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Photo-identification of gray whales in Bahia Magdalena, Baja California Sur: The use of a student-base photographic archive.

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ABSTRACT

Photographs of grey whales have been collected by students of the School for Field Studies in Puerto San Carlos, B.C.S., Mexico, since 1998. We evaluated the utility of this student-based photographic archive as a tool to identify gray whale individuals and to characterize injuries over the whale's bodies. A total of 278 individual were identified, several were re-sighted within years; however, none were re-sighted between years. The dorsal area was the most commonly photographed body region; however, photographs of the flukes proved to be useful for photographic identification as well. 6.8% of the whales photographed had injuries; most of them were big scratches followed missing tips of the flukes. Our results indicate that a well managed student-based cetacean photographic archive could easily and economically apply for short-term movement patterns investigations and for monitoring the occurrence injuries from anthropogenic interactions.

Key words: photographic identification, Bahia Magdalena, gray whales, student-based archive.

RESUMEN

Fotografías de individuos de ballena gris han sido almacenadas en un catalogo estudiantil por la Escuela de Estudios de Campo The School for Field Studies en Puerto San Carlos, B.C.S., México, desde 1998. Evaluamos la utilidad de este catalogo fotográfico como una herramienta para identificar a los individuos de ballena gris y caracterizar las heridas sobre los cuerpos de las mismas. Un total de 278 individuos fueron identificados, muchos individuos fueron observados en la misma temporada en diferentes días, sin embargo ningún individuo fue fotografiado y/o identificado en diferentes años. La parte dorsal de las ballenas fue la región más fotografiada, sin embargo, las fotografías de las aletas caudales también demostraron ser útiles para la identificación de individuos. Aproximadamente el 6.8% de las ballenas fotografiadas tenían heridas; la mayoría de estas heridas consistieron de rasguños en la piel así como la falta de puntas en las aletas caudales y algunas lesiones de origen antropogénico. Nuestros resultados indicarón que un catalogo estudiantil de fotografías de cetáceos podría ser una alternativa económica y viable para investigaciones de patrones de movimientos a corto plazo (en una misma temporada) y el monitoreo de las lesiones causadas por interacciones con humanos.

Palabras claves: identificación fotográfica, Bahía Magdalena, ballenas grises, archivo estudiante-basado.

Grey whales (*Eschrichtius robustus*) are probably the most primitive of the living baleen whales (Bonner, 1989). They are sufficiently distinctive relative to other cetaceans to be placed in their own family, the Eschrichtiidae (Reeves et al. 2002), although it has been suggested that they are closely related to the rorquals (*balaenopterids*) (Sasaki et al. 2005). Gray whales were once distributed in both the North Pacific and the North Atlantic oceans (Swartz et al. 2006). However, due to intense whaling, they were nearly brought to extinction in the 1900s (Dedina and Young, 1995); today they are only found in the North Pacific (Mead and Mitchell, 1984) where two genetically and geographically isolated populations exist: the eastern North Pacific and western North Pacific (LeDuc *et al.* 2002). Eastern North Pacific gray whales seem to have recovered from commercial whaling (Rugh *et al.* 2005) while the western population remains critically depleted (Buckland and Breiwick, 2002).

In Mexico, the eastern North Pacific gray whales congregate along the Pacific coast of Baja California during their winter breeding season, where they aggregate for calving in Laguna Ojo de Liebre and Guerrero Negro, Laguna San Ignacio, and the Bahia Magdalena Lagoon Complex (BMLC) (Alter *et al.* 2009). Current threats for gray whales in Mexican waters include mortality associated with entanglement in passive fishing gear, ship strikes and coastal development. However, in Mexico, conservation efforts to protect this species include legal (e.g. NOM-59-ECOL-2001) and habitat protection (i.e. Vizcaino Biosphere Reserve) as well as scientific research regarding gray whale reproductive behavior, abundance, distribution and feeding ecology (e.g. Jones 1990; Pérez-Cortés, 2004; Caraveo-Patiño and Soto, 2005). These investigations have contributed valuable information about the importance of their coastal lagoon habitats to their reproductive success (see Urbán *et al.* 2003).

