Laguna San Ignacio
Ecosystem Science Program
A Project of the Ocean Foundation in Baja California Sur, Mexico

www.sanignaciograywhales.org

2019 RESEARCH REPORT FOR LAGUNA SAN IGNACIO & BAHÍA MAGDALENA, BAJA CALIFORNIA SUR, MÉXICO

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Summary of Primary Research Activities in 2019

In 2019 the arrival of the gray whales (*Eschrichtius robustus*) to Laguna San Ignacio and Bahía Magdalena in Baja California Sur, Mexico was approximately two weeks late, and our colleagues monitoring the southward winter migration along the west coast of North America also reported a fewer number of southbound whales passing Los Angeles and Monterey early in the season. The numbers of mother-calf pairs arriving at the lagoons in January was very low and remained low all winter in both lagoon areas. This was the second consecutive winter that we documented reduced numbers of mother-calf pairs (i.e., low calf counts also occurred in 2018). This year, the number of mother-calf pairs in Laguna San Ignacio hovered around 20-pairs, and never exceeded 8-pairs in Bahía Magdalena. Now, reports are coming in of unexpected numbers of dead gray whales washing ashore along their North American migratory route to the summer feeding areas.

The arrival of the single whales in both lagoon areas was also two weeks later than expected, and the percent of "skinny" single whales jumped from 4.9%-7.6% during the years 2008-2011, to 23.6% skinny in 2019. These low calf counts are similar to the reduction in calves observed during the years 2007-2010, which followed the 1999-2000 range-wide mortality event when an estimated 1/3 of the North Eastern Pacific gray whale population was lost. These observations suggest that in recent years the gray whales are not obtaining sufficient nutrition during their summer feeding in the Arctic and North Pacific, and/or they may be suffering from the effects of some combination of environmental factors including disease.

So why is this happening? Perhaps the current "carrying capacity" in the gray whales' feeding areas has been reduced during the past decade. Oceanographers are describing conditions of warmer-than-normal sea temperatures in the North Pacific/Gulf of Alaska and along the west coast of North America that have persisted from 2015-present (AKA the "N. Pacific Blob"). Apparently this temperature anomaly is disrupting the normal seasonal cycle of primary production during the spring and summer months in the high latitudes where the gray whales, and other marine life feed (i,e, marine birds, fish and other marine mammals). This seasonal upwelling of deep nutrient rich sea water mixing with freshwater ice-melt from the Arctic, combined with increasing amounts of daylight as the days lengthen, normally drives the phytoplankton blooms that are the foundation of the marine food web for many marine species (including whales). Gray whales depend on the seasonal abundance of prey (e.g., benthic amphipods) to obtain sufficient energy to survive their winter/spring migrations to and from their winter breeding and calving areas, and the production and growth of their calves. Skinny gray whales and low calf production suggest that finding sufficient food over the summer is becoming a problem for the gray whales.

This summer and fall, LSIESP researchers will continue consultations with colleagues studying gray whales throughout their range to try to assess and better understand climate factors and other conditions that contributed to the 2nd year of unexpected low numbers of female-calf pairs, the increase in "skinny" whales, and the late arrival of all whales to Laguna San Ignacio and Bahía Magdalena in 2019. At this time, everyone hopes this is a cycle in the N. Pacific and, Arctic, and not a preview of the "new normal."

Additional research and achievements in 2019 of our LSIESP team include:

- Using photographic-identification methods in Laguna San Ignacio, we updated the "minimum age" estimate for gray whales to 48-50-years; documented site fidelity and calculated average duration of stay (single whales 6.4-days & females with calves 31.7-days), and revised the current calving interval to 2.39-years.

- Examined and obtained measurements and photographs of one sea-lion (*Zalophus californianus*) and 4-dead stranded whales in Laguna San Ignacio, and two-dead stranded gray whales in Bahia Magdalena.

- Used UAV-Drones with HD-Video cameras and underwater recording hydrophones to continue the collection of simultaneous behavior observations and real-time recordings of whale vocalizations to understand the development and significance of specific calls.

- Utilized UAV-DRONES with HD-Video cameras to measure female gray whale size reduction and calf growth during the winter, to evaluate maternal reproductive condition and calf growth, and document the frequency and condition of "skinny" whales in Laguna San Ignacio.

- Successfully removed 9-derelict fishing lines, floats, and lobster-fish traps from the lagoons, and the LSIESP team successfully disentangled 6- gray whales over past 5-years, saving their lives.

- Published the 1st Bottlenose dolphin (*Tursiops truncatus*) dorsal fin catalog for Baja California, and facilitated collaboration with dolphin researchers in California U.S.A. to evaluate the size and status of local dolphin populations in Baja California.

- Hosted and convened the 10th Annual “Community Reunion” mini-science symposium at the Kuyimita Campground, presented lectures to 18 visiting eco-tour groups, provided interviews with several media groups, and hosted two university undergraduate student groups studying marine science.

- Launched the LSIESP "Instagram" site (@lsigraywhales) to expand our program's outreach in the social media.

Leadership and Research Staff

Laguna San Ignacio 2018 gray whale research team.

The 2019 research teams for the Laguna San Ignacio Ecosystem Science Program (LSIESP) and the Programa de Investigación de Mamíferos Marinos (PRIMMA) at the Universidad Autónoma de Baja California Sur, La Paz, B.C.S. (UABCS), México were directed by Drs. Jorge Urbán R., Steven Swartz, Alejandro Gómez-Gallardo U., Sergio Martínez Aguilar (Laguna San Ignacio), and Lorena Viloria Gómora (Bahía Magdalena). Gray whale field researchers included: at Laguna San Ignacio, Floryser Ronzón Contreras, Paulette Durazo, Romaina Preciado Pérez, Vinnie Calcero-Garcia, and Gara Goni Goday; and in Bahía Magdalena, Mariana Hidalgo Reza, Andrés González Cisneros, Natalia Okpisz, and María Lura Marcías. Our UAV-Drone pilots were Fabián Missael Rodríguez González and Hunter Alan Warick.

