COMPARISON OF 2007-2009 WINTER COUNTS OF GRAY WHALES AND CHANGES IN WHALE DISTRIBUTION FROM 1978 TO 2009 IN LAGUNA SAN IGNACIO, B.C.S., MEXICO FROM 2007-2009

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ABSTRACT

The number of gray whales (*Eschrichtius robustus*) that utilize Laguna San Ignacio (LSI) during the winter breeding season has been monitored with standardized boat surveys since 1978 to the present (Jones and Swartz 1984; Urbán et al. 2000; Swartz et al. 2007 and 2008; and this paper) and represents the longest time series of winter breeding lagoon counts for this species. Counts from the most recent surveys (2007-2009) were compared with respect to the timing and duration of the occupation of the lagoon by gray whales, the number of adult whales, the number of non-female-calf pairs, and the number of female-calf pairs see in the lagoon from mid-January to early April. The distribution of gray whales within the lagoon during the winter was compared over three time periods: 1978-1982; 1996-2000; and 2006-2009. Counts of the total number of adult whales, female-calf pairs, and single non-calf whales indicate that gray whales began to enter the lagoon in mid-January each year, and maximum counts were obtained the last week in February each year. Counts of adult whales without calves began to decrease by the first week in March and these whales were virtually absent from the lagoon by the first week in April. Counts of females with calves of the year also decreased during the last half of February each year, but then counts of these whales increased a second time during the first two weeks in March before decreasing to low numbers by the beginning of April each year. This suggests that females whose calves were born earlier in February in other areas were visiting Laguna San Ignacio during the last month of the winter breeding season (March) before beginning their northward spring migration to their summer range. The percent of the total number of gray whales counted in the lagoon during the mid-February peak of the breeding season increased from 1978 to 2009 in the lower lagoon zone nearest the entrance and in the middle lagoon zones, while the percent of whales occupying the upper lagoon zone furthest from the entrance decreased during this period. This change in the distribution of the whales within the lagoon suggests that fewer whales are utilizing the interior of the lagoon and preferring the areas closer to the entrance to the open ocean. The lower lagoon is the zone where whale-watching activities are permitted, while the middle and upper zones are closed to eco-tourism and whale-watching. Comparison of these trends with other breeding lagoons is needed to determine if these trends are representative of gray whales occupying the entire winter range, or unique to Laguna San Ignacio.

KEY WORDS: GRAY WHALE, BREEDING LAGOONS, ABUNDANCE COUNTS, MOTHER-CALF PAIRS, DISTRIBUTION, WHALE-WATCHING

INTRODUCTION

Laguna San Ignacio (LSI) is one of the four calving-breeding lagoons of the Eastern Pacific gray whale (*Eschrichtius robustus*) that remains mostly undeveloped (Urbán *et al.*, 2002). The lagoon is located in the west coast of the Baja California Peninsula in Mexico and has a long history of commercial fishing, and whale-watching based eco-tourism that developed during the 1990's (Dedina and Young, 1995). The lagoon is part of Mexico's largest wildlife refuge of the Vizcaino Desert Biosphere Reserve which is administrated by Secretaria de Medio Ambiente, Recursos Naturales y Pesca (SEMARNAT) (Fig. 1).

Boat surveys utilizing standardized methodology have been used to monitor the number of gray whale residing within LSI during the winter began in 1978-1982 (Jones and Swartz 1984). A second series of surveys were conducted from 1996-2000 (Urbán *et al.*, 2002). A third survey series began as part of the Laguna San Ignacio Ecosystem Science Program (LSIESP) in 2006 and these surveys continue to the present (Swartz et al. 2007 and 2008, and this paper). Counts from the 2007 to 2009 surveys were compared to establish the current timing and pattern of the winter occupation, and to monitor the number gray whales that currently utilize this lagoon during the winter breeding season. The distribution of the whales in the lagoon's three main interior zones in 2007-2009 were compared with historical counts during the period 1978-1982 and 1996-2000 to evaluate changes in the whales' utilization of the lagoon interior during the winter. These zones include the lower lagoon zone nearest the entrance and the zone in which whale-watching eco-tourism is permitted, the middle lagoon zone or central portion of the lagoon, and the upper lagoon and the north zone which are the northern most areas utilized by whales (Fig. 2).

METHODS

Boat Surveys (census)

Forty-three complete census surveys to determine whale abundance and distribution within the lagoon were conducted during the period 2007-2009: 12-surveys from 5 February to 30 March 2007; 15-surveys from 25 January to 3 April 2008; and 16-surveys from 19 January to 30 March 2009 (Annex I). Surveys followed a standard survey transect (Fig. 2) and whale counts obtained by using standard observer protocol each year to allow comparison with previous survey counts and historical counts from this lagoon (Jones and Swartz 1984, Urbán *et al*., 2002, and Swartz et al. 2007 and 2008).

