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B.C.S., México for 2022 breeding season.**

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Gray whale abundance in Laguna San Ignacio and Bahía Magdalena lagoon complex, B.C.S., México for 2022 breeding season.

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Abstract

The 2022 winter occupation of Laguna San Ignacio (LSI) and Bahía Magdalena (BM) by gray whales (*Eschrichtius robustus*) was characterized by low numbers of calves-of-the-year, an increased percentage (19.5 %) of whales in poor body condition, and an unexpected early departure of whales from both areas. In LSI the highest number of single adult whales counted in vessel surveys was 172 whales on 19 February, similar to high counts observed in previous winters. Compared to previous winters, counts of females with calves remained low throughout the 2022 winter season, with the highest count of 18 pairs observed on 9 March 2022. The highest BM counts were obtained on 9 February in the most southerly aggregation area of Bahía Almejas with 173 adult whales and no female-calf pairs observed. In central Bahía Magdalena, counts were greatest on 23 January with 42 adult whales and no calves. In the northern Canal de Santo Domingo, 36 single whales and two female-calf pairs were counted on 7 February.

Key words: gray whales, calves, skinny whales, low reproduction, carrying capacity, Unusual Mortality Event (UME) Laguna San Ignacio, Bahía Magdalena.

Introduction

The winter of 2022 was the fifth consecutive gray whale breeding season (2018-2022) in LSI and BM that was characterized by: 1) an unexpected early departure of approximately two-weeks from both breeding lagoon areas; 2) very low numbers of calves-of-the-year (Urbán *et al.* 2018, 2019, 2020, and 2021); 3) increased adult mortality in the lagoons (Martínez-Aguilar *et al.* 2020, 2021, and 2022), and 4) an increase in the percent of "skinny, poor condition" adult whales (Ronzón-Contreras *et al.* 2020, 2021; Valerio-Conchas, M., *et al.* 2022).

Low numbers of gray whale female-calf pairs observed in LSI and BM from 2018 to 2022 is similar to the decreased calf abundances observed during the winter breeding seasons from 2007 to 2010 following the previous range-wide "unusual mortality event" (UME) of 1999 to 2000 (LeBoeuf *et al.* 2000, Gulland *et al.* 2005). Low calf counts were observed in the breeding lagoons in 2018, 2019, 2020 and 2021 preceding the gray whale UME of 2019-2022 (NOAA 2022). To date a primary cause of the current gray whale UME has not been identified. It is likely that this event may have multiple contributors, including mortality linked to killer whale predation, fishing gear entanglements, vessel strikes, and poor body condition possibly associated with ecosystem changes in sub-Arctic and Arctic feeding areas (Moore *et al.* 2022).

Changing environmental conditions in the gray whales' northern feeding areas may be reducing the availability of food during the summer months, necessitating additional searching time to find food. While insufficient prey could contribute to the reduced reproduction and apparent decline in the body condition of some gray whales, disease and environmental stressors (*e.g.*, climate change) cannot be ruled out (Christiansen *et al.*, 2021).

Methods

Boat Surveys for Abundance Trend Estimation: Boat surveys are conducted to document seasonal trends in gray whale abundance and to estimate the minimum number of gray whales within the primary gray whale winter aggregation and breeding lagoons along the Pacific coast of Baja California the winter breeding season (Urbán *et al.* 2003, Fig. 1). Each survey utilizes a hand-held Global Position System (GPS) device to follow a predetermined survey track line that passes through the deep-water areas (*i.e.*, > 3-m deep) utilized by gray whales in each lagoon area. Observer and sighting protocols are specified for each lagoon's unique characteristics and are used to obtain and record whales' counts along each track line. This method allows duplication of survey effort to compare within-year survey counts along identical survey tracks in each lagoon area, and for comparison with historical counts from previous years (Jones and Swartz 1984, Urbán *et al.*, 2003).

By convention, "female-calf pairs" (*i.e.*, female whales with calves of the year) are counted as a single unit, and these pairs are equivalent to calf counts. "Single whales" refer to non-parturient females, adult males, and immature or juvenile animals. Counts of "adult whales" are the sum of all non-calf whales observed (*i.e.*, single whales and female-calf pairs).

