures defined by the Working Group were found to be necessary on examination of the data. Recommendation 2 states that 'average distance offshore is known to vary with year' and the mean distances offshore of pods recorded from shore (Table 1) appear to confirm this statement. However, the estimated adjustments of Table 2 are wholly implausible. It now seems clear that estimated distances offshore from shore-based observers prior to 1984/85 are suspect. Offshore distances recorded by shore-based observers prior to 1984 appear to have been grossly underestimated. Although distance estimates were believed to be reasonably accurate (S.B. Reilly, pers. comm.), this remains by far the most plausible explanation of the data. If this explanation of the data is accepted, or if no satisfactory explanation can be found, then distance estimates prior to 1984 must be considered suspect and adjustment for whales missed during count periods cannot be made using a detection curve estimated from these recorded distances. An attempt to verify distance estimates using buoys at known distances was compromised when the buoys blew away six days after placement. Reilly *et al.* (1980) checked 542 distance estimates using an inclinometer. They found that shorter distances were significantly underestimated by observers and that some observers' estimates were more biased than others.

Therefore, Hermite polynomial models were fitted to unadjusted counts. In most cases, the Hermite polynomial fit seems to approximate the migration distribution adequately, even when migration started prior to the first watch period of the season or continued after the final watch period (Figs 1-17). Thus, estimates of the number of pods passing during night or poor conditions should be reliable, provided rate of passage is similar in these periods to watch periods and assuming that reliable adjustments for biased pod size estimation and for pods missed during watch periods are available. Evidence of over-dispersion is shown for example in Fig. 16, where the peak count per hour close to the mode

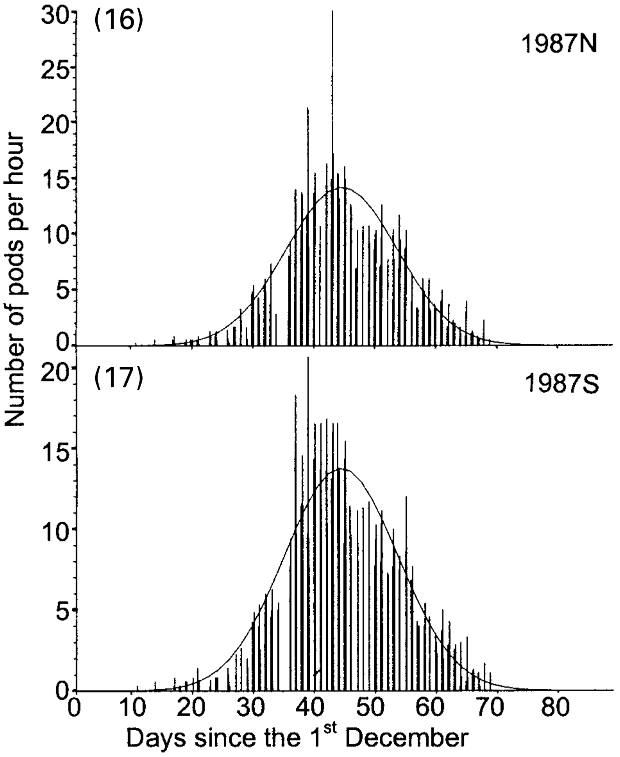


Fig. 16. 1987/88 survey, north station; Fig. 17. 1987/88 survey, south station.

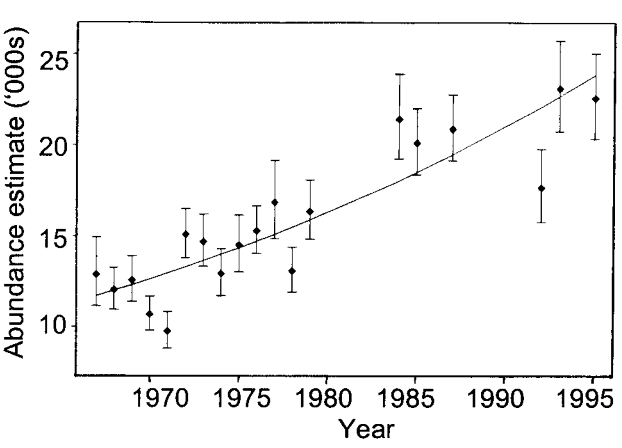


Fig. 18. Estimates of abundance of eastern Pacific gray whales and predicted abundance from a weighted exponential regression of abundance estimates on year. Vertical bars are approximate 95% confidence intervals. Year 1967 signifies season 1967/68, etc.

of the distribution is far in excess of counts either side of it. This should affect estimation little and its effect on variance estimation was reduced by scaling up the Poisson variance for counts.