Each survey was conducted from a 7-m outboard powered boat which followed a standard transect line. Boats travelled at a speed of 11 km/hr during the whale counts. Speed and transect course were verified using visual landmarks and with a hand-held GPS (Global Position System) device. This survey speed minimizes the likelihood that whales (which typically travel at 7 to 9 km/hr) do not move ahead of the survey boat and thus be counted more than once. The transect line ran along an imaginary line drawn through the lagoons deep water areas (i.e., > 2.0 m deep) from the breaker line at the lagoon entrance in the lower lagoon zone, to Isla Garzas at the north end of the lagoon in the upper zone. Each survey required about 2.5 to 3.0 hr to complete. The maximum distance from the transect line to the 2 m depth contour along shore was 2.5 km and the minimum was 0.8 km. Thus, waters inhabitable by whales and both shorelines were clearly visible at all times within the lagoon (it was assumed that essentially all animals within 2.5 km of the trackline were seen). Whales in the "North End" of the upper lagoon zone (north of the transect termination) were counted from a stationary location located at the centre of the upper portion of the lagoon by observers searching in 360-degrees around the stationary boat (Fig. 2). Surveys were aborted when sea conditions exceeded Beaufort 3 sea state (winds greater than 18 km/hr and consistent white caps).

By convention, we considered "cow-calf pairs" (*i.e.*, female whales with calves of the year) as a single unit and

counts of these pairs are equivalent to calf counts. "Single whales" refer to non-parturient females, adult males, and immature animals.

Analysis Procedure

Counts of gray whales during each winter season were analyzed as total adult (non-calf) whales, single whales, and cow-calf pairs counted within each of the three primary zones (*i.e*., the lower, middle, and upper lagoon zone including the north end area) (Fig. 2). The distribution of whales within the lagoon's three zones were expressed as the percent (%) of the total number of whales counted in each zone during surveys conducted during the period of maximum whales counts in late-February. The three time series compared were: 1978-1982, 1996-2000, and 2006-2009.

RESULTS

Boat Surveys (census)

Counts of gray whales from boat surveys are used as an index of the minimum abundance of whales within the lagoon each survey day during the winter breeding season and do not represent estimates of total abundance or the total number of whales that visit the lagoon during a winter season.

2007 Survey Counts: Twelve surveys were conducted to count gray whales between 5 February and 30 March 2007 (Annex I). The maximum count of adult whales was 217 on 22 February (Fig. 3). The highest count of single whales was 197 also on 22 February (Fig. 4), and the highest cow-calf pair count was 37 on 17 February (Fig. 5).

2008 Survey Counts: Fifteen surveys to count gray whales were conducted between 25 January and 3 April 2008 (Annex I). The maximum count of adult whales was 139 on 28 February (Fig. 3). The highest count of single whales was 110 and occurred on 9 March (Fig 4), and the highest cow-calf pair count was 41 on 24 March (Fig. 5). The high count of adult whales occurred approximately one week (6-days) later than the highest count of adult whales in 2007and was approximately 36% lower than the number of whales counted during seasonal maximum period in February.

2009 Survey Counts: Sixteen surveys were conducted between 19 January and 30 March 2009 (Annex I). The maximum count of adult whales was 139 on 24 February (Fig. 3). The highest count of single whales was 127 and also occurred on 24 February (Fig 4), as did the highest cow-calf pair count of 62 (Fig. 5). The high count of adult whales was only 13% less than the 2007 high count, and occurred within two days of the high count in 2007. The timing and duration of the lagoon occupation was also similar to that in 2007.

Distribution of whales within the lagoon:

The distribution of whales within the lagoon during the peak of the winter breeding season in February has shifted from the interior of the lagoon to the areas nearest to the lagoon entrance and the open coast since surveys began in 1978. During the period 1978 to 1982 approximately 45% to 55% of the whales occupied the lower lagoon zone nearest the entrance and the open coast (Fig. 6). Surveys conducted between 1996 and 2009 indicate that the number of whales occupying the lower zone ranged from 40% to 66% suggesting an increasing number of whales utilizing the lower zone.

The percent of whales counted in the middle lagoon zone during the period 1978 to 1982 ranged from 16% to

23%, while the number of whales counted in surveys conducted between 1996 to 2009 ranged from 22% to 46% in this zone (Fig. 7). This increase was similar to that seen in the lower lagoon zone.

The percent of whales occupying the upper lagoon zone and north end ranges from 29% to 33% in surveys conducted from 1978 to 1982 (Fig.8). Except for the survey conducted in 1997 (which had 34% of the whales counted), the percent of whales in the upper zone and north end declined to 9% to 17% in surveys conducted between 1996 and 2009. This decline was indicative of a significantly fewer number of whales utilizing the inner lagoon areas what were previously utilized extensively by females with calves of the year, and accounts for the increasing percent of whales utilizing the middle and lower zones.

DISCUSSION

The number of whales counted in boat surveys and the duration of the winter occupation of LSI were similar in 2007 and 2009, while fewer whales were counted during the same period in 2008, and the occupation of the lagoon was delayed by approximately one-week that year. The lower counts of gray whales residing within LSI during the 2008 winter season corresponded with lower than average water temperatures.

