Results of Surveys of Northbound Gray Whale Calves 2001-2010 and Examination of the Full Seventeen Year Series of Estimates from the Piedras Blancas Light Station

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ABSTRACT

Shore based surveys of northbound gray whale calves were conducted between March and June from the Piedras Blancas Light Station each year from 2001-2010. Estimates for the total number of northbound calves were 256, 842, 774, 1528, 945, 1020, 404, 553, 312 and 254 for the 10 consecutive surveys. Over this period, annual estimates averaged 4.1% of the total abundance as estimated by Laake *et al.* (2009). The estimates from 2001-2010 represent the most recent of a 17-year time series of surveys from this site and include both the highest (1528 calves in 2004) and the lowest (254 calves in 2010) estimates in this series. Average ice cover for the Bering Sea explains roughly 70% of the interannual variability in estimates of northbound calves the following spring.

KEYWORDS: GRAY WHALES; ESCHRICHTIUS ROBUSTUS; SURVEY; REPRODUCTION; SHORE-BASED; CALF ESTIMATE

INTRODUCTION

Each spring, cows with calves from the eastern north Pacific population of gray whales migrate from the nursery grounds of Baja California, Mexico to feeding grounds located primarily in the Arctic. The northbound migration of cows and calves is separated both temporally, occurring later, and spatially, passing much closer to shore, than the northward movement of other adults and juveniles. Scientists have taken advantage of this near-shore migratory pattern to count northbound calves and estimate reproductive output of this population (Hessing 1981; Herzing and Mate 1984; Poole 1984 a&b; Perryman *et al*. 2002a). Most published estimates of the number of northbound gray whale calves have been based on counts of animals passing the Piedras Blancas Light Station, located just north of San Simeon, California.

Poole (1984a&b) counted northbound gray whales from Piedras Blancas in 1980 and 1981. He found that over 90% of the observed calves passed within 200 m of the research site (Poole 1984a) and estimated that calves represented 4.7% and 5.1% of the northbound gray whales in 1980 and 1981 respectively (Poole, 1984b). Perryman *et al*. (2002a) reported on 7 consecutive surveys (1994-2000) of northbound calves from this same site. These authors reported that estimates of total northbound calves varied significantly between years, ranging from 1479 calves in 1997 to 279 calves in 2000. These authors also reported that there was a positive correlation between the length of time a particular area in the Chirikov Basin was free of seasonal ice and the number of calves seen northbound the following season.

In this report we present estimates of northbound gray whale calves for the 2001-2010 seasons from shore-based surveys conducted at the Piedras Blancas Light Station. We compare these results with previous estimates and re-examine estimates of reproductive output for the population based on the recent abundance time series published by Laake *et al*. (2009). In addition, we examine the relationship between calf estimates and average ice cover for the Bering Sea during May of the previous year.

METHODS

Shore-Based Surveys

Shore-based surveys of northbound gray whale calves were conducted from the Piedras Blancas Light Station (Figure 1) each spring from 2001-2010. This is the same site used for gray whale calf surveys in 1980 and 1981 (Poole, 1984a) and 1994-2000 (Perryman *et al*. 2002a). Survey methodologies were the same as those reported by Perryman *et al.* (2002a). Northbound gray whale calves were counted by teams of two observers who split their watch effort between inshore and offshore areas. Watches were maintained in good weather conditions for 12 hrs a day 6 days a week during the 2001-2003 and 2005 surveys and for 12 hrs a day 5 days a week during the

2004 and 2006-2010 surveys. The reduced effort in later years reflects the impact of budget constraints on the project. The primary searching technique was with naked eye, but 7X and 25X binoculars were used to search farther offshore and to confirm the presence of a calf as cow/calf pairs approached the site (Figure 2). Most calves passed within 200-400 m of the survey site (Figure 3), but for the few that passed farther offshore, distance offshore was determined by reticle measurements using the 25X binoculars (Lerczak and Hobbs 1998).

