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

www.sanignaciograywhales.org

2020 RESEARCH REPORT FOR LAGUNA SAN IGNACIO & BAHÍA MAGDALENA, BAJA CALIFORNIA SUR, MÉXICO

Steven L. Swartz, Jorge Urbán R., Sergio Martínez A.,
Lorena Viloria Gómora, and Alejandro Gómez-Gallardo

JUNE 2020

Featured Research and Monitoring Topics from the 2020 Laguna San Ignacio Ecosystem Science Program (LSIESP)

Summary: Gray whales show 3rd year of nutritional stress, low lagoon abundance, low calf counts, and increasing mortalities - Page 3

Leadership & Research Team Members for 2020 - Page 5

International collaboration with NOAA Unusual Mortality Event (UME) Working Group - Page 6

Gray whale abundance & distribution monitoring - Page 8

Poor body condition of gray whales observed at 30% - Page 15

UAV-Drones used to evaluate gray whale body & reproductive condition - Page 18

Acoustic and surface behavior research enters 3nd year - Page 21

Photographic Identification Research - Page 23

Minimum age estimates for known female whales increased to 50-years - Page 24

Community outreach and Education efforts in 2020 - Page 25

Academic training and graduate degrees - Page 27

Contact us and donate to the LSIESP research - Page 27

References cited - Page 28

Summary of Gray Whale Research Activities and Findings in 2020

The 2020 winter gray whale reproductive season in Laguna San Ignacio (LSI) and Bahía Magdalena (BM) was the third consecutive breeding season (2018, 2019, and 2020) that was characterized by: 1) an approximate two week delayed arrival of the whales to Lagun a San Ignacio; 2) very low numbers of calves-of-the-year; 3) increased adult mortality in the lagoons (Martinez-Aguilar, *et al*. 2020), and 4) an increase in the percent of "skinny" or "mal-nourished" adult whales observed compared to the previous seven winters (2011-2017) (Urban *et al*. 2018, 2019, Ronzón-Contreras et al. 2019, 2020). Unfortunately these observations continue to be mirrored in the ongoing Unusual Mortality Event (UME) that began in the spring and summer of 2019 and continues in 2020 (NOAA 2020).

Preliminary findings from full or partial necropsy examinations conducted on a subset of the stranded whales have shown evidence of nutritional stress and emaciation. A working hypothesis is that 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, delayed migrations, reduced reproduction, and apparent decline in the body condition of some gray whales.

Low gray whale calf counts in LSI and BM were also noted during the 2007 to 2010 winters following a previous range wide UME in 1999 to 2000 (LeBoeuf *et al.* 2000; see also LSIESP "Annual Field Reports" 2007-2010). Overall, the low number of female-calf pairs observed in 2018, 2019, and 2020 were indications of an impending UME. Specifically, LSIESP long-term abundance monitoring (15-years) and photographic-identification data confirmed significant declines of calf counts, and increasing percentages of "skinny" and "emaciated" whales, suggesting that in recent years the gray whales summer feeding in the Arctic and N. Pacific are not obtaining sufficient nutrition to survive and successfully reproduce following their fall southward migration, a 3-4 month winter breeding season in Mexico, and a northward spring migration to return to their summer feeding range.

In the coming 2021 winter, LSIESP researchers will focus our research on monitoring gray whale health, reproduction, and behavior from data collected from necropsies of stranded whales, abundance surveys, Photo-ID surveys, and UAV-Drone flights to quantitatively measure individual whale size, calf growth, and general body condition of all whales. This information will help to evaluate the severity of the ongoing gray whale UME in Baja California's gray whale wintering aggregation areas, and over time allow the evaluation of trends in gray whale calving success, and individual health and growth during the winter months following their summer feeding in the North Pacific and Arctic.

With the world-wide outbreak of the COVID-19 Pandemic in mid-March 2020 all field activities in LSI and BM were suspended, the field research station closed, and all researchers and students returned to their universities and homes for duration of the 2020 winter gray whale breeding season in the lagoons and aggregation areas of Baja California Sur, Mexico. Analysis of the data obtained up until mid-March, post-season meetings and conferences continue to be held remotely over the internet and social media.

Additional research and achievements of our LSIESP team in 2020 include:

• Photographic-identification methods were used to: document whale's body condition; update the "minimum age" estimate for "living" female gray whales to 48-50-years; document site fidelity and calculated average duration of stay in LSI (single whales 6.4-days & females with calves 31.7-days), and revised the current female calving interval to 2.39-years.

• Examined and obtained measurements and photographs of one dead sea-lion (*Zalophus californianus*), 7-dead stranded whales in Laguna San Ignacio, and 4-dead stranded gray whales in Bahia Magdalena.

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

• For the third winter, 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.

• Hosted and convened the 11th Annual "Community Reunion" mini-science symposium at the Kuyimita Campground, presented lectures to visiting eco-tour groups, Marine Biology Bachelor's Program students from UABCS, provided interviews with several media groups, and hosted three university student groups studying marine science; one from Zurich, Switzerland and two from UABCS in La Paz, B.C.S., Mexico.• Contributed research papers to the International Whaling Commission's Scientific Committee meeting in May 2020 (i.e., gray whale abundance, body condition, and mortalities in Mexico).

==========

Leadership and Research Staff

Laguna San Ignacio 2020 gray whale research team.

The 2020 winter marked LSIESP's 15th year of monitoring and conducting research on gray whales and other marine life in LSI and BM. We thank all of our researchers, their advisors, our students and sponsors, and the local community for their generous support and encouragement since our program's beginning in 2006.

The 2020 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 L. Swartz, Sergio Martínez Aguilar, and Alejandro Gómez-Gallardo U. Field researchers included Floryser Ronzón Contreras, Andrés González Cisneros, Lorena Citlalli Magallon, Yessica Brau Ibarra, Mónica Farriols Pérez, Patricia Casanova Gamba DVM, and Jack Heaven

Fabián Missael Rodríguez González piloted the Unmanned Aerial Vehicles flights (UAV-Drones) at LSI and conducted aerial photogrammetry to measure growth and body volume of female and calf whales to estimate body condition and reproductive health

Bahia Magdalena 2020 gray whale research team

Gray whale researchers in Bahía Magdalena were led by Dra. Lorena Viloria Gómora, and included María Laura Marcías, Rodrigo Huerta, Michelle Rosales Inda, and Minerva Valerio Conchas.

LSIESP continues its collaboration to investigate gray whale condition and energetics with Dr. Fredrik Christiansen from the Institute of Advanced Studies in Aarhus C., Denmark, and Dr. Lars Bejder from the Marine Mammal Research Program, University of Hawaii, Manoa, Kaneohe, Hawaii. The acoustics and behavior observation research team is led by Dr. Aaron

Thode, Ludovic Tenorio-Hallé, and Hunter Atkins from Scripps Institute of Oceanography, La Jolla, California, and Dr. Héloïse Frouin-Mouy (JASCO Applied Sciences).

The 2020 gray whale 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 permits No. SGPA/DGVS/013210/18 and SGPA/DGVS/00376/20 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.

==========

LSIESP AND UABCS-PRIMMA RESEARCHERS RESPOND TO GRAY WHALE STRANDINGS AND CONTRIBUTE TO INTERNATIONAL EFFORT TO UNDERSTAND GRAY WHALE UNUSUAL MORTALITY EVENT (UME)

In 2019, 123 gray whales stranded along the Pacific coast of the U.S., more than 11 times the 18-year average stranding rate of 14.8 whales/year. In total, 215 stranded whales were discovered in 2019 from Alaska to Baja California, and as of 12 May 2020 an additional 111 gray whale strandings were reported. To investigate the 2019-2020 UME the U.S. National Ocean and Atmospheric Administration (NOAA) assembled an independent team of scientists to coordinate with the Working Group on Marine Mammal Unusual Mortality Events to review the data collected, sample stranded whales, consider possible causal-linkages between the mortality event and recent ocean and ecosystem perturbations.