Counts of gray whales during any one year can be affected by physical factors such as sea temperature. For example, in 1999 and 2008 the sea temperature was unusually colder than normal, what is referred to as a "La Nina" event (Urbán *et al*., 1999). Urbán *et al*. (1999) documented a decrease in the number of gray whale cow-calf pairs visiting Laguna San Ignacio during the 1997-1998 El Nino and 1998-1999 La Nina events, along with increases in gray whale mortality, and a general shift in the winter distribution of gray whales to the northern areas during the warmer El Nino, and a shift to more southern areas during the cooler La Nina. During the first half of the 2008 winter the sea temperature in Laguna San Ignacio was 15º C and counts of gray whales were lower than expected compared to previous years. Gray whales were reported gathering in groups around the bays and points along the Baja California's Pacific coast, and they were seen migrating south around the southern tip of Baja California and into the Gulf of California as far north as Loreto (J. Urbán *pers com*). Presumably the whales were seeking the warmer water temperatures generally encountered in lower latitudes. By mid-February 2008 the sea temperature within LSI had increased to 19º C and counts of whales in the lagoon had also increased to numbers comparable with recent years (Swartz et al. 2008). Water temperature in the winters of 2007 and 2009 was 17-19 degrees °C during February and March, which was 2-3 degrees °C warmer than in the 2008 winter, and this could account for the greater number of whales seen in the lagoon these years.

The trends in water temperature within Laguna San Ignacio in 2009 were measured using autonomous recording devices placed on the bottom of the lagoon, and water temperatures reached a minimum of 15-16 degrees °C in mid February, and increased to between 19-20 degrees °C the first week in March (Fig.9). Monitoring of the number of gray whales that utilize Laguna San Ignacio and within other wintering gathering areas in Baja California indicate that water temperature can have an effect on the duration and lengths of their migration, and the aggregation areas the whales choose to use each winter.

There is no clear cause to explain the trend for fewer whales to utilize the upper lagoon zone and north end zones in recent years. During the 1980's this area was used extensively by females and their calves, and was commonly known as the nursery area (Jones and Swartz 1984). These whales only abandoned this zone following the departure of single courting whales during the last half of the winter season in mid-March and April each winter. Equally unexplained is the increase in the percent of whales utilizing the middle and lower zones of the lagoon. The lower zone is the area where whale-watching eco-tourism is permitted and whale-watching boats have operated exclusively in this zone since the mid-1990s. While it is well documented that gray whales are sensitive to some underwater noise created by human activities such as oil and gas exploration and development (Malme *et al*. 1984) and the playback of industrial and novel underwater noise in a breeding lagoon (Jones *et al* 1985). Apparently the number of whale-watching boats that have operated in the lower zone and the noise that they

produce has not caused the whales to avoid this area in recent years.

We conclude that the Eastern North Pacific gray whale population continues to respond and adapt to environmental changes throughout its range, and while fewer whales are utilizing LSI than in historical times, the timing and duration of the winter occupation of this breeding lagoon have remained relatively stable during the period 2007 to 2009. Comparison of similar information from other gray whale breeding areas would indicate whether the patterns of lagoon use in seen in LSI are representative of the population as a whole, or unique to this breeding lagoon.

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Figure 1. Laguna San Ignacio Study site.

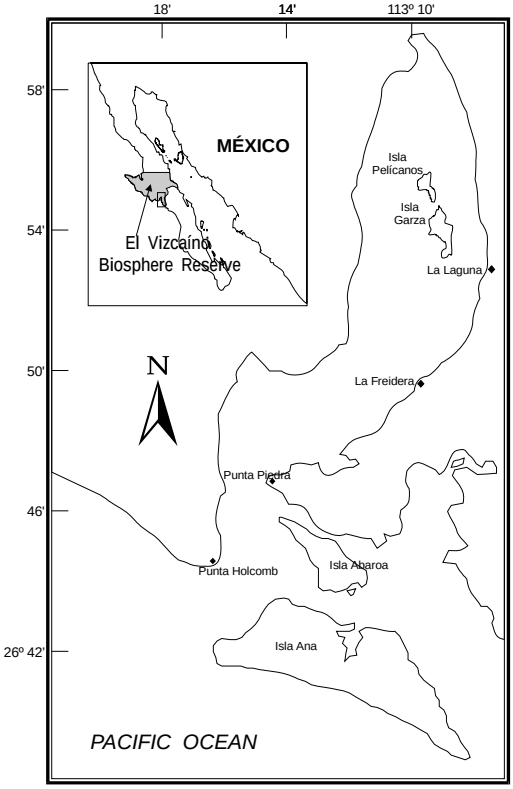
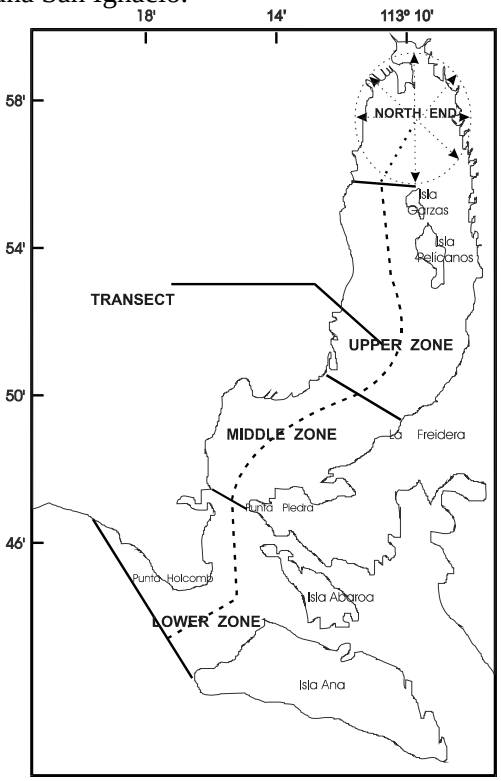


Figure 2. Boat survey transect for counting gray whales in Laguna San Ignacio.