Laguna San Ignacio: Boat surveys in LSI follow a 30-km long track line that begins at the north end of Isla Garzas in the northernmost end of the lagoon (North End Basin) to the west end of Isla Ana at Punta Holcombe at the lagoon entrance (Fig. 2). The survey track line is divided into five "zones" or segments to record the whales' distribution within the lagoon. Surveys require approximately three hours to complete. The maximum distance from the survey trackline to the 2-m depth contour along the shore is 2.5 km, and the minimum distance is 0.8 km; thus, water sufficiently deep to be inhabited by whales and both shorelines are visible to the observers at all points along the trackline. Whales in the "North End Basin" (north of the survey trackline) are counted from the center of this area by observers searching in 360-degrees around the stationary boat.

Bahía Magdalena: Boat surveys of gray whales in the BM lagoon complex duplicated surveys conducted in previous winters from 2016–2020. The surveys included three different areas where gray whales aggregate within the larger BM lagoon complex: Canal de Santo Domingo in the north from Boca la Soledad south to La Florida; in Bahía Magdalena's center, west and southwest areas; and in Bahía Almejas in the south from a point in the center of the bay south of Puerto el Dátil north to the north-east of Puerto Cortés on Isla Santa Margarita (Fig. 3).

Results

Laguna San Ignacio: In LSI, 10 surveys of gray whales were completed in 2020 to monitor the seasonal abundance and habitat use. Surveys began on 21 January and continued until 25 March (Table 1). The arrival of adult (non-calf) gray whales occurred in mid-January, and was similar to previous winters from 2018 to 2021. Departure times in 2022 were approximately two weeks earlier than in previous years. Maximum adult whale abundance count was 172 individuals on 19 February (Fig. 4).

The highest count of single adult whales (breeding males and females without calves) was 172 whales obtained on the 19 February survey (Fig. 5, Table 1). The numbers of these whales were similar to those observed in previous winters, with maximum counts ranging from 150 to 200 whales counted, but occurred approximately two weeks earlier than in previous winters.

Counts of females with calves remained low throughout the entire 2022 winter season (<10-pairs), with the highest number of 18 pairs counted on 10 March 2022; the end of the season increase of female-calf pair counts historically seen in LSI did not occur in 2021 or during the previous three winters (Fig. 6, Table 1). The number of female-calf pairs seen in recent years has been less than 50% of the abundance observed between 2011 to 2017 when female-calf pair counts in March ranged from 50 to 60 pairs to just under 130 pairs (Fig. 6).

Bahía Magdalena: The 2022 gray whale surveys in the BM lagoon complex were conducted in three different areas during three different periods: 21-23 January, 7-9 February, and 1-3 March (9-surveys in all) (Table 2). The highest counts of gray whales were obtained on 9 February in the most southerly aggregation area of Bahía Almejas with 173 adult whales and no female-calf pairs. In central Bahía Magdalena, counts were greatest on 23 January with 42 adult whales and no calves observed. In Canal de Santo Domingo, 36 single whales and 2-female-calf pairs were counted on 7 February. Gray whale abundance then declined in all areas of BM after the first week in March, and further surveys were discontinued due to the paucity of whales. In 2022, gray whales departed from the BM complex earlier than in previous winters, as was also observed in LSI in 2022 (Table 2).

As seen in previous winters, the 2022 distribution of gray whales was concentrated in the areas along the north-eastern shore of Isla Creciente, off of the south-eastern shore of Isla Santa Margarita in Bahía Almejas. Along the outer western coasts of Isla Margarita and from the pass between Isla Margarita and Punta Estrada to the north as far as Bahía Santa Maria. The northernmost concentrations of whales were observed in the Canal de Santo Domingo. Few gray whales remained in the BM lagoon complex by early March, so surveys were discontinued.

Discussion

Since January 2019 and continuing into 2022, an increase of dead gray whale strandings occurred along the west coast of North America from Mexico through Alaska, resulting in the declaration of an "Unusual Mortality Event" (UME) for gray whales (Fauquier *et al.*, 2022; NOAA 2022).

Observations of gray whales in LSI and BM detected an impending UME as early as 2018, 2019,

2020, 2021 and again in 2022. Specifically, long-term abundance monitoring (17-years) in these gray whale winter aggregation areas and photographic-identification data confirmed significant declines in winter calf counts, increasing percentages of "skinny" and "emaciated" whales (Ronzón-Contreras *et al.* 2020, 2021; Valerio-Conchas, M., *et al.* 2022), the late arrival of the whales each winter, and the early departure of whales in 2022.