Factors which may significantly affect the reliability of the abundance estimates and the estimated rate of increase of 2.5% per annum are as follows.

(1) The proportion of pods missed during count periods may have changed over time. For example, in 1987/88 there were two counting stations and the element of competition may have caused observers to concentrate harder for longer periods. Fig. 18 indicates that the estimate for that season is very similar to those for 1984/85 and 1985/86, suggesting that any such effect was small. If procedures in the last three surveys led to higher detection probabilities than in earlier surveys, the rate of increase will have been over-estimated.

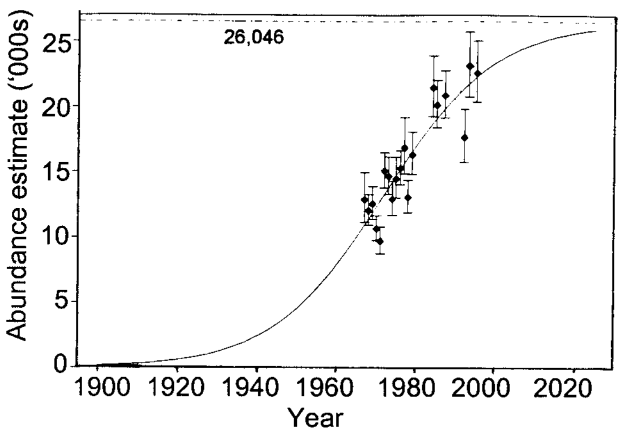


Fig. 19. Logistic curve fit to the abundance estimates. The predicted curve has been extrapolated back to 1900 and forward to the year 2025.

(2) Rate of passage may vary with weather conditions. For example, the effect of slower passage during poor weather would be to generate positive bias in the abundance estimates. Since very few counts were lost through poor weather in some years, the bias would be low in those years. Fig. 11 shows that most counts were lost in the 1977/78 season, so if the rate is appreciably slower in poor conditions, the corresponding abundance estimate should be high. Fig. 18 shows that the estimate for 1977/78 is higher than predicted by the exponential model, but only by a small amount. Rate of increase will be biased only if there has been a trend in weather conditions over the period of the surveys. There is evidence that passage rate differs between night and day. Swartz *et al.* (1987) carried out radio-telemetry experiments to assess this, but concluded that the difference between day and night passage rates was not significant. Schweder (pers. comm.) found a significant difference by reanalysing their data using a paired *t*-test and pooling Monterey and Channel Islands data. Our absolute abundance estimates include a correction for a differential rate of passage between day and night, based on a reanalysis of the radio-tagging data (Buckland *et al.*, 1993). More recent work by Perryman and Laake (1994) allows for the estimation of a more reliable correction factor.

(3) Abundance would be underestimated if a proportion of the stock did not pass Monterey every year, or if some passed by far out to sea. The latter possibility would seem to be ruled out by the absence of records, even though efforts have been made to locate animals. The number of animals that remain north of Monterey is thought to be small. The estimated rate of increase would only be biased if there is a trend over time in the proportion staying north and, given the small numbers likely to be involved, bias is likely to be negligible.

The Working Group recommended that relative abundance estimates should be rescaled to pass through the absolute abundance estimate for 1987/88 of Breiwick *et al.* (1988). That abundance estimate was obtained by retaining all periods for which the data indicated that both Beaufort and visibility code were < 5. Given that a change of conditions was usually only noted when a sighting was made, this procedure is potentially biased. Furthermore, the estimate

Table 3

Estimated number of pods, pod size and number of whales by year. The final column is found by using the multiplicative scaling factor that ensures that the 1987/88 average estimate is equal to the estimate of absolute abundance from Buckland *et al.,* 1993. (Standard errors in parentheses.)