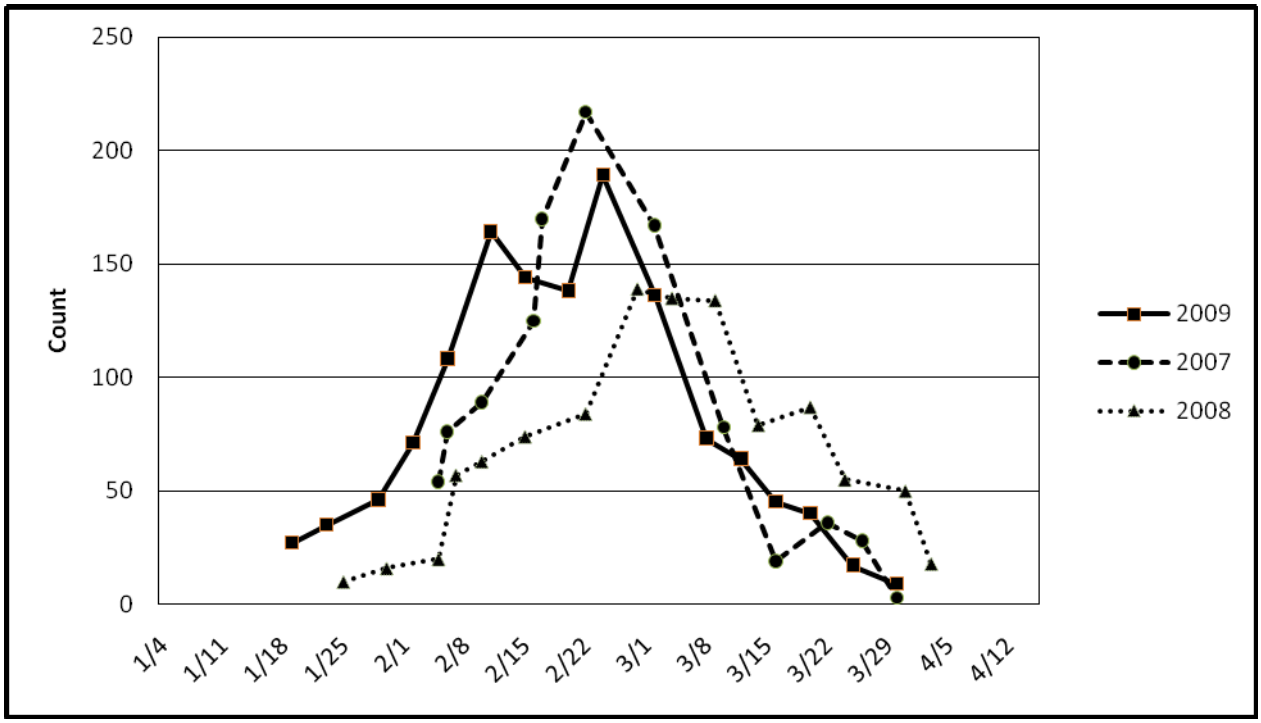


Figure 3. Number of adult whales counted during surveys conducted during 2007, 2008, and 2009.

