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First Record of Pygmy Killer Whales (*Feresa attenuata*) in the Gulf of California, Mexico: Diet Inferences and Probable Relation with Warm Conditions During 2014

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Abstract

The pygmy killer whale (*Feresa attenuata*) is one of the least studied cetacean species. It is a pantropical toothed whale not previously reported in the Gulf of California (GC). The aim of this study is to analyze the first sighting for this region in environmental and dietary terms. In October 2014, three pygmy killer whales were stranded and three others were sighted at sea in the Bay of La Paz, Baja California Sur, Mexico. We analyzed stomach contents and used skin samples from the dead individuals to evaluate stable isotopes of N and C. We found high $\delta^{15}N$ (19.2 ± 0.2‰) and low $\delta^{13}C$ (-16.5 ± 0.1‰) values, similar to those reported for other teuthophagous cetaceans in the GC. We also identified the remains of purpleback flying squids (*Sthenoteuthis oualaniensis*) in the stomach of the stranded individuals. The presence of tropical species, like the pygmy killer whale and probably the purpleback flying squid, appeared to be related to the anomalous SST in the GC in 2014, which was 1 to 1.5° C warmer than the same period during 2013. This highlights the importance of monitoring how environmental changes alter the composition and distribution of cetacean species and their prey.

Key Words: diet, stable isotopes, anomalous warm conditions, pygmy killer whales, *Feresa attenuata*

Introduction

In recent decades, 36 species of marine mammals have been reported in the Gulf of California (GC), Mexico (Vidal et al., 1993; Urbán, 2010). The GC's high diversity is due to its mid-latitude geographic location, which supports a mixture of species with different biogeographic affinities (e.g., temperate or tropical) (Rosales-Nanduca et al., 2011). Although Delphinidae is the best represented cetacean family, with 13 species, the pygmy killer whale (*Feresa attenuata*, Gray, 1874) (PKW) has not been previously reported for the GC. This species has a pantropical and oceanic distribution with an uncertain population status due to insufficient data (Taylor et al., 2008). In the Pacific Ocean, this species has been reported in Honshu (Japan), Hawaii, the Gulf of Tehuantepec (Mexico), Peru, and Queensland (Australia) (Jefferson et al., 1993; Taylor et al., 2008). Our understanding of the PKW diet derives from analysis of stomach contents—largely composed of squid, octopus, and fish—of stranded animals (Zerbini & Santos, 1997; Williams et al., 2002; Donahue & Perryman, 2009). Some researchers have reported the occasional predation of other delphinids, including the genus *Stenella* and *Delphinus* (Perryman & Foster, 1980; Jefferson et al., 1993).

The present study represents the first report of this species in the GC. Additionally, our stomach content and stable isotope analysis of stranded individuals provides the first information with regard to diet in the Mexican Pacific. We present important data on one of the least-studied

odontocetes and offer insights into the effects that environmental changes may have on the distribution of cetacean species.

Methods

Diet Inferences, Stomach Contents, and Stable Isotopes of N and C

Stomach contents were collected during the necropsy of the stranded individuals and placed in plastic bags labeled with identifying data (i.e., date, ID, and location). The structures were washed in the laboratory and identified based on comparison with specialized guides (Wolff, 1984; Clarke, 1986; Young, 2009).

Tissue (skin) samples were collected from the three dead individuals to determine their isotopic values of N and C. To preserve the samples, they were first frozen at -40° C and subsequently dried at 60° C for 36 h. Lipids were extracted using a 1:1 chloroform and methanol solution and again dehydrated. The samples were homogenized with an agate mortar, and 0.8 to 1.2 mg per specimen was weighed on an analytical balance with a precision of 0.001 mg. These samples were placed in 3.5 × 5.0 mm tin capsules and analyzed in the Laboratorio de Espectrometria de Masas (LESMA; Laboratory of Mass Spectrometry), CICIMAR-IPN. Sample values were expressed as δ values (delta) in parts per thousand (‰). In order to compare values from different samples, they were examined relative to a standard value whose relationship is given by the equation

$$\delta^{15}N \text{ or } \delta^{13}C = \left(\left(\frac{R\ sample}{R\ standard}\right) - 1\right) * 1000$$

Where the R_{sample} for $\delta^{15}N$ is the ratio of the heavy isotope ^{15}N to the light isotope ^{14}N, while the R_{sample} for $\delta^{13}C$ is the ratio of the heavy isotope ^{13}C to the light isotope ^{12}C. The internationally recognized standards for these elements are Pee Dee Belemnite for carbon and atmospheric nitrogen (N_2) for nitrogen.