LSIESP scientists were invited to join this Working Group to specifically report on gray whale strandings in Baja California in 2020. In addition to monitoring gray whales in LSI and BM, a subset of LSIESP researchers partnered with researchers from the Universidad Autónoma de Baja California Sur (UABCS) and the Research Project on Marine Mammals (PRIMMA) in La Paz, including a Doctor of Veterinary Medicine. These investigators made weekly visits to Laguna Ojo de Liebre (LOL) to collaborate with researchers from the Reserva de la Biósfera el Vizcaíno and Exportadora de Sal S.A. to enumerate stranded whales there.

Stranded whales discovered as of mid-March 2020 included: in Laguna San Ignacio 4 females, 2 males, and one sex undetermined; in BM 2 males, 1 female, and one sex undetermined; and in LOL 29 males, 18 females and 22 undetermined sex. If possible, necropsies were conducted and

samples of specific tissues were collected for future analysis and comparison with tissues collected by scientific teams throughout the gray whales range (Martínez-Aguilar *et al*. 2020).

Preliminary findings from full or partial necropsy examinations conducted on a subset of the stranded whales have shown evidence of nutritional stress and emaciation. A working hypothesis is that 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, delayed migrations, reduced reproduction, and apparent decline in the body condition of some gray whales.

This summer LSIESP researchers will continue to collaborate with the NOAA UME scientific Working Group to monitor the ongoing strandings of gray whales during their northward migration. [*Note: All field activities at LSI were suspended as of 25 March due to the world-wide COVID-19 pandemic outbreak. Field activities in LOL continued until April 5th. This suspension of observations throughout the gray whales' range will likely limit the amount of information obtained on stranded gray whales during the 2020 spring/summer northward migration*.]

Table 1. Stranded dead whales discovered in Laguna San Ignacio and the Bahia Magdalena complex during the winter of 2020. LSI = Laguna San Ignacio; BM = Bahía Magdalena.

Stranding No.	Location	Date	Sex	Size/Age Category
1	LSI	20-Jan-20	Female	Adult
2	LSL	30-Jan-20	Male	Juvenile
3	LSI	3-Feb-20	Female	Adult
4	LSI	8-Feb-20	Female	Adult
5	LSI	11-Feb-20	Male	Adult
6	LSI	2-Mar-20	Undetermined	Juvenile
7	LSI	3-Mar-20	Female	Juvenile
8	BM	17-Jan-20	Undetermined	Juvenile
9	BM	6-Feb-20	Female	Juvenile
10	BM	16-Feb-20	Male	Juvenile
11	BM	5-Mar-20	Male	Juvenile

Read the complete report of gray whale strandings in Mexico presented to the International Whaling Commission's Scientific Committee IWC-SC/68B/CMP 13 Here:

www.sanignaciograywhales.org/research/publications

Gray Whale Abundance Monitoring

Each winter gray whale abundance, distribution and reproduction in Laguna San Ignacio and Bahía Magdalena is monitored by boat (Panga) surveys. 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 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-h to complete. Whales were counted in the northernmost portion of Laguna San Ignacio from the anchored panga with observers scanning the area with binoculars 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).

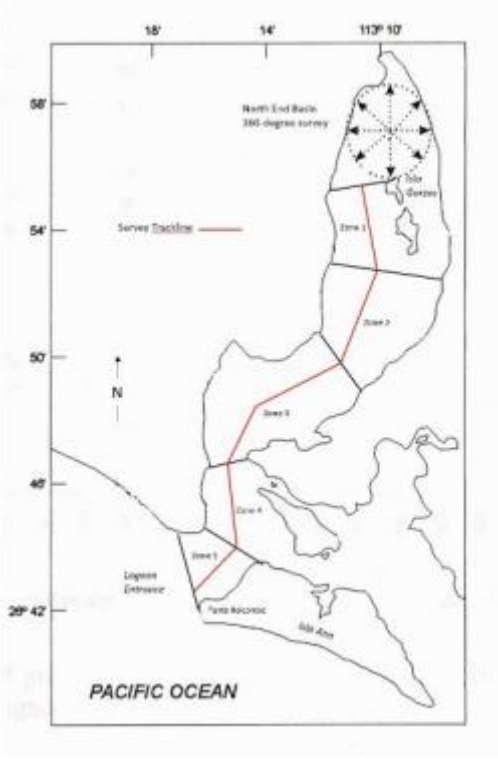


Figure 1. Gray whale boat/panga survey track-line in Laguna San Ignacio.

In LSI 11 surveys of gray whales were completed to monitor seasonal abundance and habitat use in 2020. Surveys began on 20 January and continued until 19 March (Table 1). The arrival of adult (non-calf) gray whales occurred in mid-January, approximately one

week later than observed during previous winters, while their departure from the lagoon was similar to previous years. Their abundance was approximately 100 individuals, lower than counts of single adult whales from 2011 to 2017, except for the 2015 winter (Fig. 2).

Table 2. Boat survey counts of gray whales (Female-calf pairs, Singles (whales without calves), and total Adults) in Laguna San Ignacio during the 2020 winter breeding and calving season. Number of female-calf pairs equals the number of calves observed.

Survey No.	Date	Single whales	Female-Calf Pairs	Total Adults
1	20-Jan-20	7	2	9
2	25-Jan-20	17	5	22
3	30-Jan-20	17	5	22
4	4-Feb-20	25	4	29
5	9-Feb-20	41	12	53
6	19-Feb-20	92	11	103
7	28-Feb-20	77	13	90
8	4-Mar-20	106	12	118
9	9-Mar-20	79	16	95
10	14-Mar-20	43	21	64
11	19-Mar-20	18	13	31

The highest count of single adult whales (breeding males and females without calves) was 106 whales obtained on the 4 March survey (Fig. 2, Table 2). Numbers of these whales were lower than in previous winters, with a maximum count of approximately 100 individuals and no mid-winter peak at the end of February and early March. These whale counts suggest a decreasing trend for the number of single adult whales over the past three winters.

Counts of females with calves remained low throughout the entire 2020 winter season, with the greatest number of 21 female-calve pairs counted on 14 March 2020; the end of the season increase of female-calf pair counts typically seen in LSI did not occur in 2020, or in the previous two winters (Fig. 3, Table 2). The number of female-calf pairs seen in 2020 was far less than that observed between 2011 to 2017, when female-calf pair counts in March ranged from 50 to 60 pairs to just under 130 pairs.

