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ABSTRACT

Shore based surveys of northbound eastern North Pacific gray whale calves were conducted between March and June from the Piedras Blancas Light Station on the central California coast each year from 1994-2016. Estimates of the total number of northbound calves displayed a high degree of inter-annual variability, ranging from 254 calves in 2010 to 1528 calves in 2004. Calf production has been particularly high during the past 5 years (2012-2016) with a total of >6,500 calves estimated during this period, including four of the highest years of calf production (>1,000 calves per year) since our calf counts began in 1994. The 2016 estimate of calf production (1,351) is about 5% of the reported total abundance (26,960) for the eastern North Pacific population. A trend in median migration dates was observed, indicating that the midpoint of the migration is now occurring about a week later than it did in the mid-1990s. The 23-year data set described herein serves as an excellent foundation upon which to examine the inter-play between changing environmental conditions and gray whale population dynamics.

INTRODUCTION

The majority of Eastern North Pacific gray whales *(Eschrichtius robustus)* annually migrate southward from summer feeding grounds in the Pacific Arctic to wintering areas off Baja California, Mexico (Rice and Wolman 1971, Perryman and Lynn 2002). Both the southward and northward migration is segregated, to a large extent, by age, sex and reproductive condition. During the northward migration, females with their calves of the year are the last to depart the Baja wintering areas. These mother-calf pairs are observed on the migration route between March and May and typically arrive to the summer feeding grounds between May and June.

Shore-based counts of northbound gray whale calves have been conducted off central California each spring from 1994 to 2016. This report presents an overview of results from this 23-year time series of estimates of gray whale calf production.

METHODS

Shore-based counts of northbound gray whale calves have been conducted from the Piedras Blancas Light Station (north of San Simeon, California) each spring from 1994 to 2016. Data collection methods and analytical techniques have remained consistent each year and follow those reported elsewhere (see Perryman *et al*. 2002, 2011). Briefly, counts were conducted by four observers, with two on effort at any one time, rotating through the following schedule: (a) 90-min on effort as the offshore search area observer, (b) 90-min on effort as the inshore search area observer, (c) 3-hr off effort. Weather permitting, this work was carried out for 12 hours per day; 6 days per week in 1994-2003 and 2005 and 5 days per week in 2004 and 2006-2016. Primary search effort was carried out with unaided eye but 7x50 and 25x150 binoculars were also used when needed.

Based on night/day migration rate data derived from thermal sensors (1994-1996) and aerial surveys (1994-1995) to determine offshore distribution (Perryman *et al*. 2002), we assumed that: (1) the number of gray whale calves passing the survey site far enough offshore to be undetectable by visual observers was negligible, and (2) day and night passage rates were equivalent. We also assumed that detection probabilities were the same across acceptable sighting conditions (see Reilly *et al*. 1983; Reilly 1992). To correct for imperfect probability of detection of calves by the visual observers, we corrected the observer estimates of northbound calves by the average detection probability estimates from seven consecutive years (1994-2000) of replicate counts (mean = 0.889; SE = 0.06375).

Each day of survey effort was divided into four 3-hr periods and passage rates during these periods were calculated from the observed counts multiplied by the inverse of the detection function. To correct for periods when observers were not on watch (e.g. poor weather, night time, days off), we embedded the estimators in a finite population model that was stratified by week to account for varying passage rates (Cochran 1977). A Taylor series expansion (Seber 1982) was used to calculate the variance of the estimates.

RESULTS

Estimates of the total number of northbound calves showed a high degree of inter-annual variability, ranging from 254 calves in 2010 to 1528 calves in 2004 (Table 1). Calf production has been particularly high during the past 5 years (2012-2016) with a total of >6,500 calves estimated during this period, including four of the highest years of calf

production (>1,000 calves per year) since our calf counts began in 1994 (Fig. 1). The 2016 estimate of calf production (1,351) is about 5% of the reported total abundance (26,960; Durban et al. SC/67a) for the eastern North Pacific population in 2016.

A trend in median migration dates was observed in the time series, indicating that the midpoint of the migration is now occurring about a week later than it did in the mid-1990s. The slope of the migration timing is significant ($F = 6.030$, $p = 0.023$) if the outlier from 1999, the first year of an unusual mortality event for the eastern North Pacific population, is deleted from the data set (Fig. 2).

DISCUSSION

During the 23-year time series reported here, estimates of gray whale calves displayed a high degree of inter-annual variability. Based on data from 1994 to 2000, Perryman *et al*. (2002) suggested that the reliance of female gray whales on stored fat resources during pregnancy combined with sea ice regulated access to food during the beginning of a feeding season may impact their ability to carry existing pregnancies to term. When these calf estimates were examined in the context of environmental data from the northern Bering Sea, a relationship was found between the timing of seasonal ice melt and estimates of northbound gray whale calves counted the following spring. In heavy ice years, when ice extends far to the south, the temporary lack of access to foraging areas appears to have a negative impact on calf production.

