

MOVEMENTS OF GRAY WHALES AMONG THE CALVING AND BREEDING LAGOONS IN THE BAJA CALIFORNIA PENINSULA.

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ABSTRACT

Naturally occurring markings on the skin of gray whales and photographic identification and analysis methods were used to determine the number of whales that traveled between their breeding and calving lagoons and aggregation areas along the west coast of Baja California Peninsula, in Mexico. From 1,942 individual whales photographed during the 2012 and 2013 winters, 56 photographic matches or recaptures during the same year were found between the three primary winter aggregation areas of Bahía Magdalena, Laguna San Ignacio and Laguna Ojo de Liebre (also known as Scammon's lagoon). These recaptures included 40 female-calf pairs and 16 single whales (i.e., adult whales without calves). Of these recaptures, 80.4% were between Bahía Magdalena and Laguna San Ignacio, 16% were between Laguna Ojo de Liebre and Laguna San Ignacio, and 3.6% were between Bahía Magdalena and Laguna Ojo de liebre.

KEYWORDS: GRAY WHALE, BREEDING LAGOONS, MOVEMENTS, BAJA CALIFORNIA, PHOTO ID.

INTRODUCTION

Individual recognition of animals based on their natural markings is an important tool for the study of many cetacean species. Photographic identification is a non-invasive technique that utilizes natural markings which allows repeated identification of individual whales. The comparison of photographs taken in different areas of a species range provides information on social structure, migration routes, and abundance for many whale populations.

Photographic identification based research on gray whale have documented: fidelity to feeding areas in the Western North Pacific (Weller *et al.*, 1999), the interchange of individual whales between two feeding areas in the Northwest Pacific (Tyurneva *et al.*, 2010; Burdin *et al.*, 2011), fidelity to breeding and calving lagoons (Swartz and Jones 1983, 1984; Urbán and Gomez-Gallardo 2000), estimation of female calving interval (Jones 1990), and the estimation of minimum residence time within a winter breeding lagoon and aggregation area (Urbán *et al.*, 1999).

Jones and Swartz (1984, and unpublished data), used photo-identification methods to compare photographs of individual whales taken between 1977 and 1982 from Bahía Magdalena, Laguna San Ignacio, Laguna Ojo de Liebre and Laguna Guerrero Negro. They found 18 recaptures among these four breeding and calving lagoons, of which 15 were female-calf pairs, two were males and one of a whale with unidentified sex. Seventeen of the recaptures occurred between Laguna San Ignacio and other areas: 10 with Bahía Magdalena, four with Laguna Ojo de Liebre, and three with Laguna Guerrero Negro. One recapture was between Bahía Magdalena and Laguna Guerrero Negro. It is important to mention that only four of these recaptures occurred during the same year.

Here we report the results of photographic identification research in Laguna San Ignacio, Laguna Ojo de Liebre and Bahía Magdalena during the 2012 and 2013 winters that demonstrates gray whales movements between these three main breeding and calving grounds on the west coast of the Baja California Peninsula, México (Figure 1).