Additional collaborating researchers included:

The acoustics and behavior observation research team led by Dr. Aaron Thode, Ludovic Tenorio-Hallé from Scripps Institute of Oceanography, La Jolla, California, Héloïse Frouin-Mouy (JASCO Applied Sciences), and Regina Lobo Barrera (UABCS).

Dr. Fredrik Christiansen and Hunter Alan Warick of Murdoch University, Murdoch, Western Australia, and Fabian Missael Rodríguez González (UABCS) conducted the Unmanned Aerial Vehicles (UAV-Drones) aerial photogrammetry project to measure growth and body volume of female and calf whales to estimate body condition and reproductive health, and energy conversion/transfer from females to calves.

This 2019 research was supported by grants from The Ocean Foundation, The Whaleman Foundation, Natural Habitat Adventures, and private individual donners, with in-kind support for logistics provided by Searcher Natural History Expeditions, Baja Discovery, and Kuyima Eco-Turismo, Inc. Field research was conducted under Scientific Research permit No. SGPA/DGVS/013210/18 issued by the Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT), Subsecretaría de Gestión Para La Protección Ambiental, Dirección General De Vida Silvestre, de México.

Gray Whale Abundance Monitoring

Each winter boat (panga) surveys are used to monitor of gray whale abundance, distribution and reproduction in Laguna San Ignacio and Bahía Magdalena. LSIESP's boat survey program represents the longest continuous time series of quantitative habitat use information for any cetacean population (1977 to the present). These surveys form the basis to document and evaluate trends in the whales' use of, and the management of these marine protected areas.

Laguna San Ignacio: Boat surveys in Laguna San Ignacio were conducted from a 7-m long open "panga" powered by a 75-hp outboard motor. Each survey followed a 30-km long predetermined Global Position System (GPS) track-line at a constant speed of 11-km/hr, and required approximately 3-hrs to complete. Whales were counted in the northernmost portion of Laguna San Ignacio from the anchored panga with observers scanning the area with binoulars in 360° for 20-min. (Fig. 1). The survey through the "upper", "middle" and "lower" portions of the lagoon were divided into five segments or "zones." During each survey two pairs of observers (a primary and a secondary observer) scanned the water on each side of the panga and noted the whales when they passed the beam of the panga. A third individual recorded for each sighting: the "zone," the time, number of whales, whether they were singles or female-calf pairs, and ambient weather and visibility conditions. Also noted were other marine mammals (e.g., dolphins & sealions), sea turtles, and boats (i.e., fishing and eco-tourist).

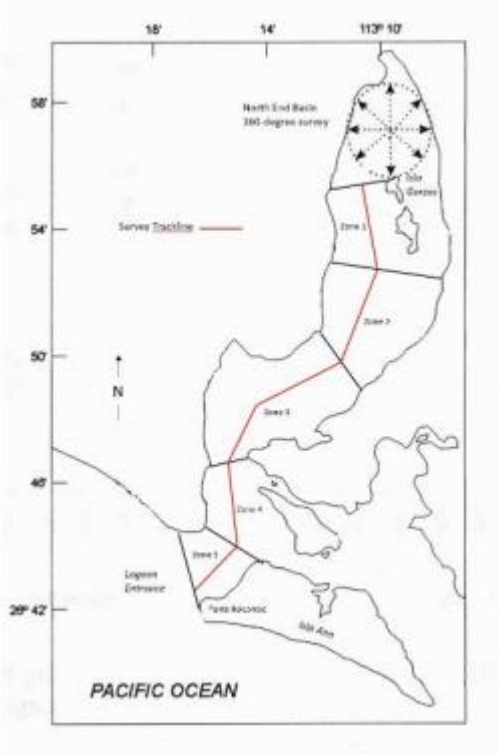

Figure 1. Gray whale boat/panga survey track-line in Laguna San Ignacio.

The highest count of single adult whales (breeding males and females without calves) was 199 whales obtained on the 25 February survey (Fig. 2, Table 1), which was greater but occurred later in the season than the 160 single whales seen in the lagoon on 15 February 2018, and greater than the 120 single whales observed on 3 March 2017. These whale counts suggest a trend for an increasing number of single adult whales over the past three winters.

Table 1. Boat survey counts of gray whales (Female-calf pairs, Singles (whales without calves), and total Adults) in Laguna San Ignacio during the 2019 winter breeding and calving season. Number of female-calf pairs equals the number of calves observed.

Abundance Survey Counts in Laguna San Ignacio in 2019				
# Survey	Date	Female-Calf Pairs	Single Whales	Total Adults
1	28-Jan-19	9	12	21
2	02-Feb-19	10	22	32
3	09-Feb-19	5	50	55
4	14-Feb-19	13	76	89
5	19-Feb-19	11	98	109
6	25-Feb-19	17	199	216
7	05-Mar-19	23	149	172
8	10-Mar-19	20	80	100
9	16-Mar-19	15	46	61
10	23-Mar-19	21	14	35
11	27-Mar-19	9	8	17

