Results of Surveys of Northbound Gray Whale Calves 2001-2009 and Examination of the Full Sixteen 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 to 2009. Estimates for the total number of northbound calves were 256, 842, 774, 1528, 945, 1020, 404, 553 and 312 for the nine consecutive surveys. Over this period, annual estimates averaged 4.19% of the total abundance as estimated by Laake *et al.* (2009). The estimates from 2001-2009 represent the most recent of a 16-year time series of surveys from this site and include both the highest (1528 calves in 2004) and the lowest (256 calves in 2001) estimates in the 16 years.

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.

On the recommendation of Robert L. Brownell, Poole (1984 a&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 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 2001-2009 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).

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 2001-2009. 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 2006-2009 surveys. The reduced effort in later years reflects the impact of budget constraints on the project. 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, their distance offshore was determined by reticule 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 15 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.

RESULTS

Shore Based Surveys (2001-2009)

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 significant trend in median migration dates over this period, but excluding the 2001 median date, there is an apparent trend toward a later median over the remaining 8 surveys (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 1994-2009)

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 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. Indices of calf production were highly variable, averaging 4.25% over these 18 estimates (range 1.55 – 8.85%). These data show no sign of a positive or negative trend in reproduction over this time period.

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. Although results from the last 8 surveys suggest a trend towards a later median migration date for this phase of the northbound migration, data from the full time series of estimates, 1980 and 1981 (Poole 1984a) and our 16-year times series (1994-2009), 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 16 consecutive surveys from this site.

The annual indices of calf production (total northbound calves/abundance) over the period from 1994-2009 averaged 4.25% 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 in this population 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). Calf production over the past three seasons has been very low, and it is likely that the series of cold winters and slow spring melts in the Bering Sea that preceded these calving seasons are a significant factor in this pattern, for the reasons hypothesized below.

Based on comparisons of ice distributions taken from satellites and estimates of northbound calves, Perryman *et al.* (2002a, 2002b) have suggested that there is a link between the timing of the melt of seasonal ice in the Arctic and calf production in this population the following winter. These authors have suggested that a late retreat of season 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 distributions) and reproductive output of a cetacean population is similar to the relationship reported for some populations of right whales (Knowlton *et al.* 1994; Greene *et al.* 2003; Leaper *et al.* 2005). We have not presented the output of the most recent model we have developed to examine the relationship between seasonal ice and calf production in this population because we are still exploring the addition of the new abundance time series (Laake *et al.* 2009) to this model. Preliminary results still suggest a significant link between the spatial distribution of seasonal ice during a relatively brief time period (April-June) and calf production the following winter (Perryman unpublished data) but it is unlikely that this simple model provides a full explanation for the observed overall low reproductive output of this population.

Most of the eastern North Pacific gray whale population depend on the highly productive shallow water benthic communities of the Arctic to accumulate the stored energy necessary to support them through the migration to and from the warm water breeding and calving grounds where prey are scarce. It appears now that one biological impact of the trend towards warmer temperatures and less ice (Parkinson *et al*. 1999) in the Arctic is a shift away from the an ecosystem based on tight pelagic and benthic coupling to one including more pelagic fish and other previously sub-Arctic forms (Grebmeier *et al.* 2006a, 2006b). It is likely that this shift is already impacting populations that feed primarily on benthic prey, and it has been suggested that the shift in feeding grounds for gray whales from the Northern Bering Sea into the Chukchi Sea is in response to these changes (Moore *et al.* 2003). This shift in feeding ground is hypothesized to be the driving force underlying the observed relationship between seasonal ice and calf production in this population and possibly an overall reduction of carrying capacity for gray whales. Certainly this population is responding to the biological processes resultant from the warming trend in the Arctic. As such, gray whales represent a valuable sentinel for the impacts of climate change (Moore 2008).