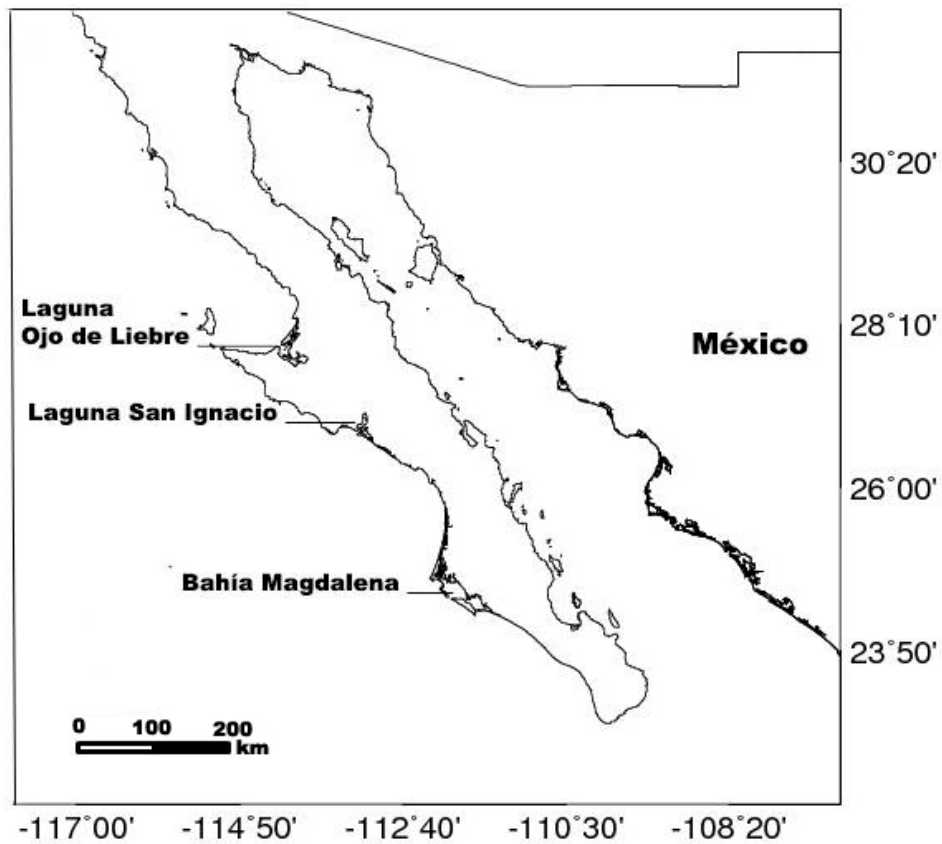


Figure 1. Gray whale breeding and calving grounds in the west coast of the Baja California Peninsula, México.

METHODS

Gray whales were photographed from a 25 foot long boat (panga), in Laguna San Ignacio and Bahia Magdalena during the 2012 and 2013 winters, and in Laguna Ojo de Liebre only during the winter of 2013. Additional information collected with each whale sighting included: weather conditions (i.e., cloud cover, visibility, wind speed and Beaufort sea state), geographical position (i.e., latitude and longitude) from a hand-held GPS unit, and characteristics of the gray whale groups (i.e., number of whales, presence of calves, and behavior). Photographs were taken in the field with digital SLR cameras equipped with 70-300 mm telephoto lenses. Digital images were stored and archived in high resolution JPEG format. In the laboratory, the best images of each whale's left and right sides were selected and matched using the "ACDSee 2.5" photographic editing software program.

Each individually identified whale was assigned an identification number that included the year the photograph was taken, followed by a four consecutive digit serial number, the initials of the location that the whale was photographed (i.e., BM-Bahia Magdalena, LSI - Laguna San Ignacio and LOL - Laguna Ojo de Liebre), and the letter "M" if the whale was a female accompanied by a calf. These photographs were then assembled into catalogs of individual whales for each year and location.

Catalogs containing images from Bahia Magdalena, Laguna San Ignacio, and Laguna Ojo de Liebre were compared, and photographic matches or recaptures of whales noted were used to determine movements between these three breeding and calving areas.

RESULTS

During the 2012 winter (mid-January to early-April), 64 days were spent photographing gray whales in Laguna San Ignacio, and 18 days in Bahia Magdalena. In total, 941 individual whales were photographed: 669 adults in Laguna San Ignacio (235 females with calves and 434 single adult whales); and 272 individual whales in Bahia Magdalena (41 females with calves and 231 single adult whales). During the 2013 winter, photographs were taken on 57 days in Laguna San Ignacio, on 28 days in Bahia Magdalena, and on 11 days in Laguna Ojo de Liebre. Photographs of 1,001 individual whales were obtained: 554 whales in Laguna San Ignacio (192 female-calf pairs and 362 single adult whales), 333 whales in Bahia Magdalena (45 female-calf pairs and 288 single adult whales), and 114 whales in Laguna Ojo de Liebre (110 female-calf pairs and 4 single adult whales) (Table 1).

Bahía Magdalena and Laguna San Ignacio 2012.