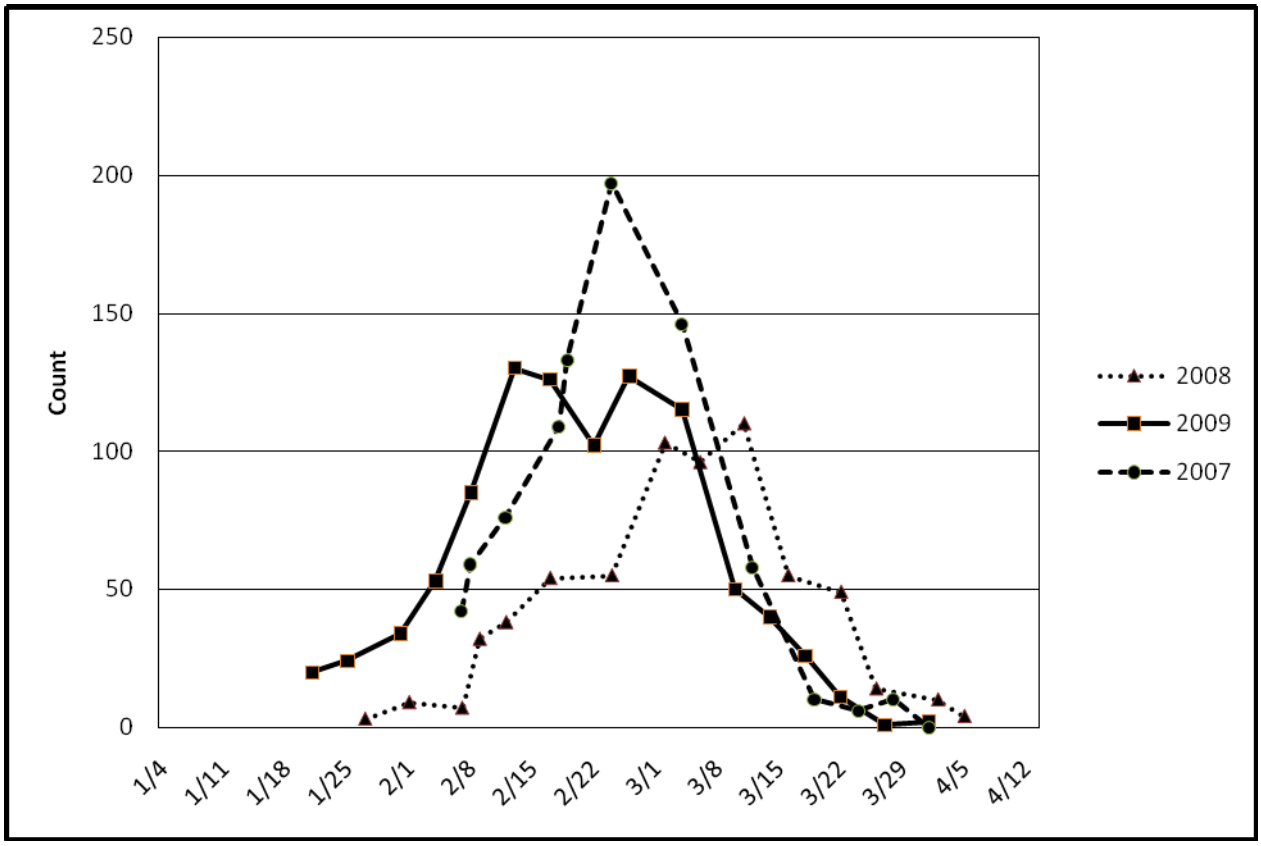


Figure 4. Number of single adult whales (except females with calves) counted during surveys conducted in 2007, 2008, and 2009.

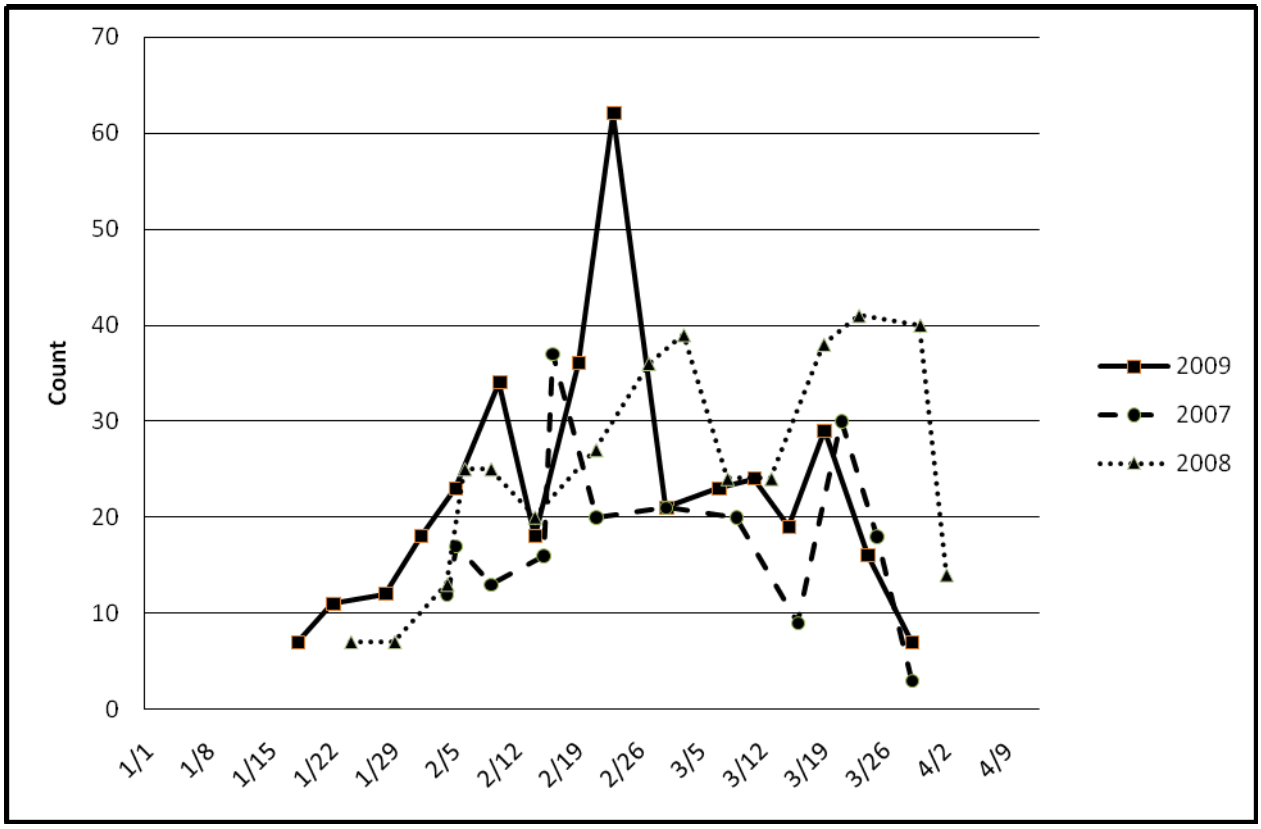


Figure 5. Number of female and calf pairs counted in surveys conducted in 2007, 2008 and 2009.