Photo-identification is one of the methods that has been used to investigate gray whales because it can be used to study a variety of characteristics, including: group composition, individual 'fidelity' to an area of distribution, short-term movement patterns, migrations, and population size (Würsig and Jefferson, 1990). This technique can be reliably used for long-term gray whale population studies due to the fact that markings on the mottled skin of gray whales may persist for at least 11 years (Darling, 1984). Gray whale markings may include natural pigmentation and extensive scarring from dead barnacles, predator attacks (e.g. killer whales), rubbing on the ocean floor or even from anthropogenic interactions (Bradford et al. 2009). In Mexico the analyses of the photographic records has been used to evaluate abundance, range and movements of gray whales in Laguna San Ignacio (e.g. Jones and Swartz, 1984; Urban *et al.* 2003). These investigations have provided evidence that some female individuals display long-term fidelity to some lagoons (Jones, 1990) although gray whales also may move between lagoons (Urban *et al.* 2003). Photo-identification data from other lagoons are in the process of being analyzed, although results are still unavailable (Alter et al. 2009).

In the BMLC, the distribution and abundance of gray whales have been studied sporadically in the last 30 years (e.g. Norris et al. 1983; Fleischer and Contreras, 1986; Gardner and Chávez-Rosales, 2000; Pérez-Cortés et al. 2004). These studies have provided some information that could contribute to the development of effective management plans for the area. For example, it has been suggested that different areas of the lagoon complex may be used by gray whales in different ways (Pérez-Cortés *et al.* 2004), and that whales may be more abundant in colder years (Gardner and Chavez-Rosales, 2000). However, there are still many research needs that could be addressed, in part, through photographic identification investigations (Urbán *et al.* 2003).

The School for Field Studies Mexico (SFSM) holds an extensive gray whale photographic archive that has been collected as part of their educational/academic activities in the last 12 years. The school is part of

a non-profit study abroad program from the United States, located in the town of Puerto San Carlos in Bahia Magdalena, where every year students and staff members have had the opportunity to collect hundreds of gray whale photographs. Consequently, this photographic archive may enable researchers to compile accurate data on, for example, population size, distribution and short-term movement patterns of gray whales. Thus, the aim of this study is to evaluate the utility of this student based photographic archive as a tool to identify individual whales that may show fidelity to Bahia Magdalena and to evaluate the body condition of gray whales in Bahia Magdalena based on the frequency and type on injuries that may be observed in the photographs.

METHODS

Study Area

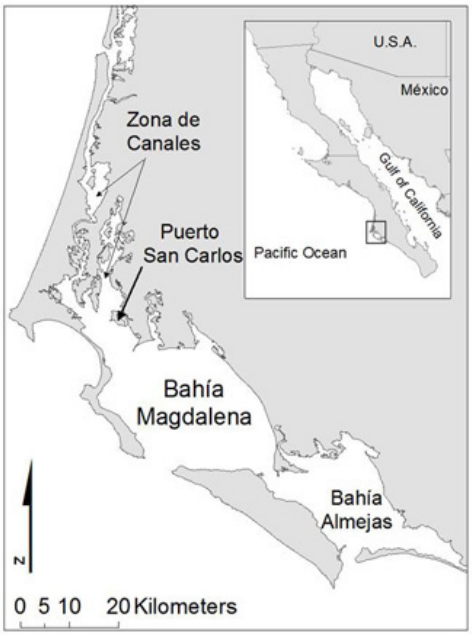
The Bahia Magdalena Lagoon Complex (BMLC) is an extremely biologically productive and diverse embayment at the Pacific Coast in Baja California Sur, Mexico (Bizzarro 2008). The BLMC is composed of three main areas: Zona de Canales, Bahia Magdalena, and Bahia Almejas (Fig. 1). This study was conducted only in Bahia Magdalena, which is located between 24°20'N-25°20'N and 111°30'W-112°10'W. The bay is roughly 31 km long and 22 km wide, connecting to the Pacific Ocean through a 6 km wide mouth, which is found between Isla Magdalena in the west and Isla Margarita in the southeast (Perez-Cortez *et al.* 2004). In general the bay has higher temperatures and salinity levels compared to the Pacific Ocean (Gardner & Chavez-Rosales 2000). Bahia Magdalena is one of the main wintering grounds of gray whales in the Baja California peninsula (Rice *et al.* 1981). In this bay, single whales occur in a much higher proportion than mother-calf pairs and up to 80 whale individuals can be observed in just one day during the peak of the breeding season (Pérez-Cortés *et al.* 2004).