In the analyses of these survey data we assumed that the number of gray whale calves passing far enough offshore to go undetected by the observers was negligible and that day and night migration rates were the same, as was found from aerial surveys and night vision sampling reported by Perryman *et al*. (2002a). We also assumed that detection probabilities were the same across acceptable sighting conditions (ranked 1-4 from Reilly *et al.* 1983; Reilly 1992). To correct for imperfect probability of detecting calves by the watch team, we corrected observed migration rates by the average detection probability estimated from replicate watch effort conducted over the 7 consecutive surveys between 1994 and 2000 (mean=0.889, SE=0.06375). We chose to use this value because of the stability of our watch teams over the 17 years of effort from this site and because detection probability did not vary significantly between years during the first 7 years of this project (Perryman *et al*. 2002a).

Each day's effort was divided into four 3-hour periods, and the passage rates during these periods were calculated from the observed counts multiplied by the inverse of the detection function. To correct for the periods when observers were not on watch (unacceptable weather conditions, at night, 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 and also to produce variance estimates for the proportion of the population represented by calves.

Seasonal Ice Cover

Gridded sea ice concentrations for the Bering Sea were taken from passive microwave retrievals from the SMMR and SSMI satellite sensors. These data are published online by the National Snow and Ice Data Center (http://nsidc.org/). The data sets for the Bering Sea were extracted from the above source and provided to us by the University of Illinois at Urbana-Champaign Polar Research Group. Daily ice cover values for the month of May were averaged, and these monthly average values were compared with calf estimates for the following spring. The analysis of ice and calf production reported here is preliminary.

RESULTS

Shore Based Surveys (2001-2010)

Shore-based survey effort began in mid to late March each year, and effort continued until counts of northbound gray whale calves fell to insignificant numbers (Table 1; Figure 4). There was no evidence of a significant trend in median migration dates over this period (Figure 5). We found that 85% of the cows with calves passed so close to shore (<400 m) that their distances could not be measured with the reticulated 25X binoculars (Figure 6). Calf estimates were highly variable between years, with no sign of a positive or negative trend in these data (Figure 7).

Calf Production Indices (1980, 1981 and 1994-2010)

We divided our estimates of northbound calves presented in this report and those published by Poole (1984b) and Perryman *et al.* (2002) by estimates of abundance for this population (Laake *et al.* 2009) to develop a total of 19 annual indices of calf production (Table 2; Figure 8). For years in which estimates of abundance were not available we assumed that change in abundance was linear between estimates, or for years after the final estimate in 2007 we assumed that abundance was stable. Indices of calf production were highly variable, averaging 4.1% over these 19 estimates (range 1.55 – 8.85%). These data show no sign of a positive or negative trend in reproduction over this time period.

Seasonal Ice and Calf Production

We found that there was a significant linear relationship ($p<.01$, $R^2=0.71$) between average ice cover values for May and the estimates of total northbound calves the following spring (Figure 9). Based on ice cover during May of 2010, we predict that 2011 will be another year of low calf production for this population.

DISCUSSION

The northbound migration of gray whales calves continues to follow a near-shore corridor past the Piedras Blancas Light Station, making shore-based surveys a very effective and inexpensive technique for monitoring reproduction in this population. Data from the full time series of estimates, 1980 and 1981 (Poole 1984a) and our 17-year times series (1994-2010), reveal no indication of a trend in the medians of northbound counts. These results are in contrast to those from counts of southbound gray whales that are migrating later than they did in the early 1980s (Rugh *et al.* 2001). The new estimates reported here include both the highest and lowest estimates of the number of northbound calves over our 17 consecutive surveys from this site.