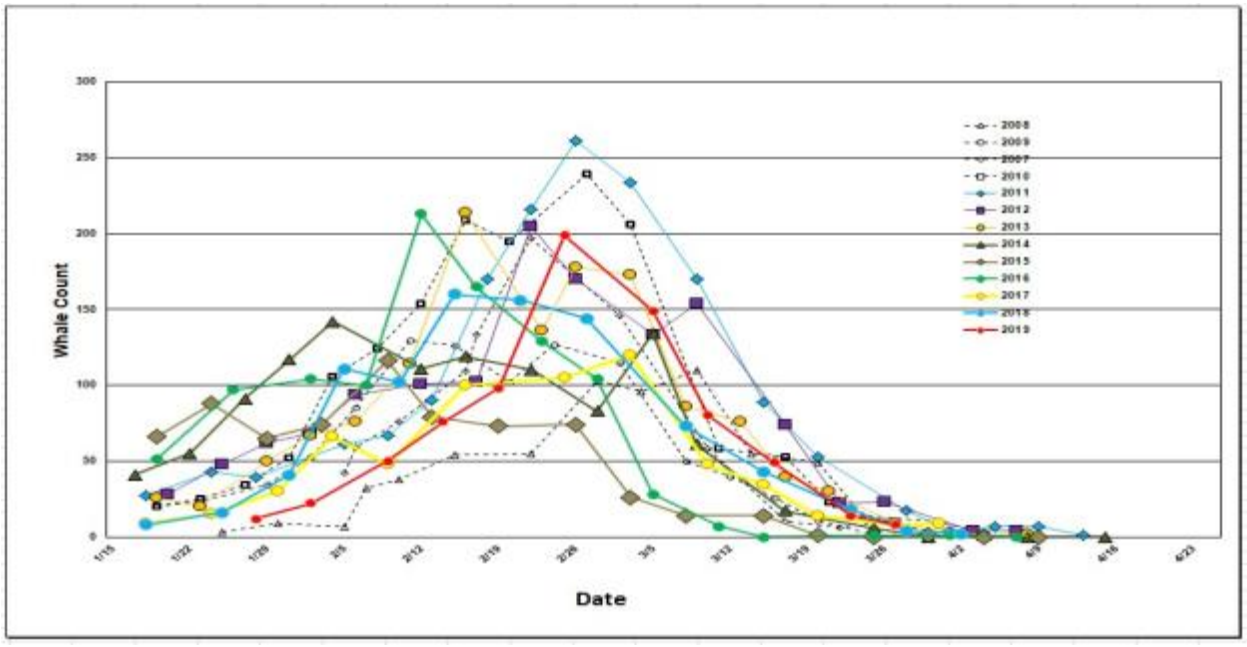

Figure 2. Survey counts of single adult gray whales (non- female-calf pairs) in Laguna San Ignacio 2007-2019.

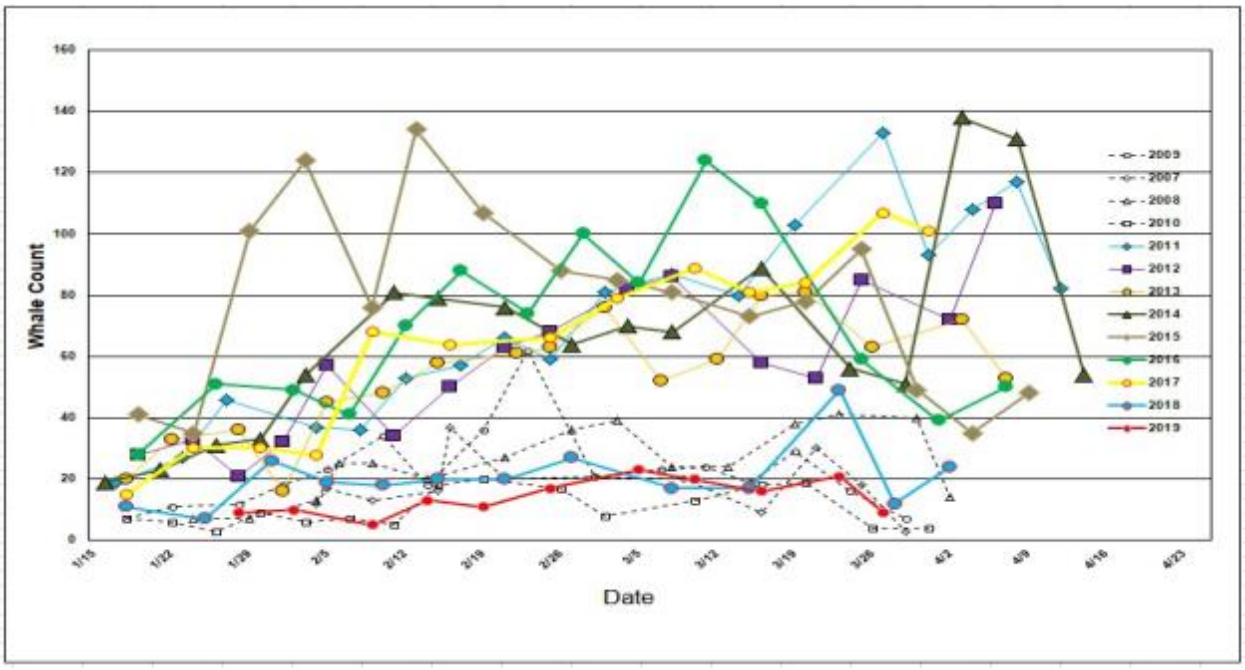

Figure 3. Survey counts of gray whale female-calf pairs in Laguna San Ignacio 2007-2019.

The arrival of adult (non-calf) gray whales occurred in the first week of February, approximately two weeks later than observed during the previous 8 winters, while their departure from the

lagoon was similar to previous years; thus their seasonal occupation of the lagoon by adult whales was later and shorter than seen in the previous years from 2011 to 2018.

Counts of females with calves in LSI remained low throughout the entire 2019 winter season, with the greatest number of calves counted of 23 on 5 March 2019; the typical end of the season increase of female-calf pair counts typically seen in LSI did not occur in 2019, or in the previous winter Fig. 3, Table 1). In 2018, the highest count of females with calves of 49 pairs occurred late in the season on 23 March. The number of female-calf pairs seen in 2019 was far less than that observed between 2011 to 2017, when female-calf counts in March ranged from 50 to 60 pairs to just under 130 pairs (Fig. 3). Female-calf pair counts in 2019 and 2018 were similar to those observed during the winter breeding seasons from 2007 to 2010 following the range wide "mortality event" in the late 1990's (LeBoeuf et al. 2000). Overall, the low number of female-calf pairs observed in 2019 was unexpected, as was their departure in early April.

Bahía Magdalena: The 2019 boat surveys of gray whales in the Bahía Magdalena lagoon complex were conducted in three different areas during four different time periods: 25-27 January, 9-12 February, 25-27 February, and from 6-8 March (12-surveys total) (Fig. 4, Table 2). The highest counts of gray whales were obtained in February in the most southerly aggregation area of Bahía Almejas; 144 adult whales, but only one female-calf pair, when in central Bahía Magdalena counts were 46 adult whales and no calves, and in Canal de Santo Domingo 58 single whales and 7 female-calf pairs were counted.