Figure 1. Map of the Bahia Magdalena Lagoon Complex. Inset: map of the Baja California peninsula depicts the location of the study area.

Photographic collection

The present study is based on photographs taken by students and staff of the SFSM in the years 1998, 1999, 2004, 2005, 2007, 2009 and 2010. Therefore, a variety of cameras were used; although it was very common that photographers utilized cameras with variable focal length (zoom) lenses, which enable them to photograph whales that were close to or far away from the boats. The management of the photographic archive was mainly conducted by the students and in general the only information available for each photograph was the date on which it was taken.

The vessels used throughout the field work were 8-9 m fiberglass boats outfitted with 115 hp engines. Small boats (<10m) are best for photo-identification because they are more maneuverable and allow for a low angle for the photos. Filed work was only conducted under favorable weather conditions (Beaufort scale < 2); for safety purposes and to improve photograph quality. Fast speeds of boats were avoided because they cause spray and can cause the animals to change their behavior (Würsig and Jefferson, 1990). Since the photographs were taken by many students, who were directed by different staff members throughout the years; there was not a standardized method to photograph whales. In general we collected photographs from head to fluke. Thus, photographs included both sides of the flanks and heads as well as the flukes. However, not all of those body regions were photographed for each individual. Photographs were stored in a computer and organized by year and labeled with the date.



Photograph Quality

Each photo was graded using a scoring matrix in order to determine which pictures were suitable for individual identification (Table 1). The photos were also cropped to retain only the whale subject within the frame. This saves computer memory space and allows the photos to load faster on the computer. Photographs with a total grade of 12 or more were discarded because they were useless for individual identification purposes. When possible, the total number of photos taken and the number of those retained was recorded.

Score	1	2	3	4	5
% photo that is whale	10-8	8-6	6-3	3-1	1-0
% whale in photo	20+	19-15	14-10	9-5	4-0
Angle of the whale	0	10-30	30-50	50-70	70-90
Photo conditions	excellent	good	fair	poor	very poor
Photo quality	clear	blurry, all marks visible	blurry, some marks visible	blurry, only distinguishing marks visible	blurry, marks cannot be distinguished

Table 1. Photo scoring matrix, a photo's total grade is between 5 (the best) and 25 (the worst).

Individual Identification

In order to identify individual gray whales from photographs, we classified them according to shared characteristics such as large white marks, large injuries, flukes, and unique coloration patterns. Since the photographs were matched by hand, placing them in separated folders according to the above categories allowed us to speed up the matching process.

Two photos were matched at a time. Two photos were be kept open in windows at the bottom of the computer screen in order to compare them to other photos that were scrolled through and examined individually for comparisons in a larger window in the top half of the screen. When a match was found, it was recorded in a database. The criterion used in this study to consider an individual whale to be re-sighted was seeing the same whale on a different day than it was originally photographed on. Photographs of a whale that were taken on the same day were not considered in this category because they were generally taken in a series at the same time. The re-sighting rate was determined according to the following formula: re-sighting rate = (# re-sighted individuals)/ (Total # of individuals)

Injuries and body regions assessment

Determining which body regions of a gray whale are photographed most frequently can lead to improve photo-identification efforts during gray whale monitoring programs. Therefore, all available photographs were examined for the frequency of appearance of 21 defined regions spanning the entire body. Regions 1-4 denote the head, 5-9 are the back and sides, and 10-20 are portions of the tail (see Bradford et al. 2009 for details). In addition, body condition of the gray whale individuals of our photographic archive was assessed through quantification of injuries or scars. Small scratches were not considered to be injuries, only severe scratches and larger injuries, such as, but not limited to, killer whale (*Orcinus orca*) rake marks were considered.