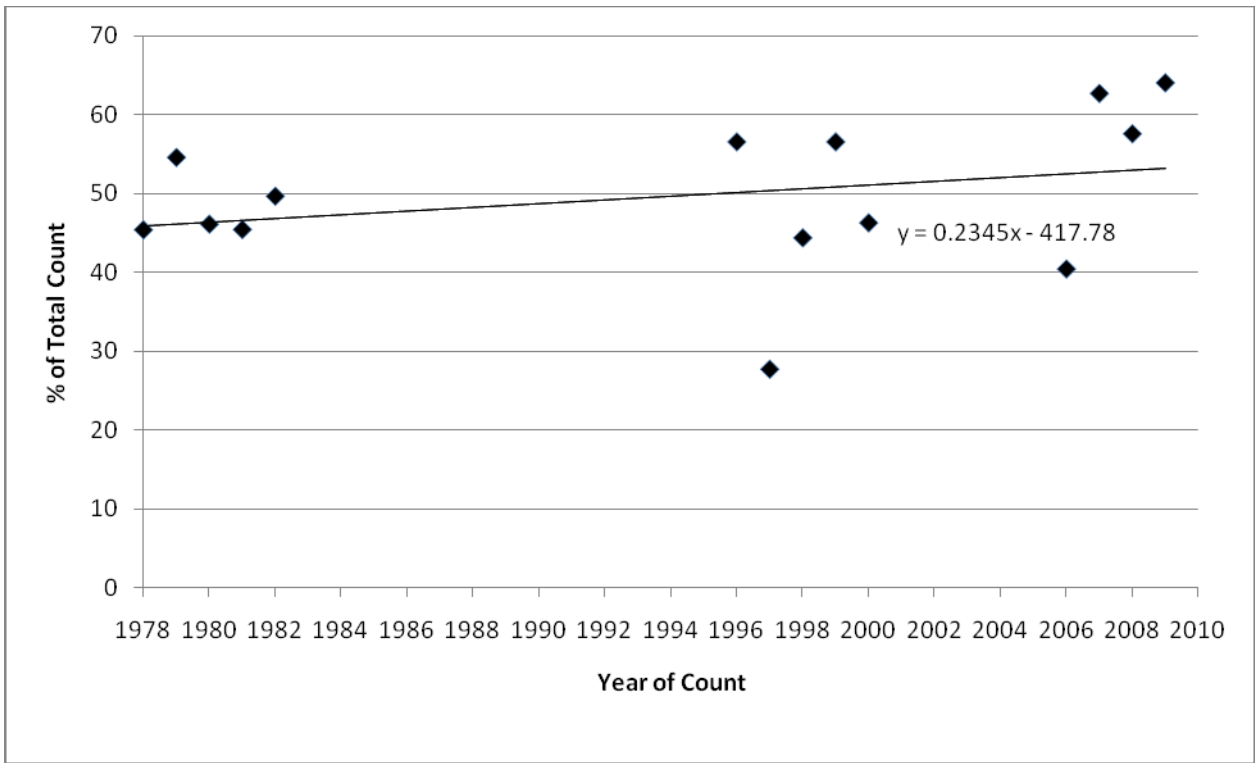


Figure 6. Percent of whales counted in the lower lagoon area during surveys conducted in 1978-1984, 1996-2000, and 2006-2009.