The annual indices of calf production (total northbound calves/abundance) over the period from 1994-2010 averaged 4.1% per year. These estimates include the impacts of early postnatal mortality but may overestimate recruitment because they do not account for the possibly significant level of predation on gray whale calves by killer whales (*Orcinus orca*) occurring north of the Piedras Blancas survey site. Our findings of relatively low reproductive output are consistent with the reports of little or no growth in this population over the same time period (Laake *et al*. 2009; Punt and Wade 2010). The most intriguing feature of this time series is the high interannual variability in calf production.

Based on comparisons of ice distributions taken from satellites and estimates of northbound calves, Perryman *et al.* (2002a, 2002b) suggested a link between the timing of the melt of seasonal ice in the Arctic and calf production in this population the following winter. The ice model used in these earlier comparisons was based on the length of time that historical feeding grounds were ice free. Here we present an analysis of a more complete data set of ice cover for the Bering Sea and find an even stronger relationship than reported previously. Our results are consistent with the hypothesis that a late retreat of seasonal ice may impact access to prey for pregnant females and reduce the probability that existing pregnancies will be carried to term. This link between weather (in this case ice distribution) and reproductive output of a cetacean population is similar to the relationship reported for some populations of right whales (Knowlton *et al.* 1994; Leaper *et al.* 2005).

In this era of shrinking ice cover it seems counter-intuitive to suggest that extensive ice cover might be a limiting factor in recruitment for this population. Although the over all reduction of seasonal ice cover in the Arctic is well documented, the rate of change in ice coverage is not consistent between seasons. Since 1979, average ice cover in September has decreased by about 11.6% per decade, while the rate in the reduction in ice cover in March has decreased only about 2.7% per decade (Richter-Menge and Overland 2010). Thus while gray whales are migrating much farther north to feed than they did in the 1980s, the earliest northbound migrants, pregnant females, are encountering ice distributions that have changed relatively little over the same time period.

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Table 1. A summary of effort and sightings for the shore-based surveys of northbound gray whale calves from the Piedras Blancas Light Station (2001-2010). Years with asterisks indicate seasons during which effort was 12 hrs/day for 5 days/week instead of the 6 days of efforts as in other years.

Year	Start Date	End Date	Hours of Effort	Calves Sighted	Median Migration Date
2001	19-Mar	5-Jun	722	87	2-May
2002	18-Mar	31-May	711	302	25-Apr
2003	17-Mar	30-May	686	269	22-Apr
2004*	22-Mar	28-May	562	456	27-Apr
2005	21-Mar	27-May	669	345	25-Apr
2006*	13-Mar	26-May	531	285	24-Apr
2007*	26-Mar	25-May	469	117	25-Apr
2008*	24-Mar	23-May	498	171	27-Apr
2009*	23-Mar	22-May	476	86	27-Apr
2010*	29-Mar	28-May	487	71	19-Apr

Table 2. Index of calf production based on estimated northbound calves and population abundance as estimated in Laake et al. (2009). In years without surveys to estimate abundance, population abundance was assumed to change in a linear pattern between estimates.

Year	Calves Sighted	Total Calf Estimate	SE	Abundance Estimate	Calf Production Index	SE(%calves)
1994	325	945	68.20	20103	4.70%	0.340%
1995	194	619	67.20	20524	3.02%	0.328%
1996	407	1146	70.70	20944	5.47%	0.338%
1997	501	1431	82.00	21040	6.80%	0.391%
1998	440	1388	92.00	21135	6.57%	0.436%
1999	141	427	41.10	19546	2.18%	0.210%
2000	96	279	34.80	17958	1.55%	0.194%
2001	87	256	28.56	16369	1.56%	0.174%
2002	302	842	78.60	16033	5.25%	0.491%
2003	269	774	73.56	16651	4.65%	0.442%
2004	456	1528	96.00	17269	8.85%	0.558%
2005	343	945	86.90	17888	5.28%	0.487%
2006	285	1020	103.30	18507	5.51%	0.559%
2007	117	404	51.20	19126	2.11%	0.268%
2008	171	553	53.11	19126	2.89%	0.278%
2009	86	312	41.93	19126	1.63%	0.219%
2010	71	254	33.94	19126	1.33%	0.177%

Figure 1. The Piedras Blancas Light Station is located just north of San Simeon, CA.