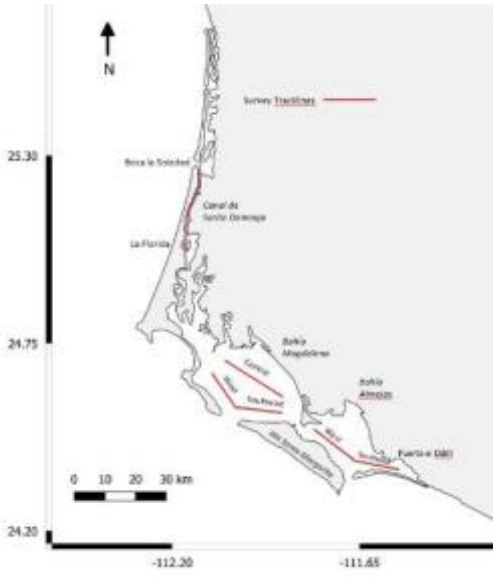

Figure 4. Gray whale abundance survey tracks in the Bahia Magdalena complex: Canal de Santo Domingo in the north, central Bahía Magdalena, and Bahía Almejas in the south.

Gray whale abundance then declined in all areas and by early March: 70 single adults and 3 female-calf pairs were counted in Bahía Almejas; 30 single whales and 2 female-calf pairs in central Bahía Magdalena; and 17 single whale and 3 female-calf pairs in Canal de Santo Domingo (Table 2, Fig. 5).

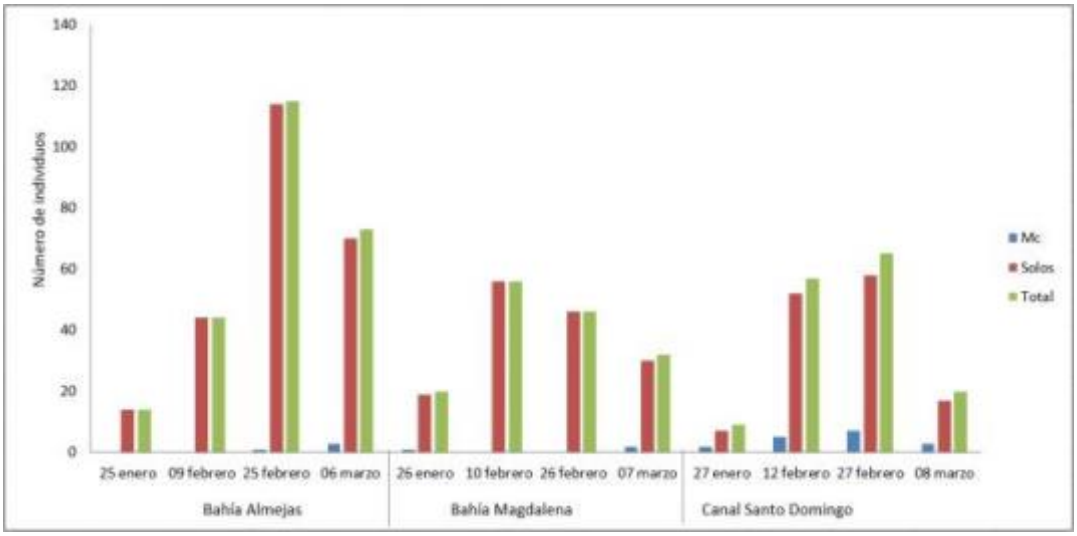

Figure 5. Boat survey counts of gray whales in three areas within the Bahía Magdalena complex during the 2019 winter breeding and calving season. Number of female-calf pairs equals the number of calves observed.

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 2019 winter breeding and calving season. Number of female-calf pairs equals the number of calves observed.

	Area	Date	Female-Calf Pairs	Singles	Total Adults
2019	Bahía Almejas	25-Jan-19	0	14	14
		9-Feb-19	0	44	44
		25-Feb-19	1	114	115
		6-Mar-19	3	70	73
	Bahía Magdalena	26-Jan-19	1	19	20
		10-Feb-19	0	56	56
		26-Feb-19	0	46	46
		7-Mar-19	2	30	32
	Canal de Santo Domingo	27-Jan-19	2	7	9
		12-Feb-19	5	52	57
		27-Feb-19	7	58	65
		8-Mar-198	3	17	20

The 2019 distribution of gray whales was concentrated in the area along the north shore of Isla Creciente and off of the eastern shore Isla Santa Margarita in Bahía Almejas, the most southern of the gray whale aggregation areas in the BM complex (Fig. 6). This distribution pattern was also seen during the 2017 winter, but not the 2016 or 2018 winters when fewer gray whales aggregated in this area. As was observed in LSI, few gray whales remained in the BM complex by mid-March 2019, so abundance surveys were discontinued.