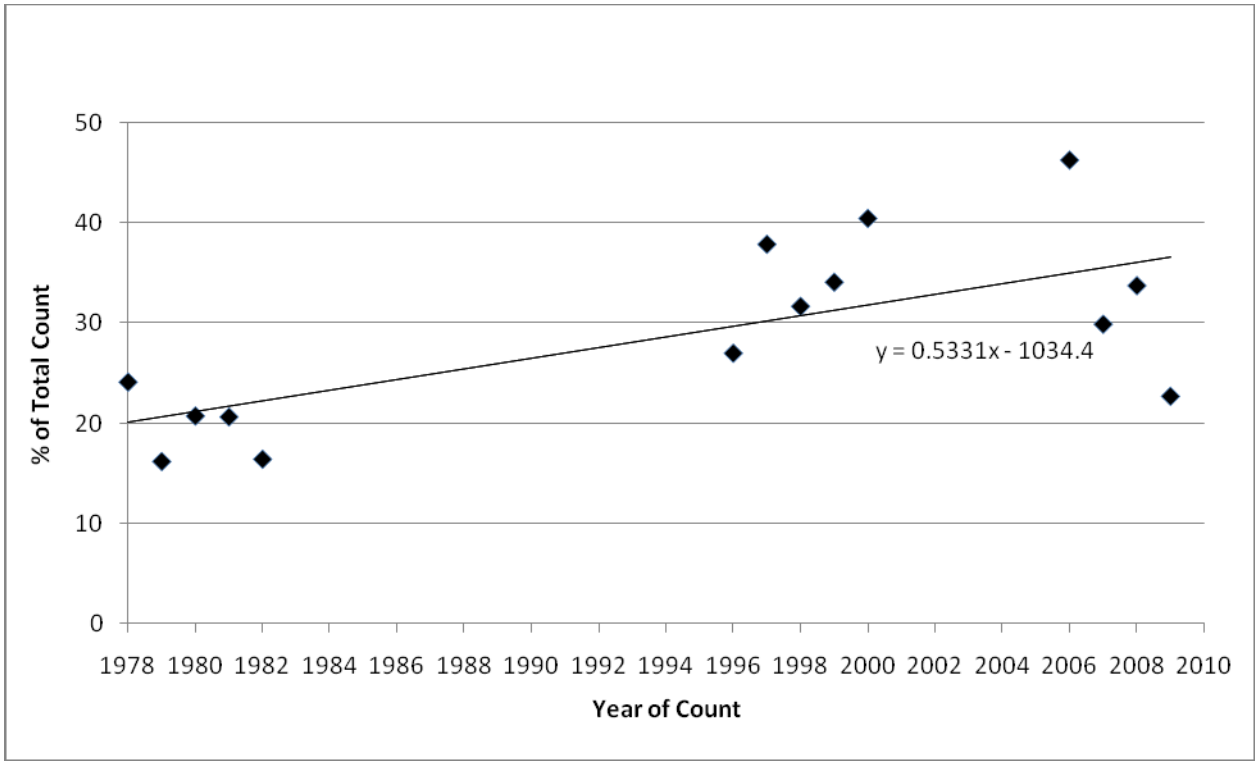


Figure 7. Percent of whales counted in the middle lagoon area during surveys conducted in 1978-1984, 1996-2000, and 2006-2009.

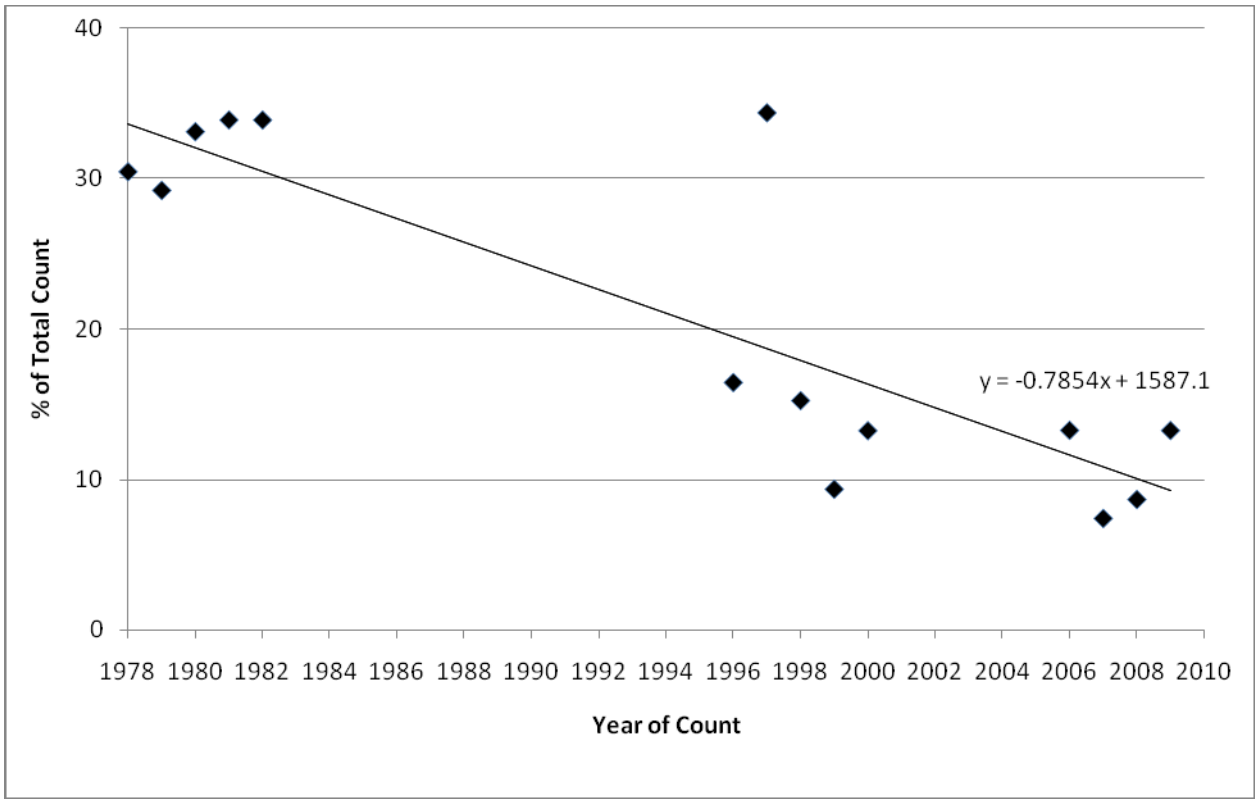


Figure 8. Percent of whales counted in the upper lagoon and north-end areas during surveys conducted in 1978-1984, 1996-2000, and 2006-2009.