Comparison of photographs taken in 2102 in Laguna San Ignacio and Bahia Magdalena yielded 15 recaptures between these two lagoons. Of these, 10 recaptures represented 24.4% of the female calf pairs photographed in Bahia Magdalena, and 4.2% of the female-calf pairs photographed in Laguna San Ignacio (Table 2). Five recaptures of single adult whales were made

between these two areas, and represented 2.1% of the single whales photographed in Bahia Magdalena and 1.1% of the single whales photographed in Laguna San Ignacio. It is important to note all of these recaptures were of whales that were first photographed in Bahia Magdalena and then re-photographed at a later date in Laguna San Ignacio. The number of days between the last sighting of a whale photographed in Bahia Magdalena and its first sighting in Laguna San Ignacio ranged between 7 and 42 days with an average of 21.6 days (Table 2).

Table 1. Gray whale photo-identification effort, made during 2012 and 2013, for each breeding and calving ground.

Year	Locality	Survey (days)	Survey (hours)	Number of sightings	# Single whales	# Female Calf pair	# Whales
2012	LSI	64	359.3	863	434	235	669
2012	BM	18	115.4	146	231	41	272
2013	LSI	57	290	607	362	192	554
2013	LOL	11	49.2	110	4	110	114
2013	BM	28	232.1	143	288	45	333

Table 2. Recaptures between gray whale breeding and calving lagoons in Baja California, Mexico during 2012 – 2013.

Calving and breeding grounds	Female calf pair	Single whales
Laguna San Ignacio - Bahía Magdalena (2012)	10	5
Laguna San Ignacio - Bahía Magdalena (2013)	19	11
Laguna San Ignacio - Laguna Ojo de Liebre (2013)	9	0
Laguna Ojo de Liebre- Bahía Magdalena (2013)	2	0

Bahía Magdalena and Laguna San Ignacio 2013.

In 2013, 30 photographic matches or recaptures were made between Bahia Magdalena and Laguna San Ignacio. These included 19 female-calf pairs, representing 42.2% of the female-calf pairs photographed in Bahia Magdalena and 9.8 % of the female-calf pairs photographed in Laguna San Ignacio. There were 11 recaptures of single adult whales representing 3.8% of the single whales photographed in Bahia Magdalena, and 3% of the single whales photographed in Laguna San Ignacio (Table 2).

As was observed with the 2012 photographs, most of the recaptured whales (28 out of 30), were photographed in Bahia Magdalena first and then subsequently re-photographed in Laguna San

Ignacio. However, in 2013 there were two female whales with calves that were photographed for the first time in Laguna San Ignacio, then photographed in Bahia Magdalena, and finally re-photographed for the third time inside Laguna San Ignacio. The number of days between the first and last sightings of these whales was 7 and 17 days for the first female (13-0383-D-LSI-M) and 32 and 29 days for the second female (13-0397-D-LSI-M). These females and their calves first moved south from Laguna San Ignacio to Bahia Magdalena, and then returned to Laguna San Ignacio.

For the 30 recaptured whales, the number of days between the last sighting in Bahia Magdalena and their first in Laguna San Ignacio ranged from 7 to 70 days with an average of 22 days.

Laguna San Ignacio and Laguna Ojo de Liebre 2013.

There were 9 recaptures of female-calf pairs between Laguna San Ignacio and Laguna Ojo de Liebre identified in the 2013 photographs. These represented 4.6% of the female-calf pairs photographed in Laguna San Ignacio, and 8.1% of the female-calf pairs photographed in Laguna Ojo de Liebre. The number of days between the last sighting of these whales in Laguna San Ignacio and their first sighting in Laguna Ojo de Liebre ranged from 10 to 39 days with an average of 22 days (Table 2).

Bahía Magdalena y Laguna Ojo de Liebre 2013.

Comparison of 2013 photographs from Bahia Magdalena and Laguna Ojo de Liebre yielded only two matches or recaptures of female-calf pairs. These represented 4.4% of the female-calf pairs photographed in Bahia Magdalena and 1.8% of the female-calf pairs photographed in Laguna Ojo de Liebre. The number of days between these recaptures was 35 and 36 days. However, these two female whales were also photographed in Laguna San Ignacio in 2013, indicating that these female whales were present in all three breeding and calving lagoons during that winter.