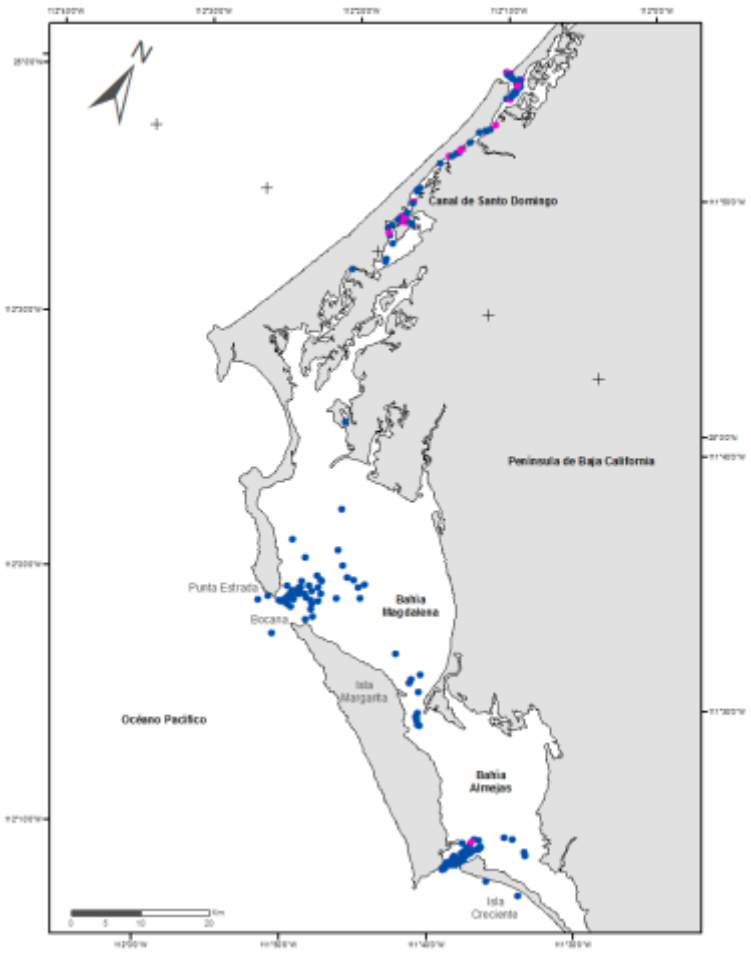

Figure 6. Gray whale sightings in the Bahía Magdalena lagoon complex and surrounded waters in the 2019 winter: Bahía Almejas (BA), Bahía Magdalena (BM) and Lopez Mateos (LM). blue circles = gray whale single animals; red circles = gray whale female-calf pairs.

Read the entire 2019 gray whale abundance report to the International Whaling Commission on our website – IWC-SC 68A/CMP/12: visit

www.sanignaciograywhales.org/research/publications

Photo-Identification, Photo Archiving and Research

Digital photography allows the documentation of individual whales and continues to be one of the most powerful and useful research tools. Over time, photographs provide the basis for evaluating the time individual gray whales spend in a specific lagoon aggregation areas, fidelity to specific areas, female calving intervals, minimum age estimation, body condition, and movements among aggregation/feeding/breeding areas throughout the specie's range.

All gray whale photographs from each winter are archived, placed into digital catalogs, compared with the catalogs from 2006-2018, and compared with photo ID catalogues of Laguna Ojo de Liebre, Bahía Magdalena, and the Western North Pacific gray whale population to determine the number and movements of gray whales that are utilizing these lagoon areas. All photo-ID catalogs are posted for viewing on the LSIESP website at:

www.sanignaciograywhales.org/research/photo-id-catalogs/

Catalogs are available to researchers for review and to search for matches with photographs of gray whales from other portions of the species range (e.g., Arctic, Western Pacific, etc.).

Laguna San Ignacio: Photographic identification (Photo-ID) effort in Laguna San Ignacio during the 2019 winter included 223-survey hours over 47-days. A total of 8,636 digital images that yielded 526 sightings of 789-individual whales. These included 748-single whales what averaged 6.4-days in the lagoon (range 1 to 34-days), and 41-females with calves that averaged 31.7-days in the lagoon (range 1 to 60-days) (Table 3).

Bahía Magdalena Complex: Researchers working in the Bahía Magdalena region obtained 4,645 digital images from 242-sightings of gray whales during 23-days and 229-hours of observations in the 2019 season. From these images, 443-individual whales were identified (428-single whales and 15-female-calf pairs), representing significantly more single whales and fewer females-calf pairs in this region compared to the previous two winters. The average minimum residency was 8.7-days for female-calf pairs, and 10.5-days for single whales.

Table 3. Photographic identification effort and preliminary results for Laguna San Ignacio and the Bahía Magdalena complex and surrounding areas. NA = not available; TBD = to be determined.

AREA	Laguna San Ignacio	Bahia Magdalena Complex
No. Survey Days	47	23
No. Effort Hours	223	229
No. Images	8,636	4,645
No. Sightings	526	242
No. Individual Whales	789	443
No. Single whales	748	428
Single whales' mean days in area	6.4 (1-34)	310.5
No. Female-calf pairs	41	15
Female-calf pairs' mean days in area	31,7 (1-60)	8.7

Calving Interval Estimation: The typical gray whale reproductive cycle is two years, or a two year interval between calves. The intervals between gray whale calf births are calculated from photographic records of individual female whales obtained during their January-April breeding/calving season during 2005-2017 in Laguna San Ignacio, Baja California Sur, México. These birth histories indicate 1,394 females produced 1930 calves over the 13years period, and of these, 356 females produced 2-5 calves each during this time. An average birth interval of 2.39 years (S.D. $\pm$ 0.556) was calculated from 375 unambiguous birth intervals ranging from 2-4 years (Martinez *et al. In press*). Low calf counts between 2005-2010 were investigated by comparing the total number of female-calf pairs photographed (n = 1930) and the number of calves produced by 356 females observed with 2-5 calves (n = 892) for two periods from 2005-2010 and from 2011-2017: 23.2% of the total number of calves and 18.2% (n= 65) of females with 2-5 calves were observed between 2005-2010, while 76.8% (n= 1482) of total calves and 81.8% (n= 291) of females with 2-5 calves were observed between 2011-2017, indicating that reproduction increased during the most recent period. This suggests that female gray whales were breeding more frequently in the years following the range-wide mortality event of 1998-2000 (LeBoeuf *et al.* 2000).

Individual Age Estimation: The minimum ages of breeding female gray whales are determined from photographs obtained during the time periods from 1977-1982 (Jones and Swartz 1984), the period from 1996-2000 (Urban et al. 2011), and the period 2005-2019 (LSIESP). Seventeen females from the earliest time period (1977-1982) were photographically matched (recaptured) in recent years, and their minimum age was estimated to range from 26 to 50 years (Martinez *et al. In Press*).

Figure 7. Female gray whale first photographed with a calf in 1977 and most recently photographed in 2019 as a single adult whale, suggesting her minimum age is 48-50-years.

The most recent recaptures of these known females in 2017, 2018 and 2019 confirm minimum ages ranging from 27 to 50-years (Fig. 7), and demonstrate that these females are continuing to reproduce and visit Laguna San Ignacio with their new calves each winter. These are the oldest photographic identification data for any living gray whales, and clearly demonstrate the fidelity of breeding female gray whales to Laguna San Ignacio.

Read the complete "Age of Gray Whales" report and the PowerPoint presentation at:
www.sanignaciograywhales.org/research/publications

Declining Body Condition Observed in Laguna San Ignacio

Eastern North Pacific (ENP) gray whales feed during the summer around the Bering, Chukchi and Beaufort seas, and migrates to winter breeding and calving grounds along the Pacific coast of Baja California, in Mexico. Measurements of the whales' body condition upon arrival at the winter breeding grounds is an indicator of "health and reproductive condition," and indirectly is an indicator of the health of the environment and the availability of prey.

