Abundance indices of eastern North Pacific gray whales from southbound migration counts, 2007-2011

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ABSTRACT

Counts of southbound whales migrating past Granite Canyon, California, form the basis of abundance estimation for the eastern North Pacific stock of gray whales (*Eschrichtius robustus*), with the observed count being rescaled by a series of correction factors to estimate the total number of whales passing during the migration. Appropriate correction factors for a "new" counting approach are currently being estimated. In the interim, here we present "naïve" indices of abundance from counts made during four recently monitored migrations (2006/7, 2007/8, 2009/10 and 2010/11) using the approach of Laake et al. (2009). The observed whale passage rates (whales/hr) over time within each survey were smoothed using a generalized additive model to predict the total number of whales passing during the migration without applying correction factors. Abundance indices ranged from 11,408 to 12,570, with generally increasing precision (cv = 0.04-0.08) over the four migration years, related to an increase in the hours of observation effort possible. These abundance indices were consistent with those reported for 23 previous migrations, and were comparatively stable across the four recent years, indicating consistency of the new counting approach. Counts using the new approach in 2006/2007 produced a higher estimated abundance index than the traditional counts conducted simultaneously in the same year, suggesting an increase in detection probability. However, it is not possible to relate these indices to the true level of abundance until we have completed an appropriate assessment of the detection bias of recent counts.

KEYWORDS: GRAY WHALE, SHORE-BASED COUNTS, ABUNDANCE INDICES,MIGRATION, MONITORING

INTRODUCTION

Counts of southbound whales migrating past Granite Canyon, California, form the basis of abundance estimation for the eastern North Pacific stock of gray whales (*Eschrichtius robustus*). To estimate the total number of whales passing during the migration, the observed number of pods has been corrected for pods missed during watch periods, pods passing outside watch periods, night travel rate and bias in pod size estimation (Buckland et al. 1993; Laake et al. 1994; Hobbs et al. 2004; Laake et al., 2009). Robust estimation therefore requires unbiased values for each correction factor, specifically estimated for the counting methodology used.

Since the 2006/2007 migration, the "traditional" approach of counts by a single observer who hand-records entries onto a data form has been replaced by a "new" counting approach whereby a paired team of observers work together and use a computer to log data and visualize whale sightings. A quantitative comparison of the performance of the traditional and new counting approaches revealed differing pod size estimation biases (Durban *et al*., 2010), highlighting the need for new calibration data specific to the new counting method and new observers before recent count data can be reliably rescaled to estimate abundance. In the interim, here we present "naïve" indices of abundance from counts made during four most recently monitored migrations (2006/7 , 2007/8, 2009/10 and 2010/11), through an estimate of the whales passing during the migration with only a correction for whales missed outside of watch periods (e.g. Laake *et al*., 2009). We compare these recent estimates to comparable indices from the 23 migration counts since 1967, including comparison of the index derived from counts from both the traditional and new counting approaches conducted simultaneously in 2006/2007 to make inference about the relative detection probabilities of these methods.

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METHODS

Counts of gray whales were conducted from a shore-based watch station at Granite Canyon, California, during the 2006 /2007, 2007/2008, 2009/10 and 2010/11 southbound migrations (Table1). Counts were conducted by a rotating team of observer pairs using naked eye aided by 7X50 binoculars, entering sightings real-time into a PC program for data logging and visualization (as described in Durban *et al*., 2010). Up to three 3-hour watch periods were used to cover daylight hours from 07:30 to 16:30, during which the observers recorded passing whales and environmental conditions, specifically visibility (subjectively categorized from 1 to 6 for excellent to useless) and sea state (Beaufort scale).

Table 1: Recorded number of whales passing during acceptable effort periods of the southbound gray whale surveys from 2006/2007 to 2010/2011 used to estimate "naïve" abundance indices ($\widetilde{W}$) and associated coefficients of variation (cv=standard error/estimate) following Laake *et al.* (2009). The observed whale passage rates (whales/hr) over time within each survey were smoothed using a GAM (Fig. 1) to predict the total number of whales passing during the migration without applying correction factors.

Migration	Dates	Whales	Hours Effort	Abun. Index, $\widetilde{W}$	cv($\widetilde{W}$)
2006/7	02 Jan – 03 Feb	2694	202.5	12,570	0.07
2007/8	02 Jan – 01 Feb	1946	192	11,408	0.08
2009/10	30 Dec – 11 Feb	2024	243	11,491	0.05
2010/11	03 Jan – 18 Feb	2909	261	11,637	0.04

We adopted the approach of Laake *et al*. (2009) to estimate "naïve" abundance indices ($\widetilde{W}$) from the watch period counts. This approach uses a migration curve fitted to the observed number of whales (sum of observed pod sizes) passing during acceptable weather periods to predict the total number of whales passing including periods when the observers were not on watch (i.e. nighttime) or during periods of poor visibility. To control for weather conditions and for consistency with previous abundance indices, we only used counts during watch periods with acceptable weather conditions throughout their entire duration, specifically visibility code <5 and Beaufort sea state <5. The migration curves were specified by fitting a different generalized additive model (GAM) to the observed whale passage rates (whales/hr) over time for each year, and the the total number of whales passing during each migration was estimated by summing the expected value from the model of the number of whales passing each day from time 0 to T_y. In all four years we used $T_y = 90$, where days were counted from 12:00am on 1 December. This estimation was conducted within the R statistical computing environment, using code from the same R package (http://www.afsc.noaa.gov/nmml/softeware/eranalysis.php) previously used to produce abundance indices from 23 seasons of shore based counts between 1967 and 2007 (Laake *et al*., 2009).