The number of mother-calf pairs in LSI was less than 10-pairs during the entire winter, except during mid-march when numbers increased to 17-18 pairs. This late season increase did not suggest additional births of calves, rather, these calves were judged from their size and color to be calves born earlier in the season. Jones and Swartz (1984) previously documented the late-season increase in calf counts in March and April that appeared from photographic identification data to be females with calves entering LSI from other aggregation areas.

The counts of females with calves observed in BM was only 5-pairs in all of the 9-surveys conducted in 2022, and the departure in 2022 of the whales in both lagoons was one to two weeks earlier than expected compared to departure times in previous winters. The decrease in annual calf production suggests that the whales are suffering from nutrition stress (e.g., lack of prey/food), environmental stress (e.g., climate and oceanographic change), and possible disease in the population.

Similar low calf counts were observed from 2007-2010 following the 1998-2000 range wide UME when an estimated 33% of the NE. Pacific population was lost (LeBoeuf *et al.* 2000, Gulland *et al.* 2005). In the winters following 2011, the numbers of female-calf pairs observed in LSI have increased following the low female-calf counts in the years immediately following the mortality event, suggesting that there has been a continuing recovery of breeding female gray whales (Urbán *et al.* 2011, 2015, 2016, 2017). However, while the counts of females and calves observed in LSI and BM from 2018 to 2022 were low, these few mothers and calves appeared to be in good to fair condition. Indications of nutritional stress or poor condition of these breeding female gray whales and their calves were not evident (Valerio-Conchas *et al.* 2022).

Several factors may have contributed to the low counts of female-calf pairs of gray whales observed in LSI and BM from 2018 to 2022. The timing and length of the gray whale migration along the Pacific coast of Baja California, the permanency of the whales in Mexican waters during the winter, and their abundance in the primary aggregation areas and breeding lagoons, are influenced by several factors, including Sea Surface Temperature (SST) (Salvadeo *et al.* 2015; Urbán *et al.* 1999). In cold winters, such as during La Niña conditions, fewer whales utilize the northern lagoon and aggregation areas along the Baja California coast, and more whales migrate further south presumably to find warmer water temperatures. Climate change driven oceanic factors may have altered the distribution of the whales' sub-Arctic and Arctic primary feeding areas causing the whales to travel further and longer to search for suitable food during the summer months (Moore *et al.* 2022).

The reduction in the number of calves-of-the-year could result from a reduction in the food-prey available to the whales in their summer feeding areas and that has reduced the "carrying capacity" (K) of the environment to support the whale population (Moore *et al.* 2001, Laake *et al.* 2009; Punt and Wade 2010). It is also possible that disease or other factors have compromised the whales' ability to maintain sufficient energy reserves to

support both reproduction and their annual migrations from the summer feeding grounds to their winter breeding aggregation areas along Baja California's Pacific coast and its coastal lagoons.

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Tables and figures

Table 1. Boat survey counts of gray whales: Female-calf pairs, Singles (whales without calves), and total Adults in Laguna San Ignacio during the 2022 winter breeding and calving season. Number of female-calf pairs equals the number of calves observed.

Survey	Date	Female-calf Pairs	Singles	Total Adults
1	19-Jan-22	3	9	12
2	26-Jan-22	3	34	37
3	01Feb-22	7	167	174
4	06-Feb-22	6	123	129
5	11-Feb-22	9	111	120
6	19-Feb-22	4	172	176
7	1-Mar-22	4	76	80
8	10-Mar-22	18	40	58
9	17-Mar-22	17	24	41
10	25-Mar-22	9	2	11

Table 2. Boat survey counts of gray whales (Female-calf pairs, Singles (whales without calves), and total Adults) in three areas within the Bahía Magdalena complex during the 2022 winter breeding and calving season. Number of female-calf pairs equals the number of calves observed.

LOCATION	DATE	FEMALE-CALF PAIRS	SINGLE WHALES	TOTAL ADULTS
Bahía Almejas	22-Jan	0	146	146
	09-Feb	0	173	173
	02-Mar	1	23	24
Bahía Magdalena	23-Jan	0	42	42
	08-Feb	1	38	39
	01-Mar	0	9	9
Canal de Santo Domingo	21-Jan	1	22	23
	07-Feb	2	36	38
	03-Mar	0	0	0

Figure 1. Primary gray whale winter aggregation areas and lagoons along the Pacific coast of Baja California, Mexico: Ojo de Liebre (Scammon's Lagoon); Laguna San Ignacio; and the Bahía Magdalena complex.