Figure 2. Observer station including mounted 25X binoculars for search to the horizon offshore and hand-held binoculars for tracking animals near shore.

Figure 3. Most gray whale cow/calf pairs passed very close to shore (>200 m) when rounding the point directly in front of the observation station at Piedras Blancas.

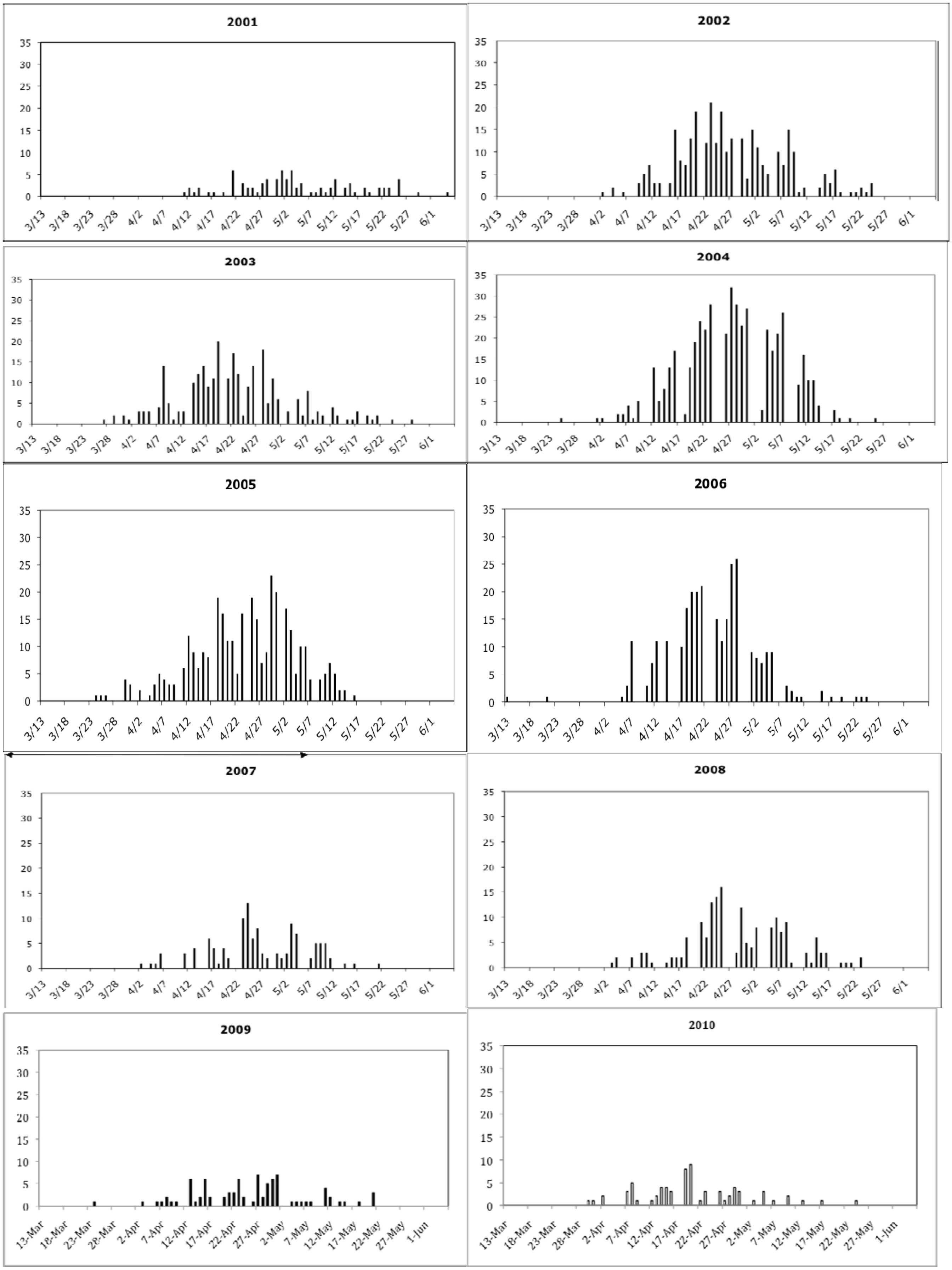

Figure 4. Histograms of daily sightings of northbound calves passing the Piedras Blancas Light Station during shore-based surveys 2001-2010. Y axis indicates total daily counts and X axis indicates sighting date.