AWKNOWLEDGMENTS

The success of this effort is due in a large part to a team of dedicated and very talented observers who have worked with us through the 15 years of this project. In addition, the work would not have been possible without the generous support of the US Department of Interior’s Bureau of Land Management. We specifically thank John Bogacki and James Boucher who provided us access to the Piedras Blancas Light Station research site, housed the survey team, and tolerated a group of biologists for about 2.5 months each of the last 16 years. This manuscript was improved by suggestions from David Weller and William Perrin.

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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 (2001-2009). 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

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%	0.00340
1995	194	619	67.20	20524	3.02%	0.00328
1996	407	1146	70.70	20944	5.47%	0.00338
1997	501	1431	82.00	21040	6.80%	0.00391
1998	440	1388	92.00	21135	6.57%	0.00436
1999	141	427	41.10	19546	2.18%	0.00210
2000	96	279	34.80	17958	1.55%	0.00194
2001	87	256	28.56	16369	1.56%	0.00174
2002	302	842	78.60	16033	5.25%	0.00491
2003	269	774	73.56	16651	4.65%	0.00442
2004	456	1528	96.00	17269	8.85%	0.00558
2005	343	945	86.90	17888	5.28%	0.00487
2006	285	1020	103.30	18507	5.51%	0.00559
2007	117	404	51.20	19126	2.11%	0.00268
2008	171	553	53.11	19126	2.89%	0.00278
2009	86	312	41.93	19126	1.63%	0.00219

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.