Individual gray whale body condition was evaluated from photographs for 569 gray whales in Laguna San Ignacio (LSI) in Baja California Sur in 2019. Photographs were sorted into two reproductive-sex categories: Females with calves, and Single whales (male or female without a calf). Condition was numerically scored as "good", "fair", or "poor" using a method developed for the Western North Pacific (WNP) gray whales (Bradford *et al.* 2012). This year the proportion of single whales with "good condition" was 22.1%; in "fair" condition was 54.3% and those in "poor" condition was 23.6% (Table 4). The percent of "poor" body condition in 2019 is the highest observed in LSI in the last ten years. The proportion of females with calves with "good," "fair", and "poor" condition in 2019 were 50.0%, 50.0%, and 0%, respectively. The decrease of single whales in "good" condition observed during 2019 was not reflected in the percent of females with calves, but may be the result of a small sample of female-calf pairs photo-identified in 2019 (n=41), compared to the average of 226 pairs photo-identified each year from 2011 to 2017.

Table 4. Numbers and percentages of gray whale base on their body condition for Laguna San Ignacio, BCS, Mexico (2008-2011 and 2018-2019)

Single whales/year	2008	2009	2010	2011	2018	2019
No. whales Photo-identified	249	588	718	424	597	847
No. whales categorized	89	236	433	347	207	529
Good Condition (%)	46 (51.7%)	119 (50.4%)	206 (47.6%)	221 (63.7%)	90 (43.5%)	117 (22.1%)
Fair Condition (%)	37 (41.6%)	99 (41.9%)	200 (46.2%)	109 (31.4%)	100 (48.3%)	287 (54.3%)
Poor Condition (%)	6 (6.7%)	18 (7.6%)	27 (6.2%)	17 (4.9%)	17 (8.2%)	125 (23.6%)

Females with calves						
No. whales Photo-identified	112	79	38	188	86	41
No. whales categorized	79	70	31	176	80	40
Good Condition (%)	52 (65.8%)	52 (74.3%)	30 (96.8%)	124 (70.5%)	35 (43.8%)	20 (50%)
Fair Condition (%)	27 (34.2%)	18 (25.7%)	1 (3.2%)	48 (27.3%)	43 (53.8%)	20 (50%)
Poor Condition (%)	0	0	0	4 (2.3%)	2(2.5%)	0

It's important to note that the percent of single whales with "poor" condition decreased as the winter breeding season progressed; at the beginning of the season (January 15 to February 15), there was a higher percentage of single whales with poor body condition 32.8%, (n= 57) compared to 19.2% (n=68) observed during the remainder of the season (February 15 to March 28 (Table 5). This suggests that some of the "poor" condition "single" whales observed early in the season may have been females that were due to have a calf, but were in such poor body condition they could not successfully give birth to and/or to nurse a calf after it was born.

Table 5. Numbers and percentages of gray whales base on their body condition for Laguna San Ignacio, BCS, Mexico separated in two periods (Jan15-Feb15 and Feb 16-March 28).

Periods	15 Jan-15 Feb	16 Feb-28 Mar
No. whales Photo-identified	256	591
No. whales categorized	174	355
Good Condition	n= 35 (20.1%)	n= 82 (23.1%)
Fair Condition	n = 82 (47.1%)	n= 205 (57.7%)
Poor Condition	n= 57 (32.8%)	n= 68 (19.2%)

Read the complete report & PowerPoint presentation on gray whale body condition in 2019 at:
www.sanignaciograywhales.org/research/publications

AUV-Drones Evaluate Body Condition, Growth, and Energetic Cost of Reproduction

Figure 8. LSIESP Drone pilots Fabian Missael Rodríguez González and Hunter Warick launch the UAV-Drone to photograph gray whales in Laguna San Ignacio.

Reproduction plays a major role in any species' life history strategy. The reproductive cycle of baleen whales is closely linked to their feeding-migration-breeding cycle as they exhibit one of the fastest mammalian offspring growth rates. Assessing the costs of reproduction of an individual over a breeding season, by monitoring changes in body condition, is an important first step to better understanding the health of the overall population.

To do this, Dr. Fredrik Christiansen, of Murdoch University, Murdoch, Western Australia, Fabian Missael Rodríguez González and Hunter Alan Warick conducted the 2nd winter of Unmanned Aerial Vehicle (UAV-Drones) aerial photogrammetry to measure growth and body volume of female and calf whales to determine relationships between maternal rate of loss in energy reserves and calf growth in gray whales for female-calf pairs, and body condition evaluation for single adult whales in Laguna San Ignacio (Fig. 8).

View UAV-Drone video at: www.sanignaciograywhales.org/project/videos/

Using methodology developed by Christiansen et al. (2018), in 2019 they measured the body volume of gray whales from UAV-Drones during 562 flights (103h) and recorded 551 body condition measurements of 337 solitary individuals (animals with no calf) and 316 body condition measurements of 40 mother and calf pairs (Table 6). Thirty-nine female-calf pairs were measured on average 4 or more times during the 3-month winter calving season, with an average of 12.5 days between measurements. From these data, growth curves (length and width) will be determined for the calves through the breeding season. Losses and gains in body volume of individual mother-calf pairs will be quantified to estimate the volume conversion efficiency from females to calves, as well as maternal investment in their calves through the breeding season (Fig. 9, Vivier *et al.* 2018).

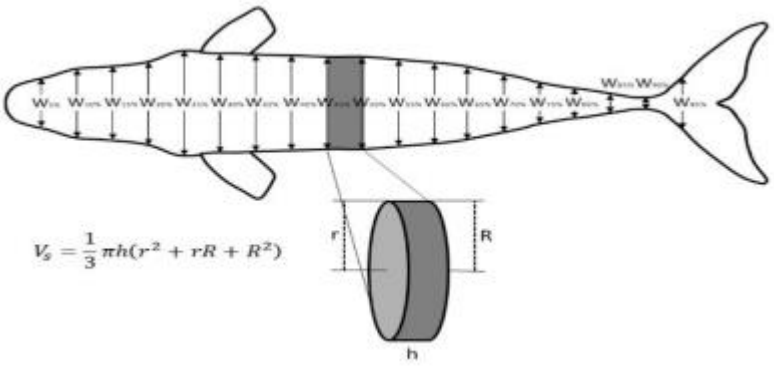

Figure 9. Method of estimating body volume from length and width measurements obtained by UAV-Drones for gray whales.