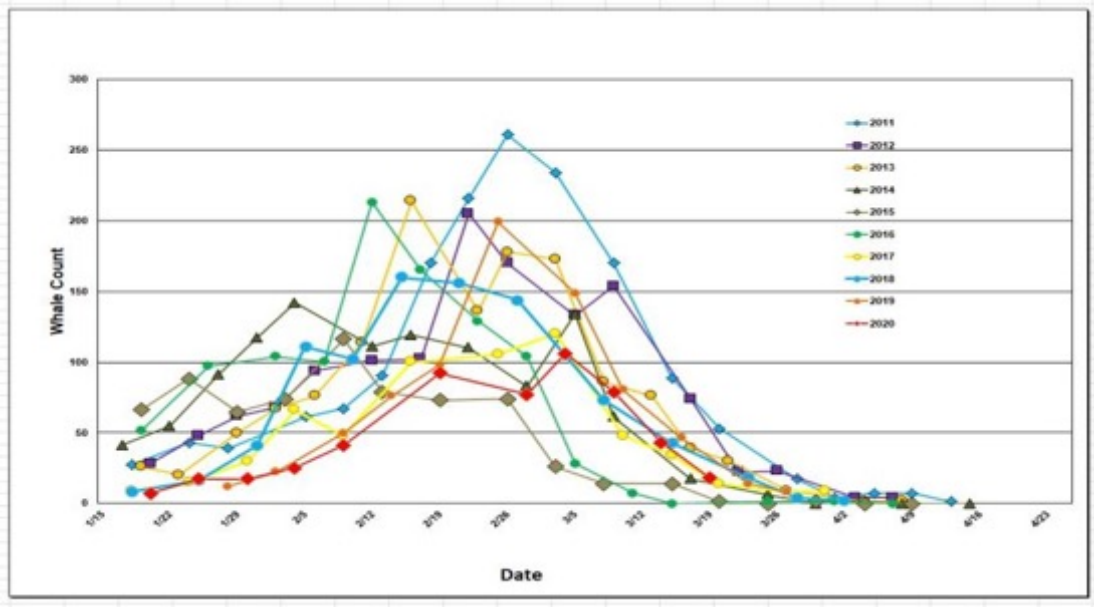


Figure. 2. Numbers of single whales (adult males and females without calves) counted in Laguna San Ignacio during the winter seasons: 2011-2020.

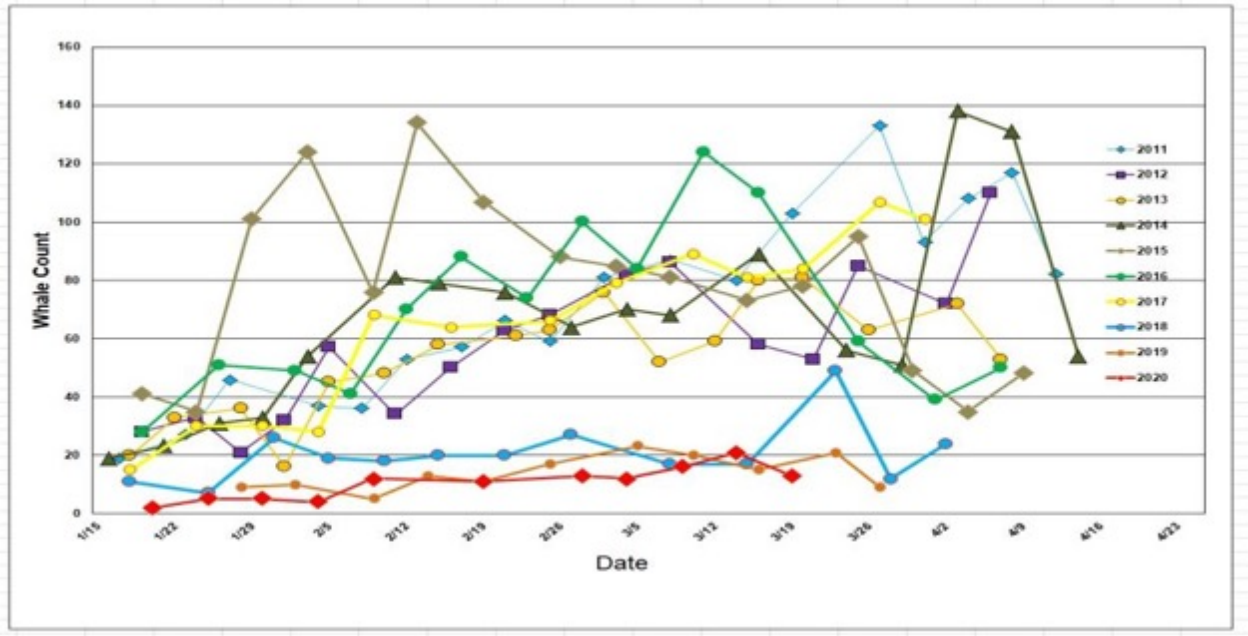


Figure 3. Survey counts of gray whale female-calf pairs in Laguna San Ignacio 2011-2020.

Bahía Magdalena: The 2020 boat surveys of gray whales in the Bahía Magdalena lagoon complex were conducted in three different areas during six different time periods: 18-20 January, 26-28 January, 8-10 February, 16-20 February, 26-28 February, and from 9-10 March (18-surveys in all) (Table 2,, Fig. 4).

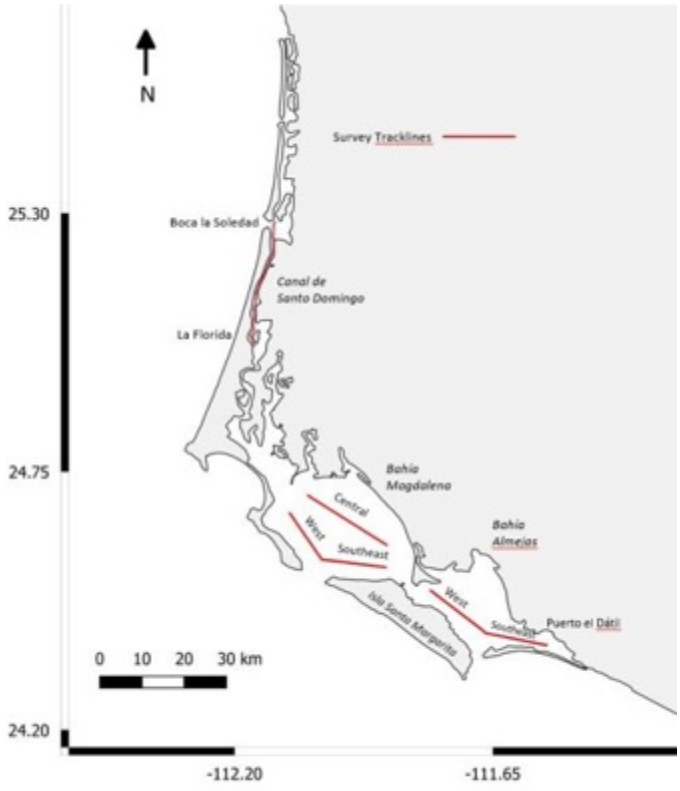


Figure 4. Boat survey track-lines for estimating gray whale abundance in the Bahía Magdalena lagoon complex in three areas where gray whales aggregate: Canal de Santo Domingo in the north; Bahía Magdalena's center, west and southwest areas; and in Bahía Almejas in the south

The highest counts of gray whales were obtained on 16 February in the most southerly aggregation area of Bahía Almejas with 176 adult whales, but no female-calf pairs. In in central Bahía Magdalena counts were greatest on 8 February with 40 adult whales and no calves. In Canal de Santo Domingo on 10 February 18 single whales and 6 female-calf pairs were counted. Gray whale abundance then declined in all areas and by the second week in March: 93 single adults and 1 female-calf pair were counted in Bahía Almejas; 2 single whales and no female-calf pairs counted in central Bahía Magdalena; and 7 single whales and 3 female-calf pairs in Canal de Santo Domingo.

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 3, Fig. 5).

Table 3. 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 2020 winter breeding and calving season. Number of female-calf pairs equals the number of calves observed.