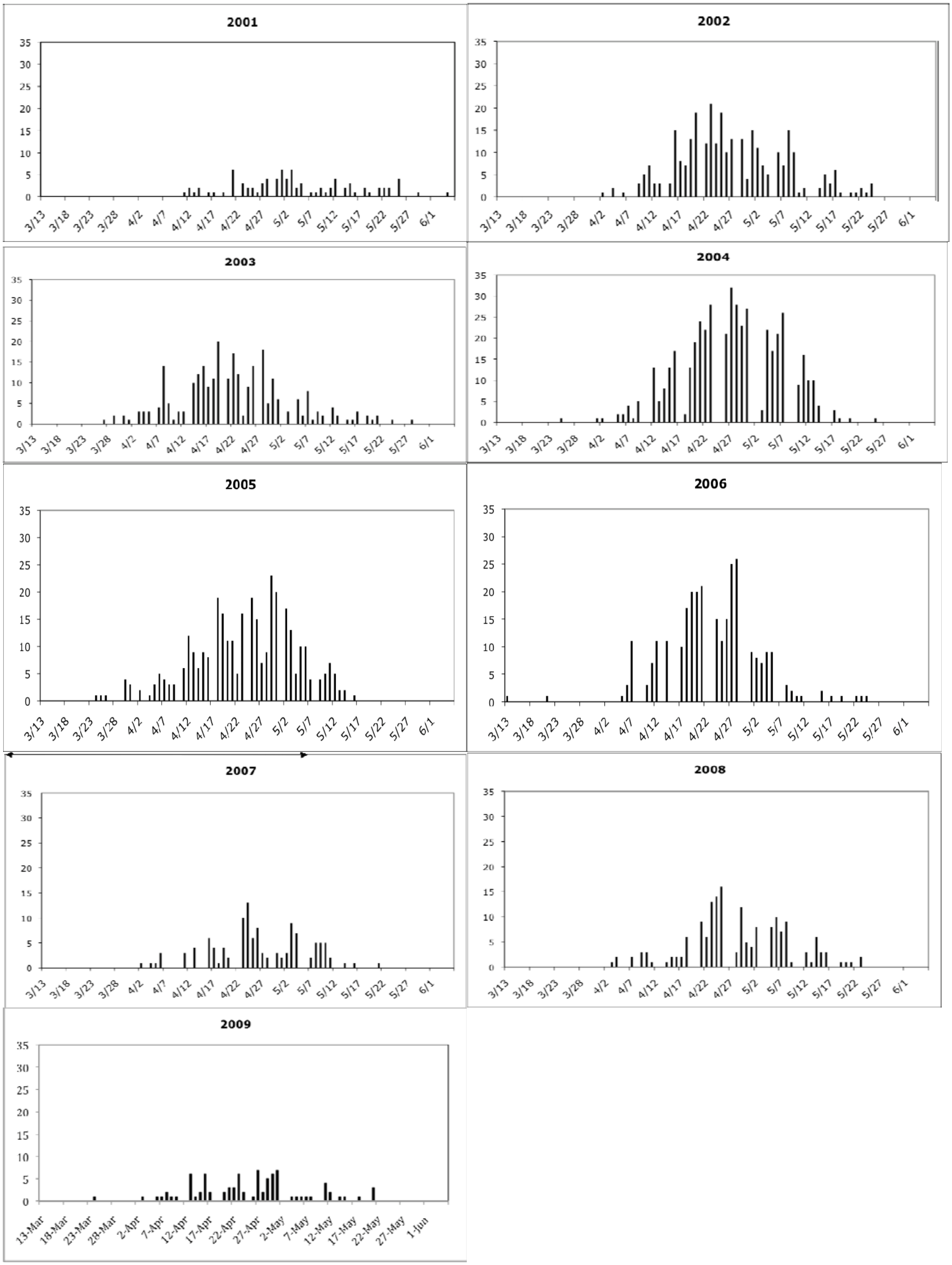

Figure 4. Histograms of daily sightings of northbound calves passing the Piedras Blancas Light Station during shore-based surveys 2001-2009. Y axis indicates total daily counts and X axis indicates sighting date.

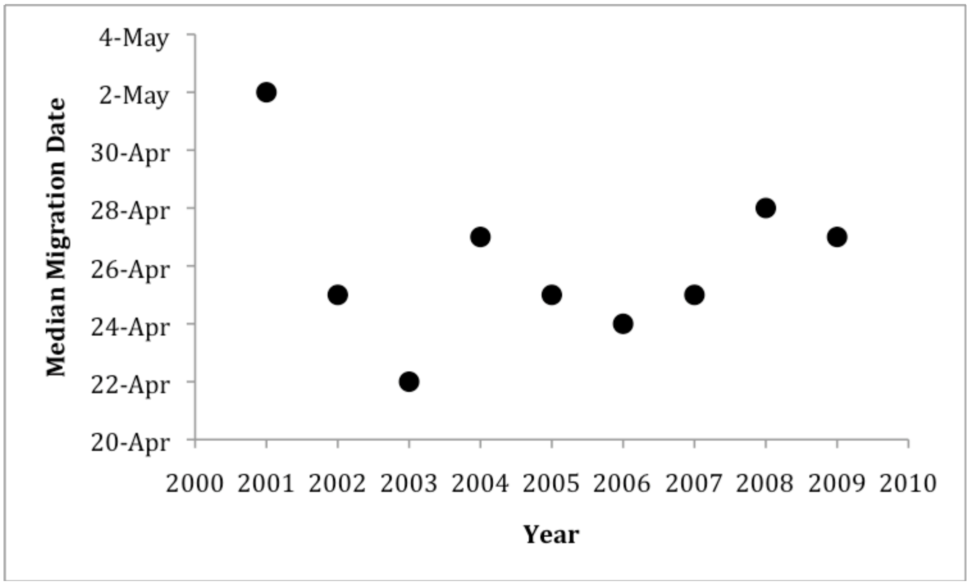

Figure 5. Medians of counts of northbound gray whale calves passing the Piedras Blancas Light Station during shore-based surveys 2001-2009.