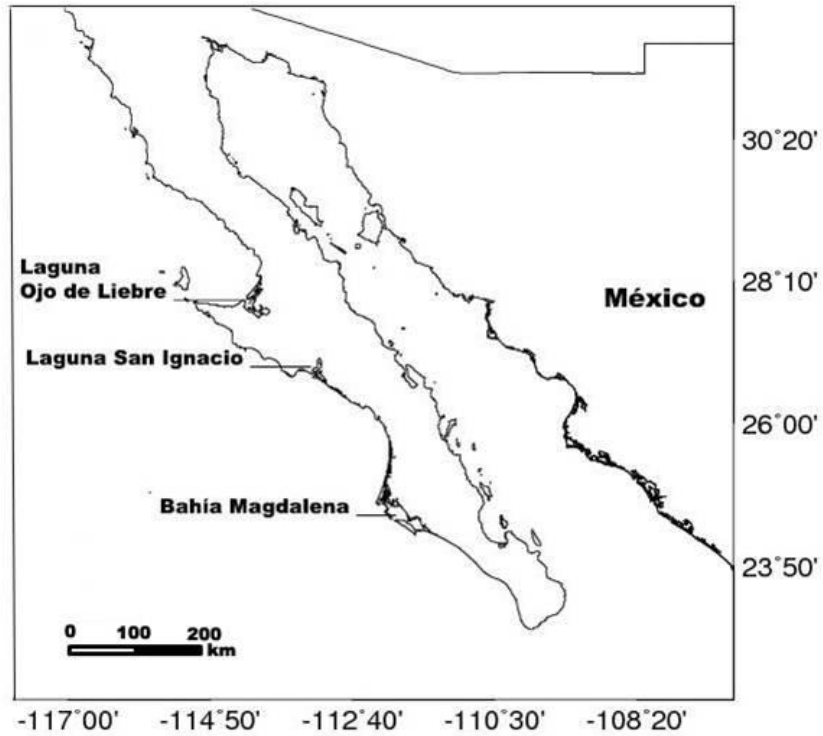


Figure 2. Boat survey track-line for estimating minimum abundance of gray whales in Laguna San Ignacio. Counts of gray whales in the “North End Basin” portion of the lagoon are obtained from a 360° scan of the area. The survey track line continues 30 km south from Isla Garzas (Zone 1) over the deepest portions of the lagoon to Punta Holcombe on the west end of Isla Ana at the entrance of the lagoon (Zone 5).