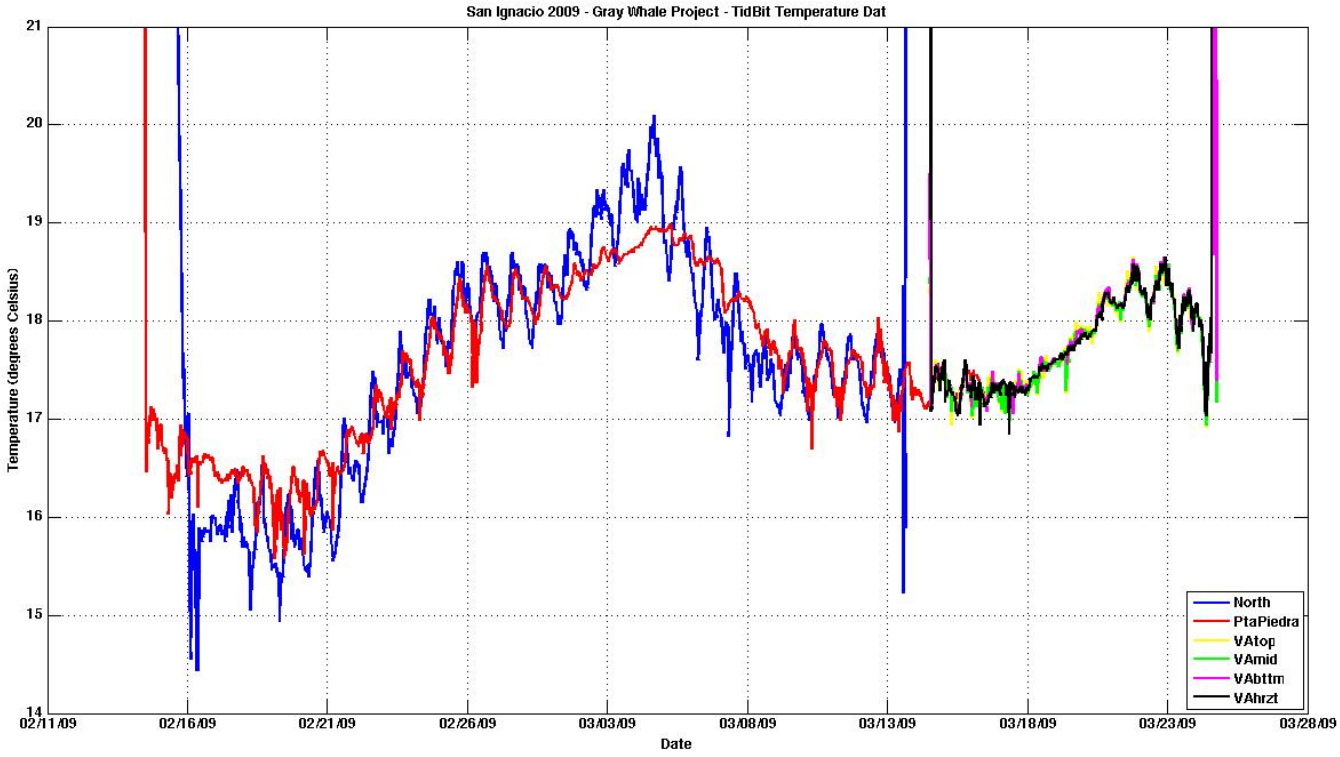


Figure 9. Water temperatures recorded in Laguna San Ignacio between 11 February and 28 March 2009.

Annex I. Survey counts of: Adult (non-calf) gray whales, Single (non-mother-calf pair) gray whales, and Female-Calf Pairs of gray whales in Laguna San Ignacio, B.C.S. from 2007 to 2009. Bold numbers are maximum counts during the season.

	Adult			Single			Female-Calf Pairs		
DAY	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**
19-Jan			27			20			7
20-Jan									
21-Jan									
22-Jan									
23-Jan			35			24			11
24-Jan									
25-Jan		10			3			7	
26-Jan									
27-Jan									
28-Jan									
29-Jan			46			34			12
30-Jan		16			9			7	
31-Jan									
1-Feb									
2-Feb			71			53			18
3-Feb									
4-Feb									
5-Feb	54	20		42	7		12	13	
6-Feb	76		108	59		85	17		23
7-Feb		57			32			25	
8-Feb									
9-Feb									
10-Feb	89	63		76	38		13	25	
11-Feb			164			130			34
12-Feb									
13-Feb									
14-Feb									
15-Feb		74	144		54	126		20	18
16-Feb	125			109			16		

	Adult			Single			Female-Calf Pairs		
DAY	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**
17-Feb	170			133			37		
18-Feb									
19-Feb									
20-Feb			138			102			36
21-Feb									
22-Feb	**217**	84		**197**	55		**20**	29	
23-Feb									
24-Feb			**189**			**127**			**62**
25-Feb									
26-Feb									
27-Feb									
28-Feb		**139**			**103**			**36**	
1-Mar									
2-Mar	167		136	146		115	21		21
3-Mar									
4-Mar		135	135		96			39	
5-Mar									
6-Mar									
7-Mar									
8-Mar			73			50			23
9-Mar		134			110			24	
10-Mar	78			58			20		
11-Mar									
12-Mar			64			40			24
13-Mar									
14-Mar		79			55			24	
15-Mar									
16-Mar	19		45			26			19
17-Mar				10			9		
18-Mar									
19-Mar									
20-Mar		87	40		49	11		38	29

	Adult			Single			Female-Calf Pairs		
DAY	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**
21-Mar									
22-Mar	36			6			30		
23-Mar									
24-Mar		55			14			41	
25-Mar			17			1			16
26-Mar	28			10			18		
27-Mar									
28-Mar									
29-Mar									
30-Mar	3		9	0		2	3		7
31-Mar		50			10			40	
1-Apr									
2-Apr									
3-Apr		18			4			14	