Sea Surface Temperature Estimation

Data on sea surface temperature (SST) for the southern portion of the GC were obtained from the National Aeronautics and Space Administration's (NASA) Giovanni portal, with images from the MODIS Aqua satellite showing the monthly average temperature of areas with a spatial resolution of 4 × 4 km (*Ocean Color Radiometry*, 2010). SST data were processed in *ArcGIS 10* for the period from August through October 2014, according to the 70-d time window for stable isotopes analysis of the skin (Hicks et al., 1985; St. Aubin et al., 1990), in order to make inferences about the variation in the study area. Data from the same period in 2013 were also analyzed in order to provide comparative SST for a year considered to be normal for the Pacific according to the National Oceanic and Atmospheric Administration's (NOAA) website (www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml).

Results

On 17 October 2014, the presence of three stranded PKWs—two dead and one live individual, which died shortly thereafter (Figure 1)—was recorded in Bay of La Paz, Baja California Sur, Mexico. These animals were all males, with a total length of 1.8 to 2.0 m (Table 1), and were located just a short distance from each other (24° 10.355' N, 110° 22.884' W; 24° 10.383' N, 110° 21.903' W; and 24° 10.493' N, 110° 24.241' W) (Figure 2).

A group of three living PKWs (Figure 3), possibly from the same stranded group, was sighted on 19 October, ~200 m from shore (24° 10.506' N, 110° 23.888' W). They were approximately the same length as their beached counterparts.

Figure 1. Pygmy killer whales (*Feresa attenuata*) (PKWs) stranded dead (upper) and the one stranded alive (lower), which died shortly after the event took place.

Table 1. Measurement of pygmy killer whales (*Feresa attenuata*) (PKWs) stranded in the Bay of La Paz on October 2014

	Individual		
Measurement (cm)	A	B	C
Total length	186	203	193
Rostrum – genital aperture	--	123	112
Rostrum – base of dorsal fin	--	94	86
Rostrum – blowhole	--	26	21
Rostrum – eye	--	24	23
Rostrum – mouth commissure	--	21	19
Max. length of flipper	37	40.5	36
Max. width of flipper	24	13	19
Max. height of dorsal fin	20	21.5	19
Base of dorsal fin	27	30	37
Width of flukes	43	58	56

Diet Inferences from Stomach Contents

The stomach contents of PKW Individuals A and C consisted only of cephalopod beaks. Individual B was devoid of stomach contents. Individual A's stomach contained ~20 of these structures, while ~200 were counted for Individual C. All beaks were identified as originating from purple-back flying squid (*Sthenoteuthis oualaniensis*; Lesson, 1830) (Figure 4), which belongs to the Ommastrephidae family.

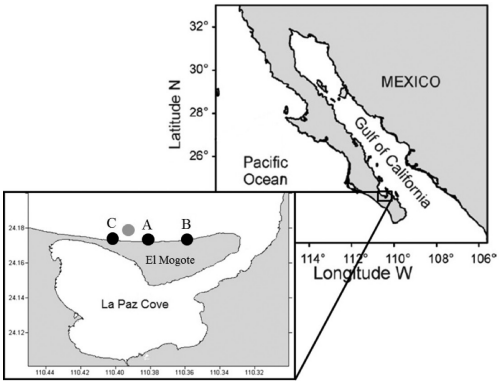

Figure 2. Bay of La Paz, Baja California Sur; black dots indicate the stranded PKWs: A = a live individual; B-C = dead individuals. The gray dot indicates the sighting of live PKWs at sea.

Diet Inferences Based on Stable Isotopes of N and C

The mean $\delta^{15}N$ value was 19.2 ± 0.2‰ (mean ± SD), with the highest value (19.4‰) belonging to Individual B and the lowest value (19.0‰) being recorded for Individual A. The average $\delta^{13}C$ was -16.5 ± 0.1‰; Individual A had the highest value (-16.4‰), and Individual B had the lowest (-16.6‰) (Table 2).

Sea Surface Temperature

The SST in the sites where the stranding and the sighting took place on 17 and 19 October was

Figure 3. PKWs sighted alive, 150 to 200 m from shore in Bay of La Paz, 19 October 2014.