RESULTS

Individual Identification

A total of 1064 photographs were analyzed. However, even when several hundred photos were taken each year, only a fraction of them were useful for individual identification purposes. In average, only 28.1% (SD = 10.1) of the photographs taken proved to be useful. Nevertheless, we were able to identify a total of 278 gray whale individuals from our archive. As expected we were able to identify more individuals in those years when we spend more days in the field. More individuals were photographed in 1999, 2004,

2005 and 2007 than in 1998, 2009 or 2010. Many individuals were matched in photographs taken the same day; however, only 24 individuals were matched in photographs taken on a different day in the same year. There were no matches of individuals photographed in different years. The average re-sighting rate in this study was 0.078; yet, it ranged from 0.00 to 0.44 for individual years (Table 2).

Year	# Days of Effort	# Photos taken	Useful Photos	# of individuals	Re-sightings (same year)	Re-sighting rate
1998	1	n/a	4	3	0	0.00
1999	7	n/a	60	54	2	0.04
2004	12	239	78	64	0	0.00
2005	8	n/a	102	48	21	0.44
2007	6	482	108	70	0	0.00
2009	4	97	17	14	1	0.07
2010	4	80	32	25	0	0.00

Table 2. Number of photos and individuals of gray whales (*Eschrichtius robustus*) for each year examined in Bahia Magdalena, Baja California Sur, Mexico.

Injuries and body regions assessment

In general the dorsal regions of the animals (regions 5-9) were most commonly photographed. The regions of the dorsa were photographed every year, while the regions of the head (1-4) were only photographed in 2005, 2007, 2009 and 2010; and the regions of the tail (10-20) were merely photographed in 2009 and 2010. It is worth mentioning that in 2010, 77.03% of the photographs taken contained regions of the flukes (Fig. 2).