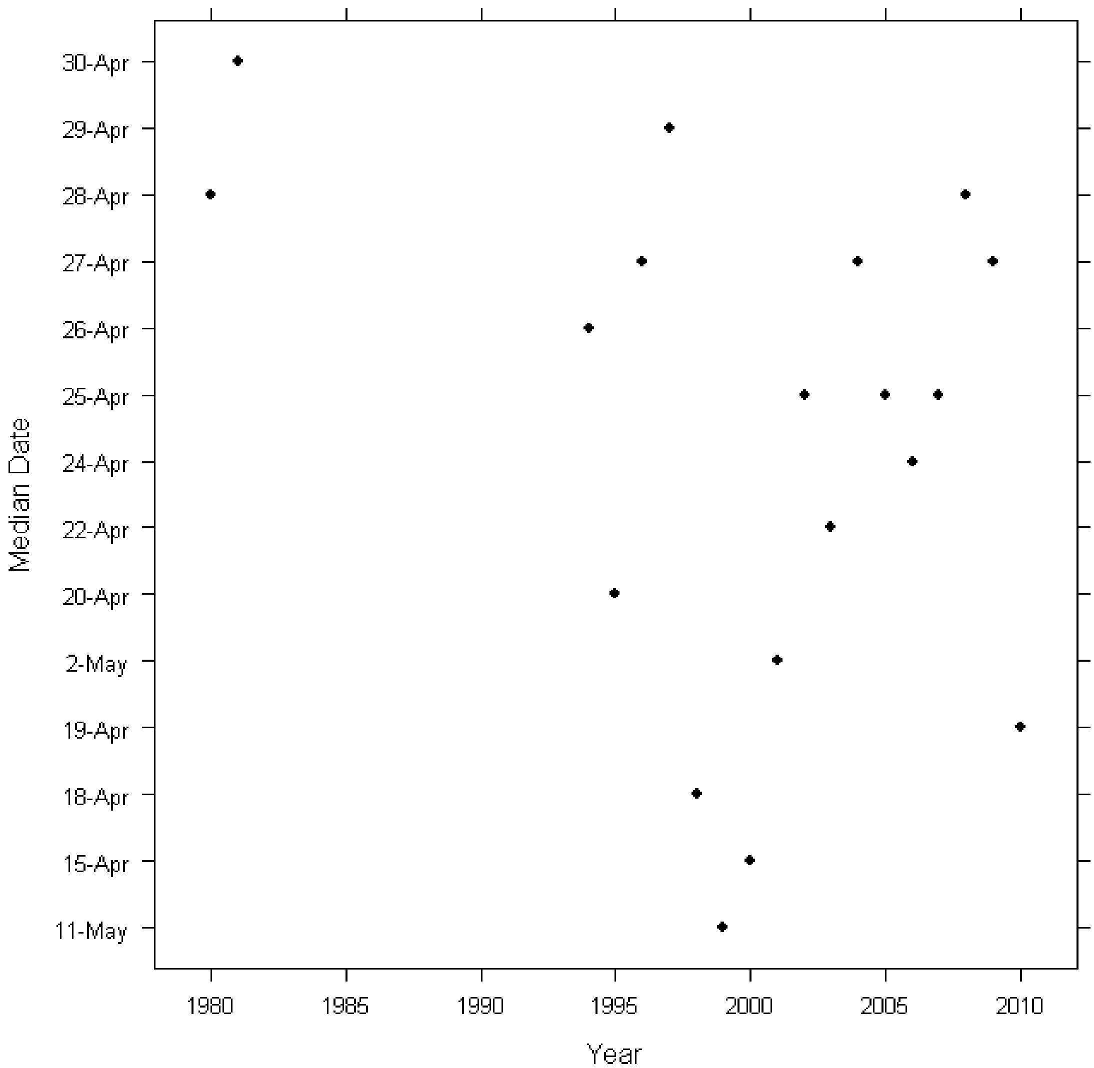

Figure 5. Medians of counts of northbound gray whale calves passing the Piedras Blancas Light Station during shore-based surveys 2001-2010.

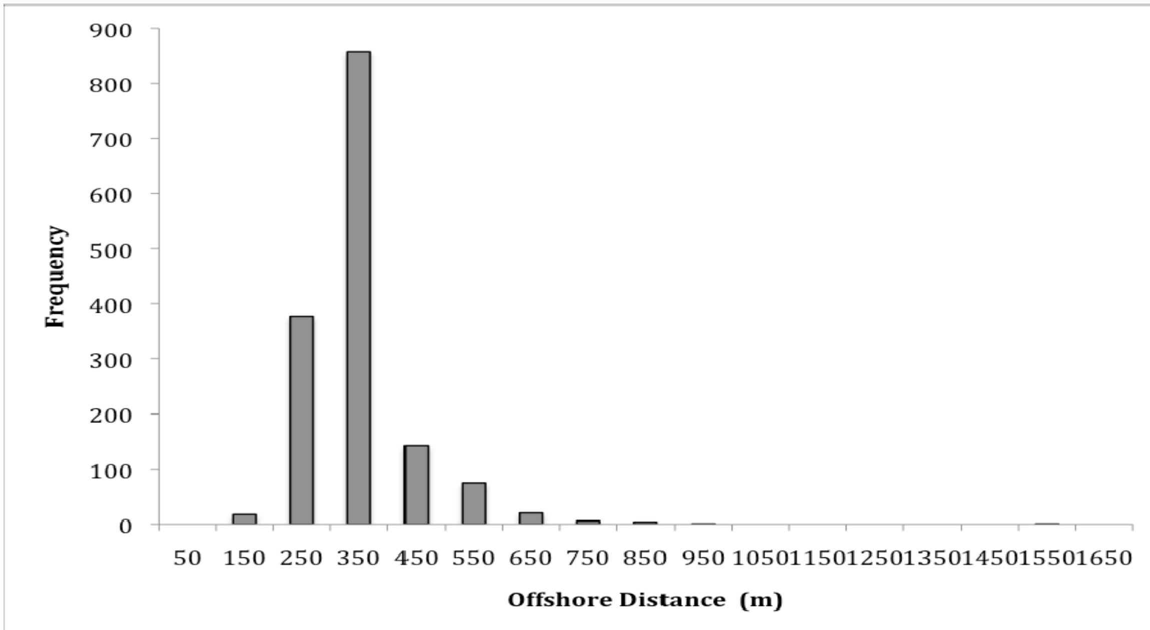

Figure 6. Estimates of offshore distance to gray whale calves passing the Piedras Blancas Light Station during shore-based surveys 2001-2010. Distances > 400m were determined based on reticle readings from 25 X binoculars. All other distances were estimated.