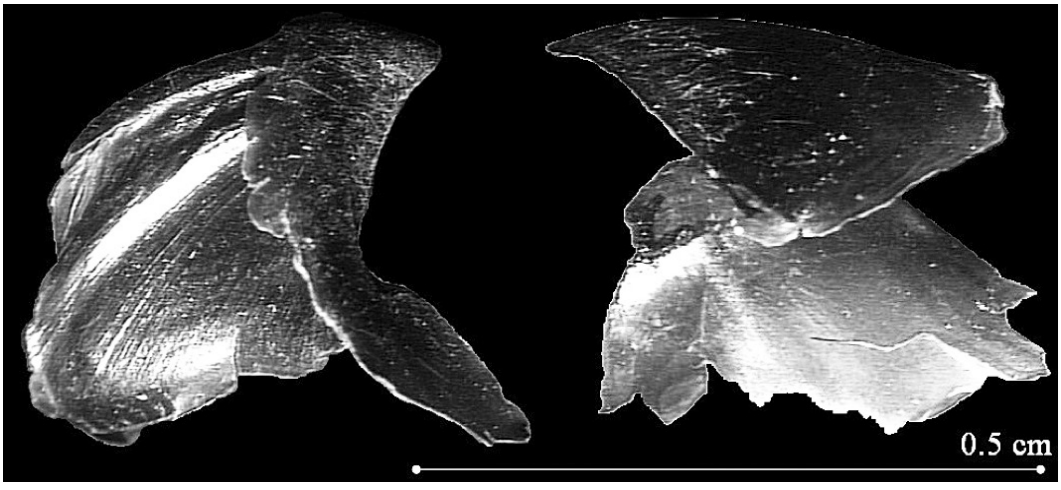

Figure 4. Beak of purpleback flying squid (*Sthenoteuthis oualaniensis*) recovered from the stomachs of two PKWs; this was the only species found in the stranded individuals.

Table 2. $\delta^{15}N$ and $\delta^{13}C$ values of PKWs stranded in the Bay of La Paz on October 2014

Individual	$\delta^{15}N$ (‰)	$\delta^{13}C$ (‰)
A	19.0	-16.4
B	19.4	-16.6
C	19.2	-16.5
Mean ± SD	19.2 ± 0.2	-16.5 ± 0.1

30.2° C. The SST in the southern portion of the GC, including the Bay of La Paz, from August to October 2014 was ~1.5° C warmer (≥ 30.5° C) than the same period in 2013 (28 to 29° C) (Figure 5).

Discussion

The present study represents the first published report of PKW—either sighted at sea or stranded on land—in the GC. The possibility of finding PKWs in the GC has been raised by other researchers (Salinas & Ladrón de Guevara, 2003; Medrano-González, 2006). However, recent studies of marine mammal diversity do not report the species among the GC mammalian fauna (Vidal et al., 1993; Urbán et al., 2005; Urbán, 2010), only documenting it in oceanic waters of the Mexican Pacific, near Banderas Bay (20° 39.079' N, 105° 17.921' W) (Halpin et al., 2009). Two of these records were made in the Mexican Pacific at a similar latitude as Bay of La Paz. These had no clear relationship with unusual SST and were catalogued as rare considering that the most usual range for this species was below the 20° latitude

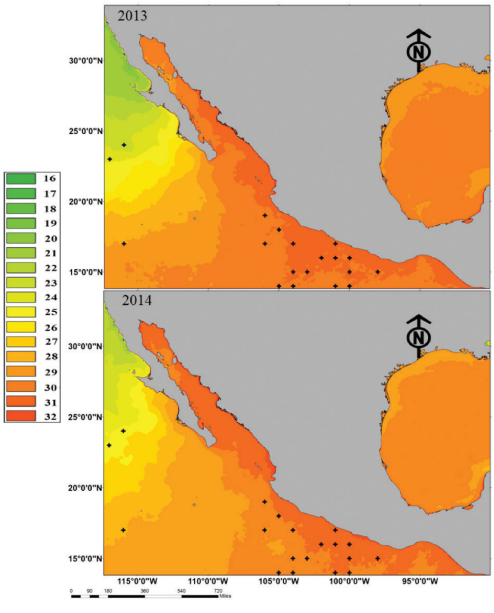

Figure 5. Sea surface temperature (SST) images of Bay of La Paz and southern portion of the GC; monthly average temperatures for August through October 2013 (upper) and August through October 2014 (lower). Historical sightings of PKWs from the Mexican Pacific are included in both maps (taken from Halpin et al., 2009).

north (Halpin et al., 2009; Figure 5). This study also provides essential information regarding the diet of the species in the Mexican Pacific based on the analysis of stable isotopes and stomach contents. These two analytical techniques yielded similar results suggesting recent residence of both

PKW and this squid prey in the GC. Additionally, the presence of these individuals in Bay of La Paz, more further north than usual, could be related with changes in SST in the Northeast Pacific that began at the end of 2013 in southern Alaska, reaching Baja California and GC waters in March 2014 and intensifying from July to December of the same year (Bond et al., 2014; Kintisch, 2015). A similar relationship was documented during October 2014 off the coast of southern California, where an unusual presence of PKWs was related to an anomalous high SST (Kintisch, 2015).

