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Short Note

Movement and Occurrence Patterns of Short-Finned Pilot Whales (*Globicephala macrorhynchus*) in the Eastern North Pacific

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Short-finned pilot whales (*Globicephala macrorhynchus*) have been studied worldwide, but little is known about their distribution and occurrence in the eastern North Pacific. Both short- and long-finned pilot whales (*G. melas*) occur in stable matrilineal social systems, where individuals remain in their natal groups for life (Heimlich-Boran, 1993; Ottensmeyer & Whitehead, 2003; de Stephanis et al., 2008; Alves et al., 2013; Mahaffy et al., 2015). For short-finned pilot whales (henceforth referred to as pilot whales), studies off Hawaii and Madeira have observed multiple matrilineal social systems periodically converging to form temporary associations (Alves et al., 2013; Mahaffy et al., 2015). Residency patterns for this species are highly variable. Some populations are nomadic with little site fidelity (Heimlich-Boran, 1993), while others demonstrate pronounced site fidelity with residency documented for at least 5 y (Mahaffy et al., 2015).

Pilot whales are commonly seen in waters surrounding the Baja California Peninsula, but their distribution is generally limited to waters south of about 30° N, with only 12 sightings in waters off northern California and Oregon during five ship-based cetacean surveys between 1991 and 2005 (Hamilton et al., 2009). Abundance was estimated to be approximately 350 (CV = 0.48) pilot whales occurring in waters off the West Coast of the United States (Barlow & Forney, 2007) based on pilot whale sightings made during these surveys. Large groups of pilot whales routinely

wintered around Santa Catalina Island from the 1960s (Norris & Prescott, 1961; Leatherwood et al., 1973; Dohl et al., 1981; Miller et al., 1983) through early 1983, but, following the 1982-1983 El Niño, the species was rarely seen there and only in small numbers (Shane, 1994, 1995). While the cause of this disappearance is unknown, a decline in prey (i.e., squid) may explain the disappearance (Shane, 1995; Zeidberg, 2006). Seasonal sightings of pilot whales continued through February 1987 off of Point Vicente, located across the San Pedro Channel from Santa Catalina Island (Schulman-Janiger, unpub. data). Sightings of pilot whales were rare in the Southern California Bight for more than two decades after 1987 but appear to be increasing in frequency in recent years. This study used photo-identification methods to analyze photographs collected between 1983 and 2015, from 20° N to about 40° N and as far east as 140° W, to determine whether individuals seen in recent years were part of the pre-El Niño group studied off of Catalina Island and to examine movement and occurrence patterns of pilot whales in the eastern North Pacific.

Photo-identification is useful in monitoring populations of pilot whales as individuals can be readily identified from naturally occurring nicks and notches on their dorsal fins, as well as from saddle pigmentation patterns and scarring (e.g., scratches and cookie cutter shark scars) on their bodies (see Auger-Méthé & Whitehead, 2007).

In the formation of this catalog, sorting was performed in accordance with the digital photo-identification methods described by Mazzoil et al. (2004). We analyzed 5,000 photos, including 70 identification photographs from 5 y of dedicated research at Santa Catalina Island between 1983 and 1989 (taken by S. Shane) and the remaining 4,930 photographs from 20 sightings off California and Baja California, Mexico, between 1996 and 2015 (taken by Cascadia Research Collective, National Oceanic and Atmospheric Administration's [NOAA] Southwest Fisheries Science Center, San Diego Whale Watch, and Pacific Nature Tours; see Table 1 for details) (Figure 1; Table 1). As expected, most sightings were in more southerly, warmer waters, with only seven sightings between 35° and 40° N and one sighting slightly north of 40° N.

All photographs were processed using ACD See (www.acdsee.com) and followed a combination of published methods (see Mazzoil et al., 2004; Auger-Méthé & Whitehead, 2007; Durban et al., 2010). Each image was assigned a grade for photographic quality, relative value, and distinctiveness of the individual. These grades were then entered into the metadata of the photographs and imported

into an *Access* database. For *photographic quality*, images were rated on a 4-point scale based on focus, the position of the fin in the frame, the presence of confounding features (glare and water spray), and the visibility of distinctive coloration patterns. A photo received a highest *relative value* of 3 if it was the best image of the animal. *Distinctiveness* was determined on a 4-point scale based on the number of permanent markings, such as a notch (Auger-Méthé & Whitehead, 2007), as well as the number of marks that may remain reliable for shorter periods of time (e.g., deep scars, cookie cutter shark bites, and saddle pigmentation).

All whales with unique fins having distinctiveness ratings greater than or equal to 2 and appearing in photographs with a quality rating of 3 or 4 were assigned identification numbers and placed in a master catalog. Each photo was compared to every other photo in the catalog to screen for matches across sightings, and each match was verified by three different analysts according to standard photo-identification methods (Mazzoil et al., 2004).