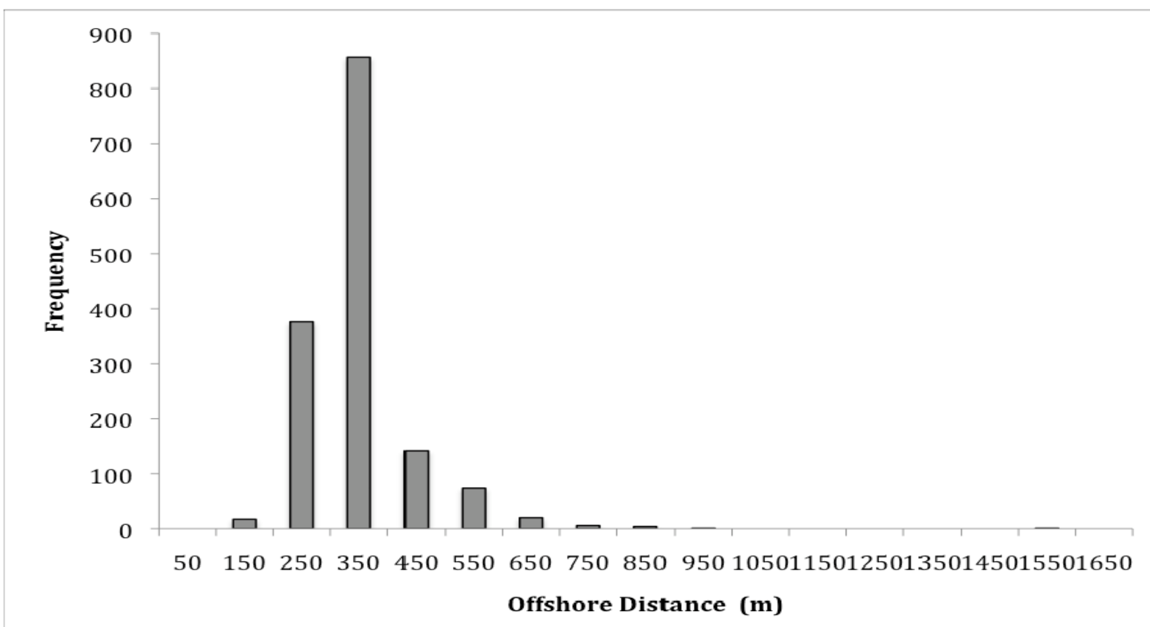

Figure 6. Estimates of offshore distance to gray whale calves passing the Piedras Blancas Light Station during shore-based surveys 2001-2009. Distances > 400m were determined based on reticle readings from 25 X binoculars. All other distances were estimated.