	Area	Date	Female-Calf Pairs	Singles	Total Adults
2020 Gray Whale Survey Counts	Bahía Almejas	18-Jan-20	0	2	2
		26-Jan-20	1	13	14
		9-Feb-20	0	145	145
		16-Feb-20	0	176	176
		27-Feb-20	0	111	111
		9-Mar-20	1	93	94
	Bahía Magdalena	19-Jan-20	0	2	2
		27-Jan-20	0	6	6
		08-Feb-20	0	17	17
		17-Feb-20	0	13	13
		28-Feb-20	1	32	33
		09-Mar-20	0	2	2
	Canal de Santo Domingo	20-Jan-20	0	1	1
		28-Jan-20	0	3	3
		10-Feb-20	6	18	24
		20-Feb-20	1	8	9
		26-Feb-20	9	12	21
		10-Mar-20	3	7	10

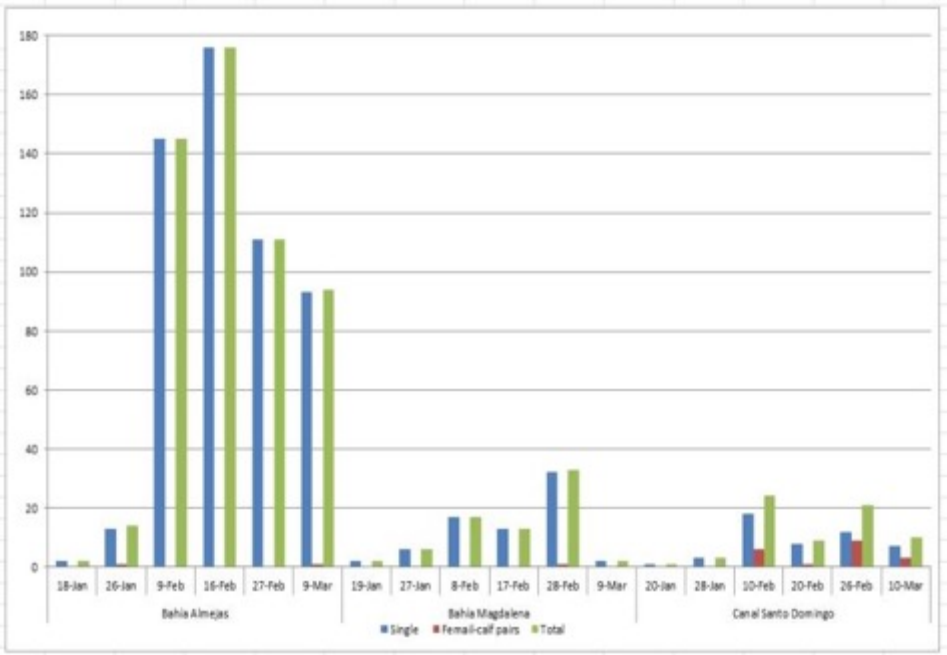


Figure 5. Boat survey counts of gray whales in three areas within the Bahía Magdalena complex during the 2020 winter breeding and calving season. Number of adult whales (Singles) without calves; female-calf pairs equals the number of calves observed. Total equals all adult whales with or without calves.

Figure 6. All gray whale sightings in the Bahía Magdalena lagoon complex and surrounded waters in the 2020 winter: Bahía Almejas (BA), Bahía Magdalena (BM) and Lopez Mateos (LM). blue circles = gray whale single animals; red circles = gray whale female-calf pairs.

The 2020 distribution of gray whales was concentrated in the areas along the north-eastern shore of Isla Creciente, off of the south-eastern shore Isla Santa Margarita in Bahía Almejas, and 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 northern-most concentrations of whales were observed in the Canal de Santo Domingo (Fig. 6). As was observed in LSI, few gray whales remained in the BM complex by mid-March 2020, so abundance surveys were discontinued.

Low calf counts were also observed from 2007-2010 following the 1998-2000 range-wide Unusual Mortality Event (UME) when an estimated 33% of the N.E. 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 in 2018, 2019 and 2020 were low, the female whales and their calves that were present appeared to be in good (50%) to fair (50%) condition, and indications of nutritional stress or poor condition of these gray whale females and calves was not evident. Apparently they were in sufficiently robust condition to bring their pregnancies to term, birth their calves, and nurse them, suggesting that unlike under-nourished whales, they had found sufficient food resources in the summers proceeding the birth of their calves.

A number of factors may have contributed to the low counts of female-calf pairs of gray whales observed in LSI and BM from 2018 to 2020. The timing and length of the gray whale migration along the Pacific coast of Baja California, the period of time the whales reside in Mexican coastal 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). In winters with cooler than average sea surface temperatures fewer whales utilize the northern aggregation areas and more whales migrating further south to utilize the more southerly aggregations areas, presumably to find warmer temperatures.

The reduction in the number of calves-of-the-year suggest a slowing of reproduction that could result from a reduction in the food-prey available to the whales in their summer feeding areas, and/or that the current size of the North Eastern Pacific population has exceeded the environmental "carrying capacity"(K) within their current range (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 their annual migrations from the summer feeding grounds to their winter breeding aggregations along Baja California's Pacific coast and its coastal lagoons.

Read the entire 2020 gray whale abundance report to the International Whaling Commission on our website – IWC-SC 68B/CMP/09: visit

www.sanignaciograywhales.org/research/publications

==========

Declining Body Condition of Gray Whales Observed in Laguna San Ignacio

The Eastern North Pacific gray whale population feeds during the summer months in the Bering, Chukchi and Beaufort seas, and migrates to winter breeding and calving grounds along the Pacific coast of Baja California, in Mexico. Upon their arrival at the winter aggregation areas in Baja California the whales should be in good physical condition having just completed a summer of feeding and replenishing their body fat and energy reserves. Therefore, the assessment of gray whale body condition upon their arrival at the breeding grounds provides an indicator of the whales' "health and reproductive condition," and indirectly is an indicator of the health of the environment.

In 2020, 553 gray whales were photographed to evaluate their body condition. Photographs were sorted into two reproductive-sex categories: 1) Females with calves, and 2) Single whales (males and females without a calf). The condition of each whale was scored as "good," "fair," or "poor" using a numerical method developed for the Western North Pacific (WNP) gray whales (Bradford et al. 2012). The proportion of females with calves in "good condition" was 70.4% (n=38); "fair" 24.1% (n=13) and "poor" 5.5% (n=3). However, the proportion of single whales (males and females without calves) with "good," "fair", and "poor" condition was 33%, 37%, and 30%, respectively. The proportion of single whales in "good" condition decreased from previous years, however a similar decrease was not reflected in the percent of females with calves (Fig. 7).

A comparison with the 2020 observations and the condition of individual whales during previous years 2008-2011 and the most recent years 2018 to 2020 suggests a trend in declining condition of single whales in recent years (Table 4). The percent of single whales with "poor" body condition in 2020 is the highest observed in LSI in the last eleven years. We conclude that the body condition of all whales was probably similarly affected; however, comparison and

correlation with environmental data from the feeding grounds (e.g. prey availability) is needed to understand the factors that contribute to the whales' body and reproductive condition.

Table 4. Comparison of numbers and percentages of gray whale body condition for Laguna San Ignacio, BCS, Mexico during two time periods: 2008-2011 and 2018-2019.