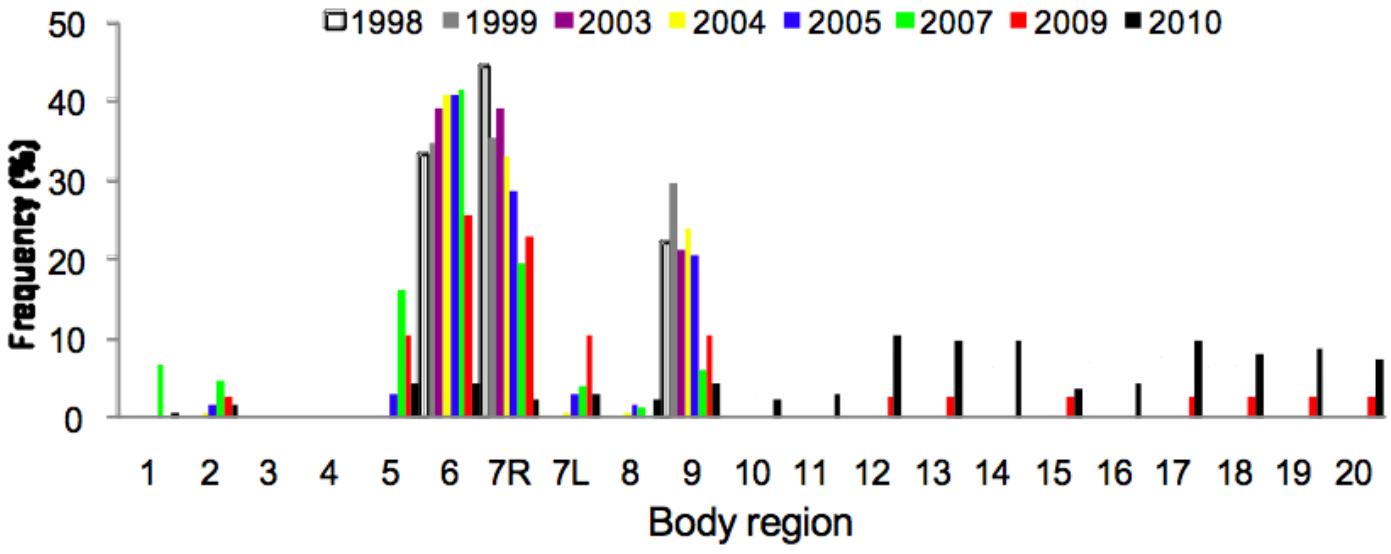


Figure 2. Frequency by year of visible gray whale (*Eschrichtius robustus*) body regions photographed in Bahia Magdalena, Baja California Sur, Mexico.

Of the 278 gray whale individuals identified in this study, 6.8% presented noteworthy injuries (Table 3). One individual presented a severe injury (Fig. 3A), 3 presented potential rake marks from predator's teeth (Fig.3B), 10 had noticeable scratches and five had the tips of the flukes missing (Fig. 3C). Only one individual was noticeably thinner in relation to the other whales photographed; however this was not considered to be an injury.

Year	# of individuals	Scratches	Tooth Marks	Serious	Missing Tips	Skinny
1998	3	1				
1999	54	5	1			
2004	64	2		1		
2005	48		1			
2007	70	1	1			
2009	14	1			1	1
2010	25				4	
Total	278	10	3	1	5	1

Table 3. Injuries and body condition of gray whales (*Eschrichtius robustus)* photographed in Bahia Magdalena, Baja California Sur, Mexico.

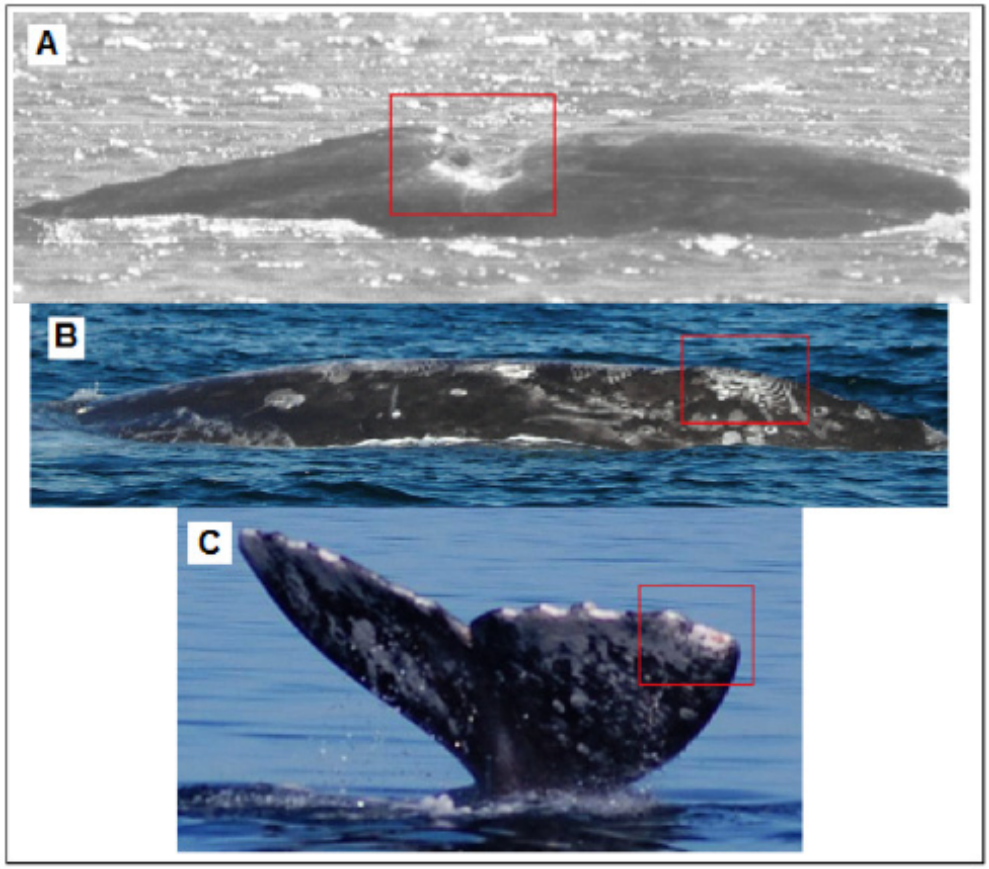


Figure 3. Examples of gray whale (*Eschrichtius robustus*) injuries. A) severe injury potentially caused by vessel collision; B) tooth rake marks and C) tail missing tips.