The long-term research program at Laguna San Ignacio (40-years) has produced calving histories for individual female gray whales over many years. It will be possible to compare UAV-Drone measurements of body condition and long-term reproductive history from photo-ID data for individual female gray whales as a means to assess possible effects of age, number of calves produced and inter-calving interval on their reproduction efficiency. This line of investigation will provide insights into challenging and complex questions about gray whale fitness at different ages, and changes in female whale breeding efficiency over time. In view of the observations of "poor" body condition of some gray whales, these photogrammetry data will also allow analysis of any correlations with variation in climate and environmental conditions that influence the availability of gray whale prey, feeding requirements, mother-to-calf energy transfer, and calf survivorship which could not previously be investigated.

Table 6. UAV-Drone photogrammetric effort to document gray whale reproductive and body condition in Laguna San Ignacio during 2018 and 2019.

Year	2018	2019
No. of flights	452	562
No. Hours	83.6	103
No. single whales	254	337
Single whale measurements	292	551
No. female-calf pairs	63	40
Female-calf measurements	377	316

Monitoring Bottlenose Dolphin (*Tursiops truncatus*) Population

The monitoring of the bottlenose dolphins (*Tursiops truncatus*) during the winters season 2009-2018 included 439-sightings and 220 days of effort, and an average group size of 6.2 individuals. The Laguna San Ignacio bottlenose dolphin catalogue currently contains 322 individuals photo-identified, and has been analyzed by the marine biologist graduated from UABCS Fabian Missael Rodríguez González who estimated the population ecology of the bottlenose dolphins in his bachelor thesis (Rodríguez Gonzáles *et al.* 2018). He assessed the abundance around 440 ± 16 individuals and the site fidelity in 0.22 ± 0.02 re-sightings by winter season. The distribution showed that the maximum relative abundance of bottlenose dolphins was in the lower part of the lagoon, indicating that the dolphins use very often as a transitional area. These results provide us base line information about bottlenose dolphin population in Laguna San Ignacio. LSIEP bottlenose dolphin catalogue will be compared with bottlenose dolphin photographs contained in the NOAA Tursiops Proto-ID Catalog for Ensenada, Mexico to Northern California, U.S.A. to estimate the relationship of the individuals observed in Laguna San Ignacio to bottlenose dolphin residing along the coast of the Californias. (www.sanignaciograywhales.org/research/photo-id-catalogs/ And Powerpoint presentation at: www.sanignaciograywhales.org/research/publications

Paring Gray Whale Behavior and Underwater Acoustics

In 2019 Ph.D. candidate Ludovic Tenorio-Hallé, his major professor Dr. Aaron Thode of Scripps Institution of Oceanography, Héloïse Frouin-Mouy and Regina Lobo Barrera conducted the 2nd year of their project to compare specific gray whale vocalizations with

the whales' behavior and interactions during the winter months in Laguna San Ignacio. Pairing observations of gray whale behavior with simultaneous directional acoustic recordings is providing the first opportunity to associate specific whale calls and call rates among conspecifics to evaluate the whales' vocal behavior in the context of their breeding behavior in the winter months.

Since 2005, the LSIESP Acoustics team from Scripps Institution of Oceanography have collected acoustic data during the gray whale breeding season, with objectives of this long-term passive acoustic monitoring study to:

- To demonstrate the potential of autonomous acoustic recorders and novel techniques such as tracking vocalizing gray whales and monitoring population trends using sound measurements alone.
- Monitor trends in the lagoon's dynamic acoustic environment.
- Study the vocal repertoire and behavior of gray whales in their breeding grounds.

During the 2018 winter, an observation tower was placed at Punta Piedra, overlooking the acoustically monitored area. This allowed recording visual observations of the whale's surface behavior. Unfortunately the tower was destroyed in a hurricane in September of that year. This year, the team conducted visual observations using an AUV-Drones with HD-video cameras, and hydrophones. The underwater acoustic monitoring system consisted of two pairs (arrays) of independent recorders placed on the bottom of the lagoon, allowing the precise determination of the whale's location when they produced vocal sounds (Fig.10). A waterproof AUV-Drone that was capable of landing on water was also used with a deployable-hanging hydrophone to make acoustic observations of whales that were simultaneously being visually monitored using a second AUV-Drone with D video cameras.

Figure 10. The orientation of hydrophone arrays to localize the source of whale calls in front of the observation tower on Punta Piedra in Laguna San Ignacio.

Read the entire Acoustic-Behavior-Paring report at:
www.sanignaciograywhales.org/research/publications

Disentanglement & Rescue Efforts

During a gray whale abundance survey in Laguna San Ignacio on February 10th 2018 a mother and calf pair were observed, and the calf had several fishing lines wrapped around its body and it was dragging a round fishing float. The next day a dis-entanglement Team successfully removed the lines, a lobster trap, and floats from the calf whale, saving its life. However, much of the custom gear, lines and floats were broken or lost. A grant from the Natural Resource Defense Council (NRDC) paid for the replacement of the damaged and lost equipment, allowing the LSIESP dis-entanglement Team remain ready to respond to any future whale entanglement incidents.

Watch the video of the 2018 rescue at:
www.sanignaciograywhales.org/project/videos/

The regulations of the Vizcaíno Biosphere Reserve do not permit the use of fishing lines, floats, traps or nets inside of the lagoon during the winter months while the gray whales are in residence. However, as the whales migrate along the outer coast, they encounter various types of lines and nets, and occasionally they become entangled in these. Each year lost fishing gear remains in the lagoon, posing a threat of entanglement to the whales. In 2019 the Eco-Tour operators and their boat (Panga) operators patroled the lagoon and collected and removed derelict fishing gear found in the lagoon. This past winter they removed 15 lost and abandoned lobster traps from areas utilized by the whales.