Single whales							
Year	2008	2009	2010	2011	2018	2019	2020
No. whales Photo-identified	249	588	718	424	597	847	696
No. whales categorized	89	236	433	347	207	529	553
Good Condition n (%)	46 (51.7%)	119 (50.4%)	206 (47.6%)	221 (63.7%)	90 (43.5%)	117 (22.1%)	166 (33.3%)
Fair Condition n (%)	37 (41.6%)	99 (41.9%)	200 (46.2%)	109 (31.4%)	100 (48.3%)	287 (54.3%)	183 (36.7%)
Poor Condition n (%)	6 (6.7%)	18 (7.6%)	27 (6.2%)	17 (4.9%)	17 (8.2%)	125 (23.6%)	150 (30%)

Female and calf							
Year	2008	2009	2010	2011	2018	2019	2020
No. whales Photo-identified	112	79	38	188	86	41	56
No. whales categorized	79	70	31	176	80	40	54
Good Condition n (%)	52 (65.8%)	52 (74.3%)	30 (96.8%)	124 (70.5%)	35 (43.8%)	20 (50%)	38 (70.3%)
Fair Condition n (%)	27 (34.2%)	18 (25.7%)	1 (3.2%)	48 (27.3%)	43 (53.8%)	20 (50%)	13 (24.2%)
Poor Condition n (%)	0	0	0	4 (2.3%)	2 (2.5%)	0	3 (5.5%)

Body condition may influence female calving-interval; if they are in "good" condition at the time that they breed on the winter breeding grounds, they may have sufficient energy to migrate from the breeding grounds to the summer feeding grounds, feed all summer while pregnant, and make the return migration and successfully birth their calves in the following winter. However, if they do not feed sufficiently during the summer, the southward fall migration and gestation of a calf may deplete their energy reserves and reduce their body condition sufficiency that may not be able to bring their pregnancy to term and/or birth a healthy calf. If food resources are limited, reproducing females may not be able to produce a calf every other year as is the gray whales' normal reproductive cycle, and they may forgo reproduction for two or more years until they develop sufficient energy/condition reserves to accomplish their Fall and Spring migrations, and the birth and nurse of a calf in the winter (Ronzón-Contreras *et al.,* 2019, 2020). These possibilities would support the observed departures from the two year calving cycle for some gray whales.

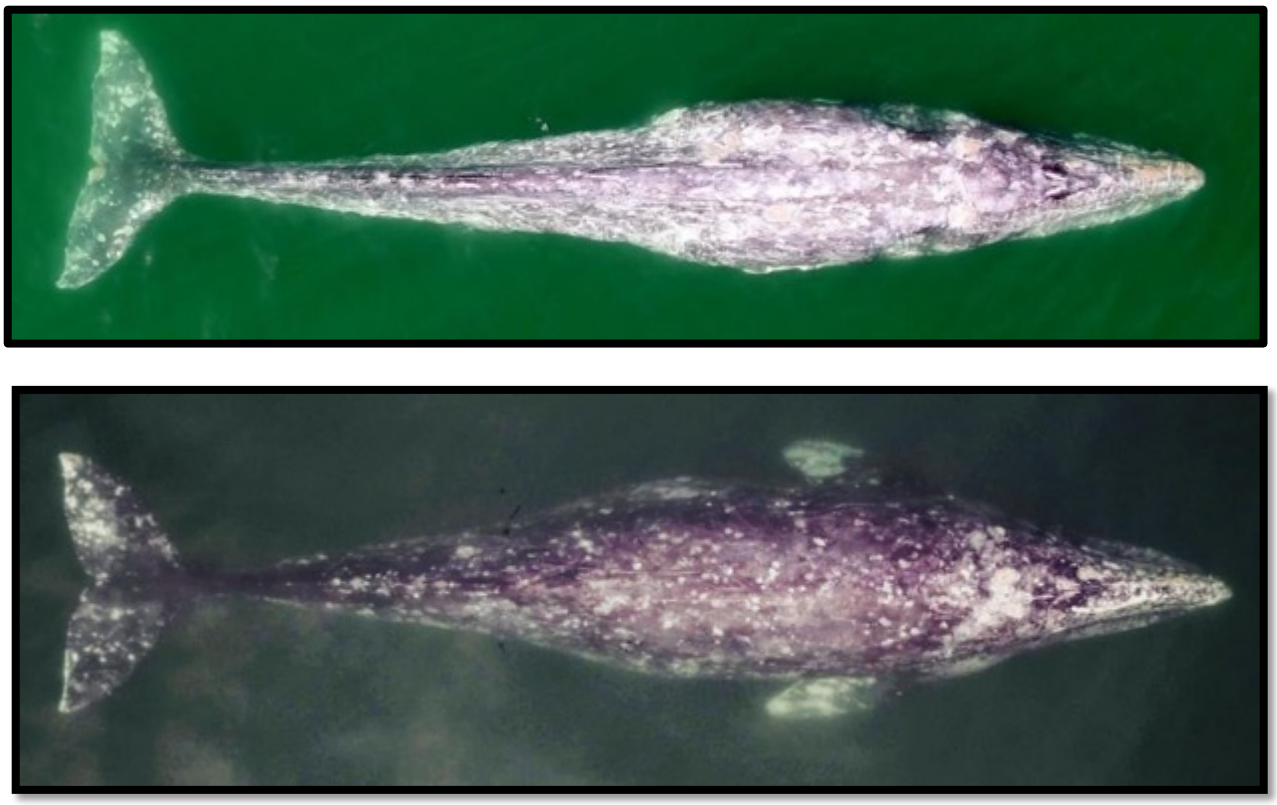


Figure 7. Example of a "skinny" or "flaca" gray whale (top), and a normal size gray whale (bottom) in Laguna San Ignacio.

Read the complete gray whale condition report presented to the International Whaling Commission's Scientific Committee IWC-SC/68B/CMP 14 & PowerPoint presentation on gray whale body condition in 2020 at: www.sanignaciograywhales.org/research/publications

==========

UAV-Drones Facilitate Evaluation of Gray Whale Body Condition, Growth, and Energetic Cost of Reproduction

Figure 8. LSIESP Drone pilot and researcher Fabian Missael Rodríguez González launches the UAV-Drone to photograph gray whales in Laguna San Ignacio in February 2020.

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 gray whale population (Christansen *et al.* 2018). Moreover in 2019 and again in 2020 the Eastern North Pacific gray whale population experienced an 'unusual mortality event' (UME), with 215 (2019) and 111 (as of May 12, 2020) whales found dead along the west coast of Mexico, the United States and Canada. We adapted the aerial photogrammetry methodology to measure the body volume of gray whales from Unmanned Aerial Vehicles (UAV) to evaluate body condition, and to determine if nutritional stress could be underlying the 2019 and 2020 unusual mortality events.

In 2020 a total of 285 UAV flights (80.15h) were conducted. Over the season we recorded 762 body condition measurements (Table 5). We identified 306 solitary individuals (animals with no calf), 35 were re-sighted on average 2±1 times (min=1, max 5) with an average of 5±1 days (min=1, max=17) between re-identifications. Moreover, 46 mother and

Table 5. UAV-Drone photogrammetric effort to document gray whale reproductive and body condition in Laguna San Ignacio during 2018 to 2020.

YEAR	2018	2019	2020
No. of flights	452	562	285
No. Hours	83.6	103	80
No. single whales	254	337	306
No. female-calf pairs	63	40	46

calf pairs were identified and 32 were re-sighted on average 3±1 times (min=1, max=6) with an average of 22±6 days (min=2, max=59) between re-sightings. Growth curves (body length and volume) will be determined for the calves through the breeding season to evaluate a "normal" healthy calf growth rate. Losses and gains in body volume of individual mothers will be

quantified to estimate the volume/energy conversion efficiency from females to calves, as well as maternal investment in their calves through the breeding season (Figs. 8 and 9).