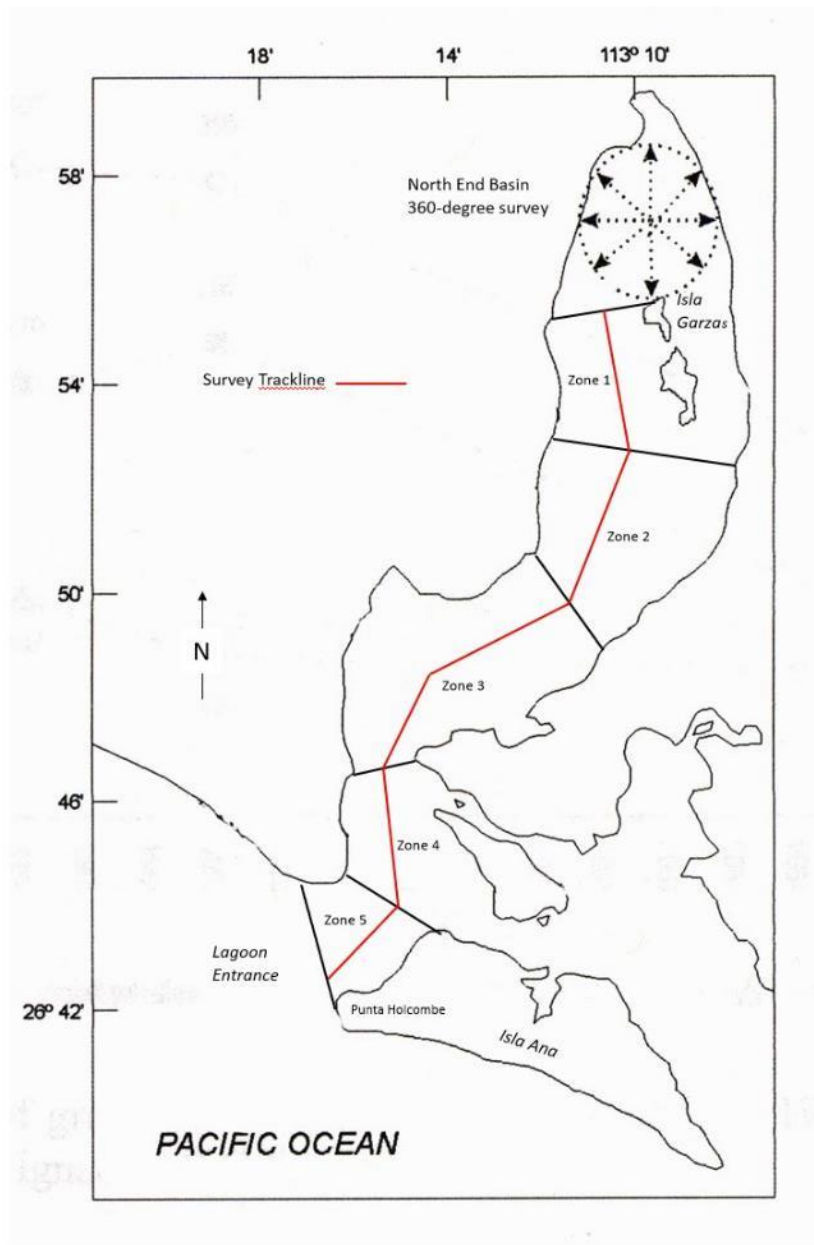


Figure 3. Boat survey track-lines for estimating gray whale abundance in the Bahía Magdalena lagoon complex in three areas where gray whales aggregate: Canal de Santo Domingo in the north; Bahía Magdalena's center, west and southwest areas; and in Bahía Almejas in the south.