Year	No. of terms	χ^2 [df]	Sample size (pods)	Estimated no. of pods	Estimated average pod size	Estimate of relative abundance	Adjusted abundance estimate[1]
1967/68	4	83.0	903	4,051	2.438	9,878	12,921
		[45]		(253)	(0.063)	(667)	(964)
1968/69	0	70.6	1,079	4,321	2.135	9,227	12,070
		[61]		(134)	(0.046)	(348)	(594)
1969/70	1	104.5	1,245	4,526	2.128	9,630	12,597
		[67]		(155)	(0.043)	(383)	(640)
1970/71	2	116.2	1,458	4,051	2.021	8,185	10,707
		[90]		(115)	(0.033)	(267)	(487)
1971/72	0	71.3	857	3,403	2.193	7,461	9,760
		[56]		(127)	(0.048)	(323)	(524)
1972/73	4	91.5	1,539	5,279	2.187	11,543	15,099
		[71]		(152)	(0.034)	(378)	(688)
1973/74	4	133.7	1,496	5,356	2.098	11,235	14,696
		[66]		(186)	(0.034)	(431)	(731)
1974/75	0	159.2	1,508	4,868	2.034	9,904	12,955
		[74]		(174)	(0.035)	(394)	(659)
1975/76	2	101.1	1,187	5,354	2.073	11,100	14,520
		[47]		(218)	(0.039)	(497)	(796)
1976/77	0	139.7	1,991	5,701	2.052	11,700	15,304
		[87]		(153)	(0.028)	(353)	(669)
1977/78	0	50.2	657	7,001	1.843	12,904	16,879
		[31]		(356)	(0.046)	(731)	(1,095)
1978/79	4	152.9	1,730	4,970	2.016	10,018	13,104
		[84]		(159)	(0.034)	(361)	(629)
1979/80	4	109.3	1,451	6,051	2.068	12,510	16,364
		[55]		(220)	(0.033)	(498)	(832)
1984/85	3	105.2	1,756	7,159	2.290	16,393	21,443
		[49]		(301)	(0.038)	(740)	(1,182)
1985/86	1	141.4	1,796	6,873	2.237	15,376	20,113
		[104]		(191)	(0.042)	(515)	(927)
1987/88N	3	205.9	2,426	7,756	2.040	15,825	
		[92]		(221)	(0.027)	(497)	
1987/88S	3	152.8	2,404	7,642	2.104	16,082	
		[91]		(194)	(0.029)	(464)	
1987/88						15,954	20,869
(average)						(481)	(913)
1992/93[2]							17,674
							(1,029)
1993/94[2]							23,109
							(1,262)
1995/96[3]							22,263
							(1,078)

[1] Absolute abundance estimates for 1967/68 to 1987/88 are from Buckland *et al.,* 1993.

[2] From Laake *et al.,* 1994.

[3] From Hobbs *et al.,* 1996.

Table 4

10th, 50th (median) and 90th percentiles of distribution of migration date. Units are days from midnight on 30 November; midnight on 31 December = 31.0 and midnight on 31 January = 62.0.

Year	10th percentile	Median	90th percentile
1967	17.0	39.5	58.9
1968	22.5	39.2	56.0
1969	22.2	36.9	56.2
1970	21.8	39.1	58.3
1971	23.5	40.5	57.5
1972	26.4	44.8	64.3
1973	24.0	40.4	56.9
1974	22.8	38.4	54.1
1975	20.3	35.5	50.1
1976	24.1	39.7	55.3
1977	22.5	37.6	52.7
1978	22.4	38.2	58.4
1979	24.3	41.7	56.6
1984	30.0	45.7	63.9
1985	28.3	45.9	65.7
1987N	33.1	43.6	56.0
1987S	32.9	43.5	56.2

was derived using data from the south station alone, except for calculation of the correction for whales missed during watch periods. We have thus used the revised estimate of Buckland *et al.* (1993), in which sighting heterogeneity was rigorously modelled and the data from both stations contributed equally to the analysis.

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