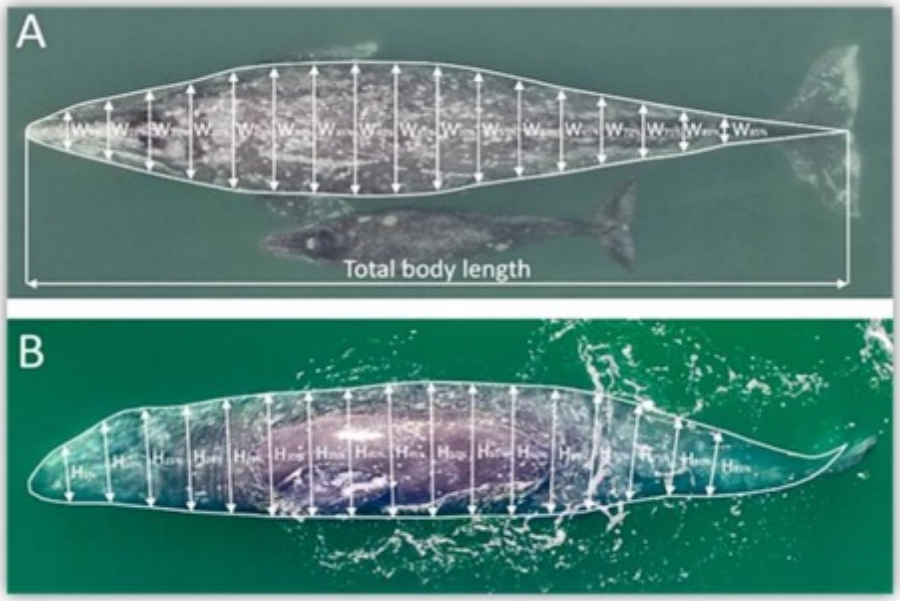


Figure 8. Examples of high definition photographs from UAV-Drone video cameras that are used to obtain precise measurements of gray whales. These photographs form the basis for estimating changes in body volume, mass, and reproductive condition of adult and calf gray whales.

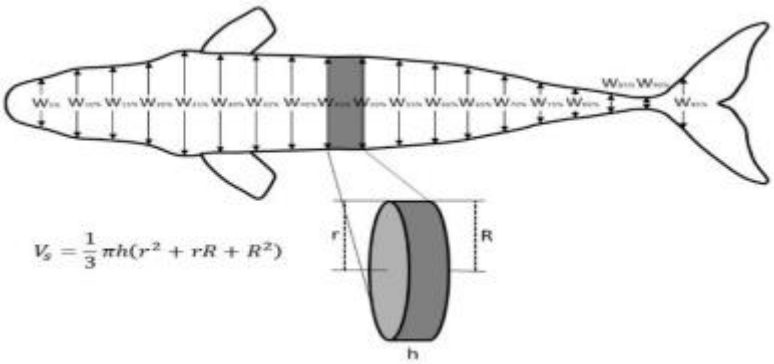


Figure 9. Method of estimating body volume from length and width measurements obtained by UAV-Drones for gray whales.

The preliminary analysis of the photogrammetric data collected during the 2017, 2018, and 2019 winter breeding seasons indicated that the whales' body condition varied between reproductive classes (calves, juveniles, adults and lactating females) and years (Fig. 10). At the beginning of the breeding season, lactating females had the highest body condition, followed by adults, juveniles and finally calves. We found a significant decline in the body condition of all reproductive classes in 2018 and 2019 compared to 2017. This coincides with lower number of

mother-calf pairs recorded by LSIESP in both 2018 and 2019, and the UME that started in 2019 and continues in 2020.

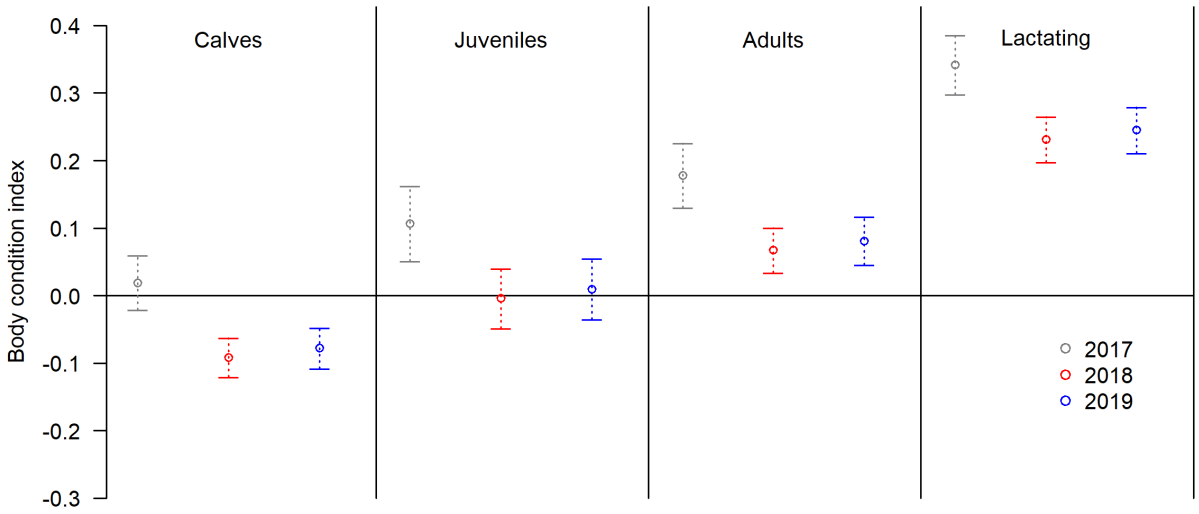


Figure 10. A comparison of calf, juvenile, adult and female gray whales measured in 2017, 2018, and 2019 was conducted in 2020, and the preliminary findings are reported in Christiansen et al. IN REVIEW.

Data for individual gray whales obtained from our long-term research program (40years) will allow us to investigate body condition and long-term reproductive history of known individual female whales using a combination of long-term boat-based photo-identification records and UAV identification photos 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 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 gray whales in 2018 and 2019, 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.

Further research will be directed at these temporal trends in condition for all age and sex classes of gray whales. For example, calves are expected to grow through the breeding season in Mexico, during which time they might also change their general body shape (relative body width to length), which could be masking yearly variations in body condition. Similarly, lactating females will lose considerable body fat/condition through the breeding season as nurse and their calves grow in size. To account for this, we will investigate the relationship between maternal body condition and calf length as they grow, and also test if this relationship differs between years. We will also investigate within-season variation in the body condition of juvenile and adult whales, to avoid potential sampling bias between years.

Read more about the gray whale UAV-Drone body and reproductive condition research, PowerPoint presentation, and Video on gray whale body condition research in Laguna San Ignacio in 2020 at: www.sanignaciograywhales.org/research/publications

and www.sanignaciograywhales.org/project/videos/

==========

Understanding Gray Whale Behavior and Underwater Acoustics

In 2018 Ph.D. candidate Ludovic Tenorio-Hallé, his major professor Dr. Aaron Thode of Scripps Institution of Oceanography, began their project to compare specific gray whale vocalizations with the whales' behavior and interactions during the winter months in Laguna San Ignacio. In 2019 researchers Héloïse Frouin-Mouy and Regina Lobo Barrera joined the acoustic team and continued gathering data to pair observations of gray whale behavior with simultaneous directional acoustic recordings. This research provides 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 under the direction Aaron Thode 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; monitor trends in the lagoon's dynamic acoustic environment; and study the vocal repertoire and behavior of gray whales in their breeding grounds.

For 2019 and 2020 the team conducted visual observations using UAV-Drones with HD-video cameras, and hydrophones to monitor whale behavior and record whale vocalizations. A waterproof UAV-Drone that was capable of landing on water was also used with a deployable-hanging hydrophone to make acoustic recordings of whales that were simultaneously being visually monitored using a second UAV-Drone with HD video cameras (Fig. 11).