DISCUSSION

Individual Identification

In this study we were able to identify 278 gray whale individuals and to re-sight 24 individuals in different days of the same season. However, we were unable to re-sight individuals in different years. In comparison, in Laguna San Ignacio, from 1977 to 1982, 562 individuals were identified from which 179 were re-sighted in different years (Jones, 1990). The fact that we were not able to re-sight individuals among years is most likely a consequence of 1) lack of a standardized procedure to obtain photographs and 2) inefficient photographic data management. However, in 2005 we were able to re-sight almost half (re-sighting rate = 0.44) of the individuals photographed in only 8 days of field work (Table 2); on a specialized photo-identification study of the western gray whale population, Yakovlev and Tyurneva (2003) obtained a similar re-sighting rate (0.47) when they observed whales for 13 days. Thus, it is expected that as long as the location, date and time of the day are recorded for each photograph taken, a student based gray whale photographic archive can be successfully used for investigations of short-term gray whale movement patterns within Bahia Magdalena. On the other hand, given that some gray whale individuals move between breeding grounds during the same winter season (Jones and Swartz, 1984), it is probable that our archive might be of use for larger scale photographic identification investigations of gray whales in their wintering grounds.

Injuries and body region assessment

The dorsal region was the most frequently photographed gray whale body region in our study; this result is consistent with the notion that both the left and right sides of the dorsal region around the dorsal hump are the most frequently observed body regions, and are good regions to use for photographic identification (e.g. Hammond et al. 1990; Jones, 1990; Calambokidis *et al.* 2002). However, it has been noted that using photographs of the flukes together with photographs of the dorsal area from the same individuals may decrease the probability of false matches (Hammond et al. 1990). Furthermore, although variations in fluke shape by themselves are seldom applicable to gray whale individual identification due to the relative rarity of gray whale fluking, it has been noted that if the flukes have distinctive marks caused by damage from propellers and from the teeth of predators, then flukes can be used for individual identification (Yakovlev and Tyurneva, 2003). Thus, it is worth mentioning that the most common type of injuries observed in our photographic record was injuries on the flukes. Fluke photos were obtained for 13 individuals and of those, 38% had the tips of the flukes missing. Moreover, although in past investigations in Baja California, fluke patterns generally were not used for identification because whales rarely raised their flukes above the water surface when diving (Jones, 1990); in our study in 2010, flukes were the most commonly photographed body region, indicating that these body regions should continue to be photographed and used in gray whale photographic identification and injury studies.

It is known that in Mexico, gray whales may be injured by passive fishing gear and/or ship strikes. Based on a photographic archive of gray whales in Mexican waters, Urbán et al. (2003) calculated that at least 2% of the whales had injuries presumably produced by impact with a large vessel. Although, 6.8% of the individuals identified in this study presented noteworthy injuries (Table 3), only one individual presented a severe injury that might be attributable to an anthropogenic interaction (< 1%). Thus, a photographic archive of this nature might be useful to monitor the abundance of injuries caused by anthropogenic interactions along time and across wintering grounds in Mexican waters.

Finally, it is considered that a photographic archive collected as part of educational/academic activities, has the potential to contribute quality information about short-term movement patterns and monitoring of anthropogenic injuries for many cetacean species. As long as all photograph associated information is well managed and retained, the utility of these archives could be increased. At present, there are some educational institutions in Mexico (e.g. UABC, UABCS, UNAM, and UV) conducting field exercises involving cetacean watching/photographing activities, which may be benefited by the resulting photographic archives produced by their students.

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