The particularly high calf production observed during the past 5 years (2012-2016), including four years of the highest calf production recorded (>1,000 calves per year) since our counts began in 1994 suggests that gray whales have been experiencing a period of favorable feeding conditions in the Arctic, possibly related due to the combination of expanding ice-free habitat (Moore 2016), increased primary production (Arrigo and Dijken 2015) and increased flow of nutrient-rich waters through the Bering Strait (Woodgate *et al*. 2012). This hypothesis is further supported by the recent (2014/2015 and 2015/2016) increase in abundance of the eastern North Pacific gray whale population (Durban et al. SC/67a)

The trend in median migration dates reported here, indicating that the midpoint of the migration is now occurring about a week later than it did in the mid-1990s, is analogous to the finding of a one week delay in annual mean sighting dates of southbound whales migrating past Granite Canyon, California (Rugh *et al*. 2001). While the impacts of climate change in the Arctic environment are far from being understood, this change in migratory timing of gray whales may reflect a response to shifting habitat parameters on the summer feeding grounds. In the short term, changes in the Arctic environment may represent "boom time" for baleen whales as suggested by Moore (2016).

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Table 1. Survey summary information and annual estimates of calves 1994-2016.

Year	Effort (hrs)	Calf Count	Calf Estimate	SE
1994	671	325	945	68.21
1995	610	194	619	37.19
1996	694	407	1146	70.67
1997	709	501	1431	82.02
1998	554	440	1388	94.84
1999	737	141	427	41.10
2000	704	96	279	34.79
2001	722	87	256	28.56
2002	711	302	842	78.60
2003	686	269	774	73.56
2004	562	456	1528	96.00
2005	669	343	945	86.90
2006	531	285	1020	103.30
2007	469	117	404	51.20
2008	498	171	553	53.11
2009	476	86	312	41.93
2010	487	71	254	33.94
2011	500	246	858	86.17
2012	435	330	1167	120.29
2013	483	311	1122	104.14
2014	529	429	1487	133.35
2015	522	404	1436	131.01
2016	436	367	1351	121.38

Figure 1. Estimates of Eastern North Pacific gray whale calf production 1994-2016.

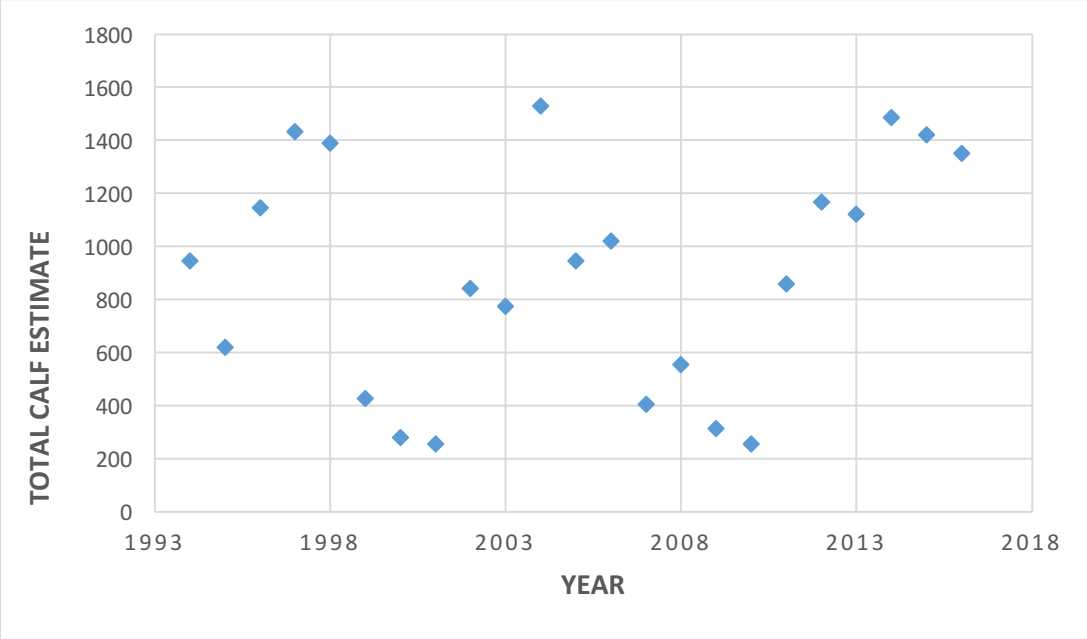

Figure 2. Annual median migration dates of northbound gray whale calves 1994-2016. Slope of linear regression is significant if 1999 point deleted (see arrow).