Figure 11. The "Swell Pro - Splash Drone 3+" and "Sound Trap 300" hydrophone used to monitor and record gray whale behavior and vocalizations off of Punta Piedra in Laguna San Ignacio.

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.12).

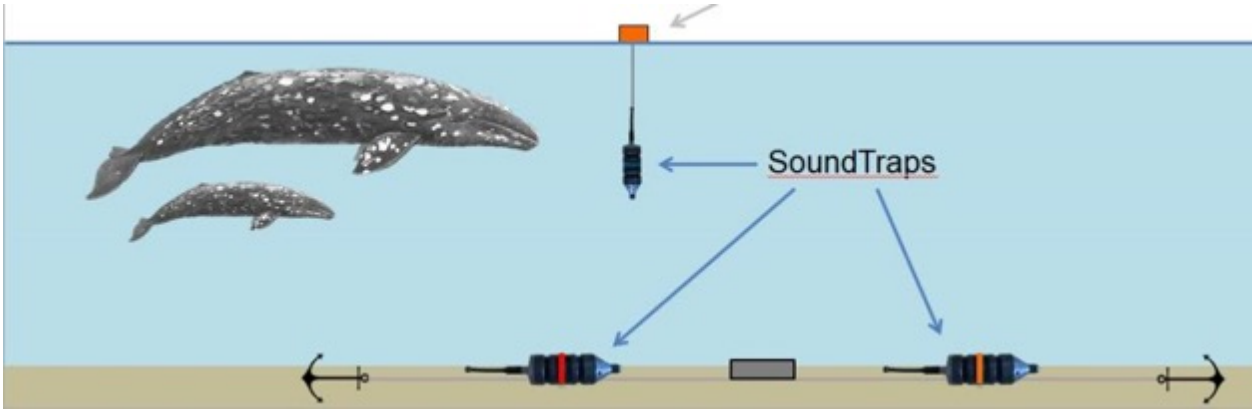
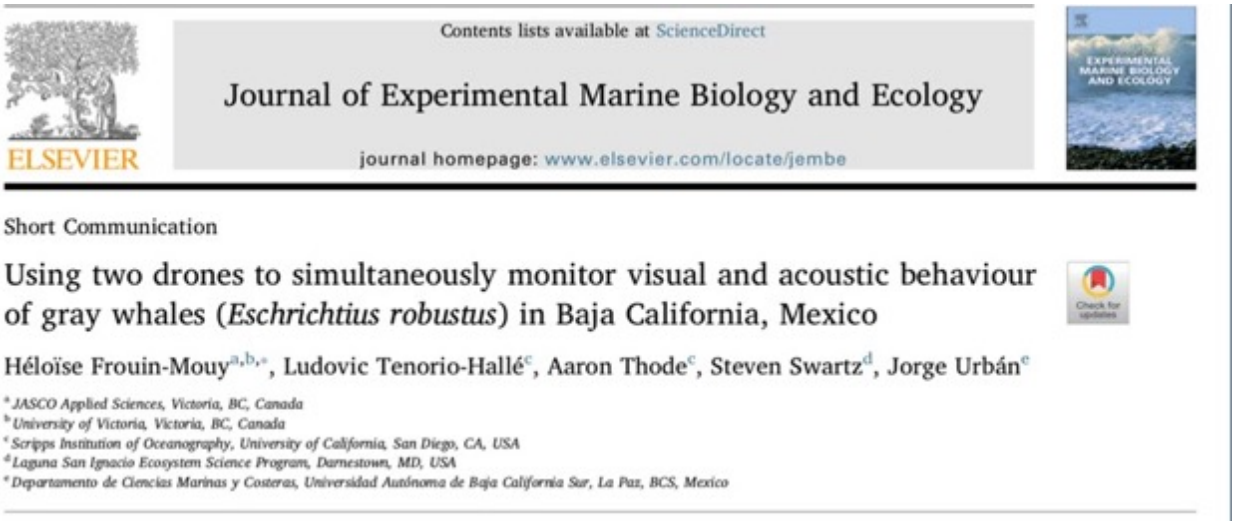


Figure 12. The orientation of hydrophone arrays to localize the source of whale calls in front of Punta Piedra in Laguna San Ignacio.

In 2019 Héloïse Frouin-Mouy and her colleagues published an article on the development and utility of their unique "dual drone" approach for studying gray whale behavior and sounds. The combination of directional acoustic arrays and UAV-drones to record underwater sounds and document surface behavior will ultimately provide insight into the context and meaning of gray whale vocalizations in the Laguna San Ignacio breeding lagoon.



Contents lists available at ScienceDirect

Journal of Experimental Marine Biology and Ecology

journal homepage: www.elsevier.com/locate/jembe

Short Communication

Using two drones to simultaneously monitor visual and acoustic behaviour of gray whales (*Eschrichtius robustus*) in Baja California, Mexico

Héloïse Frouin-Mouy[a,b,*], Ludovic Tenorio-Hallé[c], Aaron Thode[c], Steven Swartz[d], Jorge Urbán[e]

[a] JASCO Applied Sciences, Victoria, BC, Canada
[b] University of Victoria, Victoria, BC, Canada
[c] Scripps Institution of Oceanography, University of California, San Diego, CA, USA
[d] Laguna San Ignacio Ecosystem Science Program, Darnestown, MD, USA
[e] Departamento de Ciencias Marinas y Costeras, Universidad Autónoma de Baja California Sur, La Paz, BCS, Mexico

Read the entire report on paring gray whale acoustics and behavior at:
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 previous catalogs from 2005-2020 of gray whales photographed in Laguna San Ignacio (LSI), Laguna Ojo de Liebre (LOL), Bahía Magdalena (BM), 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/

Photo-ID 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 LSI during the 2020 winter included 251-survey hours over 50-days. A total of 9,717 digital images that yielded 489 sightings of 696-individual whales. These included 639-single whales what averaged 6.7-days in the lagoon (range 1 to 44-days), and 57-females with calves that averaged 22.9-days in the lagoon (range 1 to 62-days) (Table 6).

Table 6. 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	50	35
No. Effort Hours	252	368
No. Images	9,717	5,458
No. Sightings	489	215
No. Individual Whales	696	721
No. Single whales	639	696
Single whales' mean days in area	6.7 (1-44)	5 (1-28)
No. Female-calf pairs	57	25
Female-calf pairs' mean days in area	22.9 (1-62)	18 (1-43)

Bahía Magdalena Complex: Researchers working in the BM region in 2020 obtained 5,458 digital images from 215-sightings of gray whales during 35-days and 368-hours of observations in. From these images, 721-individual whales were identified (696-single whales and 25-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 18-days for female-calf pairs (range 1-43 days), and 5-days for single whales (range 1-28 days).

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 2005-2020 (LSIESP). Seventeen females from the earliest time period (1977-1982) were photographically matched (recaptured) in recent years, and their estimated minimum age was revised to range from 26 to 50 years (Martinez *et al. In Press*).

Figure 13. 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. 13), 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

==========

Community Outreach and Education

LSIESP's outreach and education activities continued in 2020 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 support 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 on February 29, 2020 continued to be well attended (over 100

people in 2020). Presentations included: The Gray Whale Unusual Mortality Event of 2019-2020, Trends of Gray Whale Abundance in the lagoon, the increase of "Skinny" whales, Evaluating Condition with UAV-Drones, the Acoustic-Behavior paring project, and Monitoring the Presence of Sealions in the lagoon (Fig. 14).

View all of the 2020 Reunion PowerPoint presentations at:
www.sanignaciograywhales.org/research/publications

Figure 14. The 2 March 2020 "Community Reunion" at the Kuyimita Camp Palapa.