The final catalog included 207 distinctively marked animals with high image quality, and 1,905 photographs of these individuals were included in

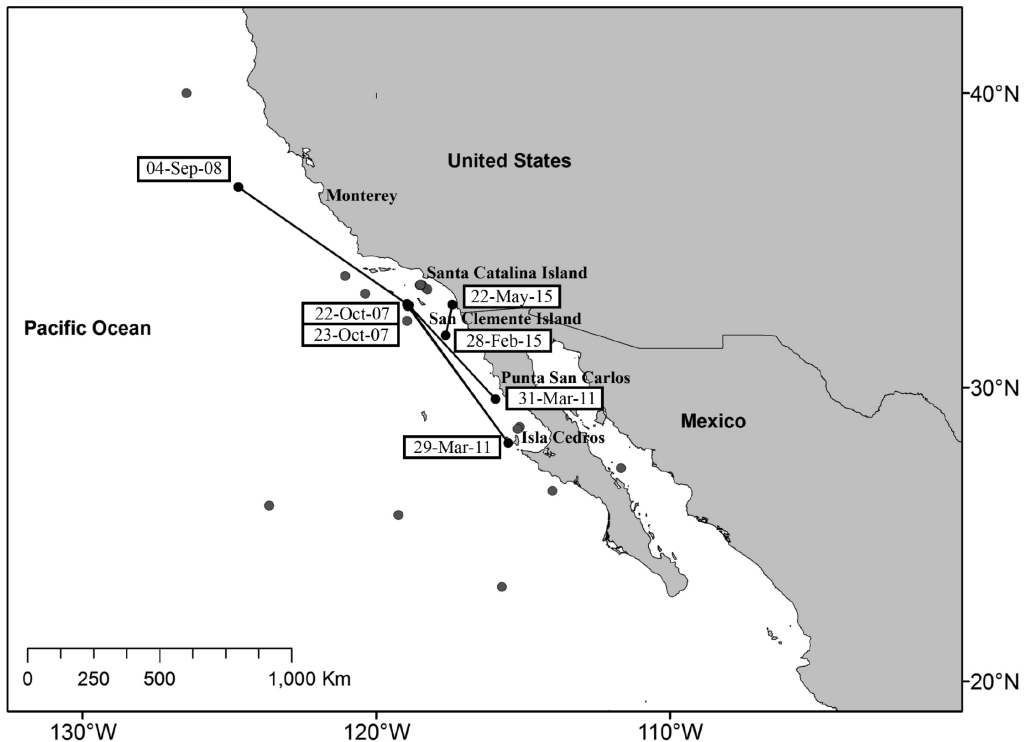


Figure 1. Map of short-finned pilot whale (*Globicephala macrorhynchus*) sightings included in catalog. Photographic matches of individuals are linked by a black line and are labeled by the date of the sighting.

Table 1. Data for all photos used in the catalog. Dates on which matches were made are denoted by an asterisk (*). The “Group size” column provides field estimates. The “IDs” column provides the number of individuals used in the catalog (excluding images with low quality or distinctiveness). Two sightings on 23 October were about 3 h apart and were given different superscripts but are described as the same sighting in the text because the latter sighting was likely the same group from earlier that day.

Source	Date	Decimal latitude	Decimal longitude	General location	Group size	IDs
Susan Shane	1983-1989	Varied	Varied	Santa Catalina Island	4-40	33
1996 NOAA Cruise	14 Aug 96	32.2585	-118.9542	Northern Baja California	16	23
1998 NOAA ETP Cruise	02 Aug 98	28.6500	-115.1167	Northern Baja California	15	1
1998 NOAA ETP Cruise	02 Aug 98	28.5833	-115.1833	Northern Baja California	13	1
1998 NOAA ETP Cruise	03 Aug 98	26.4667	-114.0000	Northern Baja California	31	0
1998 NOAA ETP Cruise	09 Aug 98	27.2333	-111.6667	Gulf of California	18	0
2003 NOAA ETP Cruise	02 Aug 03	25.9617	-123.6433	Southern Baja California	3	6
2003 NOAA ETP Cruise	07 Dec 03	25.6372	-119.2527	Southern Baja California	15	5
2006 NOAA ETP Cruise	03 Aug 06	23.1962	-115.7215	Southern Baja California	2	1
2007 Cascadia Research	22 Oct 07*	32.7905	-118.8968	San Clemente Island	60	44
2007 Cascadia Research	23 Oct 07 ¹ *	32.8370	-118.9460	San Clemente Island	35	27
2007 Cascadia Research	23 Oct 07 ² *	32.7456	-118.9171	San Clemente Island	40	7
2008 NOAA Cruise	04 Sept 08*	36.8040	-124.6960	Northern California	47	8
2011 Cascadia Research	29 March 11*	28.1085	-115.5120	Baja California	12	10
2011 Cascadia Research	31 March 11*	29.5955	-115.9445	Baja California	30	11
2014 NOAA Cruise	06 Aug 14	33.7790	-121.0547	Southern California	21	9
2014 NOAA Cruise	09 Sept 14	40.0032	-126.4643	Northern California	40	9
2014 NOAA Cruise	15 Oct 14	33.1805	-120.3765	Southern California	35	10
2014 San Diego Whale Watch	16 Oct 14	32.8000	-117.4000	San Diego	200	13
2015 Pacific Nature Tours	28 Feb 15*	31.7697	-117.6441	Northern Baja California	30	10
2015 San Diego Whale Watch	22 May 15*	32.8133	-117.4117	San Diego	50	6

the analysis. Thirty-three of these individuals were from research conducted by S. Shane between 1983 and 1989, representing a subset of the whales observed at Santa Catalina Island. All of these individuals were seen on more than one occasion, but only 16 (38%) were seen in more than 1 y (Shane & McSweeney, 1990). One hundred and seventy-four individuals were identified between 1996 and 2015, with only 22 (12.6%) of these individuals sighted on more than one occasion.