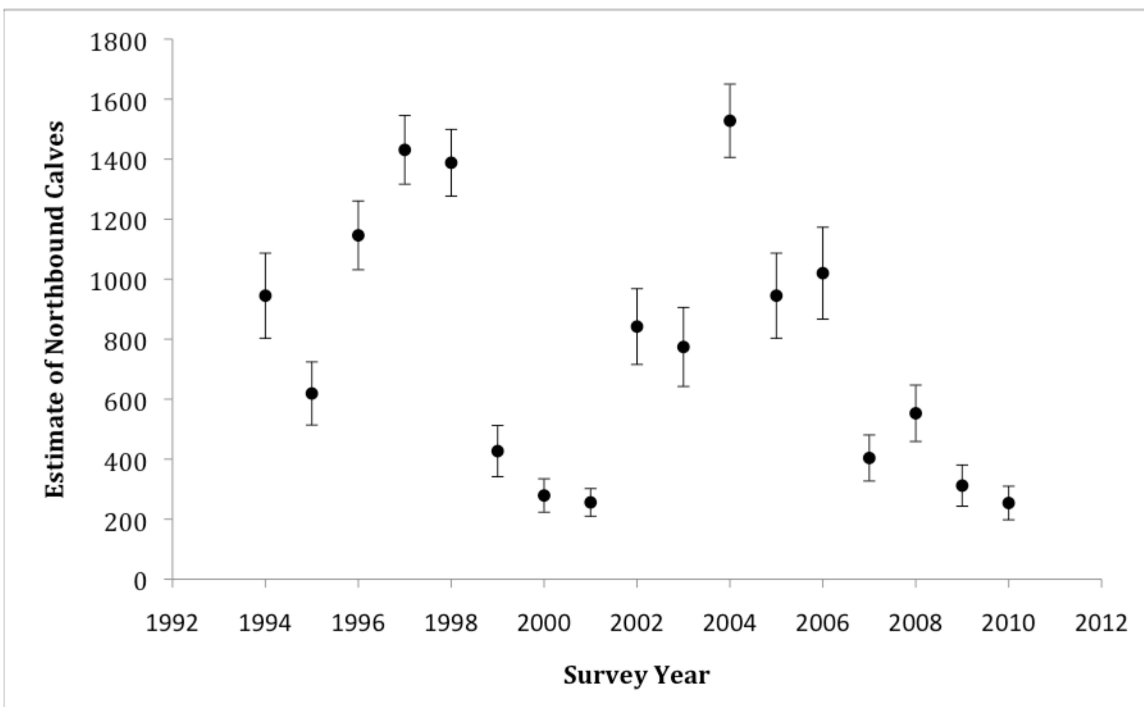

Figure 7. Estimates of northbound gray whale calves based on shore-based surveys conducted from the Piedras Blancas Light Station 2001-2010. Error bars represent ± 2 SE.