The female-calf pair (13-0528-D-LSI-M) was first seen in Bahia Magdalena on 8 March 2013, re-photographed 15 days later in Laguna San Ignacio, and finally photographed again 20 days later in Laguna Ojo de Liebre. The second female-calf pair (13-0367-D-LSI-M), was also first seen in Bahia Magdalena on 15 March 2013, then photographed 23 days later in Laguna San Ignacio, and finally photographed again 13 days later in Laguna Ojo de Liebre. This documents the progressive northward movements of these females and their calves from the southern-most Bahia Magdalena area to the northern-most breeding lagoon of Ojo de Liebre over the periods of 35 to 36 days.

To determine if the whale movements are homogeneous between the three breeding and calving lagoons, a χ^2 test was undertaken on the 2013 photographic recapture data. The test was statistically significant (χ^2 2.65, $df = 2$, $p < 0.000001$), which demonstrates that the probability of photographic recaptures between lagoon aggregation areas is different in every case, and the movement of whales between these areas is heterogeneous (Table 3).

Table 3. χ^2 , Test to recapture from 2013.

Breeding and calving grounds	Number of photo-ids comparisons	Proportion	observed recaptures	expected recaptures	χ^2
LSI - LOL	63,156	0.221	9	9.06	0.0003
LSI - BM	184,482	0.646	30	26.48	0.4679
LOL - BM	37,962	0.133	2	5.45	2.1839
Total	285,600	1.000	41	41	2.6521
χ^2 2.65 $df = 2$ $p < 0.000001$					

DISCUSSION

The 2012 and 2013 photographic identification results demonstrate a greater amount of movement between different breeding and calving lagoons for female-calf pairs than for single adult whales. This could be the result of the difference between residence times within the lagoons for female-calf pairs and single adult whales (male or female), and the specific activities that these groups are engaged in within the breeding and calving lagoons (e.g., mating versus caring for a newborn calf). However, the differences between sampling times and effort at these different locations make it difficult to confirm this assumption.

The mid-March and early-April movements of whales from southern areas to northern areas during the same year (from Bahia Magdalena to Laguna San Ignacio, and from Laguna San Ignacio to Laguna Ojo de Liebre) suggest that gray whale females seek refuge within the coastal lagoons during their northward spring migrations with their calves. However, some north-to-south movements were also observed in 2013, similar to movements of gray whales between the three primary breeding and calving lagoons documented by Jones and Swartz (1984). Moreover, the results of the test χ^2 , for 2013 data, and the records of some whales photographed in two breeding and calving lagoons in different years between 2001 and 2011 (unpublished data), indicate that the gray whale movements between aggregation areas is heterogeneous. These findings confirm that gray whales circulate among the coastal lagoons and aggregation areas along the Pacific coast of Baja California during the winter.

To determine if individual gray whales return to specific breeding and calving lagoons, if there is fidelity to certain sub-regions, or if there some areas are used randomly or in succession, an increase in the photographic sampling time and effort will be required in Bahia Magdalena and Laguna Ojo de Liebre, along with the continuation of photographic sampling in Laguna San Ignacio. The Laguna San Ignacio Ecosystem Science Program has conducted photographic identification in Laguna San Ignacio from 2006 to the present, and these data are available for comparison with photographs from Bahia Magdalena and Laguna Ojo de Liebre to better understand the interchange between the three breeding and calving lagoons.

ACKNOWLEDGEMENTS

Tabata Olavarrieta, Jessica Robles, Constanza Torres y Paulette Durazo, who assisted with the field work, and compared the photographic images for matches and recaptures. We thank The Ocean Foundation, the World Wildlife Fund-Telcel Alliance, and Exportadora de Sal S.A. for their support of this research. This research was conducted under scientific permits SGPA/DGVS/00640/12, and SGPA/DGVS/00611/13 from the Subsecretaría de Gestión para la Protección Ambiental, Dirección General de Vida Silvestre, de Mexico.

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