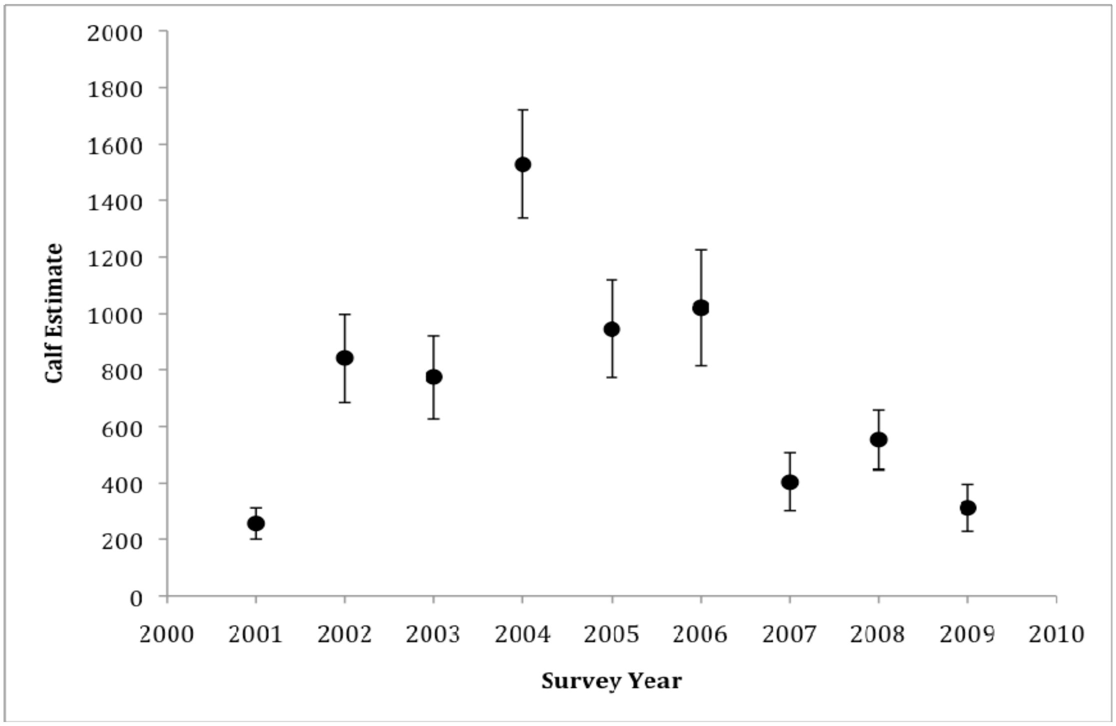

Figure 7. Estimates of northbound gray whale calves based on shore-based surveys conducted from the Piedras Blancas Light Station 2001-2009. Error bars represent ± 2 SE.

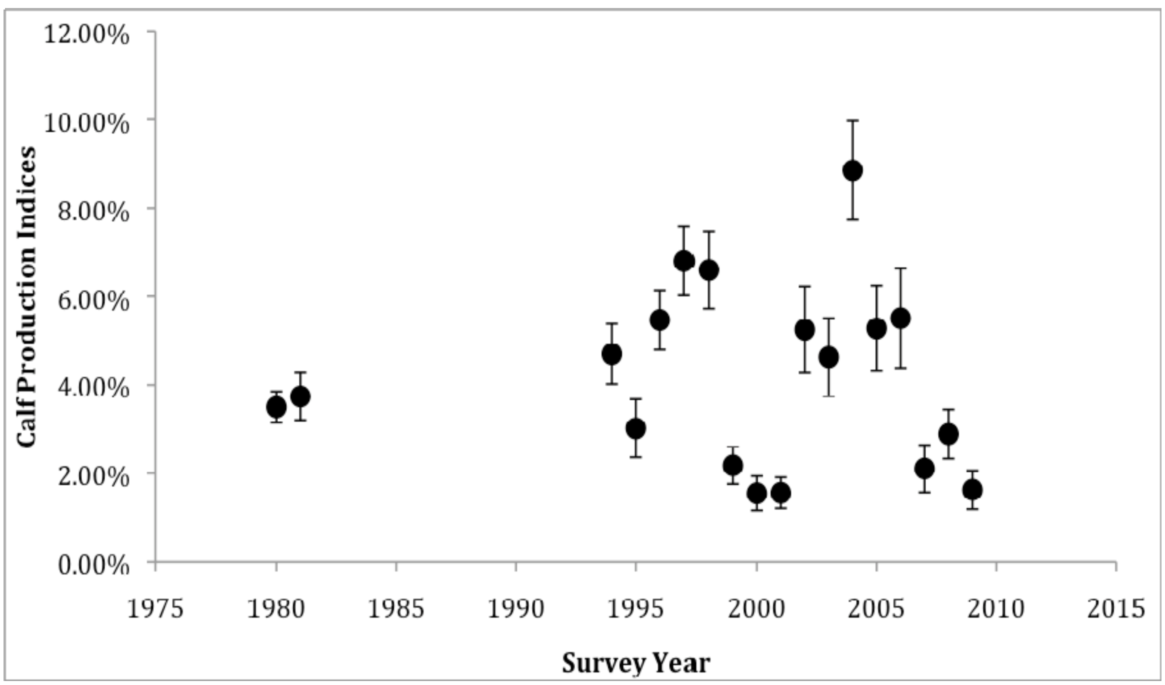

Figure 8. Indices of calf production for eastern north Pacific gray whales based on shore-based surveys of southbound whales (estimates of abundance) and northbound whales (estimates of total calves). Error bars equal ± 2 SE.