RESULTS

Counts were typically conducted throughout the month of January and into February (Table 1), during acceptable weather periods totaling from 192 to 261 hours of observation effort. The fitted GAMs (Figure 1) estimated indices of abundance ranging from 11,408 to 12,570, with generally increasing precision over the four migration years. The precision of the estimates was related to the hours of effort possible, corresponding to the number of watch-period data points, with lower coefficients of variation in years with greater effort under acceptable weather conditions.

These four abundance indices were consistent with those reported for previous migrations (Figure 2), and were comparatively stable across the four recent years. Counts using the new approach in 2006/2007 produced a higher estimated abundance index than the traditional counts conducted simultaneously in the same year (new counts $\widetilde{W}$ = 12,570, Table 1; previous counts $\widetilde{W}$ = 11,484, Table 3 in Laake *et al*., 2009).

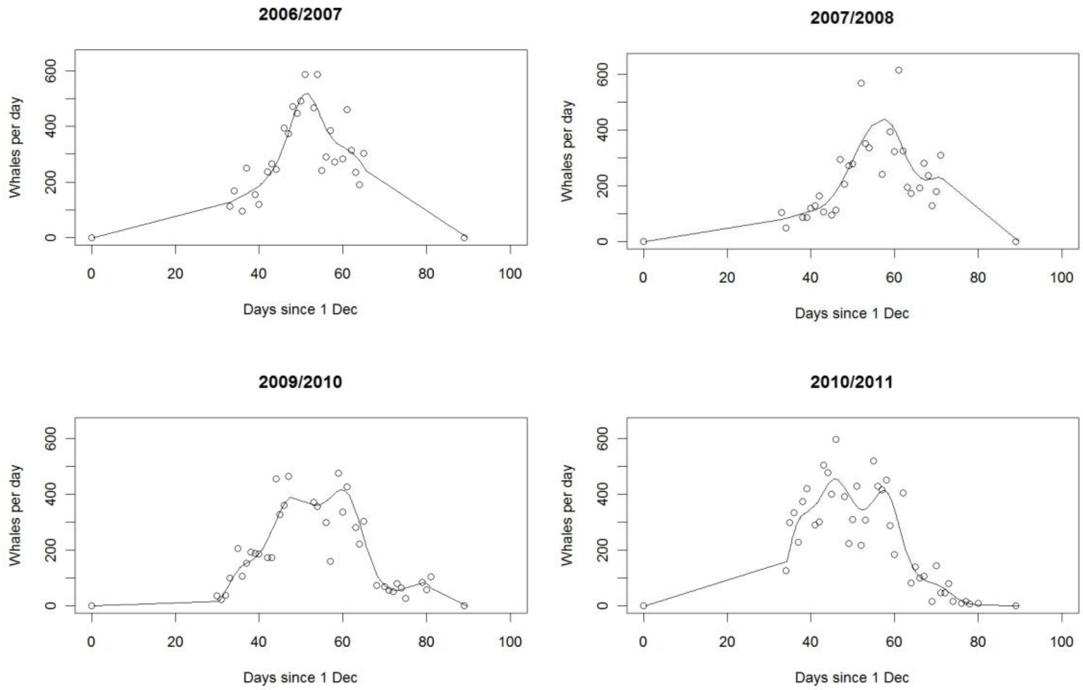

Figure 1. Observed whale passage rates expressed as whales per day (circles) and fitted GAM model (line) for the four southbound gray whale migration counts from 2006/2007 to 2010/2011.

Figure 2: Abundance indices ($\widetilde{W}$) for each of 23 southbound migrations with an end year between 1967 and 2007 (open circles, from Laake et al 2009) together with the four recent migrations reported here (closed circles, Table 1). The observed whale passage rates (whales/hr) over time within each survey were smoothed using a GAM (Fig. 1) to predict the total number of whales passing during the migration without applying correction factors.

DISCUSSION

The abundance indices for the four recent migrations were more consistent than any four consecutive indices for the 23 previous migrations. This likely reflects the consistency of the new counting approach, which was designed to reduce observer effects and the overall level of undercounting (Durban *et al*., 2010). Additionally, the higher index estimated from counts using the new approach in 2006/2007, compared to the estimated index from the traditional counts conducted simultaneously in the same year, further suggests an increase in detection probability associated with the new counting method. This is also supported by the raw count data, with a higher number of whales counted by the new approach (2,694 vs. 2,568) despite notably less observer effort (202.5 vs. 310 hours), although much of this effort difference was due to observation effort in the early and late tail of the migration by the traditional counters only (Rugh *et al*., 2008; Laake *et al*., 2009).

If this new counting approach does indeed provide a consistent and reduced level of undercounting, then we anticipate that this index of abundance will be a useful measure of the overall population size and trends. However, it is not possible to relate these indices to the true level of abundance until we have completed an appropriate assessment of the detection bias of recent counts. Data were collected using thermal imaging sensors (Perryman *et al*., 1999) concurrent to the observer counts in 2010/2011, and these data are currently being analyzed to provide an independent and more objective set of comparative counts.

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