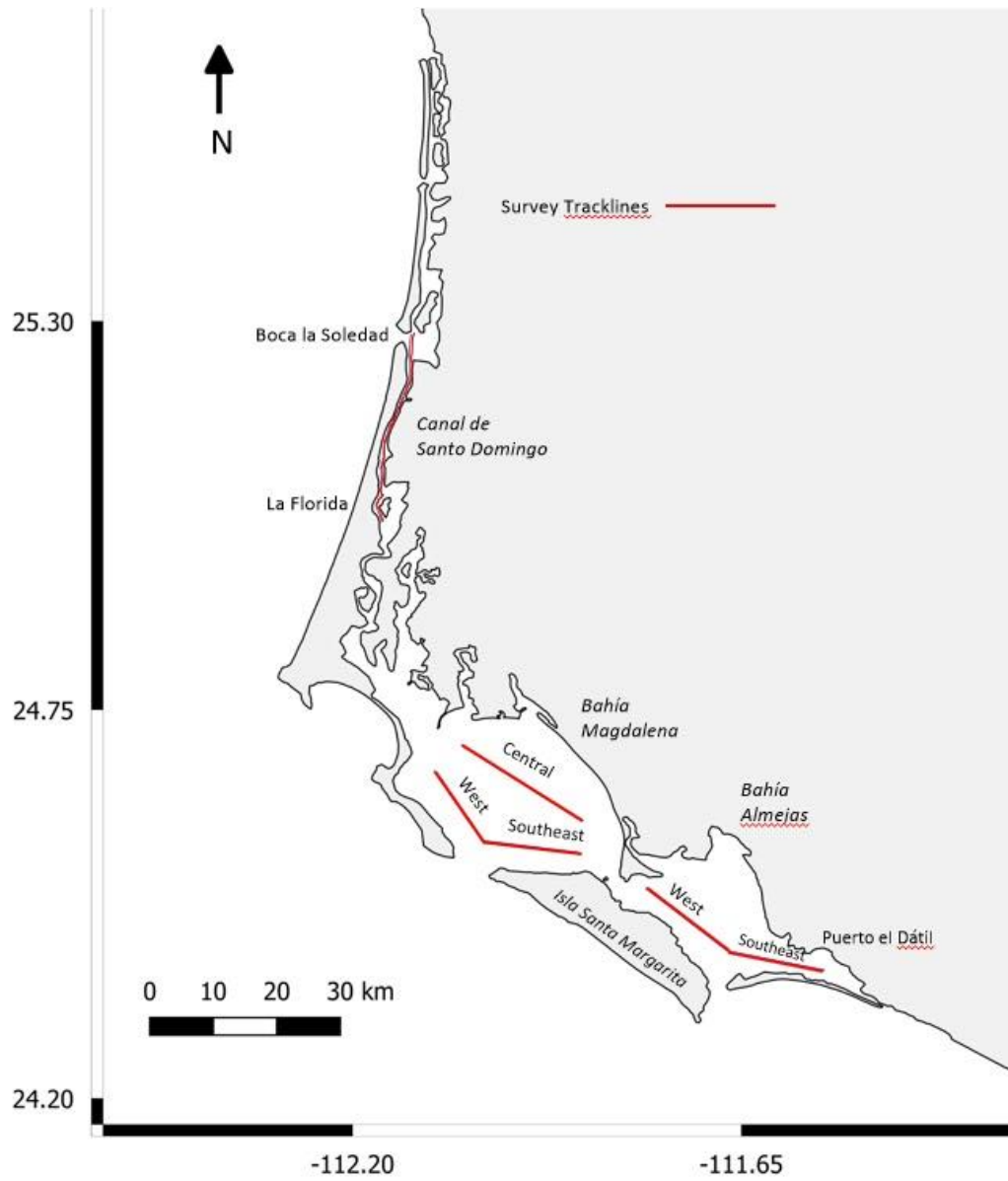


Figure. 4. Numbers of total adult whales (Adult males, females, and females with calves) counted in Laguna San Ignacio during the winter seasons: 2015-2022.