Several student groups from Mexican (*e.g.,* UABCS on February 28-March 2nd, and from March 9th to 12th) and other universities (*e.g.,* University of Zurich from 2-8 February) visited LSIESP's "Francisco 'Pachico' Mayoral" Field Research Laboratory where they received lectures and instruction from LSIESP researchers. Presentation topics included: marine mammals, vertebrate biology, natural history, desert ecology, and marine protected area conservation and management (Fig. 15). The LSIESP research program also contributed information to public and private science and education organizations (*e.g.,* the Langley Whale Center Pacific Northwest, International Whaling Commission's Scientific Committee, El Vizcaíno Biosphere Reserve in Baja California, etc.).

Figure 15.UABCS University students receive a lecture from LSIESP Co-Director Dr. Steven Swartz a the Francisco "Pachico" Mayoral Field Laboratory at Laguna San Ignacio.

Academic Training

Training the next generation of wildlife scientists and conservationists continues as part of our mission. Student researchers participating in LSIESP are supported while working to complete their thesis research. Many of our student-researchers have completed Ph.D. degrees, Master's degrees, and undergraduate theses. Our researchers submitted three scientific papers to the 2020 meeting of the International Whaling Commission's Scientific Committee, and seven abstracts for papers and posters to the World Marine Mammal Conference held in Barcelona, Spain in December 2019. Special thanks to our supporters that contributed travel funds to get our researchers to the World Marine Mammal Conference to present their research findings. You may read all our student's theses and published research findings on our website.

Visit our website at www.sanignaciograywhales.org/research/publications/ to view and read all of the reports and findings resulting from the 2020 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!

Now more than ever there is a need to continue monitoring gray whales during the winter in the Baja lagoons. Determining the impact of the UME and (hopefully) tracking the recovery of the whales will require gathering as much information as possible during the coming winters to document the conditions of the whales following their summer feeding, their abundance, and the number of calf births. This information will help scientists and the public understand what is happing to the gray whales, and hopefully identify environmental and other factors that may contribute to these increases in mortality.

Please consider supporting the gray whale research and our student researchers in Baja California by becoming a "recurring donor" to make regular contributions to our project. It is easy and safe to do on line! Please visit our donation website:

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. Rodríguez-González, F., Martínez-Aguilar, S., Urbán, J., Swartz, S.L., Warick, H., Vivier, F., and Bejder, L (*In Review*). Poor body condition explains unusual mortality event in gray whales. Marine Ecological Progress Series.

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.

Frouin-Mouy, H., Tenorio-Hallé, L., Thode, A., Swartz, S., and Urban, J. 2020. Using two drones to simultaneously monitor visual and acoustic behavior of gray whales (*Eschrichtius robustus*) in Baja California, México. Journal of Experimental Marine Biology and Ecology, 525 (2020) 151321.

Gulland, F.M.D., Pérez-Cortéz M., H., Urbán R., J., Rojas-Bracho, L., Ylitalo, G., Weir, J., Norman, S.A., Muto, M.M., Rugh, D.J., Kreuder, C., and Rowles, T. 2005. Eastern North Pacific gray whales (Eschrichtius robustus) unusual mortality event, 1999-2000. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-150, 33 pp.

Jones, M.L. and Swartz, S.L. 1984. Demography and phenology of gray whales and evaluation of whale-watching activities in Laguna San Ignacio, Baja California Sur, Mexico. In: Jones, M.L., Swartz, S.L. and Leatherwood, S. (eds.) *The gray whale, Eschrichtius robustus*. Academic Press, Inc., Orlando, Florida, pp. 309-374

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.

Laake, J., Punt, A., Hobbs, R., Ferguson, M., Rugh, D., and Breiwick, J. 2009. Re-analysis of gray whale southbound migration surveys 1967-2006. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-203.

Martínez, A. S., 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-Aguilar, S., Casanovas-Gamba, P., Farriols-García, M., González-Cisneros, A., Heaven, J.D., Castillo-Romero, F., Zaragoza-Aguilar, G.A., Rivera-Rodríguez, J., Mariano-Meléndez, E., López-Paz, N., Swartz, S.L., Viloria-Gómora, L., and Urbán R. J. 2020. Gray whale´s stranding records in México during the breeding season in 2020. Rep. Intl. Whal. Commn., SC/68B/CMP 13.

NOAA. 2020. 2019-2020 Gray Whale Unusual Mortality Event along the West Coast and Alaska: **https://www.fisheries.noaa.gov/national/marine-life-distress/2019-2020-gray-whale-unusual-mortality-event-along-west-coast-and**

Punt, A. and Wade, P.R. 2009. Population status of the Eastern North Pacific stock of gray whales in 2009. Rep. Intl. Whal. Commn. SC/62A/ WMP 02.

Ronzón-Contreras, F., Martínez-Aguilar, S., Swartz, S., Calderon-Yañez, and Urbán R., J. 2019. Gray whales' body condition in Laguna San Ignacio, B.C.S., México during the 2019 breeding season. Rep. Intl. Whal. Commn., SC/68A/CMP 13.

Ronzón-Contreras, F., Martínez-Aguilar, S., Swartz, S., Calderon-Yañez, and Urbán R., J. 2020. Gray whales' body condition in Laguna San Ignacio, B.C.S., México during the 2020 breeding season. Rep. Intl. Whal. Commn., SC/68B/CMP 14 Rev1.

Salvadeo, C.J., Gómez-Gallardo, González S. A., Nájera-Cabellero, M., Urbán , J.R., and Lluch-Belda, D. 2015. The effect of climate variability on gray whales (*Eschrichtius robustus*) within their wintering areas. PLoS ONE, 10(8); e.0134655, doi;10.1371/journal.pone0134655. 17 pp.

Urbán, J. R., Swartz, S.L., Gómez-Gallardo U., A., and Rojas-Bracho, L. 2011. Report of the gray whales censuses in San Ignacio and Ojo de Liebre breeding lagoons, Mexico. Rep. Intl. Whal. Commn. SC/62/BRG15.

Urbán J.R., Swartz, S., A. Gómez-Gallardo U, S. Martínez A., and H. Rosales N. 2015. Report of the 2015 gray whale research in Laguna San Ignacio and Bahia Magdalena, Mexico. Rep. Intl. Whal. Commn. SC/66a/BRG21, 12 pp.

Urbán J.R., Swartz, S., A. Gómez-Gallardo U, S. Martínez A., and H. Rosales N. 2016. 2016 gray whale research in Laguna San Ignacio and Bahia Magdalena, Mexico. Rep. Intl. Whal. Commn. SC/67a/BRG19, 15 pp.

Urbán J.R., Swartz, S., A. Gómez-Gallardo U, S. Martínez A., and H. Rosales N. 2017. 2017 gray whale research in Laguna San Ignacio and Bahia Magdalena, Mexico. Rep. Intl. Whal. Commn. SC/67A/CMP/11, 16 pp.

Urbán, R.,J., Swartz, S.L., Martínez A., S., Viloria G., L., and Ronzón-Contreras, F. 2019. 2019 Gray whale abundance in Laguna San Ignacio and Bahía Magdalena Baja California Sur, México. Rep. Intl. Whal. Commn. SC/68A/CMP/12 Rev 1.

Urbán, R.,J., Swartz, S.L., Martínez A., S., Viloria G., L., and Gómez-Gallardo U., A. 2018. 2018 Gray whale abundance in Laguna San Ignacio and Bahía Magdalena, México. Rep. Intl. Whal. Commn. SC/67B/CMP/09.