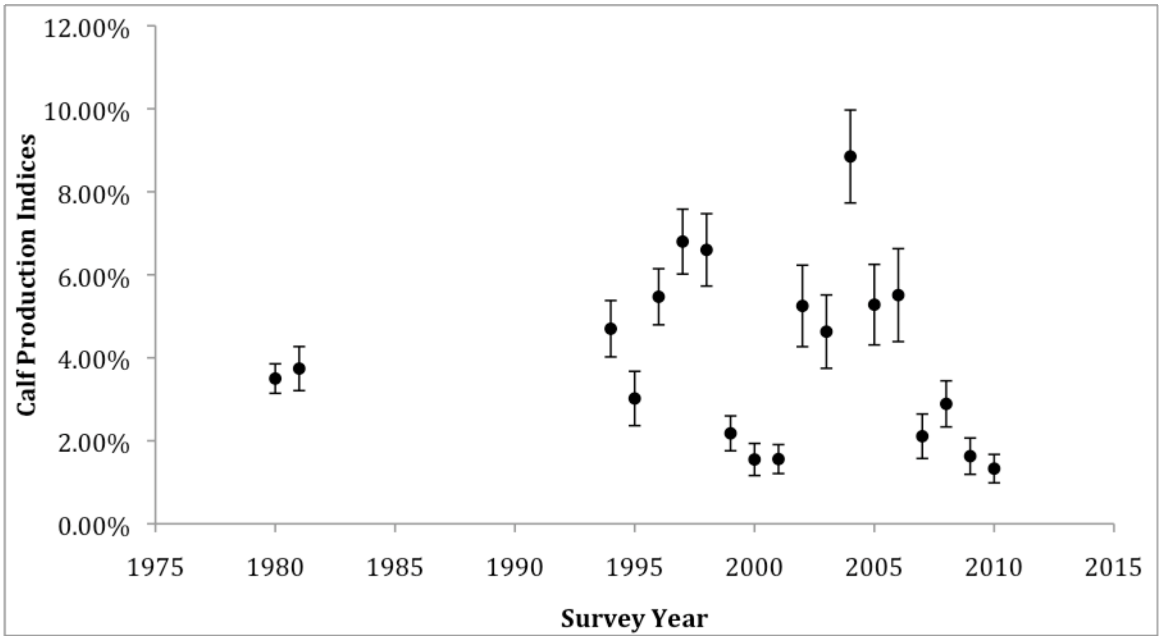

Figure 8. Indices of calf production for eastern north Pacific gray whales based on shore-based surveys of southbound whales (estimates of abundance) and northbound whales (estimates of total calves). Error bars equal ± 2 SE. For this comparison we have assumed that the population has remained stable since the last published estimate of abundance in 2007.

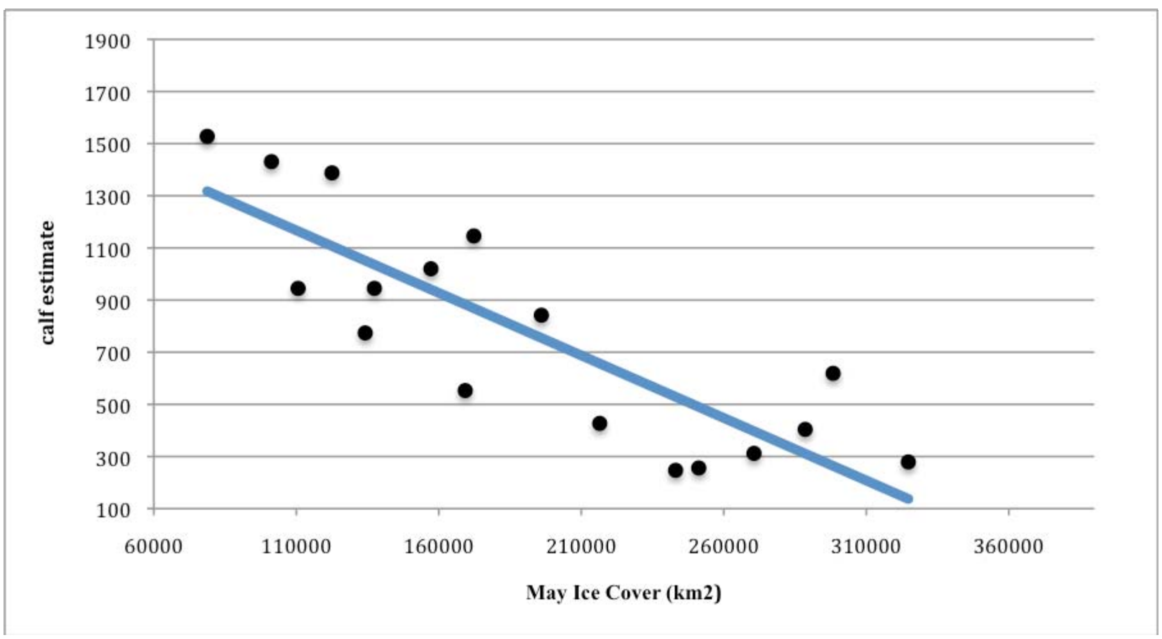

Figure 9 Plot of least squares linear regresson for estimates of total northbound calves and the area of the Bering Sea covered by seasonal ice the previous May.