Stomach Contents of PKWs

Data on *Feresa attenuata* diet are scarce. However, the few studies available (Zerbini & Santos, 1997; Aguiar dos Santos & Haimovici, 2001) indicate a diet predominantly composed of squid, consistent with the results of this study. No previous studies have examined the diet of *F. attenuata* in the Mexican Pacific; however, off the coast of Brazil, the following squid families have been reported: Onychoteuthidae, Loliginidae, and particularly Ommastrephidae (*Illex argentinus* and *Ornithoteuthis antillarum*), the latter being from the same family as the purpleback flying squid identified in the stomachs of the beached PKWs analyzed herein. The purpleback flying squid is common in tropical and subtropical regions of the Pacific Ocean—from southern Japan to northern Australia and from southern Baja California (Mexico) to northern Chile (Nesis, 1987; Staaf et al., 2010). There is no published evidence of the species' presence in the GC; however, we cannot discount that the GC is part of this squid's occasional distribution considering its presence in two PKW stomachs.

In this study, we hypothesized that the unprecedented record of PKWs within the oceanographic boundaries of the GC is primarily due to the increased SST recorded for the Pacific in 2014 (Kintisch, 2015). In this regard, other researchers have documented changes in the distribution of cetacean and squid species during periods of anomalous temperatures (Tershy et al., 1991; Jaquet & Gendron, 2002; Whitehead et al., 2008; McLeod, 2009; Ruiz-Cooley et al., 2013; Kintisch, 2015). There has been concerted research effort in the GC documenting abundance and distribution of cetaceans (Vidal et al., 1993; Urbán, 2010; Rosales-Nanduca et al., 2011) without records of PKWs. Previous unrecorded appearances of this species in the GC cannot be ruled out; however, they would be considered as rare.

Stable Isotope Analysis of the Skin of PKWs

The $\delta^{15}N$ and $\delta^{13}C$ values of the three PKW are similar to those of other toothed whales sampled in the GC (mean ± SD: $\delta^{15}N = 18.6 \pm 0.7‰$; $\delta^{13}C = -16.0 \pm 0.7‰$) (Díaz-Gamboa, 2009; Aurioles-Gamboa et al., 2013) (Table 3). The GC is characterized by ^{15}N-enriched values at the base of the food web because of denitrification processes that enrich residual nitrates (Altabet et al., 1999). One of these denitrification zones is located at the mouth of the GC, from which ^{15}N-enriched water is transported north by the West Mexican Current (Altabet et al., 1999; Voss et al., 2001). In contrast, odontocetes like false killer whales (*Pseudorca crassidens*) outside the GC (Mexican Tropical Pacific, ~18.9° N) presented lower $\delta^{15}N$ values, between 15.7‰ and 17.7‰ (Ortega-Ortiz et al., 2014). Thus, considering the ^{15}N-enriched and ^{13}C-depleted values in PKW, also reported for other teuthophagous species in the GC (Díaz-Gamboa, 2009; Aurioles-Gamboa et al., 2013), we argue that the PKWs fed in the GC during the ~70 d prior to sampling. Similar time calculations have been performed using skin samples from other toothed whales, including the bottlenose dolphin (*Tursiops truncatus*) and beluga whale (*Delphinapterus leucas*) (Hicks et al., 1985; St. Aubin et al., 1990). This 70-d period coincides with a period of unusual warming in the area between August and October 2014 (Figure 5).

Table 3. $\delta^{15}N$ and $\delta^{13}C$ values of odontocetes in the GC (taken from Díaz-Gamboa, 2009, and Aurioles-Gamboa et al., 2013)

Region from the GC	Species	$\delta^{15}N$ (‰)	$\delta^{13}C$ (‰)
Along the GC	Long beaked common dolphin (*Delphinus capensis*)	18.4	-16.7
	Bottlenose dolphin (*Tursiops truncatus*)	18.0	-15.6
Central-South	Short beaked common dolphin (*Delphinus delphis*)	18.1	-16.7
	Short-finned pilot whale (*Globicephala macrorhynchus*)	18.3	-15.6
	Sperm whale (*Physeter macrocephalus*)	20.4	-15.3
	Pygmy beaked whale (*Mesoplodon peruvianus*)	18.6	-16.7
	Bottlenose dolphin	19.1	-16.0
Bay of La Paz	Risso's dolphin (*Grampus griseus*)	18.5	-16.9
	Dwarf sperm whale (*Kogia sima*)	18.0	-14.8

Our hypothesis based on the stable isotope analysis should be considered with caution. We cannot exclude that (1) the PKW fed in a different area from the GC, but with similar isotopic baseline values as the Gulf; or (2) the possibility that the anomalous warm conditions in the study area may have altered the isotopic values of the stranded PKWs, thereby compromising any comparison with other marine mammals examined by other researchers. However, we consider the coincidence between the increased temperature and the atypical presence of PKWs in the GC to be solid. Given the limited sample size, additional studies are clearly needed to further test conclusions, including a health assessment that was not part of this work, and to evaluate any potential role in stranding events. However, this study provides data regarding how environmental changes may alter the distribution of a species, an important topic considering the current interest in environmental changes.

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