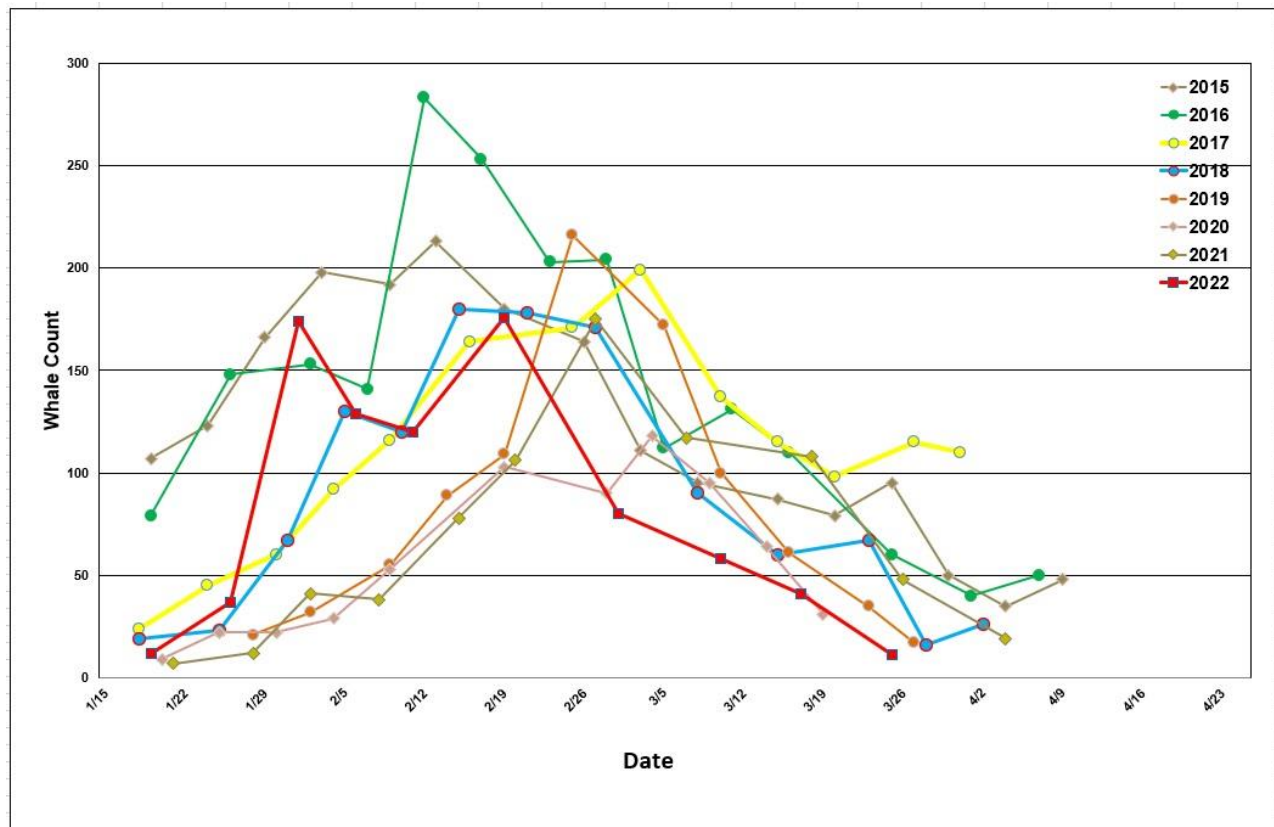


Figure. 5. Numbers of single whales (adult males and females without calves) counted in Laguna San Ignacio during the winter seasons: 2015-2022.

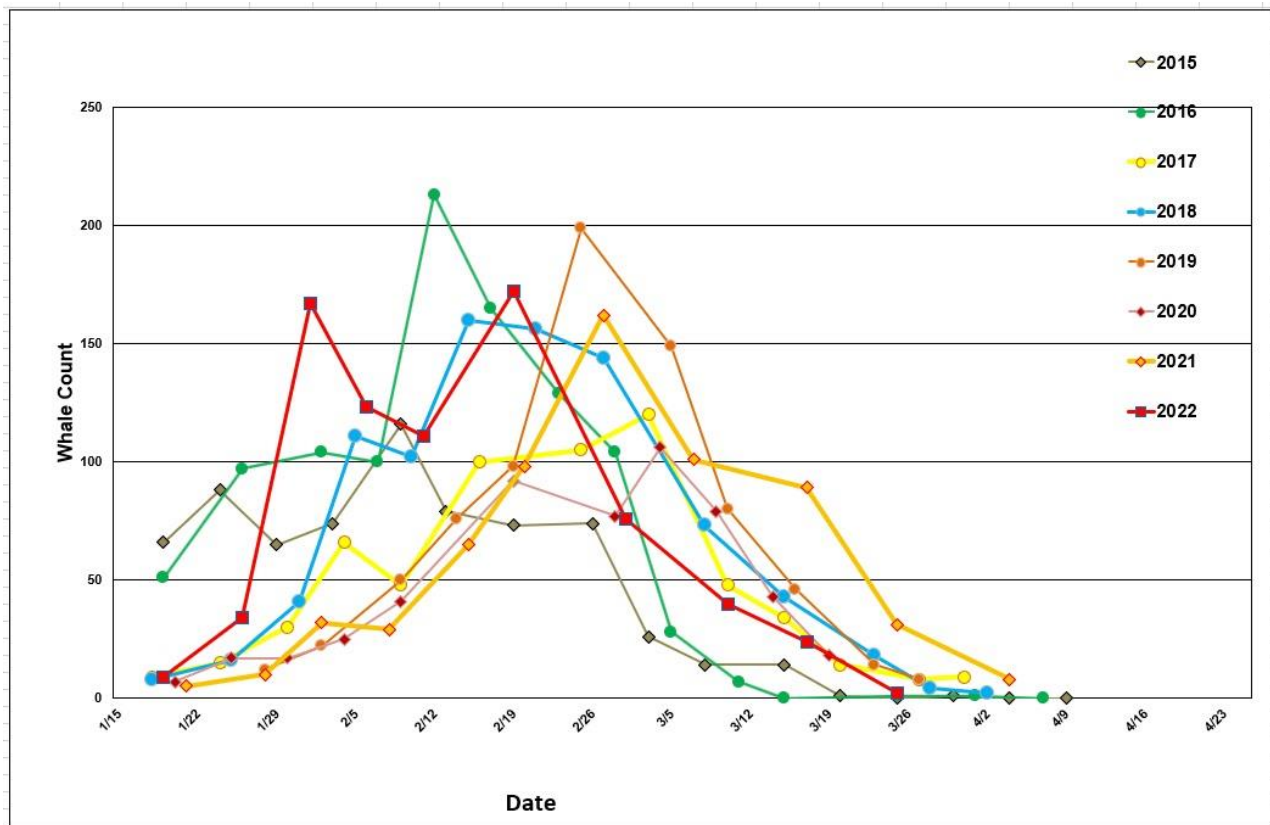


Figure. 6. Numbers of female-calf pairs (females with young of the year) counted in Laguna San Ignacio during the winter seasons: 2015-2022.