Figure11. Eco-Tour whale watching Panguero "Máximo Valentin" and the derelict abandoned fishing gear and traps that he removed from Laguna San Ignacio.

Community Outreach and Education

LSIESP's outreach and education activities continue at Laguna San Ignacio to disseminate research findings to interested public, eco-tour visitor groups and naturalists (e.g., Andiamo, Natural Habitat Adventures, NRDC, and others), and the local community. In addition to our website, we've launched the LSIESP "Instagram" site (@lsigraywhales) to expand our program's outreach in the social media.

LSIESP researchers are routinely asked to provide information about the various scientific investigations that are underway at the lagoon, and the most recent findings. The annual community "Reunion" meeting continues to be well attended (over 100 people in 2019). Presentations included: Trends of Gray Whale Abundance in the lagoon, the increase of "Skinny" whales, Evaluating Condition with UAV-Drones, Bottlenose Dolphin Population Assessment, and the Acoustic-Behavior paring project (Fig. 12).

Figure 12. The 2 March 2019 "Community Reunion" at the Kuyimita Camp Palapa.

Several student groups from Mexican (e.g., UABCS) and other universities (e.g., University of Zurich) visited LSIESP's "Francisco 'Pachico' Mayoral" Field Research Laboratory where they received lectures and instruction from LSIESP researchers. Presentation topics included: marine

Figure 13.UABCS University students receive a lecture from LSIESP Co-Director Dr. Steven Swartz a the Francisco "Pachico" Mayoral Field Laboratory at Laguna San Ignacio.

mammals, vertebrate biology, natural history, desert ecology, and marine protected area conservation and management (Fig. 13). The LSIESP research program also contributed information to public and private science and education organizations (e.g., The Whale Museum in La Paz, B.C.S., the Langley Whale Center Pacific Northwest, International Whaling Commission's Scientific Committee, El Vizcaíno Biosphere Reserve in Baja California, etc.).

Students from the Universidad Autónoma de Baja California Sur, devoted part of their time at the lagoon to participate in a community clean-up project, collecting plastic and other trash from the beaches and the desert around the lagoon, and delivering this trash to the local waste disposal facility in the Ejido Luis Echeverria Alvarez (Fig. 14).

Figure 14. UABCS students and advisors pick-up plastic and other trash from the beach in Laguna San Ignacio.

View all of the 2019 Community Reunion Presentations at:
www.sanignaciograywhales.org/research/publications/

International Collaboration with Western Gray Whale Researchers

In 2019 LSIESP researchers hosted a team of gray whale researchers from the Russian-Exxon Western Gray Whale research team that work with the Western North Pacific gray whale population around Sakalin Island, Russia. These included Ervin Kalinin, Michael Scott, Mike Doneghy, Peter Vander Wolf, and Vladimir Chernitsyn (pictured above).

Gray whales have traditionally been considered to consist of two populations, one in the western North Pacific (WNP) and the other in the eastern North Pacific (ENP). For several years LSIESP researchers have participated in a multinational effort to evaluate trans-Pacific movements of gray whales identified from both the ENP and WNP. Photographic-Identification images of gray whales identified on the summer feeding grounds off Russia are compared to individual whales identified in the wintering lagoons of Baja California, Mexico. To date a total of 54 gray whales, including breeding females, have been linked between Russia and the breeding lagoons of the west coast of Baja California, Mexico, suggesting that significant mixing between these two populations exists.

Read the entire report on movements between the WNP and ENP at:
www.sanignaciograywhales.org/research/publications/

Academic Training

Training the next generation of wildlife scientists and conservationists continues as part of our mission, and to date our student researchers have completed seven Ph.D. degrees, five Master's degrees, and nine undergraduate theses. Our researchers have submitted four scientific papers to the 2019 meeting of the International Whaling Commission's Scientific Committee, and seven abstracts for papers and posters to the December 2019 World Marine Mammal Conference in Barcelona, Spain.

Visit our website at www.sanignaciograywhales.org/research/publications/ to view and read all of the reports and findings resulting from the 2019 winter research program, and previous years' research, at Laguna San Ignacio and Bahía Magdalena.

We are also now on "Instagram". Visit us at: "@lsigraywhales"

DONATE - BECOME A SUPPORTER

Please consider supporting the gray whale research in Baja California by becoming a "recurring donor" to our project. It is easy and safe! Please visit our donation website link at:

https://www.sanignaciograywhales.org/donate/

References Cited

Bradford, L.A., Weller, D.W., Punt, E.A., Ivashenko, V.J., Burdin, M.A., VanBlaricom, R.G., and R.L Brownell, Jr, 2012. Leaner leviathans: body condition variation in a critically endangered whale population, Journal of Mammalogy, 93(1):251–266, 2012.

Christiansen, F., Vivier, F., Charlton, C. Ward, R., Amerson, A. Brunell, S. and Bejder, L. 2018. Maternal body size and condition determine calf growth rates in Southern Right Whales. Mar. Ecol. Prog. Ser. 592:267-282.

LeBoeuf, B.J., Pérez-Cortés, M., Urbán R., J., Mate, B.R., and Ollervides U., F. 2000. High gray whale mortality and low recruitment in 1999: potential causes and implications. J. Cetacean Res. Manage. 2(2):85-99.

Martínez, S.A., Swartz, S., Urban, J., Gómez-Gallardo, A., and Rosales, H. *In Press*. The age of living female gray whales (*Eschrichtius robustus*) estimated from photographic identification data. Aquatic Mammals.

Martínez, S. A., Swartz, S., Urbán J., and Romero, E.V. *In Press*. Estimation of Gray Whale (*Eschrichtius robustus*) Birth Interval based on Photo-ID in Laguna San Ignacio, BCS, México (2005-2017). Laguna San Ignacio Ecosystem Science Program website: https://www.sanignaciograywhales.org/research/publications/

Vivier, F., Bejder, L., Rodríguez-González, F.M., Martínez, S.A., Urban, J.R., Swartz, S., and Christiansen, F. 2018. Estimating lactation cost in gray whales using unmanned aerial vehicles. Poster presentation at SOMEMMA XXXVI, Villahermosa, Tabasco, Mexico.