Our study revealed no matches between the 33 whales identified between 1983 and 1989 off Catalina and more contemporary images of 174 whales collected between 1996 and 2015. However, our study did reveal two other “sets” of matches (Table 2). First, multiple matches were made to a group of about 60 individuals photographed on 22-23 October 2007 approximately 40.2 km west of San Clemente Island. Five of the individuals from these sightings were photographed 11 mo

later, west of Monterey, California (4 September 2008). Seven other individuals from the October 2007 sightings were photographed 3 y and 5 mo later off northern Baja California, west of Punta San Carlos (29 March 2011). Two days later, another four individuals from the October 2007 sighting were photographed in the same area (31 March 2011) (Table 2). In combination, 11 individuals were matched between San Clemente Island and northern Baja California.

A final match of one whale (PW0268) was made, with this individual appearing west of Ensenada in northern Baja California (28 February 2015) and again 3 mo later, just off the coast of San Diego (22 May 2015). For both of these sightings, but especially the encounter off San Diego (22 May 2015), the number of individuals identified (six) was much smaller than the estimated group size ($n = 50$); therefore, it is possible that additional matches could have been made if the

Table 2. Matching data for the 22 individuals seen more than once. Black squares represent a sighting. For re-sights, black squares represent a sighting that took place over 1 y later, dark gray over 1 mo later, lighter gray over 24 h later, and lightest gray less than 24 h later. **Note:** Two sightings on 23 October were about 3 h apart and were given different superscripts.

Catalog ID	Whale ID	Date								
		22 Oct 2007	23 Oct 2007 ¹	23 Oct 2007 ²	04 Sept 2008	29 March 2011	31 March 2011	28 Feb 2015	22 May 2015	
103	PW0167	■						■		
104	PW0169									
105	PW0171									
106	PW0237							■		
107	PW0002				■					
108	PW0003				■					
109	PW0004				■					
110	PW0006				■					
111	PW0009				■					
112	PW0183		■							
113	PW0184		■							
114	PW0182		■			■				
115	PW0208		■	■						
116	PW0195		■	■						
117	PW0196		■	■						
118	PW0191		■	■		■				
119	PW0192		■	■		■				
120	PW0193		■	■		■				
121	PW0204		■	■		■				
122	PW0194		■	■		■				
123	PW0223		■	■		■				
202	PW0268							■	■	

photographic coverage had been more complete for the group off San Diego on 22 May 2015.

A large number of individuals in our catalog were photographed on only one occasion (87.4%) compared to other photo-identification studies of short-finned pilot whales, including those from Hawaii (32%) and Madeira (71%) (Alves et al., 2013; Mahaffy et al., 2015). The sightings incorporated in the catalog were mostly opportunistic, for which group sizes were typically rough estimates, and groups may have been incompletely photographed. It is possible that the eastern North Pacific population is more transient than some populations in other locations. Alternatively, the eastern North Pacific population may be a large population within which a smaller proportion of individuals or multiple subpopulations with

distinct movement and occurrence patterns have been identified. Surveys where effort is allocated specifically to collect photographs of pilot whales may increase the probability of recapturing individuals and give a more reliable view of eastern North Pacific pilot whale occurrence.

There is added complexity in this study area due to its large size and absence of a centralized location such as an island or chain of islands as is found in both Hawaii and Madeira. However, the photo-identification matches found suggest and reinforce the contiguous nature of the eastern North Pacific population from Baja California to Northern California. The fact that matches exist at all, despite very sparse data collection, supports the current low average abundance estimate mentioned earlier in this note (Barlow & Forney,

2007). Multiple sightings of over 50 individuals (once as many as 200 in October 2014) suggest that a sizeable portion of this population may be temporarily associated. The rarity of pilot whale sightings in the area may indicate that the animals infrequently visit this region and likely spend most of their time further offshore or to the south, beyond the area currently surveyed. Long-term focused monitoring is required to make any definitive claims concerning the residency patterns and population structure of pilot whales in this study area.

Although sightings with matches occurred near San Clemente Island, the area has been heavily surveyed for over a decade, and sightings of pilot whales were rare. Overall, this study yielded no matches between recent sightings of pilot whales with those identified prior to the 1982-1983 El Niño; however, this lack of matches may be an artifact of photographic effort, image quality, or the relatively small sample of whales identified. Continued monitoring with a greater focus on photo-identification will help fill key data gaps on the distribution, occurrence, potential threats, and demographic trends of pilot whales in this region.

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